EXHIBIT 14

Number	PSJ000-17-0003 CORRESPONDENCE LOG		
14A	Mike Carlson	12/6/2017	Built similar dock w/ similar exposure 1971. Removed/stored in winter. Still there.
14B	Mary Elford	11/24/2017	Lived on property and never saw whales in cove where dock is propsed No harm to environment
14C	Doug Thompson	11/22/2017	See staff report
14D	Bob Elford	11/21/2017	Lived on property for 18 yrs. Boated his entire life. Never saw whales in cove where dock is proposed.
14E	Michelle Borsz	10/31/2017	Construction noise. Destruction of habitat of forage fish and salmon
14F	Whitney Neugebauer	10/30/2017	Critical area for endangered SRKW and chinook salmon. Habitat for forage fish and eelgrass. Precedence for docks in this area. Supports UW appeal
14G	Shirley Reuscher	10/17/2017	No docks No more construction of any kind
14H	Ross Lockwood	10/4/2017	Ill-conceived Represents a threat to scenic beauty of the area and natural environment If project results in removal of native vegetation, reseeding is not sufficient Risk of discharge of pollutants into the protected False Bay due to maintenance activity, informal fueling, accidents or weather events Current will sweep concentrated brine into False Bay Substantial visual impact, altering shoreline in this area
14I	Dr. Megan Dethier	10/2/2017	See staff report
14J	Jane Wentworth	9/22/2017	Will occupy publically-owned tidelands, cutting off public's access Threat to False Bay through noise, potential fuel and chemical spills, bottom-land shading, changing water dynamics and siltation of the bottom under and around dock Precedent for more docks in the area Rocks within cove haul-outs that dock might be considered harassment

			What is impact of brine
14K	Francine Shaw	9/22/2017	Responded to comments from Drew Harvell that his letter is not consistent with the four eelgrass surveys
14L	Charles & Eleanor Nolan	9/21/2017	Dock totally against character of habitat
14M	Albert Shepard	9/20/2017	Detrimental effects of the marine habitat and ecology Loss of spectacular uninterrupted rocky shoreline
14N	Billie Swalla	9/20/2017	See staff report
14O	Kimbal Sundberg	9/20/2017	Dock should be reduced in scope and size and confined to Honeywell's private owned tidelands Ovesight of proposed mitigation measures Damaged boats/docks leaking fuel and oil, wind and waves even in spring/summer, inexperienced/reckless boaters and the rocks and shoals
14P	Kendall Scott	9/20/2017	Threat to what makes the island so special
14Q	Tom Schultz	9/20/2017	Light penetration info probably overstated No data talking about shading of sunlight by vessel hulls
14R	Janice Riley	9/20/2017	Precedent How to ensure monitoring of mitigation measures Will Orca Dreams be held liable for environmental damage
14S	Dr. Dianna Padilla Stony Brook University	9/20/2017	Construction of the dock, trenching for the desalinization facility, hyper saline effluent, presence of the dock, boater activity will impact this protected habitat as well as the species that use the habitat Impacts of hardened structures on eelgrass and other essential species Effluent from desalinization plant will result in thermal pollution and hyper saline stress on organisms, especially animals Eelgrass survey timing

			Other fauna impacted, whales swim through the pocket bay into False Bay; haul outs for seals Continued sedimentation of the pocket bay will eventually require dredging
14T	Ruth MacGinitie	9/20/2017	Disturb movement of marine mammals and fish Sea mammals will alter their movement during construction due to noise Scar on beautiful wild shoreline
14U	Marc Kwiatkowski	9/20/2017	Large structure, aesthetically displeasing Boat traffic will disturb seals, oyster catchers, heron
14V	Kathryn Loring	9/20/2017	Need for dock of this size not explained. No analysis of how boats and the dock will be protected during storms. No analysis of dock components that do not transmit light. Brine discharge. Scouring by boat traffic. Alternatives to the dock not discussed.
14W	Tamara Kay Dean	9/20/2017	Protect False Bay
14X	Shaun Hubbard	9/20/2017	No doubt significant negative impacts from dock and desal. Mitigation in place for construction but not after. Who monitors if the measures are used?
14Y	Francine Shaw	9/20/2017	Clarification
14Z	Francine Shaw	9/20/2017	Prentiss concerns
14AA	Mike Lisitza NOAA	9/20/2017	Concerns regarding indirect impact to SRKW and other listed species. Precedent for future docks on the west side on San Juan Island.
14BB	Kyle Loring Friends of the San Juans	9/20/2017	Mitigation measures apply to construction phase, not impacts later. No analysis of impacts to possible nearby seal haul-outs; navigation; aesthetic impacts of lighted structure; cumulative impacts of only dock in 15-20 mile stretch; feasible alternatives; impacts of attaching buoy to rocks; impacts of seawater intake and brine discharge; energy use for RO

14CC	Katy Barsamian	9/20/2017	An EIS should be required. False Bay Marine Preserve will be threatened.
14DD	Sharon Grace	9/20/2017	Environmental review is required for proposed dock and RO. An EIS should be required. Proposed dock will impact threatened and endangered species. Boats will impact the environment. Likely to degrade False Bay Preserve.
14EE	Laura Derevensky	9/20/2017	4 basic principles: a precedent setting development such as this should not occur without an EIS; the proposal has failed to demonstrate need; lacks sufficient protections for the marine and terrestrial environment; proponent wants to use excess resources to the detriment of other stakeholders.
14FF	William Cowles	9/20/2017	The proposal threatens the unspoiled beauty of the island as well as the whales
14GG	Yasmin J vonDassow	9/19/2017	Noise, water pollution, sedimentation. Too close to False Bay Marine Preserve.
14HH	Michelangelo vonDassow	9/19/2017	No enforcement mechanisms for mitigation measures. Failed to address potential economic impacts should dock harm whales. Too close to False Bay Marine Preserve.
14II	Craig Staude	9/19/2017	Too close to UW-owned tidelands. Impacts from fuel, paints, solvents, bilges. Navigation hazards. Brine impacts. Cleaning of RO system.
14JJ	Bill Lewis	9/19/2017	Not in character with natural surroundings. Not a good place to put a dock due to storms.
14KK	Julie Blakeslee University of Washington	9/19/2017	See staff report
14LL	Tom R Schultz	9/19/2017	Proximity to haul-out areas for pinnipeds; strong wind storms; discharges from boats; other alternatives.
14MM	Eleanor Hartmann	9/19/2017	All development harms the shoreline, near shore, intertidal, and estuarine environments. Brine discharges.
14NN	Tom Bosworth	9/19/2017	Visual impact of dock on unblemished shoreline

14OO	Martha Scott	9/18/2017	Dock will add noise, lights, activity, and disturbance degrading the quality of False Bay; moorage available at commercial marinas; weather unsuitable; only dock in the area; impacts to False Bay; impacts to whales and salmon.
14PP	Kathleen Foley	9/18/2017	Fuel and chemical spills; impacts to eelgrass; no demonstrated need.
14QQ	Jim and Camille Uhlir	9/18/2017	Current application deficient in required surveys; community dock when community is merely the current ownership; request EIS.
14RR	Mike Prentiss	9/18/2017	Infringe on publicly owned tideland; aesthetically detrimental; precedent for more docks.
14SS	M Patricia Morse	9/17/2017	Whales; haul-outs; storms; RO waste water
14TT	Steve Ulvi	9/17/2017	Eyesore for boaters and kayakers; impacts of storms; unwise potential precedent.
14UU	Richard Strathmann	9/17/2017	Impact on killers whales, eelgrass, and other organisms; litter and toxic materials associated with boats.
14VV	Michelle M Shober	9/17/2017	Use of alternatives; no development of west side.
14WW	Gretchen Allison	9/17/2017	Impact to the access and experience the public now enjoys; public docks available; impacts to threatened and endangered species; impacts of brine discharge.
14XX	James Uhlir	9/17/2017	Copy of Allison letter
14YY	Mike Lisitza NOAA	9/14/2017	Questions to county about how we reviewed the application materials.
14ZZ	Julie Thompson	9/14/17	Response to Mike Lisitza's questions
14AAA	Walter MacGinitie	9/14/2017	Whales; brine discharge
14BBB	Deborah Strasser	9/10/2017	Potential damage to False Bay
14CCC	Dr. Drew Harvell Cornell University	9/7/2017	Impact to eelgrass from disruption of currents, brine discharge, increased siltation, potential spillage from boats
14DDD	Chris Morgan	9/6/2017	Weather impacts on dock; aesthetic impacts of dock and increased on-water activity
14EEE	Nancy Morgan	9/5/2017	Impacts on False Bay; potential fuel or chemical spills; changes to water

			dynamics and siltation; RO system impacts
14FFF	Mary Karen Ryan	9/4/2017	Affect the health of the area organisms that affect the health of whales and salmon
14GGG	Steve Porten	9/3/2017	Visual impact affect the ecology
14HHH	Charles Greene Cornell University	8/30/2017	Ongoing effects of underwater noise on SRKW; impact to nearshore habitat, esp. eelgrass beds and rocky outcrops; storms and associated risk of fuel spills
14III	Bob Fritzen DOE	5/30/17	Bottom contour map is misleading

Julie Thompson

From: Mike Carlson <mcarlson@rockisland.com>
Sent: Wednesday, December 6, 2017 9:49 AM
To: Julie Thompson
Subject: FW: Honeywell Dock

Dear Julie,

I am writing to offer my perspective and support for the proposed Honeywell private dock.

In the 60s and 70s our family lived on Waldron Island. In 1971 we built the present dock with a ramp and floats at the South end of Mail Bay.

The reason I bring up our dock as an example is because our dock is very similar in size and exposure to the proposed Honeywell dock and float system.

Like our Mail Bay dock, the Honeywell floats will be removed and stored during the winter. We have been using our Waldron dock every year on a seasonal basis without issue since 1971.

Although I am not a biologist, I have not seen one iota of environmental harm to the bay as a result of our dock and its associated usage. I have lots of photos that date back to before
the dock was built up to the present as proof.

It concerns me that EVERY dock application is so controversial to a certain segment of our community. The Honeywell proposal is no exception. I urge you and the county process to look past the folks who will pile on the Honeywell's with every catastrophic scenario imaginable....It has been my life long experience from living in this area, that impacts from the existence and use of a dock and float system like the one proposed by the Honeywell's will be completely insignificant.

I urge you to help in the process of approving the Honeywell dock permit.

Sincerely,

Mike Carlson, Friday Harbor

Julie Thompson

From: Mary Elford <marvista@rockisland.com>
Sent: Friday, November 24, 2017 10:21 AM
To: Julie Thompson
Subject: Orca Dreams Comment

I would like to introduce myself, I am Mary Elford, I moved to San Juan Island in July 1970 and have voted in San Juan County and been a resident ever since. I also have been a property owner for over 30 years.
I have noticed the "I have mine but you can't have have yours"
attitude occurring more and more in the last few years. Regarding the Orca Dreams dock, I have lived on the property formally Mar Vista Resort for over 18 years and have never seen an Orca anywhere near that vicinity. It is completely false to say this would be hurting their habitat. I personally have seen the fish and wildlife under docks to be abundant and an asset to the ecosystem. I can see no reason why a desalination unit would harm the environment with the huge tidal exchange from the Juan de Fuca Strait. I know of multiple desal units being used in the County and it is a great savings of our aquifers. If you allow the docks and desal for other county residences then the Orca Dreams LLC should also be allowed as well. Thank you for your consideration.

Mary Elford

Sent from my iPhone

State of Washington
Department of Fish and Wildlife
Mailing Address: PO Box 43200, Olympia, WA 98504-3200, (360) 902-2200, TDD (360) 902-2207
Main Office Location: Natural Resources Building, 1111 Washington Street SE, Olympia WA

November 22, 2017

SJC DEPARTMENT OF
NOV 22 2017
COMMUNITY DEVELOPMENT

San Juan County and Community Development
Julie Thompson
PO Box 947
Friday Harbor, Washington 98250

Dear Ms. Thompson:

SUBJECT: REQUEST FOR COMMENTS ORCA DREAMS LLCPSJ000-17-0003

On October 18, 2017, I received information for the project described above. The Washington Department of Fish and Wildlife (WDFW) has reviewed the application name and file #: Orca Dreams LLC PSJ000-17-0003, dated September 6, 2017 and has the following comments.

The project site is located within a pocket beach on the southwest side of San Juan Island. The site is unique with a rich diversity of flora and fauna. In a previous letter to San Juan County Community Development & Planning, dated October 5, 2015, WDFW expressed concern regarding project impacts to critical habitat that supports juvenile Chinook salmon and pinto abalone (*Haliotis kamtschatkana*). Puget Sound Chinook salmon are listed as threatened under the Endangered Species Act, and the National Oceanic and Atmospheric Administration lists pinto abalone as a "Species of Concern". WDFW has designated pinto abalone as a "Candidate Species" and a "Species of Greatest Conservation Need". There is no discussion in the SEPA checklist or the MDNS issued for this project regarding project impacts to pinto abalone and their habitat.

The Biological Assessment (BA) prepared for this project entitled, *Orca Dreams LLC*, and dated February 24, 2017, identifies pink encrusting coralline algae, *Lithothamnion* spp. as being present within the project area and notes that pinto abalone are associated with this type of habitat. A WDFW approved survey for pinto abalone needs to be completed to determine the presence or absence of this species within the project area. Without a proper survey of the project area, WDFW has no way to evaluate potential impacts to this species. If a survey determines that pinto abalone are present, then a monitoring and mitigation plan needs to be developed that will achieve no net loss for this species. The Washington Administrative Code (WAC) defines mitigation requirements for hydraulic projects (WAC 220-660-080), as sequentially avoiding impacts, minimizing and rectifying unavoidable impacts, and compensating for remaining impacts. This mitigation must achieve no net loss.

WAC 220-660-350 covers seagrass/macroalgae habitat surveys. A set of interim guidelines has been developed entitled, *Eelgrass/Macroalgae Habitat Interim Survey Guidelines*, for eelgrass

and macroalgae habitat surveys. The guidelines contain protocols for both preliminary and advanced surveys to help evaluate potential impacts to these habitats at project sites. The present eelgrass and macroalgae surveys conducted for this project as identified within the BA do not meet the standards of this code. Eelgrass and macroalgae surveys must be completed between June 1 and October 1 to accurately map the full extent of seagrass and macroalgae (kelp) distribution. Neither of these surveys were conducted within this timeframe and a new survey will need to be conducted following WDFW survey guidelines to properly evaluate potential project impacts. If the preliminary survey shows the project can be located and built without impacting eelgrass and kelp beds, the preliminary survey will meet the needs for mapping the project area. However, if the project footprint potentially impacts existing eelgrass or kelp beds an advanced survey will be required to quantify the extent of impact, and a monitoring and mitigation plan developed to ensure no net loss.

WAC 220-660-380 pertains to the construction of a new residential pier, ramp, and float in saltwater. Over-water and in-water structures can alter physical processes that create or maintain habitat that supports fish life. These processes include light regime, hydrology, substrate conditions, and water quality. Light reduction or shading is the main impact of these structures to fish life at critical life stages by affecting survival of aquatic plants. Aquatic plants provide food, breeding areas, and protective nurseries for fish life. The code, updated July 1, 2015, is based upon the best available science and incorporates rules that are designed to reduce the impacts of these structures. As part of the hydraulic review process, the proposed structure will be carefully evaluated to see that it meets the requirements of this code.

Regarding the proposed desalination system WDFW would like to have a better understanding of potential impacts the concentrated brine solution may have on adjacent invertebrate fauna and macroalgae species at the outfall location. WDFW requests that an analysis be performed or data provided discussing any potential impacts to invertebrate species and macroalgae, and show at what distance from the outfall the concentrated brine is diluted to background levels.

Thank you for the opportunity to review this project proposal and to provide the above comments. If you have any questions, please call me at 360-466-4345 ext.251.

Sincerely,

Doug Thompson
Habitat Biologist

State of Washington
Department of Fish and Wildlife
Mailing Address: PO Box 43200, Olympia, WA 98504-3200, (360) 902-2200, TDD (360) 902-2207
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Thank you for the opportunity to review this project proposal and to provide the above comments. If you have any questions, please call me at 360-466-4345 ext.251.

Sincerely,

Doug Thompson
Habitat Biologist

Julie Thompson

From: Bob Elford <bob@sanjuanislands.com>
Sent: Tuesday, November 21, 2017 8:25 PM
To: Julie Thompson
Subject: Honeywell improvements.

SJC DEPARTMENT OF
NOV 27 2017
COMMUNITY DEVELOPMENT

Hi Julie, my name is Bob Elford and I've known the Honeywell's from the very first day they came to San Juan Island. I have also lived for 18 years on the property that the Honeywell's now own. I am in complete support of everything the Honeywell's have done on the property, and have already improved it immensely. A desalination plant seems like a no brainer, as the water has always been a factor when dealing with that area of the island. They have done everything that you and the state have asked them to do,and not only with this latest project, but with every aspect of this multimillion dollar project.

And the dock is one that really surprises me. I have lived in western Washington for 60 plus years. And have boated my entire life. I am just amazed that there is such a high hurdle to obtaining a dock permit. Docks on islands only makes common sense. My parents had them, uncles, friends. And now, certain groups seem to think that if they don't want to look at something, then it shall be deemed illegal. But with all due respect that is Bull shit. (I say " stay away") They have been very good neighbors, and have single handedly supports dozens of local family over the last 3 years, and all I see is delays, harassment and False accusations from every branch of government, Oh and historically Mar Vista always had a dock, so what is the problem.

If it is the neighbor to the North, who I know has complained. They applied for a dock permit, but were not allowed to obtain one because of his proximity to the False Bay preserve, Now he seems to think that if he can't have one,(I'm a billionaire so why can't I get one. BO HO HO.) no one can.

This isn't Dave and Nancy's problem, They paid dearly for the tidelands. Maybe the winer next door should have bought Mar Vista, it was on the market for years and years.

The Honeywell's have done so many wonderful things to that property, but so many people just want them hung out to dry because they hired a crazy guy to clear a hillside of alders and willows while they were away.Oh and by the way, most of the stumps that they got busted for, I had been cutting for years in order to keep the views opened for paying guest.) just had to throw that in.

Please give them the same treatment you would give any other resident.

I know what was originally purposed and agreed too, as far as the rebuilding of cabins during the R.P.A. and now the same group that is fighting the dock and desalination plant want them to not be able to have another cabin there, and you are hopefully going to tell them to just go away, right?please Stop being afraid of their attorney.

Do the right thing PLEASE APPROVE THE HONEYWELL'S LATEST PERMIT.

And if opponents try and use the argument that it will hurt the whales. Please!

Stop the flotilla of tour boats and then we can talk about whales. Like I said,I lived 18 years on that land and No one in my family or guest ever reported seeing a whale in the cove where the dock is slated to be located. And anyone that says they have is not telling the truth, or extremely lucky. And annually very few kayaker venture near that area of the island. Only ones brave enough and even some of them needed assistance. A dock there could save a life.😉 thanks for your time with this matter.

Sincerely Bob

Sent from Bob's iPad

Julie Thompson

From: Michelle Borsz <mborsz@icloud.com>
Sent: Tuesday, October 31, 2017 7:29 PM
To: Julie Thompson
Subject: Orca Dreams Dock Comment

Hello Ms. Thompson,
I'm writing to share my serious concern about the dock proposal on the west wise of San Juan Island. "Orca Dreams" would literally be an orca nightmare if this project goes through. The construction noise; the destruction of habitat that forage fish and salmon (the orcas' food source) rely on; the physical barrier on the side of the island most commonly frequented by endangered orcas ... I can't believe this is even being taken seriously to be approved! Surely you have seen and heard the compounding reports that suggest these orca are on the brink of extinction. Please do not destroy the very creatures that make San Juan Island so unique. They are dying a death of a thousand cuts right now. Please do not add several more. Thank you for considering.
Sincerely,
Michelle Borsz

Julie Thompson

From: Whitney Neugebauer <whitney.neugebauer@gmail.com>
Sent: Monday, October 30, 2017 9:43 PM
To: Julie Thompson
Subject: Orca Dreams LLC Dock SEPA Comments

S.J.C. DEPARTMENT OF
OCT 31 2017
COMMUNITY DEVELOPMENT

Hi

To whom it may concern:

These comments are in regard to the Orca Dreams LLC dock and desalination proposal.

The proposed development is in a critical area for endangered Southern Resident killer whales and their primary prey, also endangered Chinook salmon. The location is also in the habitat of the lower food chain items such as forage fish and eel grass. The development of this area should be avoided in order to recover these species. The county's SEPA determination of non-significance is incorrect and I oppose this determination.

I am the Director of the nonprofit Whale Scout. Together with out partners we have a land-based whale watching station at the Westside Preserve to the north of the property. Our goal is to help other watch whales in a responsible manner and to provide stewardship for the Westside Preserve. The precedence and habitat destruction this project will cause will impact our program and the survival of the whales we watch. Further, there is a proposal to create an MPA along the westside of San Juan Island which potentially would prohibit boat traffic. A private dock would go against the purpose of this MPA.

I am aware of an appeal submitted by the University of Washington. I second the grounds of appeal described including: Improper scope of potential adverse impacts, Insufficient characterization about the site conditions in immediate vicinity of the project, Improper site characterizations, Insufficient disclosure of operational impacts resulting from the proposal, Insufficient analysis of environmental impacts resulting from temporary and long-term impacts within highly sensitive shoreline environment, Insufficient analysis of need for the proposed dock or the or reasonable alternatives to the proposed dock, Insufficient analysis of the cumulative impacts resulting from approval of the first dock to be developed on the west San Juan Island, and Insufficient analysis of how the project achieves no net loss to critical habitat and aquatic species in the immediate vicinity of the project and surrounding areas.

Thank you

Whitney Neugebauer

Director, Whale Scout

Julie Thompson

From: Jim And Shirley <jimshirley@centurylink.net>
Sent: Tuesday, October 17, 2017 4:33 PM
To: Julie Thompson
Subject: Help preserve Mar Vista Resort property...September 17, 2008.

S.J.C. DEPARTMENT OF
OCT 20 2017
COMMUNITY DEVELOPMENT

Hi, Julie....

This is what we islanders signed up for, to protect "Mar Vista"

I live on False Bay Drive and I knew Lee, the former owner, and she was a wonderful lady and protected her land and loved doing so. She loved all the birds and the creatures in the water and I am sure she is turning over in her grave knowing what has happened to her "home".

I cannot attend the meeting on Friday, but, I think that the powers- to -be need to be reminded of why we signed the petition, to protect what Lee loved and protected.

I know that it is too late to do much, as the Honeywell's have destroyed what Lee so loved, but, please stand up for all of us and say "NO DOCKS" and, also, say, 'NO MORE CONSTRUCTION OF ANY KIND".

I met Nancy Honeywell when she first moved to the islands and she told me that she had purchased "Mar Vista" and I said to her.''Please do not destroy this beautiful piece of property" and she assured me that she would not do so. She did tell me that she would make some improvements, but, that she would not do anything that would damage the environment. She lied to me and I will never forgive her for that.

My boss and I flew over the property and we were disgusted by what we saw. There was someone on the porche taking pictures of our plane and shaking his fist at us and we said to each other, "This is not good".

The Honeywell's got this property "cheap" and I know it was on the market for a long time, but, it should have stayed on longer .They should have been "interviewed" and asked what they had in mind for it, I know it is too late now, but, let me rant and rave, it makes me feel better.

Julie, I am not very good at explaining myself well, but, I know that everyone will do their best to stop anymore destruction of this once beautiful piece of property.

Thank you for your time and reading my rantings. Good Luck at the meeting and I am sure you will all let us know what transpired.

Have a good evening.
Shirley Reuscher
412 False Bay Drive

- MENU

Help preserve Mar Vista Resort property

- Wed Sep 17th, 2008 11:58pm
- LETTERS TO THE EDITOR

As you may know, the Mar Vista Resort property adjacent to False Bay has recently been put on the market due to the death of the estate owner.

This property is commercially licensed, making it a hot commodity as a potential site for resort development.

I ask you to please join me in encouraging a conservation-minded future for the Mar Vista property. If acquired by the San Juan County Land Bank, this land could be well-managed and open to low-impact public access.

Regardless of who buys the property, the Land Bank can encourage it to be managed in an environmentally respectful manner. The voice of the public community can be powerful in influencing the sale and development of land, as we learned so recently with Turtleback Mountain. Land Bank needs our show of support in this matter.

This 60-acre property is unique in many respects. It is still relatively undeveloped, making it a habitat that supports a wide variety of marine and terrestrial wildlife including otters, deer, eagles, foxes, harbor seals and more. The prairie fields support one of the few remaining sites of a threatened species of wildflower.

Additionally, Mar Vista provides stunning views of Haro Strait, the Olympic Mountains and west side sunsets, and could potentially provide a public access point to the westside shoreline in the "gap" area between Land Bank's Westside Scenic Preserve and American Camp. It provides excellent shore-based whale-watching, and would make a great additional site for land-based research.

You can help by signing this petition to San Juan County Land Bank that I have created, which encourages an environmentally-friendly future for the land. You can also help by leaving your own comments on the petition site; forwarding this petition to your friends, family, neighbors, and coworkers; and by promoting it on your own Web site or blog. Additionally, you can write a letter to the San Juan County Land Bank or local newspaper.

As I outlined this petition, I sat at the point of Mar Vista overlooking the water. A Steller sea lion swam by. A harbor seal poked its head up in a nearby kelp bed. A deer browsed in the brush a few yards away. Murres, gulls, cormorants, herons and harlequin ducks flew by. All this reemphasized for me how beautiful this place is and why I am so inspired to help protect it. This was the first place I saw orcas from shore, and where I truly fell in love with the islands nine years ago.

Margaret Mead said a small group of committed individuals is all it takes to change the world. I hope you will join me in being one of those individuals that helps change San Juan Island for the better.

Please sign this petition, found at

here

Thank you for your support,

Monika Wieland
San Juan Island

S.J.C. DEPARTMENT OF
OCT 04 2017
COMMUNITY DEVELOPMENT

To:

Erika Shook, Director
Julie Thompson, Planner III
San Juan County Department of Community Development

Re: Project application permit # PSJ000-17-0003

As a long-term resident of San Juan Island living on False Bay Drive, I am writing this letter in opposition to the project proposed in this permit application. The components of the proposed project are ill-conceived, and represent a threat to the scenic beauty of the area and the natural environment in and near False Bay.

Revegetation: Project proposal indicates that *"Other than reseeding the disturbed shore and upland areas are completed, no other re-vegetation is proposed."* What if project work activities result in removal of native shrubs, bushes, or trees? "Re-seeding" would not be sufficient to replace bushes, shrubs, or trees along the shore area.

While the project application indicates that there will not be fuel distribution included with this dock, the proposed dock still represents a risk of discharge of pollutants into the protected False Bay area due to maintenance activity, informal fueling (e.g., using portable fuel cans), accidents or weather events. These potential pollutants include: gasoline; lubricating oil; hydraulic fluids; cleaning solvents; bottom paints; detergents; paints, varnishes or other finishing oils, and other chemicals associated with typical boat maintenance activities.

The proposed dock location is very close to rocks that will pose a navigation hazard for boats which would be using the proposed dock. Even with the proposed warning buoy, there would be significant risk of boats colliding with, striking, or grounding on these rocks, given the sometimes-substantial currents, winds, and waves which occur in this location.

This project proposal at times indicates that this is a "community dock" but in other locations indicates that requirements for "community docks" do not apply because this proposal will serve a "family compound." As a family compound, this dock is not serving a "community."

The project proposal for reverse osmosis system indicates that this system will at times return ~9,000 gal/day of concentrated brine at a point along the west side of the mouth of False Bay. During flood tide, it is common for the current to sweep along the west side of the bay into the bay, which will carry the concentrated brine into the bay over the tidelands in the Friday Harbor Marine Labs reserve.

The project proposal for the reverse osmosis system includes a response to requirements for Section 18.50.350(B5), prohibits use of reverse osmosis systems for providing primary water supply within new subdivisions. The applicant's response indicates "There are no plans to subdivide the land. The facility will provide water to augment an existing water system."
Surely there were requirements at the time of the previous subdivision of this property for sufficient water to support the subdivision, in which case there should be no need for "augmentation" of the system.

The proposal for the reverse osmosis system indicates that construction will require removal of native grasses and shrubs, but proposes only grass reseeding for revegetation. Surely revegetation requirements which dictate that previous native vegetation must be replaced are not simply referring to planting of grasses.

In addition to these issues, please consider the following:

This proposed project represents a substantial visual impact on the shoreline. A dock in this location will substantially alter the shoreline in this area, substantially reducing enjoyment of

(over)

the Bay and this cove by kayakers that use this area (including myself) as well as other recreational boaters.

Approval of this project would set a bad precedent: There are currently no docks on the south and west side of San Juan Island from Fish Creek all the way up to a point north of San Juan County Park, providing for a wild shoreline that is of great attraction to tourists and residents that use these waters. Permitting this dock will set a precedent, likely resulting in additional dock applications for other "open cove" locations along the west side of the island.

Application for this dock was denied previously. Why should it be considered now?

For these and other reasons, I respectfully ask that you not permit this proposed project.

Respectfully yours,

Ross Lockwood
524 False Bay Dr
Friday Harbor, WA 98250

FRIDAY HARBOR LABS
UNIVERSITY of WASHINGTON
College of the Environment

S.J.C. DEPARTMENT OF
OCT 03 2017
COMMUNITY DEVELOPMENT

Julie Thompson, Planner
San Juan County Community Development and Planning
P. O. Box 947
Friday Harbor, WA 98250

Oct. 2, 2017

Comment on PSJ000-17-0003_Orca Dreams LLC

Overview: I find it distressing that San Juan County CDP, after withdrawing their Determination of Non-Significance on the first version of this project, have now issued a new MDNS even though the scope of this project is even larger than the original scope, and the most of the essential issues have not changed.

Other personnel from the University of Washington have already commented on issues relating to the dock, including noting that additional surveys have demonstrated that there is eelgrass within the project area as well as a high diversity of other marine organisms. I wish to add here a few comments about the plan for a Desalination system.

Other permit applications for desal systems that I have commented on have included far more detail than this one does; this application is lacking in critical information.

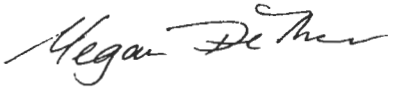
1. The amount of brine that the applicants estimate will be released is given (over 9000 gallons a day – a large amount) but not the critical information about the salinity of this brine. High-salinity water *can be toxic* to marine organisms, which are adapted to a rather small range of salinity (locally, about 22-30 parts per thousand). Eelgrass, for example, is often found in lower-salinity water but not highly saline conditions, suggesting that the release of large amounts of brine near eelgrass beds could have a significant negative impact, especially if that salinity is high. The information about brine concentration should have been provided, and greater analysis given to its effects on marine resources.
2. The application states that the brine will be released through a diffuser, but no information is given on the design of this diffuser, nor on *the circulation of water in the area around the diffuser*. Brine released into an area of little water exchange will remain pooled on the bottom where it will kill marine life. Given the diversity and high biological value of the marine life in this area, the issue of brine retention should have been explored in more detail.
3. The application states that there are not threatened or endangered species likely to be impacted by the dock or desal system. However, they note that there are Northern Abalone in the area, and this species is listed as a State Candidate (the 3rd highest category of concern). Dumping brine and adding a dock with the potential for fuel spills and concentrated bottom paint residues into a region where there is a state-listed species is a potentially significant impact.

4. The application states that there are "no hazardous chemicals" associated with the RO system, but then clearly states that there will be a 40 gallon tank of chlorine. Chlorine is used in such applications *because it is a strong poison*, for both terrestrial and marine life. A 40 gallon tank of a poison qualifies as hazardous, realistically if not legally. What safeguards are there to keep that chlorine out of the environment?
5. Most desalination systems need to use various chemicals for periodically removing deposits from the equipment; sometimes those descaling agents are flushed out with the brine. There was no mention in the application of the use and disposal of cleaning solutions for this system; since the applicants are envisioning fairly high-volume, year-round use, this issue should have been addressed.

In my view, these issues with the desalination system in addition to problems (detailed by others) associated with the proposed dock suggest that the County should withdraw its Determination of Non-Significance.

Thank you for giving FHL the opportunity to comment on this application.

Sincerely,



Dr. Megan Dethier
Associate Director for Academics and the Environment
Friday Harbor Laboratories

Julie Thompson

From: Jane Wentworth <jane@ckwentworth.org>
Sent: Friday, September 22, 2017 12:04 PM
To: Julie Thompson
Subject: Permit # PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Julie Thompson
Permit # PSJ000-17-0003
RE: Project description : 4 slip dock and RO desalination system

I offer the following comments in opposition to the proposed dock on False Bay:

1. Part of this 260 foot dock will occupy publicly owned tide lands, cutting off the public's access to enjoy what is at present a heavily used area for kayaking and nature watching. There is no pressing need for this taking and the public would suffer the loss for no good reason.

2. The construction and ongoing use of the dock presents a direct threat to the biological preserve through noise, potential fuel and chemical spills, bottom-land shading, changing the water dynamics and siltation of the bottom under and around the dock.

3. A precedent will be set for large developments along this shore where there are at present no docks from Cattle Point to Mitchel Bay.

4. The location is not only important for the studies by the University of Washington but to the many endangered species that frequent the location. The mouth of False Bay is prime feeding habitat for the Southern Resident Orca. Eel grass beds are a nursery for multitudes of organisms including the forage fish that the endangered Chinook Salmon depend on. It is an inappropriate location for a dock with it's accompanying environmental risks.

5. The rocks within the cove are haul-out locations for marine mammals including seals and otter. There are regulations protecting these animals from harassment and a special permit allowing this harassment would be needed.

6. There is no demonstrated need for this dock because the property owners have easy access to commercial docks within 10 minutes drive from their property.

7. The desalination plant is a new feature to this project. Does anyone know the impacts of pumping hypersalinated water back into the bay? And the energy it takes? Please be certain this will not adversely affect marine organisms.

8. I like to kayak in the area and feel having a dock will be an eyesore for all of us who walk , whale-watch or kayak around the mouth of the bay and will strongly impact the people living on the north side of False Bay.

Thank you for your consideration.

Jane Wentworth
368 MacGinitie Rd

Friday Harbor WA 98250

Julie Thompson

From: Planning and Permit Services LLC <francine@rockisland.com>
Sent: Friday, September 22, 2017 4:14 PM
To: Julie Thompson
Subject: RE: Comments on Orca Dream Dock and DeSal proposal

FYI - Mr. Harvell's letters are not consistent with the four eelgrass surveys that have been conducted for this site.

From: Julie Thompson [mailto:JulieT@sanjuanco.com]
Sent: Friday, September 22, 2017 7:52 AM
To: Francine Shaw (Francine@rockisland.com)
Subject: FW: Comments on Orca Dream Dock and DeSal proposal

From: C. Harvell [mailto:cdh5@cornell.edu]
Sent: Wednesday, September 20, 2017 9:49 AM
To: Julie Thompson <JulieT@sanjuanco.com>
Cc: bjswalla@u.washington.edu; sundberg@centurytel.net; ojgraham@me.com; kloring@sjilaw.com
Subject: Re: Comments on Orca Dream Dock and DeSal proposal

Dear Julie:

Please find attached a map of the location of our transects in the Pocket Bay at the edge of False Bay to append as a supplement to the Seagrass Heath Report I submitted on Sept 10.

Sincerely,
Drew Harvell

Drew Harvell Professor

Department of Ecology and Evolutionary Biology
Faculty Fellow, Atkinson Center for Sustainable Future
Cornell University
Fellow, Ecological Society of America
http://www.eeb.cornell.edu/harvell/

From: Julie Thompson <JulieT@sanjuanco.com>
Date: Wednesday, September 13, 2017 at 10:10 AM
To: Drew Harvell <cdh5@cornell.edu>
Subject: RE: Comments on Orca Dream Dock and DeSal proposal

Thank you for your comments and supplying me with all this interesting information.

From: C. Harvell [mailto:cdh5@cornell.edu]
Sent: Sunday, September 10, 2017 5:04 AM

To: Julie Thompson <JulieT@sanjuanco.com>
Cc: Billie Swalla <bjswalla@u.washington.edu>; Katie Loring <kloring@sjilaw.com>; Kimbal Sundberg <sundberg@centurytel.net>; Olivia Graham <ojgraham@me.com>; C. Harvell <cdh5@cornell.edu>
Subject: Comments on Orca Dream Dock and DeSal proposal

Dear Julie:

Please find attached my letter of concern about the proposed Orca Dream development and the surprising Determination of Non-Significance by the county. I have also appended our recent report on the health of eelgrass beds in False Bay, including the Pocket Bay. I submit these in the context of our larger studies on the health of eelgrass in the San Juan Islands and Puget Sound, and so also attach a couple of our earlier publications documenting a significant health threat to our local seagrasses from seagrass wasting disease (Groner et al 2014, 2016).

Sincerely,

Drew Harvell

Drew Harvell, Professor

Department of Ecology and Evolutionary Biology
Faculty Fellow, Atkinson Center for Sustainable Future
Cornell University
Fellow, Ecological Society of America
http://www.eeb.cornell.edu/harvell/

Julie Thompson

From: charlie nolan <charlie@nolanemail.com>
Sent: Thursday, September 21, 2017 9:42 AM
To: Julie Thompson
Subject: Orca Dreams application

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Ms. Thompson,

My family, ownders of Kanaka Bay LLC, have property that fronts on the West side of False Bay, across from the Honeywells' estate. We have owned the property for over 30 years. Three generations of our family have loved walking the tidelines at low tide, savoring the pristine ambience, which in our experience, having done our share of travel, is absolutely unique. The thought of having this sanctuary despoiled by the construction of a private dock immediately adjacent to the preserve is totally against the character of the habitat. It is particularly offensive that part of the dock would be located on public tidelands. Finally, I don't know what a desalination system is, but I am certain in my belief that it doesn't belong in this unspoiled environment.

We urge the San Juan County government to reject Permit Application #PSJ000-17-0003.

Sincerely,

Charles and Eleanor Nolan

Julie Thompson

From: Albert Shepard <albert.shepard@gmail.com>
Sent: Wednesday, September 20, 2017 6:02 PM
To: Julie Thompson
Subject: PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Ms Thompson,

I am writing in opposition to the four slip dock and RO desalination system proposed for the west side of San Juan Island. As a former San Juan County resident, naturalist and museum curator, I am deeply concerned with the project's detrimental effects on the marine habitat and ecology. Of equal importance in my mind would be the loss this spectacular uninterrupted rocky shoreline. The proposed boat dock and water treatment plant represents an unnecessary development that will have devastating effects.

With all due respect to everyone involved, please deny this application. Thank you for your attention and deliberation of this important issue.

Sincerely,

Albert Shepard

FRIDAY HARBOR LABS

UNIVERSITY *of* WASHINGTON

College of the Environment

Professor Billie J. Swalla
Director of FHL

Wednesday, September 20, 2017

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Attn: Julie Thompson
San Juan County Community Development and Planning
Friday Harbor, WA 98250

Re: Orca Dreams Dock and Desalinization System Permit# PSJ000-17-0003

Dear Julie,

We are writing concerning the requested permit by Orca Dreams LLC for construction of a large, four slip community dock and a reverse osmosis desalinization system to provide potable water for six single-family residences.

As you are aware, the University of Washington owns the nearby property known as False Bay (TPN 353312001000), and maintains it as a marine reserve for studies of sedimentation, marine invertebrates, fish and other scientific disciplines. False Bay has been the site of UW Friday Harbor Laboratories (FHL) Faculty, undergraduate and graduate student studies since the inception of FHL - from the 1904 Station Diary, the students visited "Kanaka Bay" - "MUD - Acres of it!" – which was present day False Bay.

FHL studies leading to PhDs in False Bay date back at least to Mario Pamatmat (PhD UW 1966) and continue with current studies being conducted by faculty, undergraduate students and graduate students. We have all of these studies documented in our library and with student papers and are very concerned that the marine reserve will be compromised by boat traffic, which brings oil and gas, noise, and increased human impacts to any area. We do understand the desire to have a boat in the San Juan Islands, but there are at least two marinas that have slips available within 15 minutes of the Orca Dreams LLC.

The proposed dock, which would be on the northwest tip of Orca Dreams LLC's property, would be just south of the entry to the tidal lands in False Bay, located in an East-West fashion, which is known to disturb juvenile Chinook salmon, the preferred prey of the Salish Sea resident Orca Pod. False Bay serves as an important biological preserve, and is used for a variety of research projects in connection with the University's Friday Harbor Labs. Given the importance of these tidal lands, the University is extremely concerned with the potential adverse environmental impacts resulting from the addition of a large dock and desalinization plant.

Marine reserves contribute to the health of the marine environment because they provide a place for marine animals to feed, live and, most importantly, lay eggs for the next generation. Any toxins released from the dock and boat traffic will surely be swept into the shallow waters of False Bay. To suggest that these toxins would not harm the invertebrate and fish eggs and embryos in False Bay is simply not true.

An Environmental Impact Statement (EIS) is required to analyze the following potential adverse environmental impacts of a dock and also a desalinization plant, which is sure to add super saline water to this pristine environment:

- Displacement of Public Property: The cove and pocket beach where the dock is to be located will extend out state-owned tidelands and waters, at the very end of a bay that has been studied and preserved for over 40 years.

- Displacement of Sea Grass Habitat: The dock, boats, and people will displace sea grass habitat used by fish, birds, and invertebrates and increase disturbance at the mouth of False Bay.

- Displacement of Existing Recreational Use: False Bay is a favorite kayaking spot for many San Juan Island residents. It is one of the few undeveloped shorelines on San Juan Island that is accessible to the public. A large dock with boat traffic would mar the quiet and natural beauty of False Bay and negatively affect the aesthetics.

- Disturbance of Ongoing Research: University of Washington has multiple scientists who are conducting research in False Bay and use the bay as a valuable field site for Friday Harbor Laboratories marine courses and field trips. The disturbance created by increased boat traffic will mar the False Bay marine reserve, affecting ongoing experiments. Gas and oil are killers of embryos and larvae, which are abundant in the spring and summer months in False Bay.

- Negative Impact on Resident Orcas: The West Side of San Juan Island is a critical feeding ground for the three resident Orca pods. The increased boat traffic and degraded environment is likely to negatively affect the Orcas and their salmon food source. Orcas have been shown to be negatively effected by noise, and baby whales are more sensitive to sound than the adults.

- Impact on Pocket Beach: Research has shown that pocket beaches are the most critical habitat to preserve for juvenile chinook salmon and other fishes, including herring and rockfish. This large dock will negatively affect the ability of fish to use the pocket beach for food foraging, and the gas and oil from boat traffic will kill their eggs and embryos, preventing new generations of fish.

- Impact on Marine Birds: The cove is a refuge for marine birds, including harlequin, goldeneye, bufflehead, merganser, black turnstone, black

oystercatcher, grebe, loon, and cormorant. Boat traffic will disrupt this critical refuge for marine birds with noise and disturbance of birds landed to eat and rest.

- Sea Grass and Algae will be negatively impacted: Recent sea grass surveys done by FHL researchers and others later in the season has shown eelgrass at the mouth of False Bay, which at times extends into the pocket bay. This is critical for stabilization of the sand in False Bay.

In addition, Friday Harbor Labs has the following concern about the project:

- This dock will be the only one on the West Side of San Juan Island: There are currently no docks from Cape San Juan to Mitchell Bay, making the west side a refuge for whales, fish, birds, shellfish, crabs and invertebrates who make their home near and in False Bay.

- This dock is unlikely to last in this Location: The dock will be exposed to the high winds and high waves from the Strait of Juan de Fuca and Haro Strait and is likely to be eventually destroyed by winter storms. This would lead to oil spills and debris damage in False Bay, from the boats, the dock and the floats.

- The Port of Friday Harbor Marina and Jensen's Marina are close: The owners justify the dock by stating that there are no slips at the Port of Friday Harbor. However, the Port has openings every winter. The San Juan Island marinas are a much safer and sheltered way to care for boats, reducing the damage that they may cause in high storms.

We sincerely hope that you reconsider the issuance of this permit. Many of the FHL scientists have written their own letters, magnifying their concerns where they have scientific expertise. In addition to the potential adverse environmental impacts there are a multitude of other reasons to deny this application or significantly mitigate the environmental impacts associated with the project as noted in our letter. My contact information is below; please do not hesitate to contact me if you would like to discuss any of our comments.

Sincerely,

Billie J. Swalla
Director, Friday Harbor Laboratories
Professor of Biology
University of Washington
Phone: 206-616-0764
Email: bjswalla@uw.edu

Cc: Associate Dean Stephanie Harrington, UW College of the Environment
Megan Dethier, FHL Associate Director for Academics and the Environment, FHL
Jeanette Henderson, Executive Director, UW Real Estate
Julie Blakeslee, Environmental and Land Use Planner, UW Real Estate

September 20, 2017

Julie Thompson
Planner III
SJC Department of Community Development

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Transmitted by email to juliet@sanjuanco.com

Dear MS Thompson:

RE: 9/6/17 MDNS for Orca Dreams, LLC four-slip dock, navigation buoy, and RO system, Permit #PSJ000-003

I am writing, again, to comment on Orca Dreams, LLC request to construct a 260-foot private dock and other infrastructure affecting the False Bay area near my home. I have previously commented extensively to your department and the Army Corps of Engineers in 2014 and 2015 on other Orca Dreams dock proposals. I have attached those letters for reference. As you know, the False Bay neighbors and others have spent considerable personal time and resources responding to repeated applications by Orca Dreams, LLC. The amount of public and government resources required to respond to Orca Dreams development activities is unprecedented in my view.

The current Orca Dreams proposal adds an RO desalination system, the navigation buoy, and increases moored boat size to 35-feet. The MDNS includes 16-Mitigation Measures to support the county's Determination of Non-Significance. After careful review of the MDNS and supporting documents, I continue to believe the dock portion of the project presents a significant environmental risk to False Bay and requires an EIS. I offer my concerns having considerable knowledge of the False Bay ecosystem, my professional experience as a habitat biologist who has reviewed and studied numerous marine construction projects and oil spills, and my multi-decadal experience as a yacht owner/captain in the Pacific Northwest and Alaska. Because this project requires the long-term commitment of public-owned resources and tidelands for exclusive private use, and poses unmitigated risks and identified potential impacts to the False Bay Biological Preserve (FBBP), the dock should be reduced in scope and size, and confined to the Honeywell's private second-class tidelands. Simply said, there is no private need for a dock that outweighs the public need to protect the False Bay Biological Preserve.

In October 2105, after the previous round of review, DCD withdrew its Determination of Non-Significance citing eight specific concerns. Among those concerns was the lack of information about potential pathways of pollution from the dock to the FBBP. DCD recommended the applicant conduct a study of nearshore current dispersal from the dock site before resubmitting their SEPA application. This would have been useful to evaluate both the dock and the RO system. The applicant chose not to conduct that study and instead offered unsupported opinions about the site being 'well flushed' and pollution impacts 'not significant'. Moreover, the applicant continues to misrepresent the dock and RO is sited ¼ mile south of the FBBP. I've checked with several sources including the Assessor's Office. My sources indicate UW-owned tidelands lay within 25-feet of the proposed dock. The lateral lines of the 2-acre second class tideland (parcel #34045002) claimed by Orca Dreams for a portion of their dock site have not been determined. For now, Orca Dreams tidelands border the tidelands deeded to UW in 1974. The effects of the dock and its operations on the 43-year old FBBP is a serious matter that needs to be resolved before the county can adequately determine the environmental impacts of this project.

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

My specific comments follow and are additive to the attached letters:

Proposed Conservation Measures (Mitigation) General Comment: How will the county enforce their Mitigation Measures? Most require specialized knowledge and expertise that the county lacks. Will the DCD building official or code enforcement officer be assigned to monitor Orca Dreams to determine compliance? What county resources are available for required oversight? Given Orca Dreams' track record of misrepresentations on permit applications, violations, fines, appeals, intimidation of neighbors, and court decisions, what assurances do the county and public have the applicant will voluntarily adhere to these Measures?

1. Timing limitations Comment: Timing limitations to protect fish life during construction are prescribed by the WA Department of Fish and Wildlife (DFW) in the Hydraulic Permit Approval (HPA). In commenting on the 2015 Orca Dreams Corp of Engineers permit application, DFW recommended denial of the dock permit because of concerns over impacts to fish and shellfish. Surprisingly, DFW was not included for comment on this MDNS.
2. Dive survey Comment: Who determines 'qualified diver'? Dive surveys by others deemed 'qualified' to survey eelgrass and other marine life by the applicant were conducted contrary to DFW HPA requirements and had to be done over. Post-construction dive survey(s) should be a requirement to document the as-built structure and long-term disturbance/sedimentation of marine life.
3. Pile removal Comment: WA DNR has updated BMPs for piling removal that supersede EPA 2007 http://www.dnr.wa.gov/publications/aqr_rest_pileremoval_bmp_2017.pdf
4. Rubber cushion No comment
5. Collar No comment
6. Observers Comment: Who determines 'qualified observer'? What is the purpose of measure 6.e. restricting pile driving/removal operations to daylight hours only from September 1-15 to 'protect marbled murrelet nesting'? Should we conclude after September 15, pile driving/removal can occur during twilight/darkness? How does extending the work day in dim light affect observers' ability to detect marine wildlife?
7. SCCP Comment: This should be Spill **Prevention,** Containment, and Countermeasure Plan (SPCC). It applies to construction operations storing/handling more than 10,000 gallons of petroleum products over/near water. Similar to HPA, if the contractor's SPCC is a requirement by others, why is it considered mitigation by the county? Moreover, SPCC plans may reduce the size and frequency of oil spills, but they do not prevent them. Many notorious spills including *Exxon Valdez* and *Deepwater Horizon* occurred with SPCCs in place. In my experience, once oil is spilled into the environment, particularly at a remote and exposed location like Orca Dreams, it is very difficult to respond to and clean up.
8. Eelgrass and macroalgae Comment: How can this measure stipulate eelgrass and macroalgae will not be adversely impacted? The Biological Assessment depicts a "dense band of macroalgae", Laminaria and Ulva, under portions of the dock. It is unlikely the dock and its operation will avoid impacting eelgrass and it's impossible to avoid impacting macroalgae.
9. Stormwater BMPs Comment: BMP C101 Preserve Natural Vegetation was not followed when the applicant clear-cut 2-acres of adjacent natural shoreline vegetation in 2014. Three years after this egregious violation, the shoreline has not healed and there are fresh signs of shoreline erosion. Following this violation, the applicant continued, unsuccessfully, to overturn Ecology at the Shoreline Hearings Board and Superior Court. Given Orca Dream's track record, the county and public should not be assured the applicant will voluntarily adhere to this, or any other BMPs.

10. Construction cleanup Comment: See general comment above regarding enforcement. The Orca Dreams property has been under constant disturbance and construction for three years, with no completion in sight. Why should the county or public be assured construction debris will be cleaned up at the end of this project, or that additional construction and cumulative impacts will not occur in the future?
11. Petroleum products. Comment: See general comment above regarding enforcement. Fuel and oil are required to operate power boats. They are routinely transferred from docks to boats in 6-gallon boat cans and quarts of oil, regardless of whether major fueling occurs at a fuel dock. Moreover, even well-maintained engines drip small quantities of fuel/oil. Bilge water discharged by automatic pumps is often contaminated with small amounts of petroleum. If this Measure is intended to be a permanent requirement, how will the county or public know that 'petroleum products will not be transferred on or near the dock'?
12. Navigation buoy. Comment: This stipulation states 'installed' but does not require 'maintained'. If the navigation buoy is a permanent requirement to prevent grounding, it must be maintained for perpetuity. Again, who is responsible to monitor and enforce the buoy requirement?
13. Channel approaches. Comment: There are many rocks, shoals, kelp beds and wave swell in the approach to the dock site. A prudent mariner would hesitate to enter this area with anything larger than a skiff on a calm day. Miscalculation by an inexperienced or reckless operator could result in grounding and disaster. Who will enforce the prohibition on impacts to the False Bay Biological Preserve? How are Orca Dreams' dock operations consistent with the research and education mission of the FBBP?
14. Seasonal removal. Comment: Seasonal removal is a requirement in perpetuity. Who is responsible to ensure that the ramp/float is removed by November 1? See general comments above regarding enforcement. Removal of the ramp/float during winter months is no guarantee the dock and boats will escape storm damage. During May-October 2004-2008, gale force winds ranging from 35-43 knots and significant wave heights ranging from 4.5 - 6 feet were measured at the NOAA New Dungeness Buoy #46088. These data are relevant to analyzing environmental conditions at the dock site.
15. Orca Dreams SPCC Plan. Comment: See 7. and general comment above regarding enforcement. This Plan contains four pages of BMPs that are enforceable only at the applicants' personal discretion. How will the county determine the SPCC is 'strictly followed' for perpetuity? How does the county respond when a concerned citizen observes BMPs not being followed?
16. Compliance with UDC. Comment: This appears to be the only measure the county has authority for. My check of the UDC could not identify any 'applicable' sections pertaining to docks or RO systems. The DCD should identify specific UDC sections that are relevant to mitigating the impacts of this project.

Dock Siting and Design Considerations

DCD is taking on faith Waterfront Construction will engineer and construct the Orca Dreams dock to withstand all anticipated environmental conditions at the site. Moreover, DCD assumes applicants and their 'guests' are prudent mariners who are experienced in boat handling, follow BMPs, and make no navigational mistakes. A mistake or oversight here could lead to damage/loss of all or a portion of the dock with its attached boats. An accident would be catastrophic to the FBBP because boats and their integral fuel tanks can be holed and swamped many ways including penetration by broken dock fittings, grounding on submerged boulders and rocky shores, and battering by drift logs. Holed boat(s) leaking the contents of their fuel tanks could amount to hundreds of gallons of spilled fuel and oil. According to

ECY, as little as one quart of spilled oil can contaminate 100,000 gallons of seawater.
https://wsg.washington.edu/wordpress/wp-content/uploads/marina-handbook.pdf
Between 2011-2015 some 6,000 gallons of diesel and gasoline were reported spilled by recreational boaters in Washington; most spills were less than one gallon.

No engineering calculations/analysis were provided so it is not possible to determine whether this dock is designed for all wind/wave conditions at this site. The applicant provided no data/analysis of the physical environmental conditions at the site including wind speed, directions, current speed, direction, wave height, etc. DCD should consult with an independent professional marine engineer before approving the design of the applicants' dock.

The following pictures were taken of the Orca Dreams dock site during a 2015 storm looking south from the FBBP. At the time, NOAA Buoy #46088 reported gusting WSW 23 kts, wave height 3' :

Note the breaking surf and drift logs at the dock site. As previously mentioned, NOAA data indicates winds to 43 knots (50 mph) and seas to six feet can occur during the months of May-October. This site has no natural protection from westerly winds/seas that come in from the Strait of Juan de Fuca and Haro Strait. An additional problem with this site is the collection of large drift logs. Drift logs act as multi-ton battering rams on boats and docks. Large mats of drift kelp from the adjacent bull kelp beds snag on boats, docks, and mooring systems, weighing them down and increasing strain on lines and dock fittings.

The Department of Ecology Shoreline Management Handbook, Chapter 12, Piers, Docks, and Overwater Structures provides guidance that has not been followed for this project:

- *Pier and dock construction shall be restricted to the minimum size necessary to meet the needs of the proposed water-dependent use.*
- *Assure that shoreline modifications individually and cumulatively do not result in a net loss of ecological functions.*
- *Use a north-south pier-dock orientation*
- *Avoid prop scour by placing docks at depths that are at least 4-5 feet above MLLW.*
- *Docks, piers and floats should be 8 meters from native aquatic vegetation* (including macroalgae) *or the distance that the structure will cast shade, whichever is greater.*
- *New activities and structures should avoid existing native vegetation attached to or rooted in the substrate.*
- *If space is not adequate, moorage facilities should be prohibited.*
- *Limit the length of piers and docks. Boats that need adequate water depth or located away from eelgrass areas can be moored to buoys.*

- *Allow private docks only if there are no other alternatives, such as marinas within a reasonable distance, shared facilities with neighbors, or mooring buoys.*
- *Limit the amount and types of mooring facilities that are allowed for each residence. If a mooring buoy is needed for adequate water depth, a long dock may not be necessary.*
- *Limit the total square footage of the overwater structures.*

Dock Operation Considerations

The Applicant proposes to moor four boats up to 35-feet in length. The identified 'safe channel' to the dock is through a narrow NE-SW gap through kelp beds, boulders, and shoals to the north side of the dock. The proposed 'navigation buoy' marks a group of shallow rocks off the end of the dock. Other unmarked shallow rocks and kelp beds occur in the dock area including approaches from the 'navigation buoy' to the south side of the dock. Following this 'safe channel' at low speed purportedly will 'prevent impacts to marine vegetation, pocket beach, and the marine preserve".

Below is a stock picture of a Boston Whaler 350 Outrage, of the type that Orca Dreams dock may use:

The specifications for this boat include:

LOA	35'-6"
Beam	10'-10"
Draft	25"

Weight w/engines, fuel and water	16,000 lbs.
Maximum horsepower	1,050
Minimum horsepower	750
Fuel capacity	400 gallons gasoline
Minimum speed (600 rpm)	2.5 knots

There are significant problems docking a large boat at the Orca Dreams site. A boat of this type requires more than a boat length to turn and leave the dock. Slowing a 16,000+ pound boat travelling at its slowest speed (2.5 knots) requires significant reverse thrust. Wind, waves, and operator inexperience/distraction increases the maneuvering space 2-3 times or more. Backing straight away reduces maneuverability and risks damaging the propellers on rocks or fouling in kelp. Even under calm conditions, any large boat maneuvering to/from this dock is likely to disturb sediments and adjacent eelgrass and macroalgae beds. The operator would have to use thrust from the engines to slow the boat and spin it, producing considerable prop wash. Proximity of the dock to the FBBP almost guarantees chronic boat disturbance will occur in the Preserve. Boat operations will likely scour a circular basin north of the dock devoid of vegetation. Rather than leaving this to chance, the applicant should be required to delineate and mark the restricted boat maneuvering area around the dock that avoids impacts to the FBBP.

Diagram from BA-p.20 showing channel, rocks, buoy and eelgrass. Approx. southern boundary of UW-FBBP (red line) added:

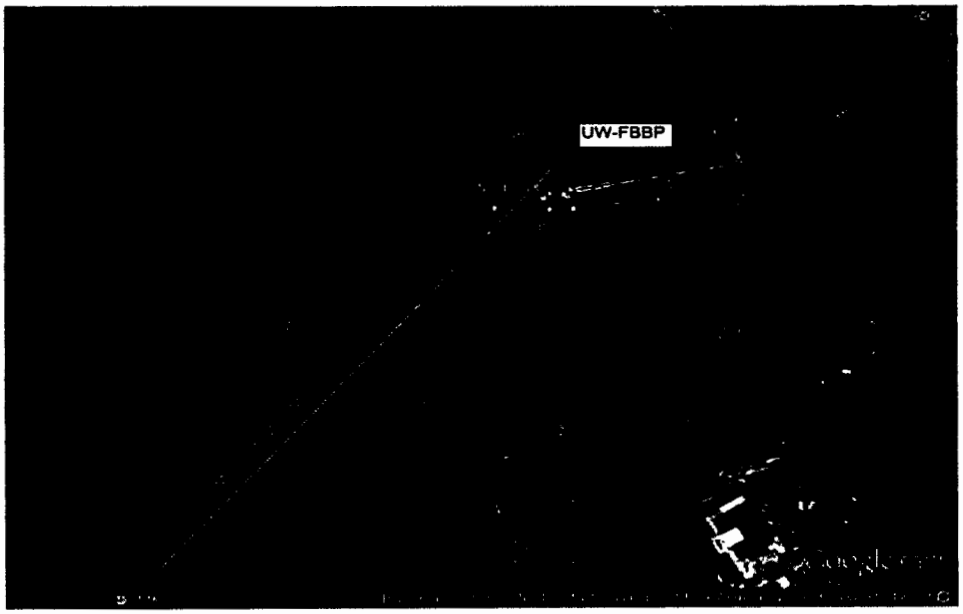


Figure 4. Deep safe-channel that boat operators will use to approach the dock. Following this channel will prevent impacts to marine vegetation, pocket beach and the marine preserve.

In summary, this is a poor location for a large private dock. The Orca Dreams proposal greatly exceeds the water-dependent needs of the upland owner. Reasonable access to the water can be met with a

smaller dock sited on the private tidelands. Reasonable alternatives for large boat moorage are available at existing marinas on San Juan Island. The False Bay Biological Preserve is a world-class asset for the University of Washington and San Juan County. It should not put at risk by hubris and private interest.

This concludes my comments.

Kimbal Sundberg
1853 False Bay Drive

From: Kimbal Sundberg [mailto:sundberg@centurytel.net]
Sent: Thursday, June 18, 2015 9:04 AM
To: 'susan.m.powell@usace.army.mil'; 'ecyrefedpermits@ecy.wa.gov'
Subject: Orca Dreams, LLC., NWS-2014-476

U.S. Army Corps of Engineers (ACE),
Regulatory Branch
ATT: Ms. Susan Powell
PO Box 3755
Seattle, WA 98124-3755

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

WA Department of Ecology (DOE)
ATT: Federal Permit Coordinator
PO Box 47600
Olympia, WA 98504-7600

RE: Orca Dreams, LLC., NWS-2014-476

I am writing to comment on the referenced application for dock work on San Juan Island.

I am a 28-year property owner on False Bay near the project the location and have made my permanent home here since 2000. I am a retired habitat biologist and lead technical advisor for salmon recovery for the San Juan County Lead Entity. I also serve on the DHCS Water Resources Management Committee and volunteer for COASST (False Bay), the Land Bank, and San Juan Preservation Trust. I am very familiar with the location and environment of the proposed project. I am a biological oceanographer by training. My professional career has involved, among other things, conducting environmental analyses and assessing the impacts of shoreline development, including docks and marinas. My comments follow:

1. This project has the potential to have direct impacts on Endangered juvenile Chinook salmon. The San Juan Island Salmon Recovery Strategy identifies the project area as a High Priority Fish Use Region with medium probability for rearing Chinook salmon. The San Juan Salmon Recovery Chapter was developed with local input. It is an ecosystem based recovery plan supporting multiple salmon species with an emphasis on Puget Sound Chinook Salmon listed under the Endangered Species Act in 1999. The local salmon recovery chapter is part of the Puget Sound Chinook Salmon Recovery Plan which was adopted by NOAA January 2007. Research in Puget Sound as summarized by Clancy, et al 2009 (PSNRP) has shown that juvenile salmon avoid swimming under floating docks and piers because of shading effects. Research in the San Juan Islands (Beamer & Fresh 2012) has identified pocket beaches, including the project location, as among the most important shoreline habitats for juvenile Chinook salmon. Best management practices call for docks to be placed in deep water and oriented north-south, where possible, to minimize impacts to the bottom and reduce shading effects. The proposed dock is in shallow water and oriented east-west, casting the maximum shadow with the most deleterious potential impact on juvenile Chinook salmon. The proposed grating will decrease, but not eliminate adverse shading effects. Float tubs, structural components, moored boats, and other non-transparent materials reduce ambient light transmission to the seabed by more than 50%. Sediment pumping will be caused by the floating dock over the shallow seabed exposed to wave action. Prop wash will be caused by boats using

the dock in this shallow cove. These impacts will likely increase bottom erosion, instability, and degrade the eelgrass/surf grass meadow found here.

2. The numerous bedrock outcrops and thin veneer of bottom sediments at this site are indicative of a shallow high-energy seafloor poorly suited for driving piles. The duration of adverse environmental impacts of on-site construction including noise and disturbance to fish and wildlife are directly related to the duration of driving and drilling needed to properly set 10 proposed piles. And, given the extreme wind/sea conditions at this site, the safety, durability, and environmental impact of the structure is directly related to how well the piling are secured to the bottom.

3. There are many surface indications of unstable soils in the vicinity of the project. Within the project location, including the shoreline to the north, there is extensive evidence of active bank slumping. And, the applicant has done extensive, and unauthorized clearing of native shoreline vegetation. Moreover, the applicant was recently cited/fined by DOE for causing, among other things, increased potential for shoreline erosion. I have observed tilted/fallen trees, seral vegetation, erosion, and exposed soils on this bank. These are common indicators of soil creep and instability. The Coastal Zone Atlas of WA classifies the shoreline at the project location as Eroding Bluff. The construction and operation of the proposed dock/marina by three families will significantly increase foot and vehicular traffic to the site and put additional erosional stresses on the Eroding Bluff and shoreline.

4. A check of NOAA's buoy data near the proposed dock site (Station 46088) confirms that storms with peak wind velocities exceeding 50 knots and seas exceeding 9 feet occur during the winter months of November through March. Westerly/southwesterly winds routinely exceed 30 knots during the summer months. There is little natural protection afforded at the dock site to westerly winds and waves off the Strait of Juan de Fuca. Storms bring drift logs weighing multiple tons to batter the shoreline and any docks/boats located there. There are good reasons why no docks have been permitted on the exposed western shore of San Juan Island. The environmental impacts from storm damage could be significant and include grounding, sinking, boats/floats set adrift, and associated release of oil, fuel, and other pollutants hazardous to fish and wildlife. A storm-related incident here could easily require emergency services to save lives and put first responders at risk. Sea level rise will greatly exacerbate the natural hazards at this site.

5. The project site is located in the Critical Habitat (summer feeding area) for the Endangered Southern Resident Killer Whale (SRKW). SRKW commonly migrate and feed on Chinook salmon along the western shoreline of San Juan Island. It is known that SRKW react to underwater noises, including boat engines and traffic by altering their normal behavior, and in some cases, cease feeding and leave the area. The construction and operation of the proposed dock will increase underwater noise and disturbance in this area. The impacts of increasing underwater noise and disturbance was cited by NOAA as justification for proposing a ½ mile "no go zone" for boat traffic along the west coast of San Juan Island. Moreover, SRKW are dependent on Chinook salmon for their diet. Scientists believe Chinook salmon recovery is directly linked to recovery of SRKW (see comment 1 concerning impacts on Chinook salmon).

6. The project will restrict public access to the shoreline and reduce recreational opportunities. The proposed pier and ramp on public tidelands will the cause people and

wildlife to have to climb over the structure to continue to utilize the public shoreline. Railings/fencing and private property signs will further discourage access to public tidelands. Similarly, the extreme length of the dock will discourage public use of this site by kayaks and other personal small watercraft. Recreational opportunities in the San Juans are degraded when public tidelands, waters and resources are appropriated for private use.

7. There is no compelling need for a private dock in this area, other than for the convenience of the upland land owner. The impacts identified above can be avoided because private boat moorage is available at the nearby Port of Friday Harbor, in addition to other existing marinas on San Juan Island. Alternatively, the upland owner can apply for a mooring buoy, which would be far less impactful to the environment and public access than the proposed dock.

Prior to issuing a decision concerning permit(s) for this project, I request ACE and DOE to conduct a Public Hearing in Friday Harbor to address issues contained in my comments and those of others. I understand that this project will require a Substantial Development Permit, among others, under the San Juan County Shoreline Master Program. It would be premature for ACE to issue a decision on the subject permit, until the additional environmental analyses and public comment opportunities are incorporated into the overall project review.

Thank you for the opportunity to comment.

Sincerely,

Kimbal Sundberg
1853 False Bay Drive
Friday Harbor, WA 98250

May 30, 2014

San Juan County
Community Development & Planning
PO Box 947
Friday Harbor, WA 98250

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

ATT: Julie Thompson, Planner III juliet@sanjuanco.com

RE: PSJ000-14-0008

I am writing to comment on the determination of non-significance (DNS) and SEPA for joint use residential dock submitted by Francine Shaw, Law Office of Stephanie Johnson O'Day (LOSJO) on behalf of Orca Dreams LLC. I am a 27-year property owner on False Bay and have made my permanent home here since 2000. I am a retired habitat biologist and lead technical advisor for salmon recovery for the San Juan County Lead Entity. I also serve on the DHCS Water Resources Management Committee and volunteer for COASST (False Bay), the Land Bank, and San Juan Preservation Trust. I am very familiar with the location and environment of the proposed project. I am a biological oceanographer by training. My professional career has involved, among other things, conducting environmental analyses and assessing the impacts of shoreline development, including docks and marinas.

In addition to the SEPA Environmental Checklist (EC) I have also reviewed the Orca Dreams LLC Biological Assessment prepared by Fairbanks Environmental Services and the Shoreline Permit Application prepared by LOSJO. I will confine my comments to the DNS/SEPA-EC at this time.

The subject SEPA-EC contains numerous misrepresentations of fact and analyses. There are significant adverse environmental impacts not identified. There are adverse environmental impacts that have not been adequately discussed.

My comments specific to the SEPA-EC, referencing their numbering system, are as follows:

A.11. *The entire decking of the fixed pier, ramp and float will be constructed with 70% light penetrating grating which will allow approximately a significant amount of sunlight falling on the dock to pass through the structure to the seafloor below.* COMMENT: Quantify "approximately a significant amount". The environmental impact of this project on endangered juvenile Chinook salmon, other species, and their habitat is directly related to the overwater structure being proposed. Research in Puget Sound has shown that juvenile salmon avoid swimming under floating docks and piers because of shading effects. Research in the San Juan Islands has identified pocket beaches, such as the project location, as among the most critical shoreline habitats for endangered juvenile Chinook salmon. Best management practices call for docks to be oriented north-south, where possible, to reduce shading effects. The proposed dock is oriented east-west, casting the maximum shadow with the most deleterious impact on juvenile Chinook salmon. The proposed grating will decrease, but not eliminate adverse shading effects. Float tubs, structural components, and other non-transparent materials make the

effective shading of the dock more than 60%. And, there would be 100% shading under the six boats moored to the dock.

A.11.3. *On-site construction will consist of driving or drilling the pier piles near shore and driving outboard piles.* COMMENT: Describe how many piles will require drilling v. driving? The numerous bedrock outcrops and shallow, wave-scoured sediments/biota at this site are indicative of a high energy seafloor poorly suited for driving piles. What subsurface data has the applicant obtained? The duration of adverse environmental impacts of on-site construction including noise and disturbance to fish and wildlife are directly related to the duration of driving and drilling needed to properly set 10 proposed piles. And, given the extreme wind/sea conditions at this site, the safety, durability, and environmental impact of the structure is directly related to how well the piling are secured to the bottom.

B.1.d. *Are there any surface indications or history of unstable soils in the immediate vicinity?* COMMENT: The applicant checked NO, a misrepresentation of fact. There are many surface indications of unstable soils in the vicinity of the project. Within the tax parcel, including the shoreline to the north, there is extensive evidence of active bank slumping. I have observed tilted/fallen trees, seral vegetation, erosion, and exposed soils on this bank. These are common indicators of soil creep and instability. The Coastal Zone Atlas of WA classifies the shoreline at the project location as Eroding Bluff.

B.1.f. *No clearing is necessary for construction of the proposed joint use dock.* COMMENT: The SEPA-EC question asks, "Could erosion occur as a result of clearing, **construction**, or **use**? The applicant checked NO, another misrepresentation of fact. The construction and use of the proposed dock/marina by six families will significantly increase foot and vehicular traffic to the site and put additional erosional stresses on the Eroding Bluff. SEPA requires the applicant to address the erosion impacts of construction and use. What additional shoreline vegetation clearing will be required? What upgrades to the primitive road and trail will be required to accommodate increased use including vehicles? What shoreline structures will be constructed to house boat gear including oars, lines, PFDs, gas & oil, outboards, dinghies, kayaks, etc.? These are important questions to be addressed by SEPA. The applicant states that water and electricity will be extended to the dock, but does not discuss how this will be done nor prescribe any measures that will be used to minimize soil erosion from excavating, ditching, etc. It is known, but not addressed, that sediment erosion occurs in the vicinity of piling due to increased/altered currents. The phenomena called "sediment pumping" is an erosional impact not addressed, caused by floating docks over a shallow seabed exposed to wave action. Moreover, the prop wash from operating six 30' boats in this shallow cove is likely to increase bottom erosion, instability, and degrade the benthic community including eelgrass. The applicant does not adequately discuss cumulative impacts that could cause erosion including additional vegetation clearing, road upgrading, and construction of accessory structures associated with the proposed dock.

B.1.g. *The existing pier head shore mount consists of 63 sq.ft. of impervious surface. It has been located on the property for many years....* COMMENT: The referenced 'pier head shore mount' is located on the active beach surrounded by drift logs. Describing this as part of the property is a misrepresentation of fact if it is located all, or in part, on state-owned tidelands. A valid shoreline boundary survey should be provided to establish which portions of this project

are, in fact, *on the property*, and which are on public tidelands. That the applicant proposes to incorporate this derelict wooden "pier head", a dubious- looking block of weathered timbers, rusted bolts, and corroded iron as a structural element in a large dock constructed in an extreme environment raises serious questions about the competency of the project design/build team.

B.2.a. *Long term emissions created by this proposal will be minimal and consist of exhaust from boats using the dock.* COMMENT: There is growing scientific evidence that Polycyclic Aromatic Hydrocarbons (PAHs) from boat exhaust and unburned gasoline and oil, are detrimental to salmon and forage fishes, including the salmon and forage fish that utilize this pocket beach habitat. PAHs are passed up the food chain into birds and marine mammals. Introducing a new chronic source of PAHs from six or more large marine engines in this shallow and relatively pristine nearshore environment is not inconsequential (minimal) to the fish and wildlife living here, and may be significantly detrimental to their health.

B.3.5. *Does the proposal lie within a 100-year floodplain?* COMMENT: The applicant checked NO yet the entire project lies within the coastal floodplain. The applicant provides no analysis of how this project will be affected by coastal flooding and sea level rise. According to the recent National Climate Assessment, the Pacific Northwest should plan for 24-inches of sea level rise by the end of this century. Due to its exposed location and using best available scientific information, the proposed +2-ft EHT pier will likely be overtopped during storm surges within the decade and submerged by the end of the century. Sea level rise continues to erode the soft base of the bank with consequences to the Eroding Bluff and all built structures on this shoreline.

B.3.a. *The property lies adjacent to the Strait of Juan de Fuca, a marine water of the state.* COMMENT: The proposed project is located in an area of extreme western exposure to winds and waves from the Strait of Juan de Fuca and Haro Strait. A check of NOAA's nearby buoy data confirms that storms with peak wind velocities exceeding 50 knots and seas exceeding 9 feet occur during the winter months of November through March, and can spring up at any time. There is little natural protection afforded by this cove to westerly winds and waves which bring drift logs weighing multiple tons to batter the shoreline and any docks/boats located there. There are sound reasons why no docks are located on the exposed west shore of San Juan Island. During COASST surveys of False Bay I routinely see remnants of docks washed up in winter along with broken beach stairs, Styrofoam logs, boat parts, etc. Last winter, during a King Tide storm, I witnessed waves/spray washing over False Bay Drive. The environmental impacts from storm damage could be significant and include grounding, sinking, boats/floats set adrift, and associated release of oil, fuel, and other pollutants hazardous to fish and wildlife. A storm-related incident here could easily require emergency services to save lives and put first responders at risk.

B.3.c.2) *Could waste materials enter ground or surface waters?* COMMENT: The applicant checked NO, another misrepresentation of fact. Boat docks and marinas commonly produce waste materials that enter surface waters including spills of gasoline, diesel and oil; paints, solvents, and varnish; scrapings and sanding dust; bilge pumping; tools/trash/debris that blow off/fall into the water; fishing line; fish/crab guts; food waste; and cleaning detergents/soaps. It is not credible to assert that no waste will enter this cove from the proposed marina.

B.3.d *No mitigating measures are proposed...* COMMENT: This is an inadequate analysis and response to commonly known environmental impacts of docks and marinas (see B.3.c.2 above).

B.4.a. COMMENT: Misrepresentation of fact. Eelgrass occurs at this site, yet it is not checked.

B.5.b. COMMENT: Misrepresentation of fact. The applicant is requested by SEPA to list "any threatened or endangered species known to be on or near the site". Threatened and endangered species likely to occur on/near the project site include: Chinook salmon, chum salmon, cutthroat trout, steelhead trout, canary rockfish, marbled murrelet, Southern Resident killer whale and Steller sea lion. Candidate/Species of concern occurring on/near the project site include: Pacific herring, copper rockfish, quillback rockfish, black rockfish, china rockfish, widow rockfish, tiger rockfish, common murre, bald eagle, peregrine falcon, golden eagle, western grebe, Pacific harbor porpoise, pinto abalone, island marble butterfly. The applicant is required to address how these protected species are impacted by the proposal, including proposed mitigation during construction and operation.

B.5.d. COMMENT: This section needs to identify and analyze impacts of the proposed dock and marina operations to wildlife species' use of nearshore habitat, including the nearshore rock outcrops immediately adjacent to the proposed dock. For example, I have observed the rock group near the end of the proposed float is used for hauling out by harbor seal, and roosting/ feeding by harlequin duck, and shorebirds including black turnstone and black oystercatcher. I have also observed killer whale, Steller sea lion, Pacific harbor porpoise, marbled murrelet, common murre, Pacific herring, bald eagle, western grebe and juvenile salmon on or near the site. The proposed dock will greatly increase human disturbance of this habitat degrading its value to wildlife. The close proximity of the proposed dock to nearshore rock outcrops allows access by dogs and other predators, additionally degrading habitat value. Damage from the float anchoring system to benthic biota should be analyzed and discussed.

B.7.b 2) *Short term noise sources will be associated with the construction of the dock when the piles are driving, the barge mount crane sets the fixed pier, ramp, and float sections in place and hand held construction tools. After construction is complete noise sources will be from boat motors and voices from people using the dock.* COMMENT: The applicant fails to identify or analyze the effects of underwater noise from operation on endangered Southern Resident Killer Whale (SRKW). It is well known that SRKW react to underwater noises, including boat engines and traffic by altering their normal behavior, and in some cases, ceasing feeding and leaving the area. The effects of underwater boat noise and disturbance was cited by NOAA as the primary justification for proposing a ½ mile "no go zone" along the west coast of San Juan Island. The proposed project is centrally sited within critical habitat used by SRKW for summer feeding. It is a serious omission that the applicant fails to acknowledge or analyze the operational impacts of the proposal including increase boat engine noise and traffic disturbance on the endangered SRKW and their critical habitat. Similarly, the applicant fails to identify and analyze the impacts of noise and disturbance from construction and operation on the numerous marine bird species using this area, including threatened and endangered species.

B.10.b. *Views for the water toward the dock will be altered due to the presence of a dock in an area where no dock exists.* COMMENT: The property owners have recently severely impacted

the aesthetics of the relatively natural shoreline of this cove in the False Bay Area by illegally clear cutting the bank. The west coast of San Juan Island is known by visitors and residents alike for its relatively natural and wild looking shoreline. This dock/marina would be the only in-water facility visible for more than 14 miles along west coast of San Juan Island from Mitchell Bay to Fish Creek.

B.10.c. *The dock will be low in profile and will be set along a 40 foot steep shoreline bank which will allow the dock to blend in with its surroundings.* COMMENT: This is a gross misrepresentation of fact. To assert that 10 galvanized steel pilings, a 271' dock and six 30' boats set in a natural pocket cove will "blend in with its surroundings" strains credulity. It should also be noted that the applicant's recent, extensive, and unauthorized clearing of shoreline riparian vegetation, including numerous mature native trees makes it less likely for this, or any other proposed shoreline development on this property to "blend in with its surroundings".

B.11.b. *There is no site illumination planned with the proposed dock construction.* COMMENT: The applicant's response is misleading. SEPA-EC asks about the finished project not construction. Lack of dock illumination creates a serious safety and navigation hazard. The applicant has identified that the dock will have electricity extended from the uplands. Why are dock lighting and its impacts not addressed?

B.12.b. *Would the project displace any existing recreational uses?* COMMENT: The applicant has checked NO, a misrepresentation of fact. The proposed pier height of 2 feet extending perpendicular to the beach will block beach walkers. Wildlife including deer will need to climb over the structure to utilize their beach habitat. Railings/fencing and private property signs will further discourage access to public tidelands. Similarly, the extreme length of the dock protruding into the cove will discourage public access by kayaks and other watercraft. The structure would become a private intrusion into a public space and reduce shoreline recreational opportunities. My friends and family have used this cove for recreation and wildlife watching for over 27 years. We have accessed this site numerous times by kayak and skiff, and via upland trails, with permission of landowners. We have included this cove in the annual Audubon Christmas Bird Count for over a decade because of its productive marine bird community. The proposed project will significantly curtail our recreational use of this cove, as it will for friends and family, adjacent property owners and their families, and countless residents and visitors who recreate in the False Bay Area.

B.12.c. *The dock will enhance the ability of six families to enjoy recreational boating and fishing activities offered in the San Juan archipelago.* COMMENT: Existing recreational activities by the public, more numerous than those of six families, will be degraded by the proposed dock/marina. Recreational opportunities in the San Juans are degraded when public tidelands, waters and resources are appropriated for private use. Alternatively, the six families can avoid degrading their neighbors' recreational experiences, and enjoy their boating and fishing activities from the Port of Friday Harbor, as we and others happily do.

B.15.a. Would *the project result in increased need for public services...* COMMENT: The applicant has checked NO. Studies in San Juan County have shown increasing population and infrastructure demand more public services than the tax base supports. Boating activity and marinas typically place increasing demand on the Coast Guard, Sheriff, IOSA, CBP, and

environmental protection agencies. It is a more efficient use of county services, and consistent with the Shoreline Master Program, to make use of existing marina facilities and their support services, like the Port of Friday Harbor, rather than a proliferation of private docks.

B16.b. *The applicant intends on (sic) extend water and electrical lines to the dock.* COMMENT: This was not adequately discussed in the SEPA nor were any potential environmental impacts of extending utilities analyzed.

Thank you for opportunity to comment.

Sincerely,

--Signed--

Kimbal Sundberg
1853 False Bay Drive
Friday Harbor, WA 98250

Julie Thompson

From: Kendall Scott <kscott112@gmail.com>
Sent: Wednesday, September 20, 2017 7:31 PM
To: Julie Thompson
Subject: SEPA Comments for Permit #PSJ000-17-003 (4 slip dock and RO desalination system)

Dear Ms. Thompson,

I urge the county to deny Permit #PSJ000-17-003 for the proposed dock and desalination plant at the mouth of false bay on San Juan Island. I currently live in Chicago but grew up on the island and return home frequently to visit family and friends. Here in Chicago, I often find myself talking to mid-westerners about the island where I grew up and am always pleased to hear how many people know of the San Juans, have been there on a trip, or hope to travel there someday to see our whales and explore such a beautiful spot. Across the country people know what I've known all my life--that the islands are a special place.

I strongly oppose the proposed dock and desalination plant because I believe it is a threat to what makes the island so special. Please consider the harm that the dock will do to the pristine west side, which people around the country know and treasure. This dock represents a grave threat to the wildness that makes San Juan Island unique, and it shouldn't be allowed

Thank You,

Kendall Scott

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Julie Thompson

From: Tom Schultz <rainshadow@rockisland.com>
Sent: Wednesday, September 20, 2017 11:10 PM
To: Julie Thompson
Subject: Orca Dreams Proposal PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Julie,

I caught one potential error in the proposal while re-reading Part 2, Appendix A regarding the light availability test.
Please add this comment to my comments sent yesterday

The light penetration lab test for the SunWalk Decking done by *Reliable Analysis Inc* (Birmingham, Michigan) uses an average of light penetration (intensity) through this decking material with an artificial light source that was calculated at incident angles from '90' degrees to '0' degrees. An average intensity that includes using an angle of of 90 degrees to the deck (directly overhead or at 'the zenith') would be significantly higher than would occur in nature. The sun never comes close to 90 degrees relative to the earth surface (directly overhead) at 48 degrees N latitude where the project site is located even at the summer solstice!

The sun only reaches 90 degrees relative to the earth's surface in the tropics between the Tropic of Cancer and the Tropic of Capricorn which are both at 23.5 degrees of latitude (north and south respectively).

These figures need to recalculated for an average of the sun's true angles especially during the months of full dock use at the correct latitude which is approximately 48 degrees, 25m, 8.5 sec North. The current figures are incorrect for what actually would occur at this site and should not be considered reliable for this project.

Also, there is no data that includes the shading of sunlight by vessel hulls up to 35 ft long and approx. 4 to 15 ft in height, during the time they moored at the float. This area could be even larger than the float itself in shading the seagrasses, micro and macro algae that exist below the project site.

Thanks Again.

Tom Schultz
242 Rainshadow Rd
Friday Harbor, WA 98250

Julie Thompson

From: Janice Riley <bountifulgarden@rockisland.com>
Sent: Wednesday, September 20, 2017 2:41 PM
To: Julie Thompson
Subject: Permit PSJ000-17-003 4 Slip Dock and RO Desalination System

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

September 20, 2017

Dear Ms. Thompson:

I am writing in response to the Honeywell's/Orca Dreams' recent application for a 4 Slip Dock and RO Desalination System.

I am very concerned that an EIS is not being required, especially considering the history of San Juan County's past interpretation of information supplied by Orca Dreams and the issues in that same information provided by Orca Dreams. If not for the considerable actions of those concerned about past proposals, much would have been missed in this process. Surely, extreme caution is the best course at this point in time.

I have lived several miles north of the property in question for over 20 years, on the shore of the west side of San Juan Island. It is a very fragile environment and those properties near the False Bay Preserve are some of the most fragile on the entire west side.

Why the County is allowing the further erosion of these environments is of great concern to me. I will let the scientific community speak to the specific issues, but as a home owner I feel my property is being put at risk as no doubt, the approval of this proposal will open the west side to similar development proposals. One property owner's determination that they have the "right" to do this due to their philosophy regarding property "rights", could, and likely will, be the catalyst to alter so many others' property rights in a way that they deem inappropriate and against their "rights".

I've read, in the documents provided, of many instances where the development proposed will be monitored. Is the County going to being ensuring this is done? What documented, publicly available process is being put in place to allow those concerned to monitor this? How is the county protecting itself from possible lawsuits that will cost all citizens of this County money, if this process isn't dealt with as proposed? The track record of how this process has been handled by the County and Orca Dreams does not bode well for this not being a likelihood.

Who is monitoring the actions promised once the dock/desal are completed? Will the information regarding such monitoring be available via public record? What is the cost to the County and the people of San Juan Island for management of commitments made by the owners of Orca Dreams? Will the owners or their representatives be on site to observe weather conditions, particularly when the dock is in full form/usage? I have observed **extreme storms** during the period the dock is proposed to be in place, yes in the summer/fall periods. Will Orca Dreams be held liable for any environmental damage incurred if an incident occurs? Will they be responsible for cleanup and restoration? Who will monitor whether observers are in place at all times?

To endanger so much to enable one property owner the ability to not drive a few miles to several available dock areas is highly disturbing. The property rights of the Honeywell's do not mitigate the property rights of those others who live on this island, those who care about the aesthetic/environment on this island.

Thank you for your consideration.

Sincerely,

Janice Riley

Stony Brook University

Department of Ecology and Evolution

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

September 20, 2017

Dear San Juan County Community Development and Planning,

I am writing concerning the Mitigated Determination of Non-significance on the Application for a Shoreline Permit by Orca Dreams LLC for a residential dock for up to 4 boats and a RO desalination plant on tax parcel number 353344008.

I am a marine ecologist and Professor at Stony Brook University (State University of New York Stony Brook) and an Aldo Leopold Leadership Fellow in Conservation through the Ecological Society of America. I was an undergraduate at the University of Washington (received Degrees in Biology and in Biological Oceanography), and have been conducting research on the shores of the San Juan Archipelago since that time. I have been conducting ongoing research on the shore communities of False Bay and the nearby pocket bay to the south (formerly Mar Vista) since 1990 and have close to annual data for the invertebrate animals, algae and seagrass along those shores for the past 25 years. I have also been a property owner on the island for almost 20 years, and spend at least three months a year here, primarily in the summer for my research.

I have written to you before in 2014 and 2015 regarding similar plans for a dock on this property, and in those letters outlined a number of important issues.. In addition to the dock, this new proposal includes a desalination system, whose installation and operation will also have sever negative impacts on the local marine species, including those that are protected and of commercial value.

1. Still of concern is the placement of the dock and the new desalination pipes (which will require digging up the benthos to bury), and intake and especially outfall of water. The original proposal placed the dock on the property line between the Orca Dreams property and the University of Washington marine reserve, which is an extension of the reserve known as the False Bay Reserve. I am including the deed for the UW property, which clearly states that the reserve includes the bottomlands extending from Government Lot 9, which includes a portion of the the Orca Dreams property. The new project states that Orca dreams owns bottomlands extending from Government Lot 1, which borders GL 9. The second proposal in 2015 moved the proposed dock 10' from the reserve and property line. The current plan shows none of the property lines, and makes no mention of the distance from the reserve for the proposed dock and desalination trenching and hyper saline water outfall. However, overlaying the map presented in this proposal with that from 2015 makes the dock in the same place - a mere 10 feet from the UW marine reserve. The proposed dock will also encroach upon (and may cross into) the Fish and Wildlife False Bay Reserve WAC 220-16-440(1), which extends the University of Washington Reserve. There is no question that construction of the dock, trenching for the desalination facility, hyper saline effluent, as well as the presence of the dock and boater activity will impact this protected habitat as well as the species that use the habitat. Again, I am happy to provide published studies

STONY BROOK, NEW YORK 11794-5245 TEL: 631-632-8600 FAX: 631-632-7626

that show the impacts of hardened structures on eelgrass, and other essential species. In addition, the effluent from the desalination plant will result in thermal pollution and hypersaline stress on organisms, especially animals. Based on long term temperature loggers I have had within the marine reserve, the temperature of ambient seawater at this site is 10-11°C (50-54°F) in the summer, and 8-9°C (46-48°F) in the winter, and salinity is typically 29. The effluent from a desalination facility will be at least 10-15°C warmer that the surrounding water, and the salinity may be as high as 60 or greater. Most animals in this habitat are adapted to cold water and intolerant of warmer temperatures. From my personal research, even animals that live in the intertidal zone in this region can have larvae and juvenile stages that are physiologically stressed and can even die when temperatures are above 15°C. Similarly, hypersaline water poses additional physiological stresses on these organisms.

2. Impact on eelgrass, macroalgae, and marine fauna is still of concern, including in the marine reserve. Surveys of eelgrass, macroalgae, invertebrates and surfgrass were conducted in the winter (January and February). That time of year, the eelgrass and macroalgal cover is a an extreme minimum (due to the short day length). This would be like going to an alpine meadow in the winter and declaring that there are no wildflowers and little grass, while going to that same place in the summer one realizes that the grass is knee deep and there is a huge abundance and diversity of wildflowers. The eelgrass and all macroalgae expand greatly in the summer, and many algae die back and have no macroscopic portion visible in the winter. I am including photos from the proposed site showing a great diversity of kelp (> 5 species) and other macroalgae as well as eelgrass in the area that will be impacted by this dock and desalination project. There are over 100 species of invertebrate animals that I have long term data on that will also be impacted, and do not appear in the surveys. Although abalone have not been seen in recent times at this site, due to their recent decline throughout the region, historic surveys have included them in this area.

3. Other fauna will also be impacted. Killer whales are regularly seen swimming into False Bay through the pocket bay where the proposed dock will be sited. They regularly swim between the large rock where the dock will be anchored and the shore into the bay. In addition, the large rocks in this pocket bay are regular haul out areas for seals. I have seen seals on these rocks every low tide when I have been at this site. They are also one of the few sites where oyster catchers are regularly seen, and are likely to nest. The large rocks that will anchor the dock are also one of the few sites where California mussels are found in the San Juan Archipelago. Because of the exposure of this site to strong tidal currents and storms, it has unusually high local biodiversity for the region.

4. There will be continued sedimentation, expansion of eelgrass and reduced depth of the pocket bay through time. The rocky outcrop (which appears as a large rock island in most photos of the area) was once isolated by deeper water. However, as sedimentation has increased with the rapid expansion of eelgrass, it is now possible to easily walk to that island during the extreme low tides of the summer in knee boots (-3.5' tides). The shallows surrounding this island make it impossible for boats to enter that area of the pocket bay except at extreme high tides. Thus to keep large boats there would require dredging to allow boats to pass most of the summer, when extreme low tides are a regular occupancy for 2 of the 4 weeks each month. In addition, a dock would increase the sedimentation by slowing the water flow, and expanding the eelgrass bed into the area. In addition, because -4 foot tides are not uncommon in many years,

having the desalination effluent at -5 foot depth will be a problem for organisms, including those in the marine reserve.

Once again I am including photographs of the area to illustrate the points that I have made as well as the deed for the UW reserve.

Allowing this proposed dock will jeopardize our marine resources, the health of our shorelines, and risk important and threatened species. If you would like any further information that I might be able to provide, please let me know.

Thank you for your consideration of my concerns.

Sincerely,

Dr. Dianna K. Padilla, Professor
Department of Ecology and Evolution
Stony Brook University
Stony Brook, NY 11794-5245
Dianna.Padilla@stonybrook.edu
631-632-7434

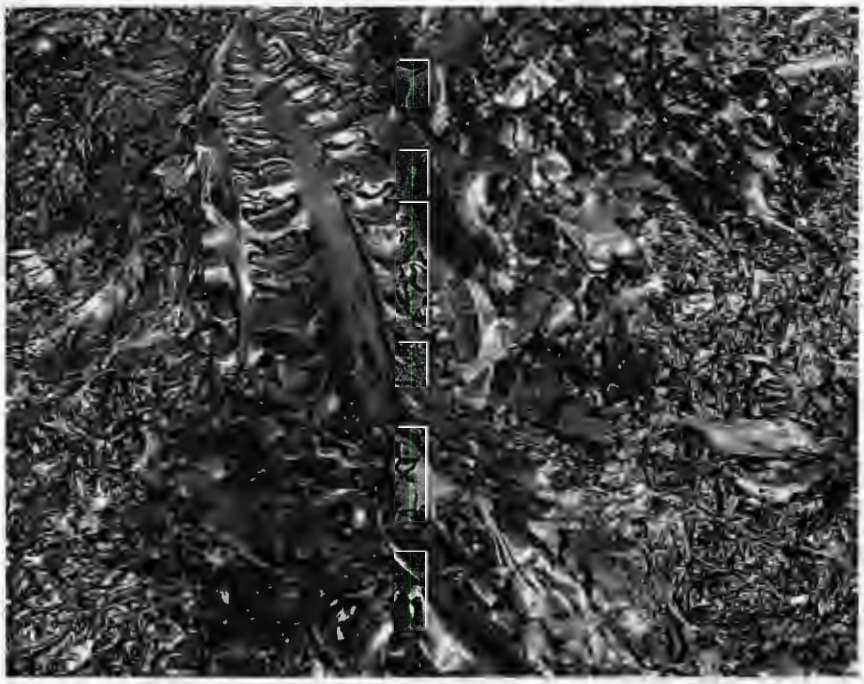
Local Address:
581 Golf Course Road
Friday Harbor WA 98250
Dianna.Padilla@gmail.com
Cell - 631 921 8739
Home 360-378-1680

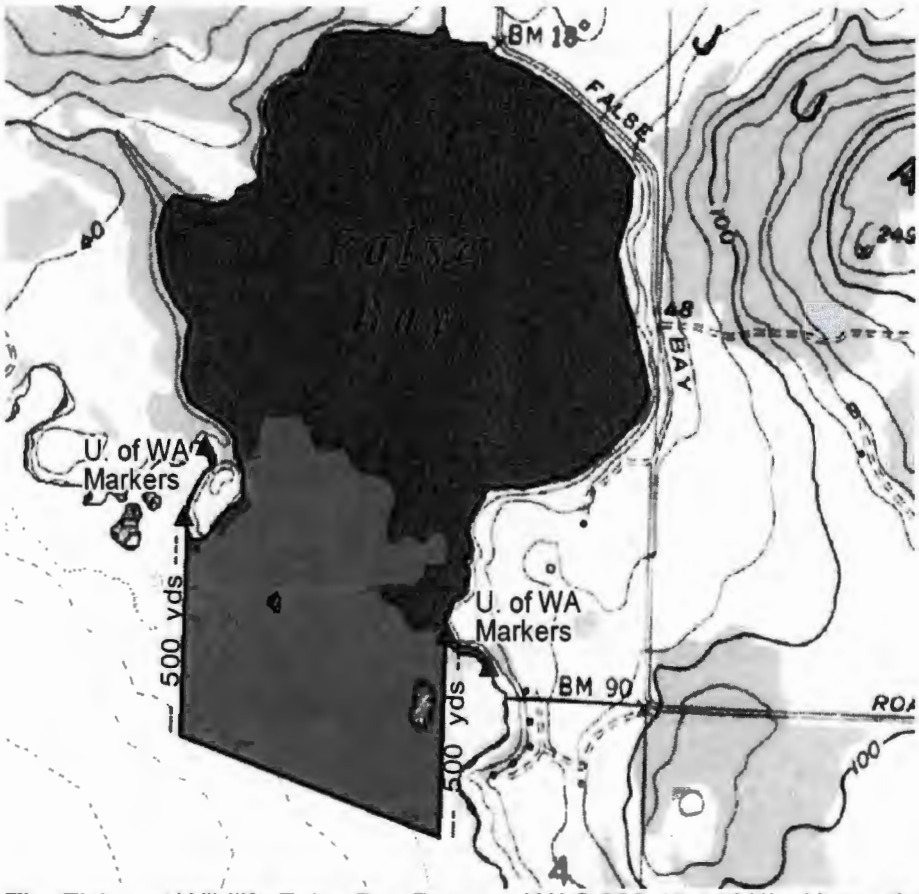
The site of the proposed dock, marina and desalination facility. Photos taken during low tide (-2 ft.) Close to the rocks in the bay and near the shore, as well as on the rocky areas where eelgrass has not encroached yet, there are large kelp and other macroalgae. The diversity of kelp is high (at least 5 species), and with the eelgrass provides important habitat for fish, Dungeness crabs and other critical species. During our short research surveys yesterday we found many juvenile Dungeness (as well as a few Red Rock crabs) along this shore

Extensive eelgrass at the proposed dock site as well as kelp at the base of the rock

Extensive kelp and other macroalgae on and around the pilings that will be removed for the proposed dock, marina and desalination facility.

Diversity of kelp and other algae at the -2 foot tidal height at the dock site. There are at lease 5 species of kelp and 7 other macroalgal species shown, none of which appear on the list of species in the proposal.





The Fish and Wildlife False Bay Reserve WAC 220-16-440(1). Note - the high shore markers for the UW reserve marked by green triangles are not the full extent of the UW reserve. The UW reserve extends to the southern edge of Government Lot (GL) 9.

300

REVENUE STAMPS

Pioneer National Title Insurance Company
WASHINGTON TITLE DIVISION

Filed for Record at Request of

TO

Filed for Record at the Request of SCHMIDT AND LINDE
DEC 1 1974 A.D., 19
at 50 min. past 10 A.M. and recorded in vol. 8 of Official Records, page 340/342
HENRY R. BYERS, AUDITOR
SAN JUAN COUNTY, WA
By Darlene Evans DEPUTY

THIS SPACE RESERVED FOR RECORDER'S USE

Filed for Record at the Request of
SCHMIDT AND LINDE
NOV 15 1974 A.D., 19
at 00 min. past 4 P. M.
and recorded in vol. 7 of Official Records, page 696
HENRY R. BYERS, AUDITOR
SAN JUAN COUNTY, WA
By Darlene Evans DEPUTY

SAN JUAN COUNTY WASH
REAL ESTATE EXCISE TAX
AMOUNT PAID $ none
Tax Exempt
NOV 15 1974
Affd 106 85
FRED R. BARNES
COUNTY TREASURER

87419

INDEXED 87157

Form L80

Statutory Warranty Deed

(CORPORATE FORM)

THE GRANTOR RUSCO FINANCIAL CORPORATION, a California corporation,

for and in consideration of $150,000.00,

in hand paid, conveys and warrants to THE BOARD OF REGENTS of the UNIVERSITY OF WASHINGTON

the following described real estate, situated in the County of San Juan, State of Washington, including all interest therein which Grantor may hereafter acquire by virtue of a Sheriff's deed to be issued by the Sheriff of San Juan County, Washington:

Parcel A
All of Government Lot 5, Section 33, Township 35 North, Range 3 West, W.M., and its fronting tidelands of the second class lying between the line of ordinary high tide and the line of mean low tide as recorded under Auditor's File No. 39037, records of San Juan County, Washington.

Parcel B
That portion of the tidelands of the second class fronting Government Lots 2, 3, 4, 6, 7, 8 and 9; Section 33, Township 35 North, Range 3 West, W.M., lying between the line of ordinary high tide and the line of mean low tide as recorded under Auditor's File 39037, records of San Juan County, Washington; EXCEPT that portion of the tidelands fronting Government Lots 4 and 6 lying landward of a line which is 100.00 feet seaward of and parallel to the line of ordinary high tide of said Government Lots 4 and 6.

Parcel C
All tidelands of the second class in front of Government Lots 2, 8 and 9; Section 33, Township 35 North, Range 3 West, W.M., lying between the line

(Continued on the reverse side hereof)

IN WITNESS WHEREOF, said corporation has caused this instrument to be executed by its proper officers and its corporate seal to be hereunto affixed this 12th day of November, 1974.

Rusco Financial Corporation

By [signature] President.

By [signature] Secretary.

STATE OF ~~WASHINGTON~~ California, } ss.
County of Los Angeles

On this 12th day of November, 1974, before me, the undersigned, a Notary Public in and for the State of ~~Washington~~ California, duly commissioned and sworn, personally appeared Robert J. Fox and Joel A. Jacobs to me known to be the President and Secretary, respectively, of Rusco Financial Corporation the corporation that executed the foregoing instrument, and acknowledged the said instrument to be the free and voluntary act and deed of said corporation, for the uses and purposes therein mentioned, and on oath stated that they are authorized to execute the said instrument and that the seal affixed is the corporate seal of said corporation.

Witness my hand and official seal hereto affixed the day and year first above written.

OFFICIAL SEAL
DEMA L. TURGEON
NOTARY PUBLIC-CALIFORNIA
LOS ANGELES COUNTY
My Commission Expires May 5, 1978

Dema L. Turgeon
Notary Public in and for the State of ~~Washington~~ California
residing at 1100 Glendon Ave., Los Angeles, Calif.

OFFICIAL RECORD VOL 8 PAGE 340
OFFICIAL RECORD VOL 7 PAGE 696

87419 87157

of mean low tide and the line of extreme low tide as recorded under Auditor's file No. 66462, records of San Juan County, Washington.

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S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Comment on Orca Dreams LLC proposal for dock and desal system

I am opposed to this project
Its name evokes the natural wildness of the island, while at the same time it would diminish that same wildness:

During construction and after, the dock would disturb the movement of marine mammals and fish in Haro Strait. I have seen orca and minke whales, seals and sea lions, harbor and dall's porpoises, and salmon travel these waters, sometimes very close to shore. For these and associated sea life, a 260 foot dock, plus navigational buoy, would be an impediment.

The proposal states that, during construction, observers will note the presence of whales, other sea mammals, and marbled murrelet near the construction site, and pile driving will be stopped. This is presented as a mitigation of the disturbance caused by the construction; it however ignores the fact that sea mammals, sensitive to sound, would alter their movements to avoid the noise and commotion of the construction. Thus, the disturbance would be caused even if observers are present. Their presence could not mitigate the effect of construction on these sea animals. And after construction, the existence of a dock and buoy would continue to hamper their movement.

A 260 foot dock, plus navigational buoy, on the west coast of San Juan Island would be a scar on the beautiful wild shoreline that stretches south all along that coast. This single dock, for the benefit of a single landowner, would be a jarring intrusion—for the rest of us, it would diminish forever the unique natural beauty that we treasure.

The SEPA application form asks "What views in the immediate vicinity will be altered or obstructed?" For this project in this highly visible location, that question, limiting the concern to the immediate vicinity does not address the impact of the project. If the question were, instead, "What views will be altered or obstructed?" the response would be that the view of the coastline would be altered for the hundreds of visitors and residents who cruise Haro Strait.

The False Bay Marine Reserve provides protection for a multitude of marine organisms on which marine life in the Strait depends. Yet the project, located very close to the reserve, proposes mooring for four boats and a desal system that would withdraw sea water from and discharge brine into the Strait. To mitigate the effect that prop wash and accidental fuel leaks from the boats would have on False Bay, the boats are to move on the south side of the dock, away from False Bay. To mitigate the effect of saltwater intake and brine discharge, points of intake and discharge are to be located at least 25 feet away from eelgrass beds. But tides and currents move water and sea floor sediments, so it is likely that those mitigation efforts would be ineffective. Brine and sediments would spread away from the dock, into the eelgrass beds and into the False Bay Marine Reserve. Inevitably, sea life in the area would change, would be diminished.

Ruth MacGinitie
533 Kilsburrow Road

Julie Thompson

From: Marc Kwiatkowski <marc.kwiatkowski@gmail.com>
Sent: Wednesday, September 20, 2017 7:46 PM
To: Julie Thompson
Subject: Re: Comment on Orca Dreams PSJ000-17-0003 RFR

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

There were a couple of typos that I missed
> On Sep 20, 2017, at 3:13 PM, Marc Kwiatkowski <marc.kwiatkowski@gmail.com> wrote:
>
> Julie;
>
> My name is Marc Kwiatkowski. I live at 265 Rainshadow Road. I wanted to submit the following in opposition to the proposed dock in False Bay. Let me know if you need any additional information.
>
> The proposed dock is an enormous structure. On aesthetic grounds alone it is alarming, however that is the least of my concerns.
>
> Boat traffic will disturb seals, oyster catchers, herons et al that frequently rest/mate on the rocks just beyond the dock. Even in a kayak I take pains to avoid the rocks to the west of where the dock will be when seals or birds are present, since they are very skittish. Even approaching wishing 20-30yds is often enough to disturb them. Two boats departing and returning from that
wishing/within
> area every day is likely to be very disruptive and could result in the wildlife populations abandoning them entires.
entires/entirely
>
> In addition, I'm concerned that the boats will very likely leak fuel, oil, bilge, cleaning fluids, and leach zinc into the shallow and sensitive waters of False Bay
>
> One thing that struck me is that the proposal repeatedly made mention of restoring things to the original 1887 appearance. This is hardly an argument in favor of the project as the late 19th century was a period of rapacious exploitation of the waters and forests of the PNW. That historical precedent was high impact and unsustainable. Hardly something to restore.
>
> As for the Reverse Osmosis plant proposal, I feel if effluent is dumped either on Orca Dreams land or directly into Haro Strait at sufficient depth it shouldn't be either an environmental nor aesthetic problem. So I have no objection to that - so long as the volume of water being processed is reasonable.
>

Julie Thompson

From: Marc Kwiatkowski <marc.kwiatkowski@gmail.com>
Sent: Wednesday, September 20, 2017 3:14 PM
To: Julie Thompson
Cc: Tom Schultz
Subject: Comment on Orca Dreams PSJ000-17-0003 RFR

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Julie;

My name is Marc Kwiatkowski. I live at 265 Rainshadow Road. I wanted to submit the following in opposition to the proposed dock in False Bay. Let me know if you need any additional information.

The proposed dock is an enormous structure. On aesthetic grounds alone it is alarming, however that is the least of my concerns.

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In addition, I'm concerned that the boats will very likely leak fuel, oil, bilge, cleaning fluids, and leach zinc into the shallow and sensitive waters of False Bay

One thing that struck me is that the proposal repeatedly made mention of restoring things to the original 1887 appearance. This is hardly an argument in favor of the project as the late 19th century was a period of rapacious exploitation of the waters and forests of the PNW. That historical precedent was high impact and unsustainable. Hardly something to restore.

As for the Reverse Osmosis plant proposal, I feel if effluent is dumped either on Orca Dreams land or directly into Haro Strait at sufficient depth it shouldn't be either an environmental nor aesthetic problem. So I have no objection to that - so long as the volume of water being processed is reasonable.

GODDU | LANGLIE | LORING | SANDSTROM PLLC
LAWYERS - ADVISORS

Peter W. Goddu
Margaret C. Langlie
Kathryn C. Loring
Thomas D. Sandstrom

September 20, 2017

SENT VIA HAND DELIVERY AND E-MAIL

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Ms. Julie Thompson
San Juan County Department of Community Development
135 Rhone St.
Friday Harbor, WA 98250

Re: Orcas Dreams, LLC Application for Dock, Navigational Buoy, and Reverse Osmosis Desalination System, PSJ000-17-0003
Comment on 9/6/17 SEPA Mitigated Determination of Non-Significance

Dear Ms. Thompson:

Please accept these comments submitted in opposition to the San Juan County Department of Community Development's (DCD) Mitigated Determination of Non-Significance (MDNS) under the State Environmental Policy Act (SEPA) as to Orca Dreams, LLC's (the Applicant) application (PSJ000-17-0003) for a four-slip dock, navigational buoy, and reverse osmosis desalination system on approximately 40 acres comprised of San Juan County TPNs 353344008, 340411003, and 340411005 (referred to as "the subject property"). These comments are submitted on behalf of the owners of several neighboring properties, Kimbal Sundberg and Debra Clausen, Gretchen Alison, Mike Prentiss, Drew Harvell and Charles Greene, Martha Scott, Jim and Camille Uhlir, and Nancy and Chris Morgan (collectively referred to as "the concerned neighbors").

I. FACTUAL SUMMARY

A. Historical use and development of the subject property.

The subject property was previously owned and operated as Mar Vista Resort, which operated a non-conforming commercial resort. The resort included numerous cabins, many of which were located closer to the shoreline than current regulations allow.

The subject property has a known history of water impoverishment and insufficient supply, as the prior operation on the subject property, Mar Vista Resort, regularly trucked in and

stored water each summer. In addition, this area of San Juan Island, particularly around False Bay, has known, documented water shortages and saltwater intrusion. The issue of water availability is of special concern here because the Applicants are seeking not just summer resort use of the property, but permanent multi-family residential development.

B. Unlawful clear cutting in the shoreline.

In November and December of 2013, contractors on the subject property clear cut approximately 80 trees within the shoreline area, ranging in diameter from 5 to 32 inches, and covering over one acre of the shoreline.[1] The clear cutting denuded the shoreline. As the Shorelines Hearings Board later found, "removal of vegetation can increase instability of a slope."[2] Further, "the environmental damages caused by the unauthorized cutting is significant due to the environmental unique and sensitive habitat."[3] "Removal of a mature riparian forest on a windswept unstable slope with poor soil creates significant environmental harm and results in the potential for long term degradation of the sensitive adjacent marine environment."[4] It is with this backdrop that the subsequent development of the subject property should be considered.

C. Prior permit applications by the applicants.

The subject property has a complicated permit history, which includes prior boundary line modifications, an application for a long plat that was previously withdrawn, an application for a "joint use" dock that was previously withdrawn, and an application for "multi-family" residential development (without subdividing the property) that was previously withdrawn. The application that is the subject of these comments is the application for a shoreline substantial development permit for a four-slip dock and a desalination system, not associated with any plat or subdivision. The ongoing and piecemeal development is difficult to track and evaluate, which reinforces why a thoughtful and complete review and analysis of all environmental impacts is so important.

While many aspects of the proposed dock appear to have remained the same, the length of the proposed dock has actually *increased* from the last proposal, and is now proposed to be 260 feet long, rather than 240 feet long. May 2017 Project Description at 3.

---

[1]*See Orca Dreams, LLC v. State of Washington Department of* Ecology, SHB No. 14-015, Shorelines Hearings Board Findings of Fact, Conclusions of Law and Order (November 17, 2015), Findings 12 and 35.

[2]*Id.* at Finding 38.

[3]*Id.* at Finding 39.

[4]*Id.* at Conclusion of Law 7.

D. Prior SEPA Determination.

On September 23, 2015, DCD issued a MDNS for the Applicants' prior application for a dock, PSJ000-14-0008. However, DCD subsequently withdrew that MDNS on October 28, 2015, "based on numerous public comments that raise issues of probable significant environmental impacts." DCD's October 30, 2015 letter summarizing the basis for withdrawing its MDNS is attached here as **Exhibit A.** That letter relied on the following comments and evidence of likely environmental impact:

- The Washington Department of Fish and Wildlife (WDFW)'s June 15, 2015 letter, which noted "eelgrass at the seaward extent of the proposed structure."[5] DFW noted that it "considers eelgrass a priority habitat as it provides refuge and feeding opportunities for out-migrating juvenile salmon and other marine fish species. Thus, eelgrass is amongst the most critical habitat to preserve." Further, WDFW stated that the movement of numerous "vessels into and out of this new moorage structure, while navigating around the rock outcroppings especially during low tide series will likely result in prop scour that will negatively impact the growth and long-term viability of this eelgrass bed." **Exhibit A** at 1. DCD's October 30, 2015 letter also relied on WDFW's statements regarding the dock being located in priority habitat for pinto abalone.

- The October 1, 2015 letter from Dr. Megan Dethier, Associated Director for Academics and the Environment at the University of Washington Friday Harbor Labs (FHL), describing potentially negative impacts associated with the increased boat traffic in the subject area associated with the dock, including:

    a. Impacts to eelgrass.

    b. Impacts to kelp and other large plants.

    c. Impacts to the pocket beach.

    d. Impacts to the marine reserve.

    e. Future impacts from a need to protect or repair the infrastructure.

---

[5] It does not appear from the "request for review" provided with the application materials that the new application and SEPA Checklist were distributed to WDFW for comment, as WDFW is not listed on the distribution sheet sent by DCD. This is concerning, given the strong comments by WDFW that were specifically relied on by DCD in 2015.

Therefore, based on the comments received, including those specifically mentioned, DCD specifically required the Applicant to undertake the following additional analysis related to the proposed dock:

- Identify impacts to eelgrass and propose mitigation measures. (**Exhibit A** at 2, first paragraph).
- Analyze impacts to priority habitat for pinto abalone, and document that the project will result in no net loss of ecological functions. (**Exhibit A** at 2, second paragraph).
- Obtain a survey showing the lateral boundaries of the second class tidelands in order to document that no portion of the proposed dock will be located on University of Washington land. (**Exhibit A** at 2, third paragraph).
- Analyze the *long-term impacts* associated with increased boat traffic in this area (including impacts to eelgrass, kelp and other large plants, to the pocket beach, and to the marine reserve). (**Exhibit A** at 2, sixth paragraph).
- Conduct a study of dispersal patterns into False Bay should an accidental petroleum spill occur. (**Exhibit A** at 2, sixth paragraph).
- Analyze how the dock and boats tied to it would be protected from storm events during the months in which the dock is left in how the water. (**Exhibit A** at 2, seventh paragraph).

E. Summary of New Application and May 2017 SEPA Checklist.

The subject application includes a 260-foot, four-slip dock, described as a "joint-use community dock," despite the fact that it is intended to serve undivided properties in common ownership (following withdrawl of the previous division proposals). No explanation is provided as to why a 260-foot dock is needed, as opposed to the previously proposed 240-foot dock (which was to provide six rather than four slips).

The SEPA Checklist states that the dock will be sited where remnants of an old Mar Vista dock are located. 2017 SEPA Checklist at 3. While the materials state that the boundary lines have been "updated," it is not clear that a new survey has been commissioned to confirm the lateral boundaries of any second-class tidelands owned by the Applicant as required by DCD in its October 30, 2015 letter. *See* **Exhibit A** at 2.

Further, the proposed dock location and/or orientation appears to have changed since the last application, and possibly even during the application process. The application materials do not clearly address the apparent change in orientation and/or location of the proposed dock. Indeed, at page 8 of Appendix C to the 2017 Biological Assessment, there are two figures on the

same page that show the proposed dock in two different orientations. This is especially important and potentially misleading, as the Applicant is relying on a preliminary eelgrass survey from August 2014, at which time it appears that the proposed dock was to be in a different location and potentially with a different orientation. A complete analysis requires clarity on the location and orientation of the dock with respect to all data relied upon.

The SEPA Checklist states that float will be removed and stored at Snug Harbor Resort from November through April. 2017 SEPA Checklist at 3. The checklist likewise states that the seaward end of the dock ramp will be lifted out of the water and secured to two landward float supports. *Id.* But no analysis is provided as to how the dock and boats tied thereto will be protected from storms while the dock remains in the water, which was specifically required by DCD in its October 30, 2015 letter. *See* **Exhibit A** at 2.

Much detail is provided in the SEPA Checklist and the Biological Assessment regarding grading of various components of the dock; however, no mention is made of the opaque, foam-filled float tubs, moored boats, and dock framing that have no light transmission.

The Applicants also seek to construct a reverse osmosis seawater desalination system (RO) to "augment" drinking water for six single-family residences. SEPA Checklist at 9. The proposed RO is intended to "augment" the water supply from an existing well, ID # BBM 060. However, it is policy of the SJC DHCS to have plans for reverse osmosis seawater desalination reviewed by the Washington State Department of Health. It is our understanding that the plans have not yet been submitted to the Washington State Department of Health because they are not sufficient for such review.

The SEPA Checklist states that 12,068 gallons of seawater will be drawn from Haro Strait each day, and 9,072 gallons of "brine" will be discharged back into Haro Strait, via a pipeline attached to the underside of the dock fixed pier (if the dock is permitted) or to a support piling, and then taken under water and attached to the seafloor. SEPA Checklist at 9. No information is provided as to how the locations/distances for the intake and discharge were determined or whether anchoring to the seafloor and discharging brine at that depth and in the chosen location will have any specific impacts.

Much detail is provided in the SEPA Checklist and other materials regarding efforts to address and minimize potential environmental impacts *during the construction phases* of the dock and DO, including "proposed conservation measures for dock construction" and "conservations measures". SEPA Checklist at 7-9, 13-14. The only specific reference to conservation or environmental impact *after construction*, and therefore for the remainder of the dock and DO's usable life, appears to be contained in the following conclusory statements offered as "conservation measures" at pages 13-14 of the SEPA Checklist:

1. "A qualified diver will mark the margins of the eelgrass beds to ensure that the dock is positioned with a minimum 25-foot buffer from the eelgrass beds."

   . . .

7. "Eelgrass and macroalgae will not be adversely impacted due to any project activities". . ."

   . . .

10. "Petroleum products will not be transferred on or near the joint-use dock. . ."

    . . .

12. "Boat operators will use the 'clear channel' along the southern approach to access the proposed dock to prevent collision with submerged rocks and avoid impacts to the False Bay Reserve."

SEPA Checklist at 13-15.

Then, at page 21 of the SEPA Checklist, the Applicants offer specific conservation measures as to eelgrass and macro algae, such as locating the dock and DO at least 25 feet from marked eelgrass beds and not "directing" prop wash to existing eelgrass beds, and conclude without analysis that "eelgrass ad macroalgae *will not be* adversely impacted due to any project activities."

The February 24, 2017 Biological Assessment contains similar conclusions with very little raw data and very limited analysis.

II. ANALYSIS AND DISCUSSION

The proposed location for the subject dock is within an area of ecological importance for numerous, independent reasons summarized below.

SEPA requires "local government agencies, including counties, to consider total environmental and ecological factors to the fullest extent when taking 'major actions significantly affecting the quality of the environment.'" *Sisley v. San Juan* County, 89 Wn.2d 78, 82, 569 P.2d 712 (1977). The SEPA review must include the proposal's direct, indirect and cumulative impacts. WAC 197-11-060(4)(d),(e).

To make a threshold determination that a proposal will not significantly affect the quality of the environment, the County must consider all environmental factors even if it ultimately

concludes that the action does not significantly affect the environment and does not require an EIS. *Sisley*, 89 Wn.2d at 83.

The application materials, SEPA Checklist, and 2017 Biological Assessment provided here have not provided reasonably sufficient information necessary to evaluate the environmental impacts of the proposed project to this ecologically rich area.

In particular, the materials have not provided the vast majority of the specific information requested from DCD in its October 30, 2015 letter withdrawing the prior MDNS, which were summarized above (**Exhibit A**). Specifically, impacts to eelgrass and mitigation measures are not fully analyzed. The new survey required is not specifically identified. The long-term impacts of increased boat traffic have not been evaluated, particularly in regard to the areas identified by DCD. No study has been conducted to analyze the tidal patterns associated with a potential petroleum spill. No specific plan to secure the dock and boats during storm events has been described.

Therefore, under SJCC 18.80.050.G.2.a and WAC 197-11-335, additional information is necessary and no threshold determination should be made until such information is available. <u>If the WDFW has not already provided comment on the new application and the May 2017 SEPA Checklist, such comment should specifically be sought as additional information</u>.

Further, given the extensive site-specific and scientific information that was previously provided and is being contemporaneously provided by comments on the proposed project and the MDNS, there is sufficient information for DCD to find a reasonable likelihood that the project will have a probable significant adverse impact on an element of the environment, requiring a determination of significance and the preparation of an Environmental Impact Statement (EIS) under SJCC 18.80.050.G.3 and WAC 197-11-330(4).

a. Analysis of Desalination and Discharge of Saline Brine.

The Applicant's 2017 Biological Assessment addresses effects of the RO desalination system's operation starting at page 34.

The Assessment states that small organisms and larval stages of marine organisms will likely be impacted at the intake screen of the intake pump pumping 12, 068 gallons per day, and the significance of that impacts is "not known." 2017 Biological Assessment at 34. Nonetheless, in the same paragraph, the Assessment concludes without further analysis that the "significance of this impact is likely to be insignificant and undetectable." *Id.*

No analysis is provided as to the location of the discharge of the brine, nor of the impact of attaching the discharge pipeline to the seafloor.

Further, the Biological Assessment provides no data as to the estimated mixing of the brine discharge, nor specific analysis of mixing and at what distance the outflow will reach ambient salinity levels. *See* 2017 Biological Assessment at 35. No data is provided as to currents in the location of the dock and surrounding area. Yet, the Assessment concludes that the subject DO desalination system "will be in an area of higher velocity currents" than the only two studies of desalination and mixing referenced. *Id.* Notably, the Applicant is thereby asserting that the current velocity in the pocket bay and surrounding area is higher than the velocity of current at the Cattle Point location referenced in the 2009 Strathmann study. While that seems impossible to believe, because the Applicant has not provided the data, it is not possible to analyze. The Assessment simply concludes that the "brine return water will likely be diluted to ambient salinity levels within 2 to 3 feet from the discharge pipe." *Id.* Similarly, while temperature is referenced, and increased temperature of brine is noted, no specific data and analysis is provided in order to analyze potential impacts on the surrounding environment. *Id.*

The discharge of saline brine has a real potential to impact nearby eelgrass and macro algae, particularly given the enclosed nature of the pocket bay, and the already high level of eelgrass disease noted in this area. (See the False Bay Seagrass Report from the Summer of 2016 authored by Olivia Graham, Morgan Eisenlord, and Drew Harvell, which already has been submitted with comments by Drew Harvell), PhD and owner of neighboring property).

b. Impacts to Eelgrass and Macro Algae.

The Applicant states in the 2017 Biological Assessment (page 11) that three "dive surveys" have been conducted to document marine vegetation. However, the first such survey was in March 2014, outside of the time period recommended by WDFW for conducting eelgrass surveys, and at a time when the dock was proposed to be located in a different location and potentially a different orientation (though this is unclear given the materials provided). Still, the Applicant acknowledges that said survey located marine algae Ulva, Laminaria, and Fucus within the location under the proposed dock. Eelgrass was located "approximately" 25 feet to the south.

A *Preliminary* Eelgrass Survey was conducted in August 2014, at which time a "dense" band of Laminaria and Ulva were observed "in the area of the proposed dock." In addition, the August 2014 preliminary survey narrative noted "patches" of eelgrass (zostera marina) to "the south," but the survey did not document the boundaries of that patch and the location of the dock was not overlayed.

While a video survey was conducted in January 2016, that was outside of the months recommended for eelgrass surveys by WDFW because it is outside the prime growing period.

SJCC 18.35.115(B) designates "kelp and eelgrass" as fish and wildlife habitat conservation critical area in San Juan County. SJCC 18.20.110 defines "kelp" as all brown algae of the order Laminariales, generally consisting of a holdfast, a stipe and a float.

Despite the acknowledged existence of these San Juan County designated critical areas *within and immediately adjacent* to the proposed location of the dock and despite the Applicant acknowledging via its Biological Assessment that dock shading can adversely impact juvenile salmon that frequent the pocket beach, the application materials and SEPA Checklist do not adequately evaluate the likely impacts of shading by the dock or impacts of boats coming to and from the dock. Indeed, at page 32 of the 2017 Biological Assessment, it states simply that "impacts due to shading from the dock will be minimal."

The Applicant over simplifies this issue by relying on the grating of the dock components while ignoring the opaque float tubs, moored boats, and framing that have no light transmission.

In addition, the Applicant fails to adequately address the likely impacts of scouring caused by boating activity, particularly given the very shallow waters in this area and the rocks near the dock location. The dive surveys provided are inadequate in process/format, detail and scope and did not provide sufficient information necessary to evaluate the true impacts of the dock and related boating activity. Further, the assertion that boats will only travel in one designated "clear" channel is unlikely and impossible to enforce.

The False Bay Seagrass Report from the Summer of 2016 authored by Olivia Graham, Morgan Eisenlord, and Drew Harvell submitted by Drew Harvell with her comment letter, as well as her supplemental map and comment attached hereto as **Exhibit B** show that there is a very real possibility of impact to the eelgrass meadow immediately adjacent to the proposed dock. Given the sheltered embayment in which the proposed dock and DO are to be located, and the high levels of seagrass disease found in this same pocket bay, there is a high probability of impact on the nearby eelgrass meadow and kelp beds.

DCD should require further analysis, including a complete dive survey properly conducted pursuant to Washington Department of Fish and Wildlife guidelines, and broad enough in scope to include the entire project and its impacts, including boat traffic, not just the footprint of the dock itself.

c. Impacts on the Pocket Beach and to Forage Fish and Migrating Salmon.

The application materials and SEPA Checklist also did not adequately analyze the likely impact of the proposed dock and increased boat traffic to forage fish and migrating salmon. Significant scientific information has been provided that the dock will likely impact the nearshore feeding habitat and refuge for juvenile salmon, including threatened species Chinook salmon, provided by the pocket beach. The shading caused by the dock will likely impact migrating salmon because of delays or disorientation and increased predation. In addition, the proposed dock is likely to cause "sediment pumping" due to its proposed location in shallow water, negatively impacting marine life. Likewise, the prop wash from the projected boat transits will further erode bottom sediments. The Biological Assessment provided by the Applicant acknowledges the potential for these impacts and wholly fails to analyze them with specificity, instead focusing on construction activities and then concluding without analysis that the project is not likely to have these adverse impacts or that impacts will be minimal.

d. Impacts to Southern Resident Killer Whales.

The proposed dock lies within the core critical habitat designated for the Southern Resident Killer Whale (SRKW), a listed species under the Endangered Species Act. The SRKW are an iconic wildlife feature of San Juan Island and a frequent visitor to the vicinity of the proposed dock location. The Biological Assessment acknowledges that SRKW behavior may be impacted. Boat motors and other sources of underwater noise caused by the proposed dock, including new boat transits in their critical habitat may have adverse impacts on SRKW, including changes in swimming speed, call duration, unpredictable travel paths, alteration of dive times, movement to open water, and unusual surface pattern behaviors (Wiles 2004). Because these behaviors affect SPKW feeding, a significant issue affecting their recovery, these are significant impacts to the Endangered SRKW and have not been adequately addressed or mitigated. Indeed, solely the construction phase of the project has been considered rather than the continued use and operation of the dock with the associated increased boating activity noted.

e. Visual and Aesthetic Impacts.

The application materials and SEPA Checklist did not adequately analyze the likely visual and aesthetic. The dock would extend now 260 feet from the shoreline. The SEPA Checklist at page 28 asserts that there will be "no lighting fixtures." This assertion seems very unlikely given the size of this dock and should be critically analyzed. The SEPA checklist asserts that the dock will not interfere with views from neighboring properties given the relative distances, yet that ignores that the dock itself will extend 260 into the water and towards nearby properties.

Finally, the proposed dock is especially significant because it will mar a significant natural shoreline along the west coast of San Juan Island that is presently unbroken by the presence of a dock.

f. Impacts to Navigation and Recreation.

The application materials and SEPA checklist fail to address the impact of the proposed dock on navigation and recreation in the area, which is a very popular area for kayaking, boating, and beach walking.

g. Potential Alternatives.

Finally, and perhaps most importantly, the application and SEPA checklist fail to sufficiently address alternatives to the proposed dock and fail to demonstrate a need to moor four or more boats in this location. The application materials assert without any specific explanation that four boats are needed at all times and would need to all be moored at the same facility. Further, the information provided shows that there are some slips available given the sizes needed.

III. CONCLUSION

The Applicant has provided insufficient information and analysis for the County to fulfill its duty of analyzing potential environmental impacts under SEPA. Therefore, pursuant to SJCC 18.80.050.G.2.a and WAC 197-11-335, additional information is necessary and no threshold determination should be made until such information is available. Further, given the extensive site-specific and scientific information that has been provided by comments on the proposed project and the MDNS, there is sufficient information for DCD to find a reasonable likelihood that the project will have a probable significant adverse impact on an element of the environment, requiring a determination of significance and the preparation of an Environmental Impact Statement (EIS) under SJCC 18.80.050.G.3 and WAC 197-11-330(4).

The concerned neighbors whom I represent therefore ask DCD to withdraw its MDNS and issue a determination of significance and require preparation of an EIS. Thank you for your consideration.

Very truly yours,

GODDU LANGLIE LORING SANDSTROM PLLC

Kathryn C. Loring

Exhibit A

Exhibit A

SAN JUAN COUNTY DEPARTMENT OF COMMUNITY DEVELOPMENT

135 Rhone Street, PO Box 947, Friday Harbor, WA 98250
(360) 378-2354 | (360) 378-2116
dcd@sanjuanco.com | www.sanjuanco.com

Law Office of Stephanie Johnson O'Day
c/o Stephanie Johnson O'Day
Francine Shaw
PO Box 2112
Friday Harbor, WA 98250

October 30, 2015

Re: Orca Dreams Dock MDNS withdrawal

Stephanie and Francine,

On October 28, 2015, the Department of Community Development (DCD) withdrew the mitigated determination of nonsignificance we issued on September 23, 2015 for the Orca Dreams LLC dock proposal, PSJ000-14-0008. The withdrawal is based on numerous public comments that raise issues of probable significant environmental impacts. All the comment letters were forwarded to your office upon receipt in this office.

The Washington Department of Fish and Wildlife noted in a letter dated June 15, 2015, attached:

> The site plan for this project shows eelgrass at the seaward extent of the proposed structure. The Washington Department of Fish and Wildlife (WDFW) considers eelgrass a priority habitat as it provides refuge and feeding opportunities for out-migrating juvenile salmon and other marine fish species. Thus, eelgrass is amongst the most critical habitat to preserve. The movement of up to six vessels into and out of this new moorage structure, while navigating around the rock outcroppings especially during low tide series will likely result in prop scour that will negatively impact the growth and long-term viability of this eelgrass bed. WDFW has a no-net-loss policy for eelgrass, and while eelgrass has been identified within the project area, there is no monitoring or mitigation plan submitted with the review documents.

The preliminary eelgrass/macro algae habitat survey prepared by Wells Construction dated August 24, 2014, shows a small patch of eelgrass approximately 220' offshore; luminaria and ulva from 60' to approximately 200'; and ulva beyond 200'. Unfortunately, the map of the dive survey did not superimpose the proposed dock location, so it is difficult to evaluate impacts to habitat.

The proposed dock appears to be in fairly shallow water, so prop wash could have an impact on underlying vegetation. Those impacts need to be identified and mitigation measures proposed.

In the same letter WDFW also points out that in their Priority Habitat and Species data base, pinto abalone *(Haliotis kamtschatkana)* is listed as present within the project area and all along the southwestern shore of San Juan Island. According to WDFW, priority species require protective measures for their survival. They have identified construction of the pier, with the driving of piles and shoreline pier connection, as likely to cause an increase in siltation within the nearshore area that may impact abalone. The critical areas regulations in SJCC Chapter 18.35 require you to show the project will result in no net loss of ecological functions associated with critical saltwater habitat.

There is a question about whether any part of the proposed dock will be located on University of Washington land. A survey showing the lateral boundaries of the second class tidelands needs to be mapped to answer that question.

There is inadequate justification for three sets of beach access structures. There is virtually no information about the amount of vegetation removal that any of the beach access structures would require. If it turns out that vegetation will need to be removed to build the structures, that should be evaluated as part of the environmental review.

The long-term impact of the increased amount of boat traffic in this area should be evaluated. The potential for up to 736 trips in and out of the dock over a six month period every year at the mouth of False Bay, as opposed to the amount of traffic in the Strait of Juan de Fuca could have serious environmental impacts, but this issue has not been addressed. The letter from Dr. Megan Dethier, Associated Director for Academics and the Environment at the University of Washington Friday Harbor Labs, dated October 1, 2015, attached, lists five type of potentially negative impacts:

a. Impacts to eelgrass.
b. Impacts to kelp and other large plants.
c. Impacts to the pocket beach.
d. Impacts to the marine reserve.
e. Future impacts from a need to protect or repair the infrastructure.

These long-term impacts need to be addressed.

While every effort will be made to prevent petroleum product spills if the dock gets built, there has been no study of dispersal patterns into False Bay should accidental spills occur. Petroleum products would be carried into False Bay on an incoming tide, but may not be completely removed on the outgoing tide. A study to understand that pattern should be undertaken.

The environmental checklist states that the ramp and float will be removed and stored on an upland site from October through May each year to prevent damage caused by extreme wind and wave action that this site experiences during the stormy season. However, as recently at August 2015, this site was exposed to an extreme storm. How would the dock and boats tied to it have been protected from sudden storms like that? Where in the upland do you plan to store the ramp and float? Will additional clearing and grading be required?

Upon submittal of a revised checklist and additional information, DCD will conduct additional SEPA review and issue another SEPA determination.

Due to the SEPA withdrawal, DCD has postponed the public hearing originally scheduled for November 19, 2015.

Please contact Julie Thompson if you have questions. She can be reached at Juliet@sanjuanco.com or 370 7588.

Sincerely,

Sam Gibboney, Director

Exhibit B

Exhibit B

Katie Loring

From: C. Harvell <cdh5@cornell.edu>
Sent: Wednesday, September 20, 2017 9:49 AM
To: Julie Thompson
Cc: bjswalla@u.washington.edu; sundberg@centurytel.net; ojgraham@me.com; Katie Loring
Subject: Re: Comments on Orca Dream Dock and DeSal proposal
Attachments: False Bay Map Supplement to False Bay Seagrass Report.pdf

Dear Julie:

Please find attached a map of the location of our transects in the Pocket Bay at the edge of False Bay to append as a supplement to the Seagrass Heath Report I submitted on Sept 10.

Sincerely,
Drew Harvell

Drew Harvell, Professor

Department of Ecology and Evolutionary Biology
Faculty Fellow, Atkinson Center for Sustainable Future
Cornell University
Fellow, Ecological Society of America
http://www.eeb.cornell.edu/harvell/

From: Julie Thompson <JulieT@sanjuanco.com>
Date: Wednesday, September 13, 2017 at 10:10 AM
To: Drew Harvell <cdh5@cornell.edu>
Subject: RE: Comments on Orca Dream Dock and DeSal proposal

Thank you for your comments and supplying me with all this interesting information.

From: C. Harvell [mailto:cdh5@cornell.edu]
Sent: Sunday, September 10, 2017 5:04 AM
To: Julie Thompson <JulieT@sanjuanco.com>
Cc: Billie Swalla <bjswalla@u.washington.edu>; Katie Loring <kloring@sjilaw.com>; Kimbal Sundberg <sundberg@centurytel.net>; Olivia Graham <ojgraham@me.com>; C. Harvell <cdh5@cornell.edu>
Subject: Comments on Orca Dream Dock and DeSal proposal

Dear Julie:

Please find attached my letter of concern about the proposed Orca Dream development and the surprising Determination of Non-Significance by the county. I have also appended our recent report on the health of eelgrass beds in False Bay, including the Pocket Bay. I submit these in the context of our larger studies on the health of eelgrass in the San Juan Islands and Puget Sound, and so also attach a couple of our earlier publications documenting a significant health threat to our local seagrasses from seagrass wasting disease (Groner et al 2014, 2016).

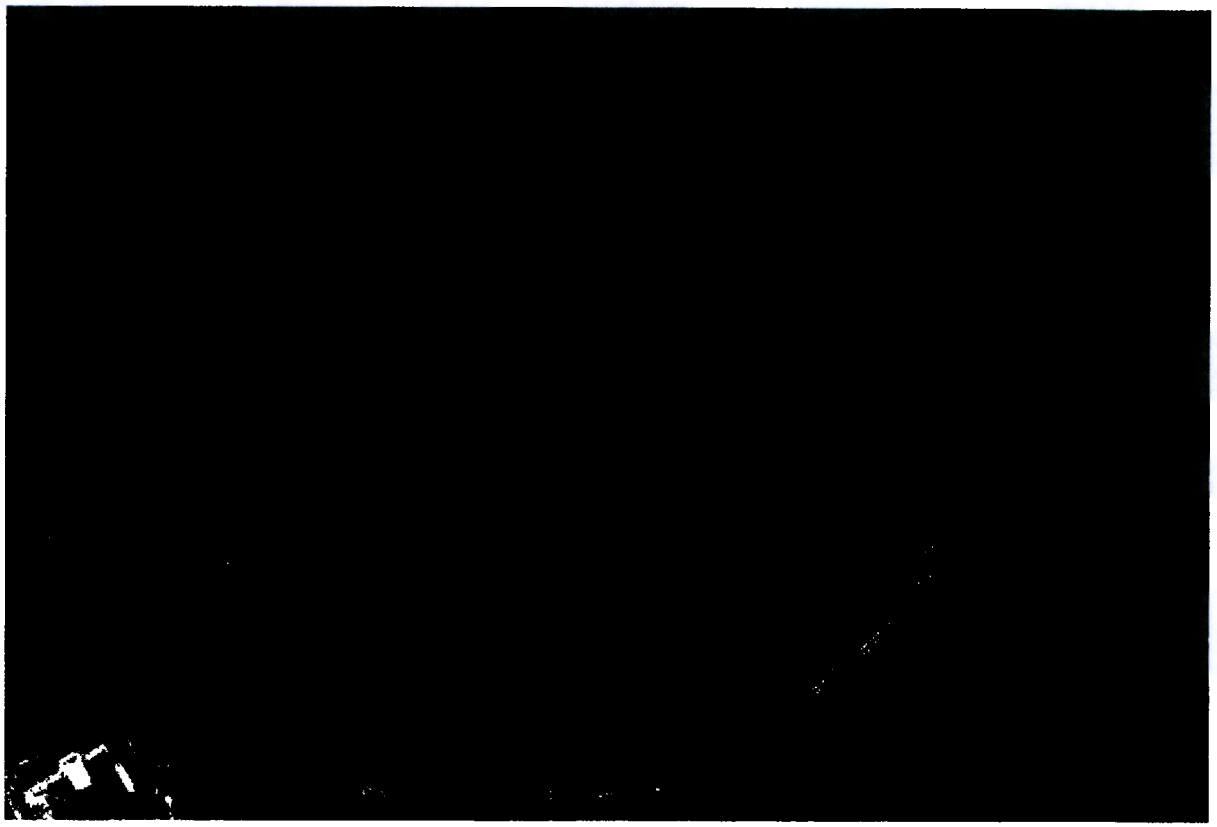
Sincerely,

Drew Harvell

Drew Harvell, Professor

Department of Ecology and Evolutionary Biology
Faculty Fellow, Atkinson Center for Sustainable Future
Cornell University
Fellow, Ecological Society of America
http://www.eeb.cornell.edu/harvell/

Olivia Graham



Map of eelgrass biodiversity surveys (blue) and eelgrass disease surveys (red) in False Bay Pocket and Middle Bays, summer 2016.

The eelgrass bed is present under most of the blue arrows where the biodiversity surveys were conducted. The red arrows represent the locations of the replicated eel grass health surveys conducted in the eel grass bed.

The significantly high levels of wasting disease in the eel grass in this Pocket Bay relative to the two other areas surveyed in False Bay (detailed in False Bay Seagrass Report) are typical of the higher risk of poor health in sheltered embayments. Sheltered embayments can have higher levels of disease since temperatures can be warmer and water flow is reduced. Such embayments are more fragile ecosystems than wave-exposed coastlines.

Although the dock will not be on top of the eelgrass meadow, its effects in a sheltered embayment are likely to reach the eel grass bed. Similarly, depending on the location of the hypersaline outfall, hypersaline waters could easily impact eelgrass regions of the Pocket Bay under certain tidal conditions.

Julie Thompson

From: C. Harvell <cdh5@cornell.edu>
Sent: Wednesday, September 20, 2017 9:49 AM
To: Julie Thompson
Cc: bjswalla@u.washington.edu; sundberg@centurytel.net; ojgraham@me.com; kloring@sjilaw.com
Subject: Re: Comments on Orca Dream Dock and DeSal proposal
Attachments: False Bay Map Supplement to False Bay Seagrass Report.pdf

Dear Julie:

Please find attached a map of the location of our transects in the Pocket Bay at the edge of False Bay to append as a supplement to the Seagrass Heath Report I submitted on Sept 10.

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Sincerely,
Drew Harvell

Drew Harvell, Professor

Department of Ecology and Evolutionary Biology
Faculty Fellow, Atkinson Center for Sustainable Future
Cornell University
Fellow, Ecological Society of America
http://www.eeb.cornell.edu/harvell/

From: Julie Thompson <JulieT@sanjuanco.com>
Date: Wednesday, September 13, 2017 at 10:10 AM
To: Drew Harvell <cdh5@cornell.edu>
Subject: RE: Comments on Orca Dream Dock and DeSal proposal

Thank you for your comments and supplying me with all this interesting information.

From: C. Harvell [mailto:cdh5@cornell.edu]
Sent: Sunday, September 10, 2017 5:04 AM
To: Julie Thompson <JulieT@sanjuanco.com>
Cc: Billie Swalla <bjswalla@u.washington.edu>; Katie Loring <kloring@sjilaw.com>; Kimbal Sundberg <sundberg@centurytel.net>; Olivia Graham <ojgraham@me.com>; C. Harvell <cdh5@cornell.edu>
Subject: Comments on Orca Dream Dock and DeSal proposal

Dear Julie:

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Sincerely,

Drew Harvell

Drew Harvell, Professor

Department of Ecology and Evolutionary Biology
Faculty Fellow, Atkinson Center for Sustainable Future
Cornell University
Fellow, Ecological Society of America
http://www.eeb.cornell.edu/harvell/

Olivia Graham

Map of eelgrass biodiversity surveys (blue) and eelgrass disease surveys (red) in False Bay Pocket and Middle Bays, summer 2016.

The eelgrass bed is present under most of the blue arrows where the biodiversity surveys were conducted. The red arrows represent the locations of the replicated eel grass health surveys conducted in the eel grass bed.

The significantly high levels of wasting disease in the eel grass in this Pocket Bay relative to the two other areas surveyed in False Bay (detailed in False Bay Seagrass Report) are typical of the higher risk of poor health in sheltered embayments. Sheltered embayments can have higher levels of disease since temperatures can be warmer and water flow is reduced. Such embayments are more fragile ecosystems than wave-exposed coastlines.

Although the dock will not be on top of the eelgrass meadow, its effects in a sheltered embayment are likely to reach the eel grass bed. Similarly, depending on the location of the hypersaline outfall, hypersaline waters could easily impact eelgrass regions of the Pocket Bay under certain tidal conditions.

September 20, 2017

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Permit #PSJ000-17-003
Project Description: 4 slip dock and RO desalination system

Dear Ms. Thompson,

Here we are again. You have received letter after letter from top area Scientist explaining how this dock and desalination system would adversely impact the ecology of False Bay. I urge you to read each of these documents very carefully and deny this permit. I' m sitting here this morning overlooking the unspoiled shore line of False Bay. No sound other than the seabirds and seal flaps. Its one of the most beautiful places on earth. We are all entrusted to care for this planet. Today you have the power to do just that··· Protect False Bay!

Sincerely
Tamara Kay Dean
527 Mountain Shadows Lane
Friday Harbor, WA 98250

Julie Thompson

From: Shaun Hubbard <shaunalice@gmail.com>
Sent: Wednesday, September 20, 2017 11:00 AM
To: Julie Thompson
Subject: Comment on Permit # PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Julie,

Thank you for this opportunity to submit comments on Mitigated Determination of Nonsignificance re. Shoreline Permit Application for Orca Dreams LLC.
Permit # PSJ000-17-0003

I am writing to ask the County to deny this permit.

I do not agree with the premise that building a dock and de-sal system along the fragile shoreline and adjacent to the False Bay Marine Preserve would not have *any* significant impacts to the marine environment. However, I am not a scientist, so I hope that you will hear from scientists who will question this determination using science-based research. I can only question the decision from a common sense point of view — how would a dock and de-sal unit *not* impact where forage fish feed, where seals and otters come to rest, where salmon migrate, where eel grass grows, and only inches away from a marine preserve? Of course there will be significant impacts and they will ripple out to effect the already fragile, on-the-brink orca population we all dream about and to which we owe our island way of life.

Our county is in the midst of a discussion about how to protect the orcas, but while we are discussing, we lost another member (K13) this year, and now we are down to 77. Denying this permit is our opportunity to walk our talk.

There is no doubt that there will be significant and negative visual and aural impacts along the shoreline where boaters, fishers, kayakers, whale watchers and residents live and play. To not consider these injuries as significant does a disservice to our county's reputation (upon which our economy relies) as a destination known world-wide for our natural beauty and healthy marine environment.

There appears to be a ton of mitigation measures in place for protecting the marine environment during the construction phase of the dock and de-sal system (items 1-10), but what about post-construction, when this dock and de-sal unit will be used continually and for years into the future? The mitigation measures for ongoing use need to be equally scrupulous. And who is really going to enforce these? Try as you might to protect the orcas from these impacts by putting mitigation measures in place, they are only as effective (if they are indeed effective) as the enforcement. If the County approves this permit, then I ask that the County include an enforcement and accountability plan for this project as recent history regarding this property has proved skepticism and vigilance to be warranted.

If we are serious about protecting what residents and visitors love about these islands, then we need to face the fact that *anything* we do to alter the shoreline environment is significant.

Thank you.

Shaun Hubbard

Julie Thompson

From: Planning and Permit Services LLC <francine@rockisland.com>
Sent: Wednesday, September 20, 2017 10:57 AM
To: Julie Thompson
Cc: Stephanie Johnson O'Day; 'David Honeywell'; 'Nancy Yahoo'
Subject: RE: #PSJ000-17-0003; 4slip dock and RO desalination system
Attachments: Orca Dreams TIDELANDS TOPO 1-30-17.pdf; Orca Dreams Second Class Tidelands Deed.pdf

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Julie:

For clarification purposes, the beach in front of the Honeywell property is owned by the Honeywells, out to the meander line, due to their property being patented before statehood. Furthermore, they own the majority of the tideland over which the dock would be built. (See attachments.) I can attest for the Honeywells they do not "share" their beach with Mr. Prentiss and they do not use Mr. Prentiss's beach.

Francine

From: Julie Thompson [mailto:JulieT@sanjuanco.com]
Sent: Wednesday, September 20, 2017 9:00 AM
To: Francine Shaw (Francine@rockisland.com)
Subject: FW: #PSJ000-17-0003; 4slip dock and RO desalination system

From: Mike Prentiss [mailto:mvp@mprentiss.com]
Sent: Monday, September 18, 2017 9:09 AM
To: Julie Thompson <JulieT@sanjuanco.com>
Subject: #PSJ000-17-0003; 4slip dock and RO desalination system

Dear Ms Thompson:

Once again, I am writing to express our concerns and adamant opposition to the construction of the proposed dock and desalination system being proposed by Orca Dreams LLC. As I said in my letter of May 16, 2014, we are the owners of the property abutting the applicants property. The beach where they propose to place the dock is shared by us, so our use of the beach is directly adversely impacted by what is proposed.

This beach is very pristine and is treasured by all our neighbors. The dock will be detrimental to the esthetics of the area, as it will be seen by all the frequent kayaks and boaters that transit the area. I am perplexed as to why the County would even give any consideration to this application,

since the applicant has already demonstrated their lack of concern about the environment, by illegally clear cutting a substantial portion of the cove, for which they were fined by the State.

The proposed dock will infringe upon publicly owned tidelands, that the University of Washington uses for biological research. There is no justification to use public lands for the private benefit of the applicant, particularly because will will definitely be harmful to the surrounding environment.

If this project is allowed to proceed, it will set a terrible precedent that will lead to numerous other attempts to despoil the waterfront for personal gain. The San Juan Islands are a special place that we all should be obligated to make every effort to preserve for future generations. I strongly urge you to reject this application.

Sincerely,

Mike

--

Mike Prentiss
P.O. Box 7046
Dallas,Texas 75209

214-668-1207(cell)

San Juan County, WA
F. Milene Henley, Auditor
QCD
Pgs=4 KIRAS

2014-1203014
12/03/2014 02:16 PM
Total:$75.00

0004518020141203014004046

Recorded at the request of:
WEISSINGER LAW OFFICES

Filed for Record at Request of:
Mimi M. Wagner, Attorney at Law
When recorded return to:
Law Offices of William J. Weissinger
425-B Caines Street
Friday Harbor, WA 98250

SAN JUAN COUNTY WASH.
REAL ESTATE EXCISE TAX
AMOUNT PAID $ Ø

DEC 03 2014
075625
JAN SEARS
COUNTY TREASURER

Quit Claim Deed

Grantors:
(1) David E. Ketter, as Trustee of Milton M. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 02/17/1983, as to a 28.75% interest;
(2) David E. Ketter, as Trustee of the Milton M. Bave GST Exempt Trust FBO Peter M. Bave UAD 02/17/1983, as to a 28.75% interest;
(3) David E. Ketter, as the Trustee of the Emelia L. Bave GST Exempt Trust FBO Peter M. Bave UAD 05/22/1989, as to a 21.25% interest;
(4) David E. Ketter, as Trustee of Emelia L. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 05/22/1989, as to a 21.25% interest.

Grantee: Orca Dreams LLC, a Washington limited liability company

Legal Description: Second class tidelands abutting the north 132 feet of GL 1, Sec 4, Twp 34 N, R 3 W, W.M.

Assessor's Tax Parcel Number: 340445 002 000

Reference Auditor File Numbers of Documents assigned, released or amended:

Unofficial Copy

Background

1. By statutory warranty deed dated July 9, 2013, and recorded under AFN 2013-0710010 and real estate excise tax affidavit number 073914, Grantor and others conveyed a portion of Government Lot 1 in Section 4, Township 34 North, Range 3 West, W.M., in San Juan County, to Grantee Orca Dreams LLC.

2. Since that conveyance, Grantors and Grantee have learned that 132 feet of second class tidelands abutting the north 132 feet of said Government Lot 1 should have been included with the property conveyed by that deed.

3. Because Grantors are the sole testate heirs of Milton and Emilia Bave, both deceased, and want to give a quit claim deed for these 132 feet of tidelands, rather than a statutory warranty deed, and for other reasons, re-recording the statutory warranty deed to make this conveyance is not an option, and Grantors are giving Grantee this quit claim deed.

Now, therefore, the Grantors, David E. Ketter, as Trustee of the Milton M. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 02/17/1983, as to a 28.75% interest, David E. Ketter, as Trustee of the Milton M. Bave GST Exempt Trust FBO Peter M. Bave UAD 02/17/1983, as to a 28.75% interest; David E. Ketter, as the Trustee of the Emelia L. Bave GST Exempt Trust FBO Peter M. Bave UAD 05/22/1989, as to a 21.25% interest, and David E. Ketter, as Trustee of the Emelia L. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 05/22/1989, as to a 21.25% interest, for and in consideration of **WAC 458-61A-201 (transfer without consideration)** and **WAC 458-61A-217 (re-record to correct a legal description), convey and quit claim** to ***Orca Dreams LLC***, a Washington limited liability company, the following described real estate, situated in the County of San Juan, State of Washington, together with all after acquired title of the grantor(s) therein:

The tidelands of the second class, situate in front of, adjacent to, or abutting upon the north 132 feet of Government Lot 1, Section 4, Township 34 north, Range 3 West, W.M., with a frontage of 2.00 lineal chains, more or less.

DATED this 21st day of November, 2014.

Unofficial Copy

David E. Ketter, Trustee of the Milton M. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 02/17/1983, as to a 28.75% interest:

David E. Ketter, as Trustee of the Milton M. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 02/17/1983

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David E. Ketter, as Trustee of the Emelia L. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 05/22/1989

STATE OF WASHINGTON

COUNTY OF KING

ss

On this day personally appeared before me ***David E. Ketter,*** to me known to be the individual described in and who executed the within and foregoing instrument, as ***Trustee of the Milton M. Bave GST Exempt Trust FBO Marsha L. Bave Fuller UAD 02/17/1983***, and acknowledged that he signed the same as his free and voluntary act and deed, for the purposes therein mentioned, and on oath stated that he was authorized to execute the said instrument as the Trustee of said Trust.

IN WITNESS WHEREOF I have hereunto set my hand and affixed my official seal the 21 day of November, 2014.

MARCELLA SCANNELL
STATE OF WASHINGTON
NOTARY PUBLIC
MY COMMISSION EXPIRES
04-23-16

Marcella Scannell
Notary signature

Marcella Scannell
Name printed

NOTARY PUBLIC in and for the State of Washington,
residing at Seattle, Washington.
My appointment expires on 042316.

STATE OF WASHINGTON

COUNTY OF KING

ss

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MARCELLA SCANNELL
STATE OF WASHINGTON
NOTARY PUBLIC
MY COMMISSION EXPIRES
04-23-16

Marcella Scannell
Notary signature

Marcella Scannell
Name printed

NOTARY PUBLIC in and for the State of Washington,
residing at Seattle, Washington.
My appointment expires on 042316.

Unofficial Copy

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04-23-16

Marcella Scannell
Notary signature

Marcella Scannell
Name printed

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My appointment expires on 04 23 16.

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MY COMMISSION EXPIRES
04-23-16

Marcella Scannell
Notary signature

Marcella Scannell
Name printed

NOTARY PUBLIC in and for the State of Washington,
residing at Seattle, Washington.
My appointment expires on 04 23 16.

Unofficial Copy

SURVEYOR'S NOTES

1. THIS TOPOGRAPHIC SURVEY MEETS OR EXCEEDS THE REQUIREMENTS OF WAC 332-130-090.

2. THIS MAP REPRESENTS A TOPOGRAPHIC SURVEY WHICH LOCATED EXISTING MONUMENTS, STAKES AND PHYSICAL FEATURES. NO BOUNDARY MARKERS OR STAKES WERE SET. ALL PARTIES ARE HEREBY ADVISED THAT THIS MAP DOES NOT CONSTITUTE A BOUNDARY SURVEY, AND IS EXEMPT FROM THE REQUIREMENTS FOR FILING UNDER THE PROVISIONS OF THE WASHINGTON STATE SURVEY RECORDING ACT PER RCW 58.09.090(1)(D)

3. FOR MORE INFORMATION ON THE EXISTING BOUNDARIES SEE THAT BOUNDARY LINE MODIFICATION RECORDED UNDER AUDITOR'S FILE NO. 2014-0929019, RECORDS OF SAN JUAN COUNTY, WASHINGTON.

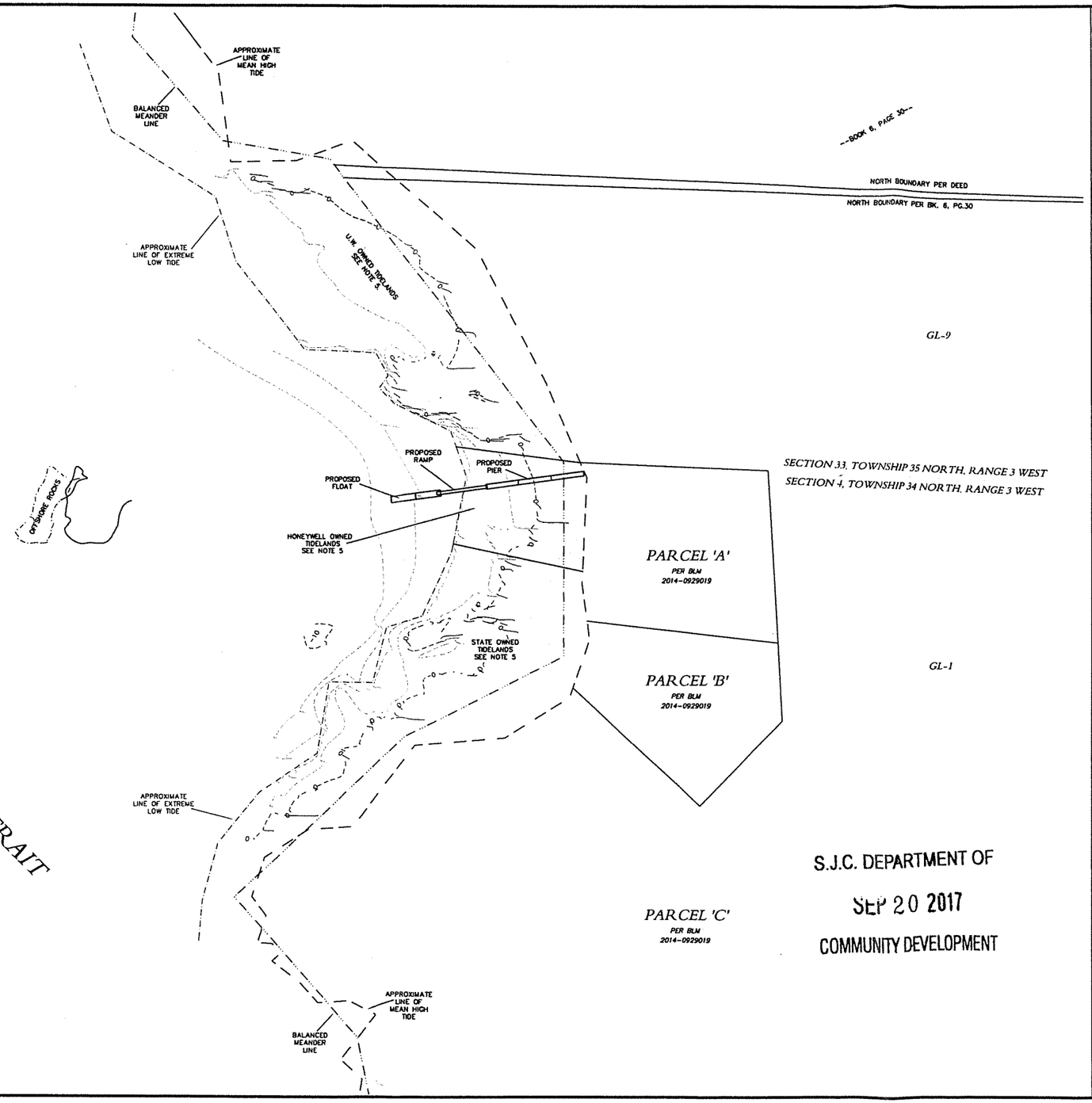
4. THE PURPOSE OF THIS SURVEY IS TO SHOW THE UNDERWATER CONTOURS FOR DOCK PLANNING PURPOSES. THE LINE OF EXTREME LOW TIDE HEREON IS -4.2 FEET PER NOAA FRIDAY HARBOR TIDAL BENCHMARK SHEET 9449880 PUBLISHED 10/30/2003.

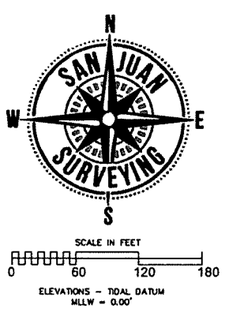
5. THE LATERAL BOUNDARIES OF SECOND CLASS TIDELANDS SHOWN HEREON WERE DETERMINED DURING NOVEMBER OF 2015 AND A RECORD OF SURVEY WILL BE RECORDED SHOWING HOW SAID LATERAL BOUNDARIES WERE DETERMINED.

6. THE BASIS OF BEARINGS FOR THIS SURVEY IS THE WASHINGTON STATE PLANE COORDINATE SYSTEM - NORTH ZONE. ON-SITE STATIC OBSERVATIONS WERE POST PROCESSED USING THE LEICA PROPRIETARY SPIDERNET WITH THE BASE STATION BEING AT THE SAN JUAN SURVEYING, LLC OFFICE LOCATED IN FRIDAY HARBOR, WASHINGTON.

LEGEND

- - - - - - 10 - - - - - -	10-FT CONTOURS
	2-FT CONTOURS ABOVE MLLW
	2-FT CONTOURS BELOW MLLW





EQUIPMENT AND PROCEDURES

EQUIPMENT: LEICA 1201+ (ONE SECOND THEODOLITE)
LEICA 1200 GPS

PROCEDURE: FIELD TRAVERSE

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

ORCA DREAMS, LLC
PO BOX 928
FRIDAY HARBOR, WA
98250

TOPOGRAPHIC SURVEY
FOR
ORCA DREAMS, LLC
ON
SAN JUAN ISLAND

DRAWN BY: NSR	COMP. FILE: 13-073 (TOPO)	JOB NO: 13-073	
CHECKED BY: RJW	DATE: 1/30/17	SHEET 1 OF 1	

SAN JUAN SURVEYING
P.O. BOX 611
FRIDAY HARBOR, WA 98250
360.378.2300
WWW.SANJUANSURVEYING.COM

QUARTER	SECTION	TOWNSHIP	RANGE
GL 9	33	35	3
GL 1	4	34	WEST
		NORTH	

ROBERT J. WILSON, STATE OF WASHINGTON, REGISTERED PROFESSIONAL LAND SURVEYOR

PROPERTY INFORMATION

SITE ADDRESS: 1801 FALSE BAY DRIVE

TAX PARCEL NUMBER: XXXXXXXXX

DESCRIPTION: TOPOGRAPHIC SURVEY

MISC:

Julie Thompson

From: Planning and Permit Services LLC <francine@rockisland.com>
Sent: Wednesday, September 20, 2017 11:17 AM
To: Julie Thompson
Cc: Stephanie Johnson O'Day; 'David Honeywell'; 'Nancy Yahoo'
Subject: RE: #PSJ000-17-0003; 4slip dock and RO desalination system
Attachments: K Loring Comment Letter Re Wells.pdf

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Julie:

Please see the attached letter from attorney, Katie Loring, who is representing Mr. Prentiss regarding use of well water to serve the Honeywell property. Mr. Prentiss is represented as having concerns of the impact that use of well water to serve the Honeywell property will on his well water source. The desal plant will eliminate Mr. Prentiss's concerns.

Francine

From: Julie Thompson [mailto:JulieT@sanjuanco.com]
Sent: Wednesday, September 20, 2017 9:00 AM
To: Francine Shaw (Francine@rockisland.com)
Subject: FW: #PSJ000-17-0003; 4slip dock and RO desalination system

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Sent: Monday, September 18, 2017 9:09 AM
To: Julie Thompson <JulieT@sanjuanco.com>
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If this project is allowed to proceed, it will set a terrible precedent that will lead to numerous other attempts to despoil the waterfront for personal gain. The San Juan Islands are a special place that we all should be obligated to make every effort to preserve for future generations. I strongly urge you to reject this application.

Sincerely,

Mike

--

Mike Prentiss
P.O. Box 7046
Dallas,Texas 75209

214-668-1207(cell)

GODDU | LANGLIE | LORING | SANDSTROM PLLC
LAWYERS - ADVISORS

Peter W. Goddu
Margaret C. Langlie
Kathryn C. Loring
Thomas D. Sandstrom

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

June 24, 2016

SENT VIA HAND DELIVERY

Kyle Dodd
San Juan County Department of Health and Community Services

Re. Orca Dreams, LLC – Plat Application – Water Availability

Dear Mr. Dodd:

I am writing on behalf of several property owners in the False Bay neighborhood, including owners of properties nearby the Orca Dreams property, Kim Sundberg and Debby Clausen and Mike Prentiss, to urge the San Juan County Department of Health and Community Services to require the Applicant Orca Dreams, LLC (Applicant), to monitor neighboring wells during the required pump tests to determine water availability for their proposed plat of eight residential lots and related Group B water system.

Neighboring property owners are extremely concerned about potential impacts and impairments to their own, existing wells in the form of lowering static water level, which may be caused by the increased demand on the limited bedrock, shoreline aquifer resulting from the Applicant's proposed eight-lot subdivision. Further, neighbors are concerned that the additional stress on the aquifer may cause increased risk of saltwater intrusion to their wells in any area with existing, known risk for saltwater intrusion.

As you know, the proposed subdivision is located in an area of the Island that has a history of known water issues and limitations. The predecessor owner of the subject property historically purchased and trucked-in water from off-site. As you know, County regulations do not allow trucked-in water for an 8-lot subdivision.

Further, the nearby subdivision formerly known as "Westview Estates" and now known as the plat of "Gleneagle" was required by the San Juan County Hearing Examiner to monitor neighboring wells in their pump test protocol prior to approval. Neighbor's stated concerns about Gleneagle were born out by additional hydrogeological data and analysis from the more rigorous pump tests and monitoring of adjacent wells, as required by the Hearing Examiner. After the rigorous and monitored testing, including a third-party review by Pacific Groundwater Group, representing the Neighbors, the County ultimately required as conditions for plat

365-E Spring Street • PO Box 668 • Friday Harbor, WA 98250
Phone (360) 378-2181 / (360) 378-2191 • www.sjilaw.com

approval, among other things, additional wells to be drilled, pumping rates to be restricted, permanent expanded water storage, and a prohibition on outdoor landscape watering.
It is important to note that only two of the potential nine connections on the Gleneagle Group B system have been connected to developed parcels, and one of those two developed parcels is only used seasonally, not full-time. Therefore, in considering potential impacts of the Applicant's proposed Group B water system, the County should consider the full potential "build out" of the nearby Gleneagle subdivision, and its likely increased demands on the aquifer once all nine properties served by the system are connected.

Here, peer reviewer James Hay has concluded that the Applicant's prior pump tests were deficient and failed to comply with San Juan County Code (SJCC) 8.06.150 in numerous aspects, including by failing to conduct the tests at the required time of year and failing to have adequate, approved pump test protocols.

Indeed, SJCC 8.06.150(D) requires at least one monitoring well to be used, if available. Well driller Al Mauldin asserted in an e-mail on November 17, 2015, which was forwarded to you by Stephanie O'Day on the same day, that they "could not get permission from others in the area to shut off their wells to monitor their water levels." (A true and correct copy of that e-mail is attached hereto.) The implied assertion that Mr. Mauldin or the Applicant asked neighboring property owners to monitor their wells during the prior pump tests is simply false. My clients have informally surveyed owners of the properties closest to the Applicant's property and not one owner has confirmed that they were asked to have their well monitored.

Further, Mr. Hay concluded that the Applicant's hydrogeologic site evaluation was deficient and failed to comply with SJCC 8.06.150(F)(1)(b)&(c) and (F)(2)(c)&(d), including specifically failing to analyze patterns of groundwater in the nearby area and groundwater availability in the area, including historic failures or history of seawater intrusion.

As Mr. Hay essentially concluded, the Applicant's so-called site evaluation fails to discuss in any depth or detail groundwater availability of the area at issue and the known history of failures and related issues.

Given the known history here and the existing need to perform new pump tests, it only makes sense to require the Applicant to conduct meaningful tests resulting in reliable data, which include the monitoring of numerous, nearby, neighboring wells. My clients are willing to work with the Department of Health and Community Services to arrange monitoring of their wells under agreed parameters and protocols.

I urge you to require genuine and rigorous testing that includes the monitoring of nearby wells. I welcome your phone call to discuss the parameters of such monitoring.

Thank you for your consideration.

Sincerely,

GODDU LANGLIE LORING SANDSTROM PLLC

Kathryn C. Loring

Julie Thompson

From: Mike Lisitza - NOAA Affiliate <mike.lisitza@noaa.gov>
Sent: Wednesday, September 20, 2017 1:49 PM
To: Julie Thompson
Subject: Comments on the Orca Dreams, LLC Dock Project (Permit # PSJ000-17-003)
Attachments: Giles 2014.pdf; Noren 2009.pdf; Lusseau 2009.pdf; Williams 2007.pdf; Williams et al 2009 effects of vessel .pdf

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Hi Julie,

NOAA's National Marine Fisheries Service (NMFS) has concerns regarding this proposal. We are currently in formal Endangered Species Act (ESA) Section 7 consultation with the Army Corps of Engineers for potential effects of this project to southern resident killer whales (SRKWs) and other listed species. While we are evaluating many potential effects of this proposal, our most serious concerns are regarding indirect impacts to SRKWs. We have not yet completed a review of the project and concluded the consultation process. Therefore, our comments in this letter or not conclusive determinations, but rather areas of interest and concern for endangered SRKWs.

The applicant's response to the public comments received by the US Army Corps of Engineers describes Mr. Honeywell as an avid whale watcher and states that he will observe the no-approach zone when whales are present (Shaw in litt.). We understand from these statements that one of the purposes of the dock is to moor vessels to follow and observe SRKWs and other marine mammals.

The west side of San Juan Island is the core of SRKWs summer habitat. It is a hot spot for SRKW foraging. Limited prey availability is one of the primary limiting factors for the SRKW population, so uninhibited foraging access is particularly important for SRKW survival and recovery. For these reasons, the Pacific Whale Watch Association established a special operating area on the west side of San Juan Island. These guidelines direct vessels to remain a minimum of 400 yards from the main shoreline of the west side of San Juan Island when between Eagle Point and Mitchell Point when whales are present. While commercial whale watching vessels usually follow these guidelines, Giles et al. (2014) found recreational boats to be the most common boats out of compliance with the whale watching regulations and guidelines.

Numerous studies confirm that the presence of vessels reduces SRKW foraging behavior (Giles 2014; Lusseau et al. 2009; Noren et al. 2009; Williams and Ashe 2007; Williams et al. 2009). The presence of vessels has the potential to exacerbate the impacts to SRKWs from limited prey availability by interfering with their ability to exploit the prey that is available. Currently, there are no docks between Eagle Point and Mitchell Point. The proposed dock would be the only one. Typically, whale watching vessels, both commercial and recreational, must get reports on the whales' location in the morning, load passengers, and travel to the west side of San Juan Island from their mooring location. Currently, SRKWs can forage during the early morning hours with little or no disturbance from vessels. The proposed dock could allow boats to begin whale watching during these early

morning hours, thereby eliminating this boat-free foraging time. The proposed project has the potential to measurably decrease the amount of boat-free daylight hours the SRKWs have during the summer. This could risk measurably reducing the amount of prey SRKWs are able to consume.

We are also concerned that approval of this proposal will serve as a precedent for the approval of future docks on the west coast of San Juan Island. Any future docks could compound all of the potential impacts described above. Multiple docks between Eagle Point and Mitchell Point would also have the potential to permanently degrade SRKW critical habitat.

--
Mike Lisitza
NMFS Contractor
Oregon and Washington Coasts Area Office
Phone: (206) 305-9475
Core office Hours: Mon-Fri 6am-2pm

Southern Resident Killer Whales (*Orcinus orca*):
The evolution of adaptive management practices for vessel-based killer whale watching in the Salish Sea,
A novel non-invasive method to study southern resident killer whales (*Orcinus orca*) and vessel compliance with regulations, and
The effect of vessels on group cohesion and behavior of southern resident killer whales (*Orcinus orca*)

By

DEBORAH A. GILES
B.A. (University of California, Davis) 2004
M.A. (University of California, Davis) 2007

DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY
in
Geography

in the
OFFICE OF GRADUATE STUDIES
of the

UNIVERSITY OF CALIFORNIA
DAVIS

Approved:

_____
Deborah L. Elliott-Fisk, Chair

_____
James F. Quinn

_____
A. Peter Klimley

_____
Dawn P. Noren

Committee in Charge
2014

UMI Number: 3626639

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Deborah A. Giles
March 2014
Geography

Southern Resident Killer Whales (Orcinus orca)

Abstract

This dissertation concerns the southern resident killer whales (*Orcinus orca*), a genetically isolated population of fish-eating killer whales that frequent the international waters of the Salish Sea between the United States and Canada in the eastern Pacific Ocean. Research was conducted from June 1 to October 31, 2007 and from June 7 to October 31, 2008, between geographic coordinates: 48°12′ to 49° N latitude by 122°43′ to 123°50′ W longitude.

The southern resident killer whale population has experienced multiple fluctuations since population surveys were initiated by the Center for Whale Research (CWR) in the mid 1970's. In November 2005, the U.S. National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS), Northwest Regional Office listed the southern resident killer whales as an endangered distinct population segment of the species *Orcinus orca* under the United States Endangered Species Act (ESA). Several risk factors including reductions in the quantity and quality of prey (salmon), exposure to persistent toxins, and disturbance from vessel presence and associated noise were identified as contributing to the decline of this already small population. With the listing under the ESA, critical habitat was designated in the inland waters around the U.S. San Juan Islands, Washington State and the Canadian Gulf Islands, British Columbia, Canada.

Chapter one, *Managing Vessel-based Killer Whale Watching: A Critical Assessment of the Evolution from Voluntary Guidelines to Regulations in the Salish Sea*, provides background

on the southern resident killer whales and the robust international whale watching industry in the region. This chapter also provides a detailed history of local, state, federal and international vessel laws and guidelines for watching whales in the Salish Sea.

Chapter two, *Non-invasive methods to study southern resident killer whales and vessel compliance with regulations,* describes a novel equipment package, consisting of a differential GPS integrated with a digital compass and laser rangefinder that allowed me to collect accurate geo-referenced locations and behavioral data on whales and vessels throughout the whale's critical habitat. To improve both the spatial and temporal data on whale-vessel interactions, the information collected with this equipment was used to assess vessel compliance with local, state and federal laws and the regionally accepted best-practices Be Whale Wise Guidelines.

Chapter three, *The effects of vessels on group cohesion and behavior of southern resident killer whales* (Orcinus orca), discusses research investigating changes in killer whale group cohesion in response to vessel density, distance and mode of operation. Future cetacean studies would benefit from using the equipment and methods presented here, especially in areas that are not conducive to land-based theodolite collected data.

CHAPTER 1

Managing Vessel-based Killer Whale Watching: A Critical Assessment of the Evolution from Voluntary Guidelines to Regulations in the Salish Sea

DEBORAH A. GILES*
KARI L. KOSKI+

1. INTRODUCTION

Southern Resident killer whales (SRKWs) are a genetically isolated population of fish-eating killer whales (*Orcinus orca*) frequenting the international waters of the Salish Sea between the United States and Canada in the eastern Pacific Ocean (Figure 1). Since the mid-1980s, these killer whales have been the star attraction for a large, international, recreational and commercial whale watch industry. The popularity of whale watching and the rapid growth of the industry spurred local non-governmental organizations (NGOs) to press for measures that would prevent the whales from being harmed by disturbances caused by vessels. Their primary achievement in this campaign was the adoption of a community driven or bottom-up adaptive management process to implement and evaluate whale watching guidelines, enforced through a partnership between the NGOs and the whale watch industry.

Despite this initiative and several others aimed at increasing salmon populations and reducing persistent toxins in the environment, the SRKWs suffered a significant population

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decline in the late 1990s and public demand for protective status resulted in the whales being listed as an endangered species, first under Canada's Species at Risk Act (SARA) in 2003[1] and later under the United State's Endangered Species Act (ESA) in 2005.[2] Several cumulative risk factors including reductions in the quantity and quality of prey (salmon), exposure to persistent toxins, and disturbance from vessel presence and associated noise[3] were identified as contributing to the decline of an already small population and as justification for moving from voluntary to mandatory regulation.

Long-term data showing relationships between vessels and SRKWs, for example, showed a trend towards large congregations of vessels traveling with whales throughout the whales' summer core habitat and boaters routinely out of compliance with the established voluntary guidelines.[4] This trend, coupled with a growing body of scientific research confirming impacts to whales from vessels,[5] spurred government agencies to entertain specific vessel regulations.[6] This

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[1] Canada, Department of Fisheries & Oceans, Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada (Species at Risk Act Recovery Strategy Series, Ottawa, 2011). Online at http://www.sararegistry.gc.ca/virtual_sara/files/plans/rs_epaulard_killer_whale_1011_eng.pdf (accessed 27 Jan. 2012) [hereinafter SARA/Recovery Strategy].

[2] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Endangered and Threatened Wildlife and Plants: Endangered Status for Southern Resident Killer Whales, Final Rule. 70 Fed. Reg. 69903 (Nov. 18 2005) [hereinafter NMFS Status Rule].

[3] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*) NMFS Northwest Region, Seattle, Jan. 2008). Online at http://ecos.fws.gov/docs/recovery_plan/whale_killer.pdf (accessed 27 Jan. 2012) [hereinafter NMFS/Recovery Plan]

[4] Kari Koski, Soundwatch Program Annual Contract Report (Annual Report to NOAA under Contract CN-0221, 75 pp. The Whale Museum, Friday Harbor, WA. 2011). Online at http://www.whalemuseum.org/ programs/soundwatch/2011%20Soundwatch%20NOAA%20Contract%20CN-0221%20Report.pdf (accessed 27 Jan. 2012) [hereinafter Koski].

[5] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Advance Notice of Proposed Rulemaking, Protective Regulations for

happened first in the U.S. with the adoption of San Juan County vessel regulations for SRKWs in 2007,[7] and then Washington State SRKW vessel regulations in 2008[8] and finally federal killer whale vessel regulations in Washington State inland waters in 2011.[9]

Initial unfamiliarity with the new regulatory process, together with the perceived adverse economic impacts of the new protective measures on the whale watch industry, were the source of considerable political conflict. And this in turn affected the working relationships between the industry, NGOs, and government agencies at the heart of the collaborative and community based adaptive management process ushered in by the voluntary guidelines. It is possible, of course, that as the whale watching community, NGOs, and government agencies all become more familiar with how mandatory vessel regulations, as well as other government led recovery actions, are being implemented, a new model of adaptive management driven by government agencies, a top-down model, will evolve. And there might then be a reestablishment of the kinds of collaborative relationships that are needed to carry on the work of assessing the efficacy of mandatory regulations and their economic impacts, and then making recommendations for management adjustments or new initiatives.

Killer Whales in the Northwest Region under the Endangered Species Act and Marine Mammal Protection Act, 72 Fed. Reg. 13464 (22 Mar. 2007) [hereinafter NMFS/Advance Notice].

[6] *Id.*

[7] San Juan County, Wa., Ordinance Regulating the Operation of Vessels in Proximity to the Southern Resident Killer Whale, an Endangered Species, and Establishing Penalties for the Violation Thereof, Ordinance 35-2007, (2007). Online at http://www.whalemuseum.org/ordinance/SJCOO.pdf (accessed 27 Jan. 2012) [hereinafter San Juan Vessel Regulations].

[8] Protection of Southern Resident Orca Whales-Penalty. WASH. REV. CODE 77.15.740 (2008). Online at http://apps.leg.wa.gov/RCW/default.aspx?cite=77.15.740 (accessed 27 Jan. 2012) [hereinafter Washington Vessel Law].

[9] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Protective Regulations for Killer Whales in the Northwest Region under the Endangered Species Act and the Marine Mammal Protection Act, Final Rule, 76 Fed. Reg. 20870 (14 Apr. 2011) [hereinafter NMFS/Final Vessel Rule].

There are signs that top-down adaptive management is what the mandatory regulations anticipate. Both the Recovery Strategy for SRKWs[10] and the Final Environmental Assessment (EA) for the new regulations[11] developed by the U.S. National Marine Fisheries Service (NMFS) use the language of adaptive management. The agency wants continued monitoring, for example, to compare vessel trends before and after the introduction of vessel regulations. It wants on-going reviews of research focused on vessel effects. It anticipates an economic assessment of the unexpected impacts on the whale watch industry and surrounding communities of implementing the regulations. And it is calling for annually updated information that can be used to assess whether vessel regulations actually have the effect of aiding the recovery of endangered killer whales in the Salish Sea. The results from all these reviews, when coupled with inputs from various stakeholders, including the whale watch community, could in theory provide the basis for continuous adjustment of management actions, or for new initiatives. Indeed, on their face, these agency expectations exemplify all the classic, textbook attributes of an adaptive ecological management process.

But will top-down adaptive management of SRKWs in the Salish Sea be distinguishable from bottom-up adaptive management? Will one be better than the other? How exactly, come to think of it, are they to be distinguished?

It is very hard to find these days in the literature on ecological management anyone who thinks adaptive management is a bad idea, assuming it is considered as a theoretical possibility

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[10] NMFS/Recovery Plan, *supra* note 3.

[11] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Final Environmental Assessment, New Regulations to Protect Killer Whales from Vessel Effects in Inland Waters of Washington, RIN 0648-AV15 (NMFS Northwest Region, Seattle, Nov. 2010). Online at http://www.nwr.noaa.gov/Marine-Mammals/Whales-Dolphins-Porpoise/Killer-Whales/Recovery-Implement/upload/Vessel-Rule-EA.pdf (accessed 27 Jan. 2012).

and divorced from any empirical reality. But it is even harder to find careful analyses of how different models of adaptive management come into being, how one transitions to another, whether the change makes sense from a resource management perspective, and, if not, what might be done about it. In this paper, therefore, we make an important contribution by taking on these empirical questions.

The Salish Sea is a good place to do this because, as readers can readily tell from glancing at the map in Figure 1, an international boundary runs through it. The much-heralded interest U.S. federal agencies have in adaptive management of SRKWs will have to be squared with comparable expectations on the Canadian side of the line. Indeed, the complications of adaptive management in practice only begin there. They do not end until the visions of adaptive management held by state and provincial and local agencies, as well as by NGOs and the industry, among other interested parties, are all taken into account. The story is still unfolding, so there is no firm conclusion. It is, however, a fascinating tale.

2. THE SALISH SEA AND ITS RESOURCES

The international waters of northwestern Washington State, United States, and southwestern British Columbia (B.C.), Canada, are now designated as the Salish Sea.[12] This is an inland sea of roughly 18,000 square kilometers (7,000 sq mi.) named in honor of the Coast Salish indigenous people. The name recognizes the transboundary nature of the physical,

[12] The nomenclature "The Salish Sea" was entered by the United States government the Geographic Names Information System (GNIS) on 17 Nov. 2009 (http://geonames.usgs.gov/pls/gnispublic/ and then search for Salish Sea) and by the British Columbia Ministry of Forests, Lands and Natural Resource Operations into the British Columbia Geographical Names Unit on 9 Feb. 2010 (http://apps.gov.bc.ca/pub/bcgnws/names/53200.html) (both accessed 27 Jan. 2012).

biological, and human community components of Puget Sound and the Georgia Basin ecosystem (Fig. 1), a dynamic ecosystem that is home to roughly 3000 invertebrates, 219 fishes,[13] 172 birds[14] and 29 mammals and provides some of the best and most reliable killer whale viewing opportunities in the world.

2.1 The Killer Whales of the Salish Sea

Three distinct ecotypes of killer whales occur in the Salish Sea. Genetic and behavioral research shows that these different ecotypes do not interbreed or socialize. The least frequently seen of the three are known as the "offshore" type, whales most often spotted far offshore[15] and known to predate on sharks.[16] The second killer whale ecotype comprises the "transients," mammal eaters foraging primarily on harbor seals (*Phoca vitulina*), harbor porpoises (*Phocoena phocoena*) and Dall's porpoises (*Phocoenoides dalli*), but also known to consume other marine mammals common in the Salish Sea. The third and most commonly encountered ecotype of killer whale is known as the "resident" type and is the most widely studied and viewed of the three.

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[13] Nicholas A. Brown & Joseph K. Gaydos, Species of Concern within the Georgia Basin-Puget Sound Marine Ecosystem: Changes from 2002 to 2006, in Proc. 2007 Puget Sound Georgia Basin Research Conference 1-10 (Vancouver, B.C., Canada. Mar. 26-29, 2007). Online at http://www.vetmed.ucdavis.edu/whc/seadoc/pdfs/brown-gaydos07.pdf (accessed 27 Jan. 2012). The SeaDoc Society (www.seadocsociety.org, accessed 27 Jan. 2012) is a program of the UC Davis School of Veterinary Medicine's Wildlife Health Center, dedicated to finding scientific solutions to the environmental problems impacting the entire Salish Sea ecosystem and its wildlife, without regard to national borders.

[14] Joseph K. Gaydos & S.F. Pearson, *Birds and Mammals that Depend on the Salish Sea: A Compilation,* 92 NW. NATURALIST 79-94 (2011).

[15] Marilyn E. Dahlheim et al., Eastern temperate North Pacific offshore killer whales (Orcinus orca): Occurrence, movements, and insights into feeding ecology, 24 MAR. MAMM. SCI. 719–729 (2008)

[16] John Ford et al., Shark predation and tooth wear in a population of northeastern Pacific killer whales, 11 AQUAT. BIOL. 213-224 (2011)

There are two resident killer whale communities in the northeast Pacific ocean: the Northern, found most often in Johnstone Strait, off the northeast coast of Vancouver Island, B.C.; and the Southern, most frequently found in the transboundary waters of the Salish Sea during the summer months. The whales in both resident communities are fish eaters, preferentially foraging on Chinook and Chum salmon *(Oncorhynchus shawytscha* and *O. keta)* during the spring, summer and fall months.[17]

After early research confirmed that there were two distinct populations of resident fish-eating killer whales in the northeast Pacific, the Northern Residents and the Southern Residents became the objects of long term census projects recording annual changes due to births and deaths. This census research has been conducted since the mid-1970s by the Canadian Department of Fisheries and Oceans (DFO) and the Center for Whale Research. At the end of 2010, records showed that there were 261 Northern Resident Killer Whales[18]and, as of August 2011, there were only 88 Southern Resident killer whales.[19]

Resident killer whales are unique in the mammalian order not only because they live in highly structured matrilineal societies, but also because neither sex disperses from the natal group.[20] They are most often observed in groups of related individuals known as pods, with each pod having a unique dialect. Pods that share overlapping vocal calls with other pods are

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[17] M. Bradley Hanson, et al., Species and stock identification of prey consumed by endangered southern resident killer whales in their summer range, 11 END. SPEC. RES. 69-82, (2010)
[18] Graeme M. Ellis, J.R. Towers, & J.K.B. Ford, Northern Resident Killer Whales in British Columbia: Photo-Identification Catalogue and Population status to 2010, CAN. TECH. REP. FISH. AQUAT. SCI. 2942 (2011).
[19] David Ellifrit, Kenneth C. Balcomb III & Erin Heydenreich, Official Orca Survey: A Naturalist's Family Tree Guide to Orca Whales of the Southern Resident Community (The Center for Whale Research, Friday Harbor, WA. 2011).
[20] John Ford, Graeme Ellis & Kenneth Balcomb III, Killer Whales: the natural history and genealogy of *Orcinus orca* in British Columbia and Washington State (2d ed. 2000) [hereinafter Ford et al.].

considered to be in the same clan. Whale pods frequently observed together in the same range are considered to be members of the same community or population.[21] The Northern resident community is comprised of three clans and the Southern resident community is considered to be a single clan. The two "resident" populations are acoustically, culturally, and genetically distinct[22] and both are recognized and managed by the U.S. and Canadian governments as distinct stocks or populations.

2.2 Population Declines among SRKWs in British Columbia and Washington State

In 1970, because of growing concern from fisheries managers and the general public surrounding the live removal of killer whales for marine parks that began in 1965,[23] research on killer whales in British Columbia and Washington State intensified. The official census of the Southern Resident community in 1976 documented three unique pods (J, K and L pods), consisting of a total of 70 whales. This census came after 47 whales were taken from the wild between 1962 and 1973. Of those 47, 35 were transported alive to marine parks and 12 were killed in the process. The last whale removed from the Salish Sea was captured in Menzies Bay, B. C., in 1977, and just one Southern Resident killer whale now remains alive in captivity and on display: a female member of L-pod, captured over 40 years ago, on August 8th, 1970, in Penn Cove, Washington.[24]

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[21] *Id.*
[22] L.G. Barrett-Lennard & G.M. Ellis, Population structure and genetic variability in Northeastern Pacific killer whales: toward an assessment of population viability, CSAS Res. Doc. 2001/065 (2001). Online at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2001/2001_065-eng.htm (accessed 27 Jan. 2012).
[23] FORD et al., *supra* note 20.
[24] NMFS/Recovery Plan, *supra* note 3.

Since 1976, when most live captures ended, the population of SRKW has fluctuated (Figure 2). By 1980, the whale population had increased by 19 percent, going from 70 to 83 animals. However, this period of growth was followed by an 11 percent decline over the next four years, most likely stemming from skewed age-sex ratios and a direct result of the live capture preference for immature or juvenile males.[25] Between 1985 and 1995 there was an overall population increase of 32 percent, starting with 77 animals is 1985 and peaking with 98 individuals in 1995. However, this decade of increase was followed by a decline of 17 percent between 1996 and 2001, with a loss of 16 whales across all three pods. Unlike the previous decline, this decrease could not be explained as a result of live capture.[26] And then beginning in 2002, annual census numbers continued to increase until 2006, when the population reached 90 whales. Subsequent censuses have counted between 85 and 88 whales.

Overall, research suggests that annual changes in survival rates since the mid-1990s are the result of exposure to anthropogenic persistent toxins, reduced prey quantity and quality, disturbance from vessels, and associated noise,[27] or, more likely, a combination of these and other factors. They had resulted, in any event, in federal protections in both Canada and the U.S. by 2005. While not implicated as factors affecting past declines in the Southern Resident killer whale population, several additional risks have been identified as potential threats to the population including oil spills, disease, and perhaps inbreeding.

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[25] P.F. Olesiuk, M.A. Bigg, and G.M. Ellis. *Life history and population dynamics of resident killer whales (Orcinus orca) in the coastal waters of British Columbia and Washington State*, 12 SPEC. ISSUE REP. INT'L WHALING COMM. 209-244 (1990).
[26] NMFS/Recovery Plan, *supra* note 3.
[27] *Id. See* also M.M. Krahn et al., Status review of southern resident killer whales (Orcinus orca) under the Endangered Species Act (U.S. Department of Commerce, National Oceanic & Atmospheric Administration, Tech. Memo. NMFS-NWFSC-54, Seattle, 2002).

3. RECENT TRENDS IN WHALE WATCHING

3.1 Worldwide Trends

A comprehensive 2009 report commissioned by the International Fund for Animal Welfare (IFAW) documents the growth of marine mammal ecotourism throughout the world during the decade between 1998 and 2008.[28] The report exhaustively examines the economic implications of whale watching on a country by country basis and provides more focused discussions for countries that have unique or especially high rates of associated ecotourism, such as the United States and Australia, the two countries with the highest percentage of people participating in marine ecotourism worldwide, 38 percent and 13 percent respectively.[29]

This global increase in marine mammal ecotourism is both a blessing and a curse for the animals themselves. From 1955, when the first fisherman began taking paying customers out to see whales for $1.00, marine mammal ecotourism blossomed into an annual $2.1 billon USD industry by 2008, an increase of $1 billion just since 1998. In the past half-century, the value of commercial whaling has plummeted and commercial whale watching has soared. Worldwide, 13 million people participated in marine mammal ecotourism in 2008, an increase of 5 million compared with just 1998.[30] The increases are widely distributed across Europe (7%), Oceania/Pacific Islands and South America, both (10%), and Asia (17%). The number of people participating in whale watching in Japan has increased 6.4%, to a total of 191,970 in 2008,

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[28] International Fund for Animal Welfare (IFAW), Whale Watching Worldwide: Tourism Numbers, Expenditures and Economic Benefits (IFAW Special Report, Yarmouth, MA 2009). Online at http://www.ifaw.org/sites/ default/files/whale_watching_worldwide.pdf (accessed 27 Jan. 2012) [hereinafter IFAW 2009].
[29] Id.
[30] Id.

despite the controversial "scientific whaling" that Japan continues to practice.[31] Overall, there were more than 3,000 marine mammal ecotourism operations employing approximately 13,200 people worldwide in 2008.[32]

3.2 Industry Trends in the Salish Sea

Commercial whale watching in the Salish Sea was virtually non-existent prior to 1976. Between 1984 and 1998, a new industry emerged, chiefly focused on killer whale viewing, and then showed steady growth in both the U.S. and Canada.[33] Since 2000, the number of commercial companies, as well as the total number of commercial whale watching vessels, has remained nearly constant (Figure 3).[34] In 2010 there were 76 *active* commercial whale watching vessels (those that operate at least 1 day per week between May and September), originating from 35 commercial companies, 16 of them American and 19 Canadian.[35] Annual ticket sales for commercial whale watching in the Salish Sea went from $10,000 (USD) in 1985 to roughly $5.7 million by 1997.[36] Members of the Pacific Whale Watch Association estimate that whale watching companies operating in the Salish Sea have an impressive 90 percent success rate for finding whales to watch, because of the regular occurrence of killer whales in the inland waters between May and October.[37]

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[31] P. Corkeron. Whale Watching, Iconography, and Marine Conservation. 18 CONS. BIOL. 847-849 (2004).
[32] IFAW 2009, *supra* note 28.
[33] R.W.Osborne, A historical ecology of Salish Sea "resident" killer whales (Orcinus orca): with implications for management (1999) (unpublished Ph.D. dissertation, University of Victoria, British Columbia) (on file with the authors) [hereinafter Osborne 1999] .
[34] Koski, *supra* note 4.
[35] *Id.*
[36] Osborne 1999, *supra* note 33.
[37] IFAW 2009, *supra* note 28, at 219.

Commercial vessels vary in size from small open boats about 20 feet long and carrying around a dozen passengers to large vessels over 150 feet carrying over 250 passengers. Most U.S. vessels are large, slow passenger-style craft making one or two trips daily. Canadian vessels by contrast are mostly open, high-speed craft making up to four trips a day. Smaller Canadian vessels carry less people but make more trips. Overall, then, vessels in both countries probably take out nearly equal numbers of passengers.[38]

The Salish Sea also attracts large numbers of private boaters, both for fishing and general recreation, with many engaging in whale watching activities. Nearly 30 percent of all vessels observed traveling with the whales are private recreational boaters.[39] Long term monitoring from 1998 to 2010 shows annual averages of between 15 and 20 boats of all types observed within a half-mile of whales. There is, however, wide daily and monthly variability in the numbers of boats with whales. In 2010, for example, the highest vessel count near the whales was 54 and in 1999 the highest vessel count was 120.[40] Shore based whale watching has also increased in popularity because of increased access to and knowledge of choice public viewing locations throughout the region,[41] such as Lime Kiln Point/Whale Watch State Park, which receives 200,000 visitors a year on a consistent basis.[42] An estimated 530,000 people engage in whale watching activities from private and commercial vessels, kayaks, and aircraft, along with countless shore based observers in the Salish Sea region.[43]

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[38] Koski, *supra* note 4.
[39] *Id.*
[40] *Id.*
[41] Such sites are listed, for example, at http://www.thewhaletrail.org (accessed 27 Jan. 2012).
[42] This stems from Lime Kiln State Park being designated as "Whale Watch Park" in 1983 and currently being advertised as such on popular San Juan tourism websites such as http://www.thesanjuans.com/san-juan-island-places/sanjuan-parks-forest/lime-kiln-state-park.shtml (accessed 27 Jan. 2012).
[43] Koski, *supra* note 4.

Traditionally, the whale watching season begins in May and goes through the summer into October, with most viewing taking place from 9 a.m. to 9 p.m. The highest concentrations occur in July and August and between the hours of 10 a.m. and 5 p.m. In recent years, however, several commercial companies have begun offering "sunset trips," staying out until nearly 10 p.m. during peak summer months. And some commercial operators are whale watching year round.[44] Clusters of commercial whale watch vessels attract recreational boaters to whales, and this particularly holds true outside of the core summer viewing season, times and locations. As more people participate in whale sighting networks via social media, such as list-serves, on-line hydrophone networks, blogs, Twitter, and Facebook feeds,[45] near real-time information is available daily on the whereabouts of whales, and this helps the whale watching industry to operate even in the winter months, weather permitting.

4. AN ANALYTIC HISTORY OF ADAPTIVE MANAGEMENT FOR WHALE WATCHING IN THE SALISH SEA

Adaptive management has been defined in many ways.[46] Our preferred definition sees adaptive management as:

> Rational, data driven objective-based management that links research and management to their mutual benefit. It is a process of questioning existing assumptions, exploring alternative ones, envisioning potential scenarios for management, experimenting with

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[44] *Id.*

[45] The Orca Network is a non-profit organization dedicated to "connecting whales and people in the Pacific Northwest." See http://orcanetwork.org/ (accessed 27 Jan. 2012).

[46] For treatments in textbooks, *see* C.S. HOLLING, ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT (1978); C.J. WALTERS, ADAPTIVE MANAGEMENT OF RENEWABLE RESOURCES (1986); B. MITCHELL, GEOGRAPHY AND RESOURCE ANALYSIS (2d ed. 1989); T.F.H. ALLEN & T.W. HOEKSTRA, TOWARDS A UNIFIED ECOLOGY (1992).

> solutions, and monitoring the uncertain outcomes to refine actions. Adaptive management is the integration of research and management to affect policy through feedback and decision-making, using the observed results of the experiments to design, develop and implement future experiments.[47]

Vessel-based whale watch management in the Salish Sea essentially began to resemble this definition in the late 1980s in the wake of NGO pressure to provide the whales with better protection. The core idea was to generate a stake-holder initiated set of voluntary guidelines that could be regularly evaluated and adjusted to accommodate changing conditions. The crucial data on which to base the process would come from NGO monitoring of vessels and be combined with the best available science from engaged killer whale researchers. Ideally, it would be an annual process, driven by the NGOs, but in close partnership in the first instance with the international commercial whale watch industry and then later with federal marine mammal protection agencies.[48]

4.1 Stakeholder Participation in Protecting the Whales

The need for community supported vessel guidelines became increasingly evident as the industry experienced growth and as more was understood about potential impacts from whale watching. By 1988, The Whale Museum in Friday Harbor, Washington, was fully engaged in research documenting the growth of the industry in the Salish Sea, amassing data through a combination of approaches, such as surveys of industry members, vessel and shore based vessel

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[47] Kari Koski & R.W. Osborne, Evolution of Adaptive Management Practices for Vessel-based Wildlife Viewing in the Boundary Waters of British Columbia and Washington (Paper presented at the Puget Sound-Georgia Basin Research Conference, Seattle Washington, 29 March 2005).
[48] *Id.*

monitoring and outreach, and the launch of a "1-800 Whale Hotline" for public reporting of whale sightings and potential whale harassment.[49]

The following year The Whale Museum sponsored the first transboundary Whale Watcher Workshop with the goal of creating the first set of voluntary whale watch guidelines for boaters that were consistent with the U.S. federal Marine Mammal Protection Act (MMPA) of 1972.[50] Subsequent workshops paved the way for establishing a transboundary commercial whale watch industry association and a set of guidelines specific to the Salish Sea segment of the industry. The workshops became annual events, ran for more than a decade, and brought together commercial, private and shore-based whale watchers, relevant NGO's, and scientists to discuss emerging whale watching issues and techniques to reduce potential vessel impacts to whales. This ambitious multi-year effort became the framework within which an annual adaptive management cycle began to appear to be feasible and within which The Whale Museum, along with the commercial whale watch industry, also created the first set of adaptive transboundary whale watch guidelines. During this same decade, the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce was also working on a set of regional viewing guidelines for marine mammals in the Northwest.

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[49] R.W. Osborne. *Trends in killer whale movements, vessel traffic, and whale watching in Haro Strait.* Proc. Puget Sound Research '91 672-688 (Puget Sound Water Quality Authority, Olympia, Washington, 1991).

[50] The 1972 Marine Mammal Protection Act pays only cursory attention to potential impacts from vessels with a prohibition preventing disturbance. 16 U.S.C.1362§(3)(18)(A)(ii). The 1985 Canada Fisheries Act made no provision for non-lethal marine mammal protection until it was amended in 1993. Canadian Fisheries Act, R.S.C., ch. F 14(1985). This is now the statute under which rules prohibiting disturbance of marine mammals are promulgated as Marine Mammal Regulations (Fisheries Act) SOR/93-56 (Can).

4.1.1 Soundwatch: On-the-Water Education and Monitoring

In 1993, The Whale Museum, in conjunction with The School for Field Studies, a well-established NGO promoting study abroad experiences in field research, established an on-the-water program whereby undergraduates could take an ecology course focused on the Southern Resident killer whales. In 1993 and 1994, students participated in field data collection on whale and boat interactions and distributed the voluntary guidelines as part of their course work. Research platforms included an on-the-water patrol vessel called the *Soundwatcher* and two land-based sites where students utilized sophisticated survey instruments to record vessel locations in relation to whales within two study areas. The vessel patrols were used over two field seasons to educate private boaters on proper operating etiquette in the vicinity of wildlife and ecologically sensitive areas in local waters. Materials were also prepared and distributed on killer whale identification, operating requirements for different boat types, and the legal reach and significance of the MMPA.

Since 1995, the on-the-water education and monitoring program has been known as the Soundwatch Boater Education Program. It is now run as a stewardship program of The Whale Museum but the objective remains unchanged – to reduce disturbance to marine wildlife by educating boaters and by monitoring vessel behaviors around marine wildlife. The resulting annual Soundwatch datasets, characterizing whale and vessel trends, have become the indispensable basis for evaluating whale watching practices and for making, if needed, annual adjustments to the guidelines or recommendations for new rules. Without them the idea of an adaptive management cycle could not be made a reality.

4.1.2 Commercial Whale Watch Industry

Once an international Whale Watch Operators Association Northwest (WWOANW)[51] was formed in 1994 a partnership with The Whale Museum quickly yielded an operators' code of conduct. The code encapsulates best practices specific to the commercial whale watch industry and for this reason, in addition to the fact that it is transboundary, it goes well beyond the NOAA guidelines for viewing whales in the American Northwest, and those disseminated to the public by Soundwatch.

Since the industry association first formed, the majority of commercial companies operating in the Salish Sea have been WWOANW members. This makes the association an important collective voice whenever issues of marine wildlife in relation to commercial operations come up in the region. The meetings of WWOANW members held each Fall and Spring eventually displaced the workshops hosted by The Whale Museum as a preferred forum for discussing current issues affecting the industry and for assessing the ability of the guidelines to address these.

Thus, over time the various stakeholders whose active participation in adaptive management is essential to its success developed a workable division of labor. Regular consultations between WWOANW, The Whale Museum, local residents, regional scientists, and eventually the U.S. and Canadian marine mammal protection agencies provide much of the basic intelligence that is needed for guideline adjustments. Soundwatch presents the whale watch trend data from the previous season's monitoring efforts at Fall meetings, and then works with

[51] The Whale Watch Operators Association Northwest changed its name to the Pacific Whale Watch Association in 2009. A list of members and the current version of the Operators Code of Conduct can be found on the Association's website at http://pacificwhalewatch.org/ (accessed 27 Jan. 2012).

the industry association to create amended guidelines that can be presented and refined at Spring meetings. WWOANW also holds annual international driver trainings before the beginning of each season to update operators on present new whale information. The industry also promotes efforts to self-regulate, by putting peer pressure on member company drivers deemed not to be following the guidelines. This involves sending anonymous courtesy reminders from an industry advisory council to member company owners who need to improve their compliance. This industry self-regulation is now reinforced by having Soundwatch, as a neutral third party, share with individual company drivers feedback reports on their behavior, a practice started in 1997.

4.1.3 Canadian Monitoring Programs

In Canada, efforts to build capacity for monitoring whale watching and its impacts have followed a similar course. In fact, The Whale Museum's Soundwatch Boater Education Program modeled itself after the Canadian Robson Bight Warden Program operating at the Robson Bight (Michael Bigg) Ecological Reserve[52] near Telegraph Cove, British Columbia, a reserve established in 1982 as a sanctuary for killer whales. Access by boat or land is prohibited in the reserve and the warden program was created to educate visitors about the Ecological Reserve and to keep them outside of the reserve boundaries. In 2001, the non-profit Veins of Life Watershed Society, based in Victoria, B.C., and the federal DFO piloted a Marine Mammal Monitoring Project (M3),[53] using Soundwatch as a model and partner. Four years later, the Cetus Research

[52] The Robson Bight (Michael Bigg) Ecological Reserve managed by BC Parks; information online at http://www.env.gov.bc.ca/bcparks/eco_reserve/robsonb_er/robson_b_brochure.pdf (accessed 28 Jan. 2012).
[53] Marine Mammal Monitoring Project, Annual report, 2001-2002 (Marine Mammal Monitoring Project, Victoria, British Columbia).

and Conservation Society's Straitwatch program assumed responsibility for the Canadian education and monitoring program.

Since 2005, Soundwatch and Straitwatch have worked as transboundary counterparts to increase the effectiveness of both on-the-water-education and monitoring programs by using standardized data collection and program operation protocols. Annual data sets from both programs can, thus, confirm analogous regional vessel trends and are used by both U.S. and Canadian governments, as well as the whale watch industry, to characterize whale watching in the Salish Sea. Currently, the Robson Bight Warden Program is operated by Cetus Research and Conservation Society.

4.1.4 Transboundary Be Whale Wise Guidelines

As the decline of SRKWs continued into the late 1990's, and with a growing body of scientific evidence regarding impacts of vessels on whale behavior,[54] and communication,[55] both the U.S. and Canadian governments became increasingly interested in managing vessel activities around the whales. The result was the collaborative development and release in 2002 of the Be Whale Wise Guidelines for Watching Marine Wildlife, a product to which Soundwatch, M3, WWOANW, NMFS, and DFO all contributed and which constituted a single set of unified

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[54] S. Kruse, *The interactions between killer whales and boats in Johnstone Strait, B.C.*, in DOLPHIN SOCIETIES: DISCOVERIES AND PUZZLES 149-159 (Karen Pryor & Kenneth S. Norris eds. 1991); Rob Williams, A. W. Trites & D. E. Bain. *Behavioural responses of killer whales* (Orcinus orca) *to whale-watching boats: opportunistic observations and experimental approaches* 256 J. ZOOL. 255-270 (2002); . Rob Williams et al., *Behavioural responses of male killer whales to a 'leapfrogging' vessel,* 4 J. CETACEAN RES. MGMT. 305-310 (2002).

[55] Andrew D. Foote, R. W. Osborne & A. R. Hoelzel, *Whale-call response to masking boat noise*. 428 NATURE 910 (2004); J.K. Ford & G. M. Ellis, Prey selection and food sharing by fish-eating 'resident' killer whales (Orcinus orca) in British Columbia, CSAS Doc. 2005/041 (2005).

voluntary guidelines for recreational and commercial boaters – a document that was easy to understand and to which all stakeholders had subscribed.

Moreover and importantly, the declared intention of the contributors was the same as it had been for the earlier WWOANW guidelines, namely that to remain relevant and responsive the new guidelines would need to be periodically adjusted. In the beginning, both governments endorsed the Be Whale Wise Guidelines and adopted them as regional best practices. Later, after SRKWs were listed as endangered in both countries, both governments made a public campaign to Be Whale Wise part of larger killer whale recovery efforts. And since 2002, the Be Whale Wise Guidelines have been amended and reprinted four times. The most significant adjustment from the original WWOANW guidelines is the recommendation for vessels not to be in the path of whales up to 400 yards. This was adopted in 2002 and remains in the latest version of the guidelines, updated in 2011 to reflect the new killer whale vessel regulations instituted in the U.S.[56]

4.2 Factors Affecting the Community Based Adaptive Management Process

To bring some analytical perspective to the preceding summary of the way whale watching guidelines evolved, it is important to highlight several contributing factors. One is that the entire Pacific Northwest region experienced unprecedented prosperity and population growth during the mid to late 1990s. Another is that about this same time, and not unrelated to the prosperity, there was also explosive growth in recreational and commercial whale watching, even

[56] The current Be Whale Wise Marine Wildlife Guidelines for Boaters, Paddlers and Viewers are online at a website managed cooperatively by transboundary Be Whale Wise partners (NMFS, DFO, Straitwatch, and Soundwatch) and hosted by NMFS at http://www.bewhalewise.org/marine-wildlife-guidelines/ (accessed 28 Jan. 2012) [hereinafter Whale Wise Guidelines].

as there was a continued decline in SRKW numbers. This conjunction of factors played directly into the subsequent listings of this population in Canada and the U.S. as endangered. But it was also buttressed by a growing body of world-wide scientific literature regarding vessel impacts and mounting public concern about irresponsible whale watching practices in regional and international media. This, too, was a factor that opened the doors for increased government intervention and more stakeholder involvement.

This is the context, then, in which by 2007 a more formalized structure for adaptive management was starting to take the place of annual industry and NGO meetings. Large groups of stakeholders were now being invited to participate in agency public comment periods for the review of proposed recovery plans as well as attending workshops on identified threats and potential conservation actions. This new and more official process was driven by a variety of statutory mandates, such as the MMPA, the ESA, SARA, and the National Environmental Policy Act (NEPA), mandates that anticipated and required the development, implementation, and assessment of specific actions to address identified threats to whales.

Given these proliferating legal requirements and performance expectations, the vessel monitoring data collected by Soundwatch and Straitwatch were, without mincing any words, dynamite, because they showed that despite increased outreach efforts and promotion of the Be Whale Wise Guidelines, persistent non-compliance routinely occurred throughout the whales' summer range.

The most common vessel incidents recorded by both programs included, for example, vessels parked in the path of whales, vessels motoring inshore of whales, vessels motoring within 100 yards of whales, and vessels motoring fast within 400 yards of whales. The data also showed that vessel incidents were primarily committed by private operators (over 50%),

followed by Canadian commercial operators, and then by U.S. commercial operators.[57] Both monitoring groups began to recommend that specific vessel regulations for proximity and speed be enacted and implemented, along with the voluntary Be Whale Wise Guidelines, to better protect whales from vessel disturbances, a recommendation endorsed when the U.S. recovery plans for killer whales also said that the voluntary guidelines needed to be re-evaluated.

And so, as the factors shaping the overall context for protecting the whales shifted and the pressure to make transparent, mandated improvements intensified, conflict began to appear alongside cooperation and collaboration among the NGOs, the industry, the agencies, and other public groups with a stake in Salish Sea whale watching. The pressure ratcheted up again when vessel regulations were introduced – first in San Juan County in 2007, and then by Washington State in 2008, and then by the federal government in 2011 – and when Soundwatch and Straitwatch then both started to report monitoring data on vessel compliance with these new rules, not just with the voluntary guidelines.

Now, monitoring data held the potential for real consequences for vessel operators in the form of citations for violations of the rules, area closures, and monetary fines, as well as the loss of a commercial whale watching company's reputation. In this climate, the relatively informal community-based adaptive management process stalled. Attention shifted to what adaptive management might look like when defined in the context of agency rulemaking, and to how,

[57] Kari L. Koski et al., The Emperor's New Clothes: After a decade of watching the whale watchers, is it finally time to declare the need for federal vessel regulations to better protect the endangered population of Southern Resident killer whales? (unpublished paper presented at the18th Biennial Conference on the Biology of Marine Mammals Quebec City, Québec, Canada, October 2009); Nic Dedeluk & D. Sandilands. Straitwatch (unpublished paper presented at the18th Biennial Conference on the Biology of Marine Mammals Quebec City, Québec, Canada, October 2009) (copies on file with the authors).

within such a process, the various stakeholders would be able to protect and pursue their diverse interests.

4.3 A New Adaptive Management Process

To be clear, the preceding analysis should not be understood as an argument that the evolution from bottom-up voluntary guidelines to top-down government regulations for whale watching in the Salish Sea was inevitable or that the outlines of an adaptive management process responsive to this transition are now apparent. We do think that during the first twenty years of targeted whale watching in the region the community-based adaptive management framework and annual cycle of guideline adjustments did effectively address vessel pressures on the whales from the growth of this recreational and commercial activity. We would even go so far as to say that this community driven model was essential in laying the foundation for how killer whale watching is conducted in the Salish Sea region. Looking to the future, however, some important new factors have to be taken into account.

One is that the emerging top-down process must address considerations the bottom-up model would have had difficulty assessing. U.S. and Canadian government agencies responsible for the management of marine mammals and their habitats are required, for example, to address systematically the exposure of whales to persistent toxins, threats from oil spills and leakage, and the impacts of reduced prey quantity and quality, as well as disturbance from vessels and associated noise. Adaptive management frameworks still have a role to play, and were identified as integral to successful implementation of actions outlined, for example, in the U.S. federal killer whale recovery plan. This plan, it said, "lays out an adaptive management approach and a recovery strategy that addresses each of the potential threats based on the best available science.

The recovery program outline links the management actions to an active research program to fill data gaps and a monitoring program to assess effectiveness. Feedback from research and monitoring will provide the information necessary to refine ongoing actions and develop and prioritize new actions."[58]

But another important new factor is that no similar commitment to adaptive management has been made by the Canadian government. Indeed, there is not as yet a Canadian SRKW action plan. It is true that the current Canadian SRKW recovery strategy espouses many of the same principles as the U.S. plan, but it does not expressly endorse an adaptive management framework as its model.[59] Unless both federal governments commit themselves to a timely and transparent framework, one that engages stakeholders in structured feedback on implemented recovery actions and can be used periodically to adjust actions, then it is hard for us to see how a new adaptive management process can match the results obtained by the bottom-up process used over the last two decades.

5. CURRENT MECHANISMS USED TO PROTECT SRKWs

We now turn to a review of the various legal mandates relied upon for managing threats to SRKWs. There is no shortage of law to apply, whether in the form of statutory enactments, agency regulations, and less formal policies. The transboundary nature of this population of whales makes it especially hard, however, to achieve commensurate protections -- protections consistent across the border and among jurisdictions on each side of the line.

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[58] NMFS/Recovery Plan, *supra* note 3.
[59] SARA/Recovery Strategy, *supra* note 1.

5.1 International Law

5.1.1 CITES and the CMS

All killer whales, as a single species under the Linnaean taxonomic classification *Orcinus orca,*[60] were included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1979. CITES seeks to protect wild animals and plants from overexploitation by controlling the international trade and movement of listed species and their parts.[61] Killer whales were also added to the Convention on the Conservation of Migratory Species of Wild Animals (CMS) in 2002 as migratory animals that "have an unfavorable conservation status and require international agreements for their conservation and management."[62] The most recent 2008 Red List assessment from IUCN includes killer whales as a species of "Lower Risk/Conservation Dependent," mainly because all killer whales are treated as one global species. When IUCN lists are revised to reflect genetic data showing different groups of killer whales as unique populations, if not separate subspecies or even completely independent species, this risk assessment will be revised.[63] The chief value of internationally recognized instruments such as CITES, CMS and the IUCN Red List is in ensuring that other distinct populations of killer whales around the world do not suffer the same deleterious population declines that SRKWs saw in the 1970s.

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[60] B.L. Taylor et al., Orcinus orca, in IUCN Red List of Threatened Species, Version 2011.2, online database at http://www.iucnredlist.org (accessed 28 Jan. 2012) [hereinafter Taylor et al.]
[61] *Id.*
[62] Cetacean Conservation under the Convention on Migratory Species (Report by UNEP/CMS Secretariat, Bonn, Germany, 2010). Online at http://www.cms.int/reports/small_cetaceans/cetacean_conservation.htm (accessed 28 Jan. 2012).
[63] Taylor et al., *supra* note 59.

5.2 United States Law

5.2.1 Marine Mammal Protection Act

All marine mammals are protected under the 1972 MMPA, which prohibits, with certain exceptions, the "taking" of marine mammals in U.S. waters and by U.S. citizens on the high seas, as well as the importation of marine mammals and marine mammal products into the U.S. Taking encompasses behaviors that "hunt, harass, capture,[64]or kill" any marine mammal, or attempt to do so. It also includes the negligent or intentional operation of an aircraft or vessel, or any other negligent or intentional act which results in disturbing, molesting, feeding or attempting to feed a marine mammal in the wild. Level A harassments under the MMPA are defined as "any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild." Level B harassments are those that have the "potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."[65] Under section 112(a) of the Act, the broad authority to prescribe regulations necessary to carry out the purposes of the law was used, prior to listing

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[64] One SRKW known as Lolita currently in captivity in Florida was captured in August 1970, prior to enactment of the MMPA, and is therefore not protected either by the statute or by subsequent legal action, such as the lawsuit brought by People for the Ethical Treatment of Animals (PETA) on behalf of wild-caught killer whales captive in U.S. facilities. See the background to the lawsuit at http://www.peta.org/mediacenter/news-releases/PETA-Marine-Mammal-Experts-Sue-SeaWorld-for-Violating-Orcas-Constitutional-Rights.aspx (accessed 28 Jan. 2012).

[65] Marine Mammal Protection Act, 16 U.S.C. 1361 et seq.

under ESA, to designate the SRKW designated as *depleted,* which triggered the development of a conservation plan, comparable to an ESA recovery plan.[66]

5.2.2 Endangered Species Act

The 1973 Endangered Species Act (ESA) aims to conserve species determined to be threatened or endangered, in part by protecting the habitats listed species depend on for survival in the wild. It is illegal to "take" a listed species, where taking is again broadly defined as behaviors that "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct," although the terms harass and pursue are not further defined.[67] Again and importantly, as with the MMPA, the statute provides broad rulemaking authority to enforce the law.

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[66] The process leading to determination of depleted status began in May 2001, when the Center for Biological Diversity petitioned NOAA to list Southern Resident killer whales as 'threatened' under the Endangered Species Act. In August 2001, NOAA formally accepted the petition and started the assessment process to verify whether the whales were eligible for protection under the ESA. In July 2002, NOAA acknowledged that, while it was clear the population was declining, the Southern Resident killer whales did not qualify for protection because they were not members of a single, worldwide species (*Orcinus orca*) and did not, therefore, meet the criterion of biological "significance" established under the ESA for listing a species as "threatened." In recognition of the decline, however, NOAA did start the process needed to declare the Southern Residents a "depleted" stock, and this is what led to their listing under the MMPA in May 2003. This listing triggered the development of a conservation plan, which is similar to a recovery plan under the ESA for listed species.

[67] The Orca Relief Citizens' Alliance, a Washington State NGO, is challenging the meaning of the term "pursue" as it is currently used in ESA prohibitions. The issue goes to the impact of whale watching when ESA listed species are involved. The argument is that whale watching vessels leaving port with the express intention of locating and following-to-observe listed animals are in violation of ESA's "pursue" prohibition. See the information at http://www.orcarelief.org/ (accessed 28 Jan. 2012).

SRKWs gained endangered species status when they were found to be a Distinct Population Segment (DPS)[68] of an unnamed sub-species of North Pacific resident whales. This was based on multiple lines of evidence, including distinct differences in genetics, morphology, and ecology.[69] NOAA then designated critical habitat for the SRKW in 2006 to include all inland waters of Washington State (U.S. side of the Salish Sea) and declared the area around the San Juan Islands as Summer Core Habitat.[70] Listed species must also be the subject of a recovery plan, linked to an established research plan. The SRKW Recovery plan was released in 2008.[71]

5.3 Washington State Law

5.3.1 State Endangered Species Act

In 2000, the Washington Department of Fish and Wildlife (WDFW) listed killer whales as a "candidate species," allowing them to be listed as endangered under state law.[72] Following evaluation by a WDFW commission, all ecotypes of killer whales were listed as endangered in

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[68] In December 2003, a federal court ordered NOAA to reconsider the processes used to determine which species are eligible for listing under the ESA. One year later, NOAA proposed to list the Southern Residents as "threatened." After a subsequent yearlong review of the most recent science, NOAA declared the Southern Residents a Distinct Population Segment (DPS) of the worldwide species (*Orcinus orca)* in November, 2005, and afforded them the highest protections available under U.S. law by listing them as "endangered." NMFS Status Rule, *supra* note 2.

[69] NMFS/Recovery Plan, *supra* note 3.

[70] Under the law, "critical habitat" is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, which features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation. U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Endangered and Threatened Species: Designation of Critical Habitat for Southern Resident Killer Whale, Final Rule, 71 Fed. Reg. 69054–69070 (29 Nov. 2006).

[71] NMFS/Recovery Plan, *supra* note 3.

[72] Washington Vessel Law, *supra* note 8.

2004. Killer whales are further protected under the state law which "prohibits the capture, importation, possession, transfer, and holding in captivity of most wildlife in the state." In 2005, Washington designated killer whales as the official state marine mammal.[73]

5.4 Canadian Law

5.4.1 Canadian Fisheries Act

In Canada, marine mammals are protected under the 1985 federal Fisheries Act, which defines fish to include marine mammals and, although the Marine Mammal Regulations did not appear until 1993 and are not conservation regulations, they do prohibit the disturbance of marine mammals and have somewhat the same impact as the MMPA.[74] The Regulations apply with respect to the management and control of (*a*) fishing for marine mammals and related activities in Canada or in Canadian fisheries waters, and (*b*) fishing for marine mammals from Canadian fishing vessels in the Antarctic.[75] The focus, therefore, is on regulating the hunting of species, not their viewing. DFO does promote the Be Whale Wise guidelines, but they are unenforceable in Canada and Canadian courts are unwilling to accept them as a basis for determining what disturbance means under the Regulations.[76]

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[73] NMFS/Recovery Plan, *supra* note 3, at II-70.
[74] The Marine Mammal Regulations (Fisheries Act) SOR/93-56 (Can) provide in §7 that "No person shall disturb a marine mammal except when fishing for marine mammals under the authority of these Regulations."
[75] Under *id.* §4 and for payment of only $5Can. a permit is available to fish a "Cetacean other than beluga, bowhead whale, narwhal or right whale."
[76] Koski & Osborne, *supra* note 47, at 6.

5.4.2 Marine Mammal Regulations

DFO started a public process of evaluating proposed amendments to the Regulations in 2003, with the intention of enacting standard national vessel approach distances for some species of marine mammals under the Fisheries Act. The process was active until 2005, when it was abandoned. It may be revived.[77] However, no new material has been generated to substantiate the amendments, which remain as they were originally drafted.[78] The proposed amendments are very controversial because they would expand the focus of the regulation to include the watching of marine mammals and activities that may cause their disturbance. If adopted, they would codify the current Be Whale Wise guideline standard for a 100 meter buffer zone around marine mammals and allow for greater buffer zones for species listed under SARA.[79] Moreover, the amendments anticipate licenses for commercial operators.

5.4.3 COSEWIC

SRKWs were first listed as endangered in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2001 and were, thus, immediately designated as endangered under the federal Species at Risk Act (SARA), when it came into force in 2004.[80]

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[77] *See* http://www.pac.dfo-mpo.gc.ca/consultation/fisheries-peche/mamm-mar/index-eng.htm (accessed 28 Jan. 2012).
[78] They are described in the consultation workbook at http://www.pac.dfo-mpo.gc.ca/consultation/fisheries-peche/mamm-mar/docs/mmra.pdf (accessed 28 Jan. 2012).
[79] Thus, proposed amendment 9 would provide that subject to some exceptions no person shall approach within 100 metres of any cetacean or walrus. *Id.* at 6.
[80] Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Species Database (2002, updated in 2012). Online at http://www.cosewic.gc.ca/eng/sct1/searchform_e.cfm (accessed 28 Jan. 2012).

5.4.4 Canadian Species at Risk Act (SARA)

SARA emerged in 2003 as the Canadian federal government's attempt to "provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity."[81] Recovery of a listed species is a detailed process in which threats are identified, removed, or mitigated until such time that long-term existence in the wild is secured.[82] Under Section 37 of the Act, the Minister of Fisheries and Oceans must prepare and finalize a detailed recovery strategy for listed species, outlining goals, objectives, and actions to be taken to arrest or reverse the decline of the species. Generally, recovery strategies are augmented with one or more action plans, outlining specific measures to be taken to help recover the focal species.

A mandatory part of a recovery strategy is the identification of critical habitat, defined in SARA as "the habitat that is necessary for the survival or recovery of a listed wildlife species that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species." (SARA s.2 (1)). Once critical habitat is identified, the Minister has a legal duty to protect that habitat from destruction, either by using the provisions of the Species at Risk Act,[83] or by relying on existing provisions of other Canadian laws.

Recent litigation[84] has confirmed that the Minister's duty to protect critical habitat includes both the physical and biological aspects of that habitat. In the case of resident killer

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[81] SARA/Recovery Strategy, *supra* note 1.
[82] *Id.*
[83] The Species at Risk Act, 2002 S.C., ch. 29 (Can.) provides in §58(1) that no person shall destroy any part of the critical habitat of any listed endangered species or of any listed threatened species — or of any listed extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada.
[84] In December 2008, and again in April 2009, Canadian NGOs challenged in court the DFO's statement on protecting critical habitat, arguing that it failed to adequately protect resident killer whale habitat. For the statement, *see*

whales, the court has confirmed that this includes protection of availability of prey, water quality, and some level of freedom from both acoustic and physical disturbance.[85] In response, DFO amended the 2008 recovery strategy to acknowledge this obligation.[86] However, in January 2011 DFO also filed an appeal, arguing in its brief for overturning the trial court's specific declaration that "ministerial discretion does not legally protect critical habitat within the meaning of section 58 of SARA, and it was unlawful for the Minister to have cited discretionary provisions of the Fisheries Act in the Protection Statement."[87] In response, a consortium of Canadian NGOs filed suit to uphold the trial court's decision and in early February 2012 the court of appeal in most respects agreed with them.[88]

5.5 Vessel Regulations for Killer Whales

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http://www.sararegistry.gc.ca/virtual_sara/files/ch_killer_Whale_0908_e.pdf (accessed 28 Jan. 2012). The court consolidated the proceedings and in December 2010 issued its Judgment. *See* David Suzuki Foundation et al. v. Minister of Fisheries and Oceans 2010 F.C. 1233 (Can.).

[85] Essentially, DFO is under a duty to prohibit vessel noise that destroys the whale's acoustic environment. In the U.S., it is rare for a court to tell the government specifically what it has to do. In the Canadian trial court, the Minister had argued that outreach programs, stewardship programs, voluntary codes of conduct or practice, voluntary protocols and guidelines, and policy could protect critical habitat sufficiently under SARA, but this argument was soundly rejected. For background and commentary, *see* http://www.davidsuzuki.org/media/news /2010/12/decisive-killer-whale-court-win-offers-hope-for-at-risk-species/ (accessed 28 Jan. 2012).

[86] SARA/Recovery Strategy, *supra* note 1.

[87] Appellant's Memorandum of Fact and Law, Minister of Fisheries and Oceans v. David Suzuki Foundation, et al., Court File No. A-2-11, filed April 28, 2011 (copy on file with the authors).

[88] Respondent's Memorandum of Fact and Law, Minister of Fisheries and Oceans v. David Suzuki Foundation, et al., Court File No. A-2-11, filed June 9, 2011 (copy on file with the authors). The appellate decision comes in Minister of Fisheries and Oceans v. David Suzuki Foundation et al., 2012 FCA 40 (Can.).

5.5.1 San Juan County, Washington State County Vessel Ordinance for Southern Resident Killer Whales (2007)

Using the federal ESA listing as a basis and in the absence of any specific laws from higher authorities, the San Juan County Council in 2007 passed a local ordinance to protect SRKWs from vessel harassment by making it illegal to feed or "knowingly" approach within 100 yards of a whale within county waters.[89] This law was later pre-empted by the state regulations described in the following section.

5.5.2 Washington State Vessel Regulations for Killer Whales (2008)

Under the 2008 Washington vessel law, it is unlawful to (a) approach, by any means, within three hundred feet of a southern resident orca whale,[90] (b) cause a vessel or other object to approach within three hundred feet of a southern resident orca whale, (c) intercept a southern resident orca whale in part by placing a vessel in or allowing a vessel to remain in the path of a whale when the whale approaches within three hundred feet of that vessel, (d) fail to disengage the transmission of a vessel that is within three hundred feet of a southern resident orca whale, for which the vessel operator is strictly liable, (e) feed a southern resident orca whale, for which any person feeding a southern resident orca whale is strictly liable. Violations are punishable as

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[89] San Juan Vessel Regulations, *supra* note 7.

[90] Protection of Southern Resident Orca Whales-Penalty. WASH. REV. CODE 77.15.740 (2008). This law is less restrictive than the federal vessel law subsequently enacted in 2011. It remains to be seen if Washington State will pursue increasing the distance restriction to make it match the federal law, if they will keep it as is, or they will retire this regulation.

either a gross misdemeanor or a class C felony and can result in fines up to $10,000 and/or up to 5 years in prison.[91]

5.5.3 U.S. Federal Vessel Regulations for Killer Whales (2011)

After requesting public input on potential regulations to protect killer whales from vessel disturbances in 2007,[92] NOAA released proposed vessels regulations in July of 2009,[93] and held a public comment period on them until January of 2010. The final regulations for Washington waters, based on authorities in the MMPA and the ESA, were released in April, 2011.[94] They include as prohibitions, effective in May 2011, that "it is unlawful for any person subject to the jurisdiction of the United States to: (i) Cause a vessel to approach, in any manner, within 200 yards (182.9 m) of any killer whale. (ii) Position a vessel to be in the path of any killer whale at any point located within 400 yards (365.8 m) of the whale This includes intercepting a killer whale by positioning a vessel so that the prevailing wind or water current carries the vessel into the path of the whale." The rules apply to all types of vessels, including motor boats, sail boats and kayaks, in Washington's inland waters. Some exemptions apply for situations where safety is a concern, for commercial fishing vessels with actively engaged fishing gear, and for cargo vessels traveling in established shipping lanes. Government vessels in the course of official duties and research vessels under permit also have exemptions.

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[91] Id.
[92] NMFS/Advance Notice, *supra* note 5.
[93] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Protective Regulations for Killer Whales in the Northwest Region Under the Endangered Species Act and Marine Mammal Protection Act, Proposed Rule, 74 Fed. Reg. 37674 (29 July 2009).
[94] NMFS/Final Vessel Rule, *supra* note 9.

When originally proposed in July 2009, the rules also included a half-mile no-go zone along the west side of San Juan Island from May 1 through the end of September, each year. But because of opposition from several stakeholder groups, based on the need to assess the viability of suggested alternatives and concerns about economic impacts, the final regulations excluded a no-go zone, pending further consideration of this type of special management area in the future.[95]

6. TOWARDS NEW VESSEL REGULATIONS FOR SRKWs

If the SRKWs in the Salish Sea are going to get the most benefit from the various legal measures that now protect the species and regulate whale watching, Canadian vessel laws commensurate with those adopted in the U.S. are essential. And along with them must go adequate funding for enforcement, on both sides of the border. Insufficient funding for enforcing U.S. vessel regulations together with the lack of vessel laws in Canada create a situation in which, to put it very plainly, there are unacceptably uneven protections for endangered killer whales in the Salish Sea. Boaters in these transboundary waters are subject to inconsistent vessel laws and are unlikely to be able to distinguish easily or as an everyday practical matter between the transboundary Be Whale Wise Marine Wildlife Guidelines[96] and the newer U.S. vessel laws. The voluntary guidelines promote a 100 yard (91.4-meter) buffer around all species of whales in the transboundary waters of both the U.S. and Canada. But the new, stricter U.S. rules also prohibit

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[95]The Whale Museum's Soundwatch program has made recommendations for special management areas based on long-term monitoring data from areas where vessels and killer whales most often overlap and where there are the highest numbers of vessel operators not in compliance with exiting guidelines and vessel laws. See Kari Koski, Soundwatch Recommendations for Special Management Areas for Killer Whales (unpublished paper presented to
the Salish Sea Ecosystem Conference, Vancouver BC, Canada, October 2011).
[96] Whale Wise Guidelines, *supra* note 55.

vessels from (1) approaching whales closer than 200 yards (182.9 meters), and (2) getting in the path of oncoming killer whales at any point within 400 yards (365.8 m) in U.S. waters.[97] In Canada, only the voluntary guidelines apply.

A focus on vessel regulations should not obscure a bigger picture view of SRKW conservation in the Salish Sea. Marine protected areas have been widely used throughout the world for species conservation as well as other purposes, for example, and although they may be too small to protect wide ranging species, they can provide some needed protections in important high use areas.[98] It seems to us they would make sense in those U.S. and Canadian waters of the Salish Sea known as *hot spot areas* where conflicts between whales and boaters have become routine and where mandatory regulations have great value. They could be used to address the possibility of varying vessel restrictions by season, according to the presence/absence of whales, as well as variations according to vessel type, vessel activity, vessel speed, and other relevant factors. Protected areas are consistent, moreover, with an adaptive management approach that tries to bring to bear on the conservation of SRKWs ongoing monitoring data on long term vessel trends, new research on killer whale habitat use, better understanding of the effects on the behavior of whales, and the sorts of rich, sustained inputs from the whale watching industry and other stakeholders that made such a crucial difference in getting the voluntary program off the ground and sustaining it to good effect for so long.

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[97] NMFS/Final Vessel Rule, *supra* note 9.
[98] Erich Hoyt, Marine Protected Areas for Whales, Dolphins and Porpoises: A world handbook for cetacean habitat conservation and planning (2011).

FIGURE CAPTIONS

Figure 1-1. The Salish Sea.
Map used with permission: The SeaDoc Society, 942 Deer Harbor Rd, Eastsound, WA 98245

Figure 1-2. Trends in Southern Resident Killer Whale Population (1976-2011).
Data used with permission: The Center for Whale Research, 355 Smugglers Cove Rd, Friday Harbor, WA 98250

Figure 1-3. Trends in US and Canadian Commercial Whale Watching Vessels (1976-2011).
Data used with permission: The Whale Museum, 62 1st St, Friday Harbor, WA 98250

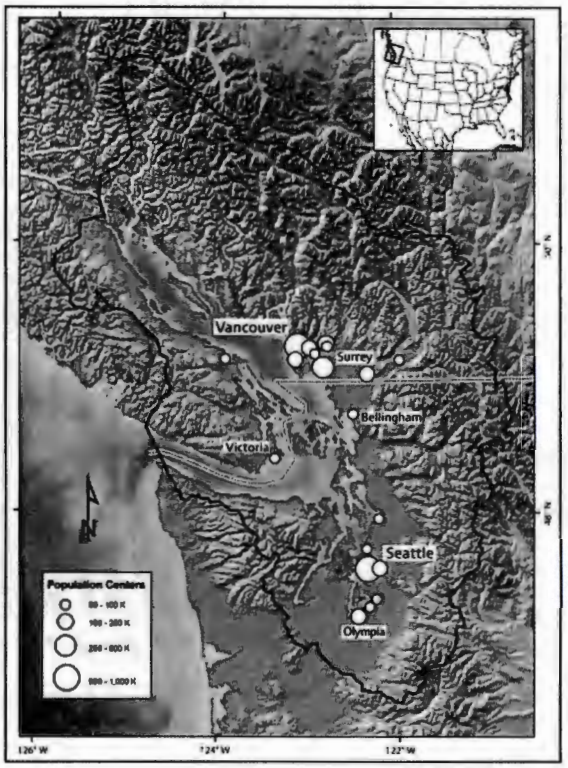

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Figure 1-1. The Salish Sea. Map used with permission: The SeaDoc Society, 942 Deer Harbor Rd, Eastsound, WA 98245.

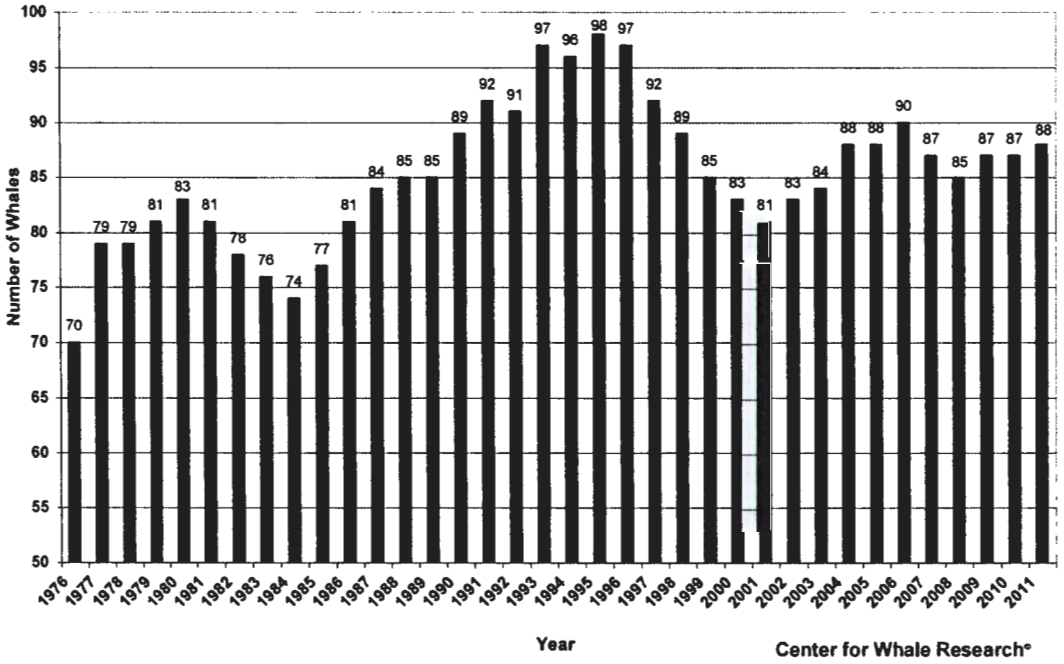

Figure 1-2. Trends in Southern Resident Killer Whale Population (1976-2011).

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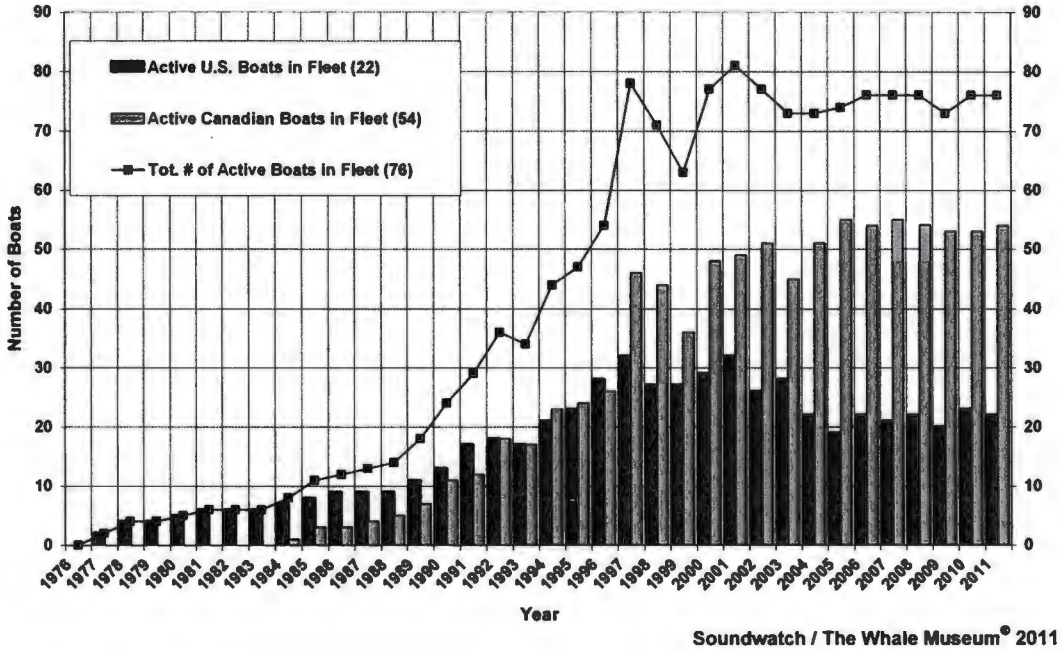

Figure 1-3. Trends in US and Canadian Commercial Whale Watching Vessels (1976-2011).

Data used with permission: The Whale Museum, 62 1st St, Friday Harbor, WA 98250.

CHAPTER 2

Non-invasive methods to study southern resident killer whales (*Orcinus orca*) and vessel compliance with regulations

INTRODUCTION

Worldwide, marine mammal researchers have conducted land-based research using theodolites to study whales and dolphins for at least 35 years (Würsig 1978), documenting cetacean movement patterns and habitat use (Würsig and Würsig 1979; Tyack 1981; Acevedo 1991; Norris et al. 1994; Harzen 2002), cetacean response to swimmers (Lundquist et al. 2008), and seismic surveys (Gailey et al. 2007). To a great extent, our knowledge of cetacean behavioral response to vessels has come from multiple theodolite studies focused on changes in whale and dolphin foraging (Williams et al. 2006; Lusseau et al. 2009; Christiansen et al. 2013), changes in swim speed (Kruse 1991; Williams et al. 2009), path predictability (Schaffar et al. 2013; Williams et al. 2002a, 2006, 2009) and group cohesion (Bejder et al. 1999). Indeed, much of the information on fish eating "resident" killer whales (*Orcinus orca*) in the Pacific Northwest has come from land based theodolite research.

While theodolite-based studies will likely continue for researching cetaceans relatively close to shore, there is a need to study cetacean behavior in response to anthropogenic (Noren et al. 2009) and ecological influences (Felleman et al. 1991) in areas too far from shore to use a theodolite. Advances in technology in the past ten years have made it possible to follow cetaceans

throughout their range, including nearshore and offshore, in order to collect accurate geo-referenced latitude and longitude locations and accompanying behavior data in varied ecological settings.

The purpose of this research was to study the effect of vessels on the federally listed endangered (NOAA/NMFS 2005) southern resident killer whales (SRKW), to document vessel compliance with boating laws and guidelines, and to collect location and behavior information on whales in order to document how the whale use different parts of their critical habitat. Knowing precise locations for both whales and vessels is essential for these analyses; I utilized a novel equipment package, or laser positioning system (LPS), to generate geo-referenced locations and store behavioral information on the SRKW and the vessels watching them. For this study, data on whales and vessels were recorded throughout the southern resident killer whale's critical habitat in the Salish Sea, the waters surrounding the San Juan Islands, Washington, United States and the Canadian Gulf islands, B.C., Canada.

Disturbance from vessels was identified as a contributing factor to the continuing decline of this genetically and socially isolated population (NOAA/NMFS 2005), consisting of 81 individual whales (Center for Whale Research 2013). The critical habitat of SRKW receives heavy vessel traffic, including large cargo ships, whale watching vessels, fishing boats, passenger ferries, etc. Beginning in 1984, the tourism industry saw unprecedented annual growth in the Salish Sea that peaked in 2001with 81 commercial vessels (Giles and Koski, 2012). Daily and seasonal vessel exposure periods have also increased with whale watching vessels and other recreational boating activities occurring as early as 0600 to as late as 2200 (dusk) from early April through October

(personal observation). Since 2002, an international standardized set of viewing guidelines, the Be Whale Wise, *Marine Wildlife Guidelines for Boaters, Paddlers and Viewers* (The Whale Museum 2013), has been promoted by U.S. and Canadian law enforcement agencies, non-profit vessel monitoring programs, and the commercial whale watching (CWW) industry in both the U.S. and Canada. In 2007, portions of the Be Whale Wise Guidelines were codified with the passage of San Juan County, Washington vessel regulations (San Juan County 2007) followed by state law (Washington State 2008) in the spring of 2008, establishing whale watching minimum distance laws of 100 yards. More stringent U.S. federal regulations went into effect in May 2011 prohibiting vessels in United States waters from approaching any killer whale closer than 200 yards and from positioning in the path of any killer whale within 400 yards (NOAA/NMFS 2011).

This paper describes new technology, the laser positioning system and methods used to acquire accurate locations and record behavior data on SRKW and nearby vessels. Vessels operator compliance with local and state laws and regional best-practice guidelines was examined to determine if certain vessel classes (e.g. commercial or private whale watching vessel) were more often in violation of different guidelines. Spatial analysis was used to examine vessel compliance with recognized "no-go-zones" or buffers along the Westside of San Juan Island, Washington State. Additional data collected for this study were analyzed for changes in whale cohesion and behavior states in response to vessel densities, distances and modes of operation throughout the SRKW designated critical habitat; these findings are discussed in detail in chapter 3 of this dissertation (Giles 2013b).

METHODS AND MATERIALS

Study Site

This research was conducted in the waters surrounding the United States, San Juan Islands and Canadian Gulf Islands which constitute a small portion of the international inland waters known as the Salish Sea (Fig. 2-1). The geographic coordinates for the research area are between 48°12′ to 49° N latitude by 122°43′ to 123°50′ W longitude.

Effort

In 2007, data were collected from June 1 to October 31. The data collection crew consisted of the lead researcher, two research assistants, and a vessel driver. Southern resident killer whales were located each day by using the CWW industry's sightings network which used a spotter and individual whale watching vessel captains to post whale location updates on a paging system (see Hauser et al. 2006 for a complete description of the Pager Network) or by spotting the whales in areas they frequented. Due to the variability of whale presence in the study area, crewmembers remained "on-call" to work on all days of the week (except Wednesdays between June 1 and September 1), between the hours of 0730 hr and 1600 hr in order to maximize the number of days data could be collected when whales were present and to capture the widest variety of vessel mode of operation and density the whales were exposed to throughout the summer. Between June 1 and October 31 there were a total of 106 days when whales were known to be inbound in the Strait of Juan de Fuca or the Strait of Georgia or present in inland waters; of these, there were 86 days in which the whales were considered to be within

the study range and 20 occasions when the whales turned around and headed back out of range. Out of the possible 55 days when whales were present, data were collected on 41 days, with an average of 6.5 hours per day, during which time 93 focal follows were conducted, resulting in 5,434 geo-referenced location points that included behavioral attributes of boats and whales that were included in analyses described in chapter 3 of this dissertation (Giles 2013b).

In 2008, data were collected from June 7 to October 31. The research crew of four was the same as in 2007. In 2008, all members remained on call every day of the week, between the hours of 0730 hr and 1600 hr. In 2008, the whale watching industry stopped funding the Pager Network so additional whale spotting effort was initiated by having one member of this research project drive to the South Beach Overlook on San Juan Island, Washington State at 0700 hr to scan for whales each day. These scouting efforts lasted between 30-45 minutes depending on visibility. Whales were again located by monitoring the VHF radio, via direct observations, or by communication with individual whale watching captains who provided whale location data. There were a total of 78 days when whales were known to be present in or approaching the research area between June 7 and October 31; of these, 21 days were not spent collecting data due to bad weather, training of personnel or vessel maintenance. An average of 6.3 hours per day was spent on the water during 57 days of field data collection, during which 127 usable focal follows were conducted, resulting in an estimated 11,079 geo-referenced data points including behavioral attributes of boats and whales to be used for analysis.

Research Equipment

For this vessel-based study, a new mobile technology was used to acquire accurate latitude and longitude coordinates of southern resident killer whales and the vessels following them throughout their summer range. Two complete integrated equipment packages or Laser Positioning Systems (LPS) were used for this study; one was used to collect latitude and longitude locations and behavior data on focal whales (Table 1) and the other LPS was used to collect the same information on vessels (Table 2) in the vicinity of a focal whale group. Each LPS combined a global positioning system (GPS) receiver with built-in data collector to record attribute data (e.g. whale ID, cohesion, behaviors), a laser rangefinder to determine distance, and a digital compass for azimuth angles. All components of the LPS were cable connected and synchronized via built-in RS232 serial ports to communicate as one unit to generate geo-referenced data points with the push of one button. The equipment components were mounted on a monopod for maneuverability and secured to the researcher via a custom harness (Fig. 2-2). The data collected with this equipment allowed for sophisticated spatial and temporal analyses of the complex interactions between vessels and whales in different geographic regions.

The GPS receivers used for this study included one Trimble GeoXH and one GeoXT 2005 series handheld units (Trimble Mfg., Sunnyvale, CA), both with sub-meter accuracy. Both receivers were powered by Microsoft Windows Mobile and used TerraSync software (Trimble Mfg., Sunnyvale, CA) to create a custom database for collecting and maintaining attribute data on whale and vessel positions.

Given the open environment of the marine realm, GPS data collected on the water avoids several factors that can affect the accuracy of GPS positions on land, such as multipath errors which are caused when satellite signals are blocked by or bounce off of nearby objects, (e.g., buildings or tree canopy). Marine based GPS data also increases the chance of having at least four visible satellites, the minimum number of satellites needed to calculate accurate 3-dimentional location data. GPS data collected during this study most often had seven visible satellites, which further increased position accuracy.

To maximize vertical and horizontal accuracy, both GPS receivers were set internally to ignore or filter positions where poor satellite geometry would produce questionable readings. Additional internal settings were applied to disregard satellites that produced weak signals and those that were too low on the horizon as these factors can also degrade the accuracy of the overall signal being received. On the few occasions when the visible satellites were too close together or too low on the horizon, thus producing low quality GPS positions, data collection was halted, typically for no more that 15 minutes.

All data were post-processed and differentially corrected using one of several GPS reference stations located within 15 nautical miles to determine errors and apply corrections to GPS data; the use of nearby reference stations greatly increased the accuracy of the data collected on the water.

The laser rangefinder (Impulse 200 XL, Laser Technologies Inc., Englewood, CO) was engineered using pulse-laser technology which took long-range distance measurements without

using a reflector and without losing accuracy, ± 1 m up to 1500 meters. The FDA Class 1 eye-safe laser rangefinder calculated distance by measuring the flight time for very short pulses of infrared light, as many as sixty pulses per measurement, to bounce off a target and return to the laser sensor. This method is a fast and more accurate way to document distance compared with traditional lasers that measure phase shifts by comparing incoming wavelengths to the phase of the outgoing light. The Impulse 200XL laser rangefinder was fitted with a 1.5-4x power scope for easy targeting on killer whale dorsal fins and a built-in tilt sensor ensured that accurate horizontal distance was measured regardless of variation in wave swell.

An electronic compass (MapStar Compass Module II, Laser Technologies Inc., Englewood, CO) calculated azimuth (compass bearing) to the whale or to the vessel. The compass was mounted to the side of the laser rangefinder with a bracket that allowed the laser to pivot +/- 90 degrees (for range and tilt) while maintaining a level compass head needed for accurate, ± 0.3 degrees, azimuth measurement. The compasses two built-in RS232 serial ports simultaneously received the distance measurements from the rangefinder and exported all necessary position data to the GPS receiver which supplied the latitude/longitude to derive x,y coordinates for a target. Regular compass calibrations using a built-in audio tone-guide were quickly conducted (less than one minute) to adapt to local magnetic interference.

Potential accuracy errors inherent in each instrument (GPS receiver, laser rangefinder, digital compass) may be amalgamated to produce distance errors worth noting. Manufacturer's errors are reported (Table 2-3) to demonstrate the worse case scenarios for any given measurement, however actual location errors were significantly smaller.

Sampling Protocols

Distances between whales and vessels were recorded and analyzed using United States Customary units (yards) in-line with published U.S. vessel regulation units (NOAA 2011). Research was conducted from one of two vessels, a 7.31 meter Proline fiberglass powerboat (R/V Scordino, NOAA/NWFSC) with a 200 hp Honda four-stroke outboard motor, and a 6.4 meter Munson metal flat-bottom powerboat (R/V Buzzard, The Whale Museum) with twin 50 hp Honda four-stroke outboard motors, depending on which vessel was available and in working condition. Data were collected in Beaufort sea state ≤ 3 between 0730 hr and 2100 hr as conditions allowed.

The research vessel was oriented parallel to the whales, typically as far away as the whale-watching fleet (> 100 yards.), with very rare close approaches to within 50 yards for whale identification confirmation conducted under ESA/MMPA Permit for Scientific Research No. 781-1824(01), and/or Canadian Marine Mammal/SARA Scientific License Nos. 2007-08/SARA-68 and 2008-06/SARA-86. County and state laws and regionally accepted Be Whale Wise guidelines were strictly adhered to in order to minimize the potential for the research vessel to alter the behavior of either the other vessels or the whales.

Whale Data Collection

Location and behavior data were collected for whale groups in close proximity to varying numbers of vessels, including situations when the research vessel was the only one present

within 1,000 yards. When the only one present, the research vessel maintained a distance greater than 100 yards as required by state law at that time and in order to minimize the possibility that the research vessel would alter group cohesion. In order to limit observer errors, only the lead researcher collected information on whales. I utilized a laser positioning system package to record whale data using an individual-follow protocol, and both predominant group activity and scan sampling methods were used during focal follows (Altmann 1974; Mann 1999). A focal whale was chosen and subsequent attribute data (Table 1) were documented based on the position and behavior of the focal whale in relation to other whales nearby and/or whales engaged in similar behaviors. If the focal animal left a group, the research vessel remained with that animal for the duration of the focal follow with notes marking the transition to a new group. Behavioral assessments of the focal animal and predominant group activity assessments were made at 5 minute fixed intervals during 15-60 minute sampling tracks. Tracks were limited to 60 minutes per individual whale per day to lessen potential impacts to individual whales. Tracks that were less than 15 minutes were deemed unsuitable for statistical analysis. Scan sampling (Mann 1999) was used to record the gross behavioral activity state (resting, foraging, socializing, and traveling) in which the focal whale and most other group members were engaged. Additional killer whale group attributes (Table 1) were documented including: 1) *cohesion* (contact: whales touching, tight: < 10 m between whales, loose: 10-100 m between whales, spread: > 100 m between whales), 2) *orientation* (flank: side-to-side, linear: head-to-tail, non-linear: no orientation detected), 3) *speed* (stationary, slow, medium, fast, porpoising), and 4) *directionality* (< or > 90° change in direction from previous surfacing). These whale attribute data were coded using a behavioral sampling methodology developed by participants in a SRKW Behavior Coding Workshop held in Seattle in 2004 (NOAA 2004). Scan sampling was also used

to record focal group size, pod identity, identity of non-focal group whales/sub-pods in area, approximate total number of whales in the greater area. Whale swimming speed was assumed to equal that of the research vessel, which attempted to parallel the focal whale during follows. This provided a detailed record of the actions of the boats and the behavior of whales for analysis.

Vessel Data Collection

While I collected whale location and behavior information, a research assistant used a second laser positioning system to recorded geo-referenced vessel latitude and longitude locations and vessel attributes relative to the focal whale using scan sampling techniques in 5-minute intervals simultaneous to the corresponding 15-60 minute whale sampling track. The vessel attribute data (Table 2) included: 1) *vessel class* (private, commercial, research, monitoring, etc.), 2) *vessel activity* (whale watching, fishing, non-whale oriented, transiting), 3) *vessel type* (inflatable, small, medium or large hard bottom), 4) *vessel speed* (stationary: slow 0-2 knots; medium 3-4 knots; fast 5-6 knots; very fast 7+ knots), 5) *vessel placement* relative to focal whale (inshore: vessel between focal whale and shoreline; in path: vessel in the path of approaching focal whale; offshore: vessel offshore of focal whale), 6) *vessel position* relative to whale group (parallel: vessel oriented with port or starboard closest to focal whale; bow-in perpendicular: vessel bow pointing toward focal whale; bow-out perpendicular: vessel motor(s) closest to whale), and 7) *vessel location* relative to whale swim direction (in front: vessel in front of approaching whales; to the side: vessel is to the side or abreast of focal whale; on top of: vessel within one body length of surfaced focal whale; behind: vessel is behind whale in relation

to whale swim direction). These vessel attributes provided a detailed record of vessel distance, density and actions near focal whale groups.

A second data collection protocol used scan sampling during the first 20-minutes of every other hour in order to assess vessel operator compliance with local and state laws and regionally accepted Be Whale Wise whale watching guidelines. During each scan detailed vessel descriptions were made, (e.g., one vessel may be described as: commercial/fishing/gill net/non-whale oriented), for every vessel within 1,000 yards of the focal group. When a vessel appeared to be out of compliance, all vessel attributes (as described above) were recorded: class, activity, type, speed, placement, position, and location. All 'incidents' or violations of the Be Whale Wise guidelines and/or local or state laws or regulations were documented including: 1) motoring within 100 yards of whales, 2) parking in the path of approaching whales within 100 to 400 yards, 3) parking with whales passing within zero to 100 yards from the vessel, 4) motoring faster than 5-7 knots within ¼ mile (440 yards) of whales, 5) being within a voluntary ¼ mile no-go zone along the westside of San Juan Island, Washington State, and 6) being inshore of whales when whales are within ½ mile (880 yards) shore. Specific vessel names/identifications were not recorded for incident reporting; however, all other vessel attribute data were noted in order to determine which classes of vessels were more/less often out of compliance with current guidelines. Research vessels that were federally permitted to be near whales were not recorded as being in violation of laws or guidelines.

Post-processing data

At the end of each day, whale and vessel location and attribute data were downloaded from the two laser positioning system GPS receivers onto a desktop computer running Pathfinder Office software (Trimble Mfg., Sunnyvale, CA) and differentially corrected using nearby reference stations. Differential correction substantially increases the positional accuracy of GPS location information which increases the accuracy of the offset latitude and longitude recorded for each whale and vessel. After differential correction was complete, all whale and vessel tracks were transferred to a custom software program developed for this project that calculated the distance between each vessel and the nearest whale in time, thus producing the most accurate vessel-to-whale distance measurements. Specifically, it was important to make sure the distances between each vessel and the focal whale were as accurate as possible. Given that the objects (whales and vessels), as well as the data collectors were all on/in the water and often moving, only vessel offset locations that were paired with whale offset locations within 3 seconds were considered to be accurately measured. All other vessel and whale distance measurements were excluded from analysis.

Analysis

In years 2007 and 2008, 75 and 96 20-minute compliance scans were taken, respectively. Observed incidents were summarized separately for 2007 and 2008 to determine if changes to Washington State Law (RCW 77.15.740) regulating boating behavior, which became effective June 12, 2008, were reflected in the number of observed incidents from one year to the next. Additionally, analysis of the top five observed incident types was conducted to determine which vessel classes were most often observed in violation of different laws and/or guidelines.

Spatial analysis, using buffer tools in ArcGIS v9.1 (ESRI, Redlands, CA) was used to visualize and assess vessel compliance with regionally recognized voluntary "no-go-zones" or buffers extending ½ mile (880 yards) from Lime Kiln-Whale Watch State Park and within ¼ mile (440 yards) of shore along the westside of San Juan Island from Eagle Point to Mitchell Point when whales were present.

RESULTS

In both 2007 and 2008, private vessels were most often observed in violation of local or state laws and/or Be Whale Wise guidelines (Fig. 2-3), followed by Canadian Commercial Whale Watching (CWW) vessels and then U.S. CWW vessels.

Analysis of the top five observed incident types by vessel class (Fig. 2-4) for 2007-2008 combined showed private vessels to be the most frequently observed vessel class in violation of

guidelines and laws compared with all other vessel classes. Canadian CWW vessels were more often observed committing all five incident types compared to U.S. CWW vessels. Between years, the differences in the proportion of violations by each vessel class were minimal. Specifically, when comparing violations by vessel class in 2007 and 2008, private vessels were observed in 62% and 60% of all guideline or law violations. Similarly, Canadian CWW vessels committed 25% and 24% of all observed violations in 2007 and 2008, compared to U.S. CWW vessels with 6% and 7% for the same years respectively. However, the overall number of observed violations did drop between years, from 126 in 2007 to 80 in 2008.

Spatial analysis was used to visualize vessel compliance by CWW and all private vessels (regardless of activity), in recognized vessel "no-go zones" or buffers along the westside San Juan Island, Washington State when whales were present. The no-go-zones are regionally known to be used by the southern resident killer whales, most notably for travelling and foraging. Occurrences of CWW and private vessels observed within ½ mile (880 yards) of Lime Kiln State Park and within ¼ mile (440 yards) of shore along the westside when whales are present within ½ mile of shore illustrate compliance with current voluntary no-go-zones (Fig. 2-5 and Fig. 2-6). CWW vessels were documented as being appropriately offshore of whales occupying the ¼ mile and ½ mile buffer zones significantly more often than private vessels.

Private vessels were observed being inshore of whales within the ¼ buffer 63% of the time and within the ½ mile buffers 29% of the time (Fig. 5) compared with CWW vessels observed within those buffers 12% and 10%, respectively (Fig. 6). CWW vessels were not observed in violation of the parking in the path guideline within the ¼ mile buffer but they were observed to be in

violation of parking in the path within in the ½ mile buffer (5%) of all observed commercial whale violations within the ½ mile buffer (Fig. 5).

DISCUSSION

A theodolite, a land surveying instrument that measures vertical and horizontal angles to a remote object, can be used to precisely calculate the latitude and longitude of cetaceans at the sea surface (Würsig 1991). However, to ensure accurate measurements, a great deal of site-specific effort is required. Readings are taken using a theodolite with a stated accuracy of 20 arc seconds or less from shorelines with high topographic relief, > 20 m above the surface of the water, with an unobstructed view of an area where animals come close to shore (usually within 5 km) (Würsig 1991). The theodolite's vertical angle is calibrated in reference to the horizon through the eyepiece and a known stationary reference point, such as a lighthouse, is used to calibrate or "zero" the horizontal angle at regular intervals (Harzen 2002). Precise altitude (within ± 10 cm) of the instrument above sea level must be tracked as it changes with tide cycles and weather. Trigonometry is used to calculate x,y coordinates for remote targets such as vessels or cetaceans. Given the effort required to locate a suitable site, accurately determine the theodolite's location and its orientation relative to a reference location, establish a mechanism to track ever-changing sea level, and modify software to correctly calculate and display data, it is common for researchers to collect land-based theodolite data from only one (Acevedo 1991; Kruse 1991; Barr and Slooten 1999; Harzen 2002; Christiansen et al. 2013) or two locations (Würsig and Würsig 1979; Bejder 2006; Williams et al. 2009) within a species range. The resulting limited survey area may exclude important information on cetacean response to anthropogenic pressures.

This study demonstrated the utility of the effectively integrated laser positioning system (LPS) to collect spatially explicit location and behavior data on vessels and southern resident killer whales throughout their summer range. Future cetacean studies may benefit by incorporating similar equipment and methods to those presented here, especially in areas that are not conducive to land-based theodolite collected data. Federal, state and local agencies tasked with conducting on the water law enforcement patrols may also benefit from using the LPS to accurately document infractions of distance laws.

An examination of vessel compliance with local and state laws and regional best-practices guidelines reveals that private vessel operators, followed by Canadian CWW vessel operators, were most often in violation of all incident types observed in 2007 and 2008 (Fig. 2-2 and Fig. 2-3); these findings are commensurate with long-term Soundwatch findings (Koski 2006, 2009; Eisenhardt 2012). Surprisingly, the first two incidents types (vessels being stopped within 100 yards of whales and vessels being under power within 100 yards of whales), remained part of the top five incidents in 2008 despite the June 12, 2008 enactment of Washington State law (RCW 77.15.740) which made it unlawful for vessel drivers to: (a) approach, by any means, within 100 yards of a SRKW; (b) cause a vessel or other object to approach within 100 yards of a SRKW; (c) intercept a SRKW by placing a vessel or allowing a vessel to remain in the path of a whale and the whale approaches within 100 yards of that vessel; (d) Fail to disengage the transmission of a vessel that is within 100 yards of a SRKW (Washington State 2008).

The higher number of private vessel operators observed out of compliance with guidelines may be a result of this user group being less familiar with boating laws and regional guidelines

compared with CWW vessel operators. Additionally, the CWW vessel operators communicate with one another via VHF radio allowing them to share information concerning whale locations, weather conditions, sea states, etc., while private vessel operators do not have that advantage thus their odds of being 'surprised' by the presence of whales is higher.

Although aware of the laws and guidelines pertaining to whales in the Salish Sea, Canadian CWW vessels continue to account for a larger proportion of the overall vessel incidents observed in this study, compared to U.S. CWW. One possible explanation why there were fewer incidents committed by U.S. CWW is that the U.S. fleet is markedly smaller, with 22 whale watching vessels owned by 17 companies compared to the Canadian fleet of 54 vessels owned by 16 companies (Eisenhardt 2012).

The ¼ mile buffer zones along the westside of San Juan Island and the ½ mile buffer around Lime Kiln-Whale Watch State Park, Washington State are regionally recognized as being important habitat for the southern resident killer whales. Spatial analysis of vessels and whales in or near the buffers clearly demonstrate the ability of commercial whale watch vessels to abide by distance guidelines from shore. Advanced yet inexpensive GPS receivers are now routinely used by the commercial whale watch fleet. GPS units allow vessel operators to determine their distance precisely to mapped landmarks such as shorelines, nautical hazards, or buoys making it easier for them to know when it is necessary to maneuver more offshore in order to maintain appropriate shoreline buffer distances. When comparing instances of when CWW vessels versus private vessels were located inshore of whales while whales were within the ¼ mile no-go-zone buffer (Fig. 2-5 and Fig. 2-6), commercial vessels were only occasionally observed (12%)

compared to private vessels (65%). This finding suggests that CWW vessels are aware of and tend to observe the no-go-zone, even though it is merely a voluntary guideline. Private vessels are more likely to be unaware of the voluntary buffer, hence the high proportion of non-compliance.

Past studies have shown that the SRKW spend a disproportionate amount of time along the westside of San Juan Island, Washington state (nearshore to several miles offshore) when they are in the inland waters of the Salish Sea (Heimlich-Boran, J. 1988; Osborne, 1999; Hauser et al. 2007). Not surprisingly, long-term Soundwatch vessel monitoring data show that the highest concentrations of vessels and the majority of vessel incidents observed since 1998 occurred in the same area (Koski, 2006; Eisenhardt 2012). Although a proposed no-go-zone was not codified when federal vessel laws went into effect in May 2011, NOAAs Fisheries Service continues to collect information in order to consider the possibility in the future.

Recommendations

Additional research documenting southern resident whale behavior throughout their summer range is needed to determine if particular areas warrant protection as marine protected areas or no-boat-zones (Ashe et al. 2010). The laser positioning system (LPS) field tested for this research is an effective tool to record accurate latitude and longitude information on cetaceans and vessels in the area. The ability to simultaneously record whale and vessel locations and behaviors will allow further research on vessel effects in conjunction with changes in behavior in response to oceanographic and geologic features of the habitat (Heimlich-Boran, J.

1988; Hoelzel 1993). Data recorded for this study are being analyzed in combination with fine-scale bathymetry data from SeaDoc Society to determine ecological features associated with different regions of the whale's summer range that might explain why the whales engage in certain behaviors (resting in particular) more often in some areas than others. Further, these data can be analyzed to compare change over time for fairly well studied behavior such as foraging (Heimlich-Boran, J. 1988; Hoelzel 1993; Felleman, 1991, Hanson et al. 2010; Ashe et al. 2010). Spatially explicit location and behavior data should continue to be collected with the LPS in order to document vessel interactions and violations and to assess the need for additional vessel restrictions.

The lack of corresponding vessel laws in Canada may be partly to blame for the fact that vessels of all classes continue to violate basic vessel laws and guidelines in United States waters. Specifically, unlike in the U.S., Canada lacks vessel laws that establish minimum viewing distances for vessels and instead merely urge boaters to maintain a 100 yards distance when viewing marine mammals. Further, while Canadian mammal laws prohibit the "disturbance" of marine mammals, there is no clear definition for what constitutes a disturbance; therefore, even egregious vessel behavior near marine mammals is rarely penalized. The passage of Canadian laws commensurate with U.S. vessel laws will likely increase vessel compliance by all vessel classes in both countries' waters.

Current voluntary guidelines supported by the whale watching industry should be codified to further protect the endangered southern resident killer whales and eliminate ambiguity regarding what is allowed in Canadian versus U.S. territory. These guidelines include: limits to viewing

any one groups of whales to 30 minutes, reducing speed to less than 7 knots within 400 yards of whales, and only approaching whales from the side, not the front or back.

The continuing trend for vessels to violate laws and guidelines may be partly attributable to a lack of on-the-water enforcement of whale watching laws and guidelines. Until recently, funding for enforcement has been minimal; however, in August 2013, the National Marine Fisheries Service announced that a $925,000 grant from NOAA will go into effect in 2014 to pay for a "killer whale cop" who will spend up to 500 hours per summer for three years enforcing Federal vessel laws pertaining to killer whales.

Given the lack of information on vessel conduct when engaged in whale watching activities in the evenings, it would be prudent to focus monitoring and/or enforcement efforts during evening hours, 1700 hr to 2100 hr, to document vessel behavior around whales during "sunset trips" as both private and commercial vessel operators take advantage of the long summer days in the Salish Sea. Further, as more whale watching companies are offering whale watching trips year round, it would be sensible to monitor vessel behavior in non-peak season months (October through April) to better characterize vessel pressure on marine mammals throughout the year.

The ability to collect location information and document animal behaviors throughout large ranges provides unique opportunities to study anthropogenic and ecological influences on marine mammals that may aid in their conservation.

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TABLE CAPTIONS

Table 2-1. Definitions of whale attribute data observed in 2007-2008 based on Southern Resident Killer Whale Coding Workshop, Seattle WA (2004). Whale Attribute Data recorded every 5 min during sampling.

Table 2-2. Definitions of vessel attribute data observed in 2007-2008. Vessel attribute data recorded every 5 min during sampling.

Table 2-3. Manufacturer's specifications by instrument with summed maximum potential errors.

Table 2-1. Definitions of whale attribute data observed in 2007-2008 based on Southern Resident Killer Whale Coding Workshop, Seattle WA (2004). Whale Attribute Data recorded every 5 min during sampling.

Behavior / Activity State	
Travel	any orientation, any cohesion, slow to porpoising speed, directional, often synchronous
Forage*	any orientation, any cohesion, slow to fast speed, directional or non-directional
Socialize/Play	any orientation, any cohesion, any speed. Social play (touching, percussives), solitary play with objects (kelp, floats, prey)
Rest**	flank or non-linear orientation, contact or tight cohesion, stationary to medium speed,* directional
Milling***	non-linear orientation, any cohesion, any speed, non-directional
	** Foraging behavior was coded with sub-activities whenever possible. For example, forage-search might be coded when the whales were seen to be both foraging and traveling and forage-prey would be coded when the whales were seen eating prey. However, all foraging activity states were counted together for statistical analysis*
	*** Resting whales traveling at medium speed were likely being carried by water currents*
	**** Milling was often coded as an intermittent sub-activity during any of the primary behavior states or as a speed*
Spatial Arrangement / Cohesion	
Contact: physical contact	
Tight: (<10 meters)	
Loose: (10-100 meters)	
Spread: (>100 meters)	
Orientation	
Flank: side-to-side	
Linear: head-to-tail	
Non-linear: no orientation detected	
Speed	
Stationary: 0 knots, logging, hanging	
Slow: < 2 knots, jerky, less smooth surfacing	
Medium: 2-6 knots, slow roll	
Fast: 6-10 knots, fast roll	
Porpoising: >10 knots, part of body out of water	
Directionality	
Directional: < 90° change in direction from previous surfacing	
Non-directional: > 90° change in direction from previous surfacing	

Table 2-2. Definitions of vessel attribute data observed in 2007-2008. Vessel attribute data recorded every 5 min during sampling

Vessel Class*	
	Private
	Commercial
	Research
	Enforcement
	Monitoring
	Kayak
	Ferry
	Shipping
Vessel Activity	
	Whale Watching
	Fishing
	Non-Whale Oriented
	Transiting: vessels were coded as transiting when moving from one group of whales to another, usually > 400 yards from any whale
Vessel Type	
	Inflatable
	Sailboat (any size)
	Small Hard Bottom
	Medium Hard Bottom
	Large Hard Bottom
Vessel Speed**	
	Stationary
	Slow 0-2 knots
	Medium 3-4 knots
	Fast 5-6 knots
	Very Fast 7+ knots
Vessel Placement	
	Inshore of Whales: vessel between focal whale and shoreline
	In Path: vessel in the path of approaching focal whale
	Offshore of Whales: vessel on the offshore side of focal whale
Vessel Position	
	Parallel to Whales: vessel oriented with port or starboard closest to focal whale
	Bow In-Perpendicular to Whales: vessel bow pointing toward focal whale
	Bow Out-Perpendicular to Whales: vessel motor(s) pointing toward focal whale
Vessel Location Relative to Focal Whale Swim Direction	
	Front of Whales: vessel in front of approaching whales
	Side of Whales: vessel is to the side or abreast of focal whale
	Behind Whales: vessel is behind whale in relation to whale swim direction
	On Top of Whales: vessel within one body length of surfaced focal whale

* All vessels were identified by name or unique feature in order to identify repeated measures during analysis

** Vessel speed most often based on research vessel speed. Occasionally, vessel speed was estimated based on water displacement at the bow and/or spray from a motor

Table 2-3. Manufacturer's specifications by instrument with summed maximum potential errors.

Distance	Compass Error +/- 0.3°	GPS Error < 1 yd	Laser Error < 1 yd	Maximum Potential Error	
100 ft.	+/- 0.52 ft.	+/- 3.28 ft.	+/- 3.28 ft.	+/- 2.36 yd	+/- 2.16 m
200 ft.	+/- 1.05 ft.	+/- 3.28 ft.	+/- 3.28 ft.	+/- 2.53 yd	+/- 2.32 m
300 ft (100 yd)*	+/- 1.57 ft.	+/- 3.28 ft.	+/- 3.28 ft.	'+/- 2.71 yd	+/- 2.48 m
500 ft.	+/- 2.62 ft.	+/- 3.28 ft.	+/- 3.28 ft.	+/- 3.06 yd	+/- 2.80 m
1000 ft.	+/- 5.23 ft.	+/- 3.28 ft.	+/- 3.28 ft.	+/- 3.93 yd	+/- 3.60 m
3280.8 ft. (1000 m)	+/- 17.18 ft.	+/- 3.28 ft.	+/- 3.28 ft.	+/- 7.91 yd	+/- 7.24 m

* Whale watching distance laws of 100 yards were enacted in 2007 (San Juan County Vessel Ordinance #35-2007) and 2008 (Washington State law RCW77.15.740) to protect killer whales in the Salish Sea.

FIGURE CAPTIONS

Figure 2-1 Regional map of Northwest Washington State and Southeast British Columbia, Canada with study area outlined. Map used with permission from The SeaDoc Society

Figure 2-2 Researcher wearing harness with monopod and laser positioning system on the bow of research vessel collecting whale behavior latitude and longitude locations in 2007

Figure 2-3 Proportion of all law/guideline violations committed by Canadian and U.S. commercial whale watching vessel operators and private boaters by year, 2007 and 2008

Figure 2-4 Top five observed incident violations by vessel class for 2007-2008 combined

Figure 2-5 Summary of all sampled occasions in 2007 and 2008 combined when commercial whale watch vessels were found to be within ¼ mile (440 yards) and ½ mile (880 yards) of the Westside of San Juan Island

Figure 2-6 Summary of all sampled occasions in 2007 and 2008 combined when private vessels were found to be within ¼ mile (440 yards) and ½ mile (880 yards) of the westside of San Juan Island

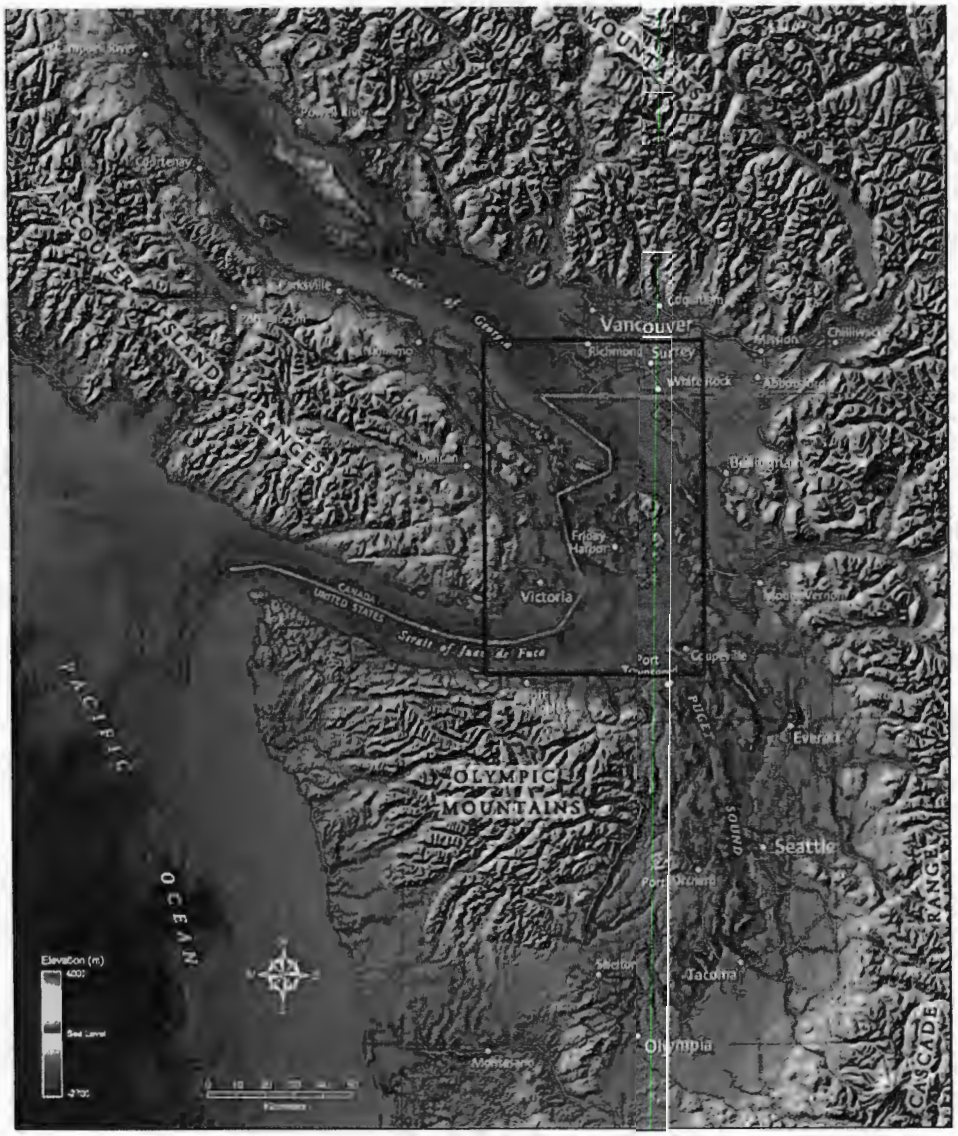

Figure 2-1. Regional map of Northwest Washington State and Southeast British Columbia, Canada with study area outlined. Map used with permission from The SeaDoc Society.

Figure 2-2. The author wearing harness with monopod and laser positioning system on the bow of research vessel collecting whale behavior latitude and longitude locations in 2007.

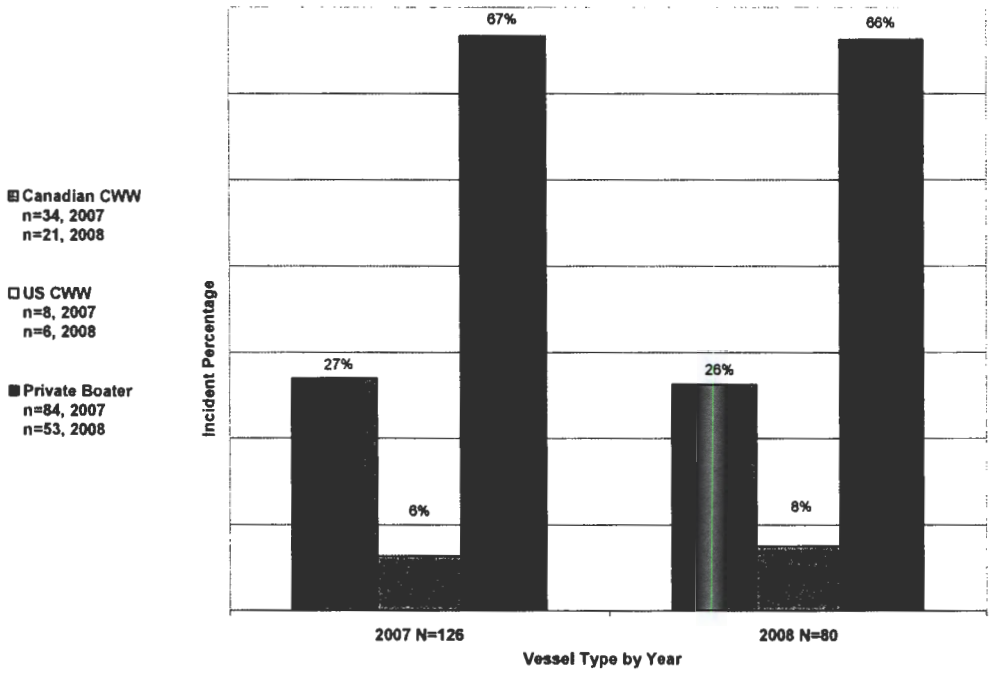

Figure 2-3. Proportion of all law/guideline violations committed by Canadian and U.S. commercial whale watching vessel operators and private boaters by year, 2007 and 2008.

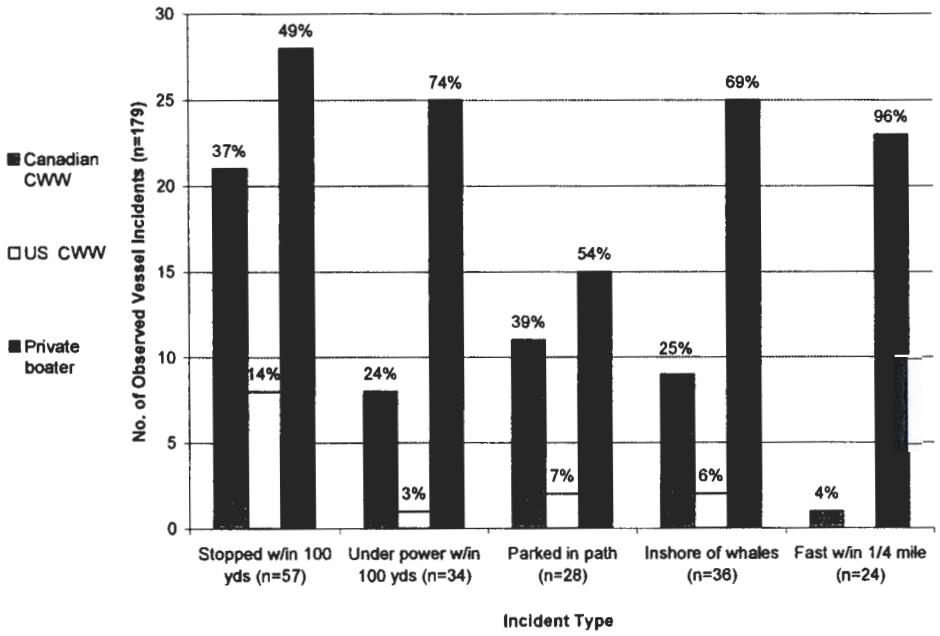

Figure 2-4. Top five observed incident violations by vessel class for 2007-2008 combined.

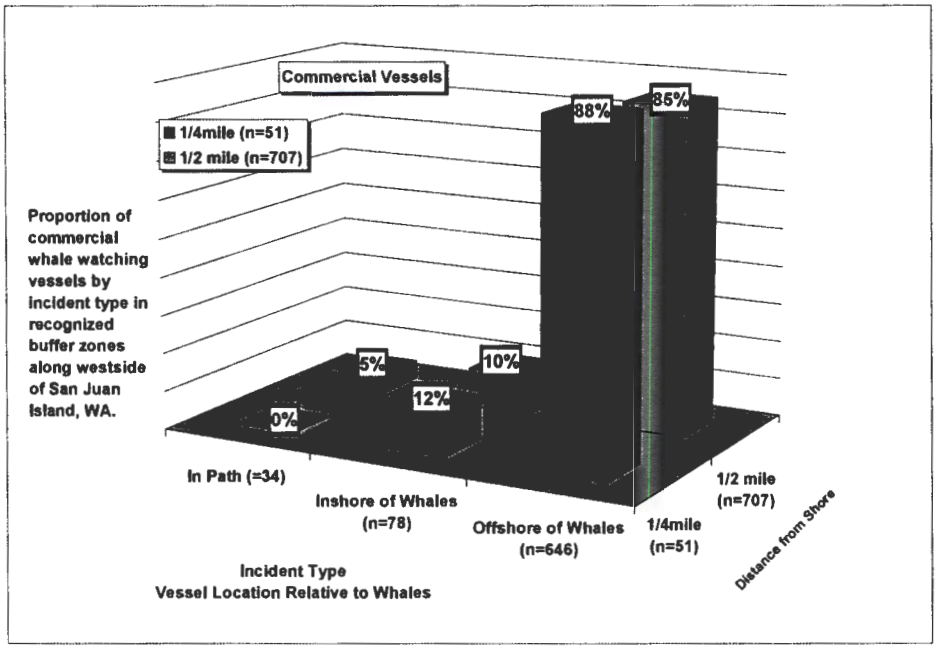

Figure 2-5. Summary of all sampled occasions in 2007 and 2008 combined when commercial whale watch vessels were found to be within ¼ mile (440 yards) and ½ mile (880 yards) of the Westside of San Juan Island, Washington State.

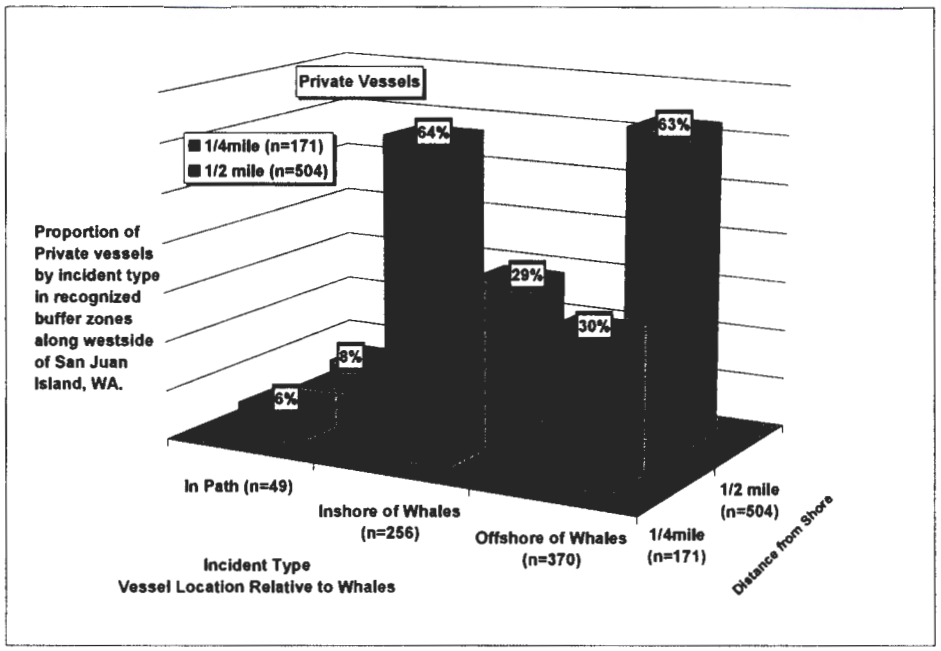

Figure 2-6. Summary of all sampled occasions in 2007 and 2008 combined when private vessels were found to be within ¼ mile (440 yards) and ½ mile (880 yards) of the westside of San Juan Island, Washington State.

CHAPTER 3

The effects of vessels on group cohesion and behavior of southern resident killer whales (*Orcinus orca*)

INTRODUCTION

After more than thirty years of intensive research on marine mammals around the world it is evident that routine marine mammal ecotourism can induce both short-term (Corkeron 1995; Janik and Thompson 1996; Constantine 2001; Bejder 2005; Arcangeli and Crosti 2009) and long-term (Bejder 2003, 2006; Lusseau 2004; Gill et al. 2001; Constantine 2004) behavioral responses in whales and dolphins. Short-term behavioral responses in cetaceans such as surfacing patterns (Janik and Thompson 1996), directionality (Williams 2002), vocalizations (Foote et al. 2004), and behavior state responses (Kruse 1991; Lusseau 2003; Lusseau et al. 2009; Christiansen et al. 2013) that occur as a result of ecotourism have been reported for nearly two decades. Yet, because it has been difficult to determine long-term impacts that may result from short-term behavior responses, few regulations have been implemented to protect whales and dolphins in the wild. Nevertheless, recent analysis of longitudinal cetacean data from several countries is now yielding information that demonstrates biologically significant long-term behavioral changes in several cetacean populations in reaction to ecotourism. For example, novel aggressive behavior has been recorded in dolphins interacting with humans and conspecifics at an established wild dolphin feeding resort (Smith et al. 2008), and changes in habitat use, and displacement of large numbers of animals from traditional core areas has been documented (Lusseau 2005). Reduction in fecundity in females subjected to repeated high-levels of ecotourism vessels is now evident (Bejder 2005), as well as documented changes in

activity budgets (Constantine 2004; Lusseau, 2004) represent long-term biologically significant behavioral changes in response to ecotourism. Such findings are particularly important to heed when making management decisions for small and/or endangered populations of marine mammals.

The southern resident killer whale (*Orcinus orca)* population has experienced multiple fluctuations since population surveys were initiated by the Center for Whale Research in the mid 1970s. Several periods of population gains and losses since the 1980s can be explained as residual effects related to live-captures for marine parks during the 1960s through the mid 1970s. However, a significant and steady decline in the population beginning in 1996, deemed unrelated to the removals, led to an interest in listing the whales under the United States Endangered Species Act (ESA). In November 2005, the U.S. National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA/NMFS), Northwest Regional Office listed the southern resident killer whales (SRKW) as an endangered species under the ESA. Several risk factors including reductions in the quantity and quality of prey (salmon), exposure to persistent toxins, and disturbance from vessel presence and associated noise were identified as contributing to the decline of this already small population. The listing of the SRKW population as endangered prompted the creation and 2006 release of NMFS Draft Research and Recovery Plans, and the designation of Haro Strait and the waters around the San Juan Islands, Washington State as the whale's summer core critical habitat (NOAA 2006).

This study explicitly addressed the *Recovery Plan's* schedule of tasks to monitor vessel activity around whales. Here, we utilized new technology to accurately record latitude and longitude locations and behaviors of whales and vessels throughout the entire SRKW critical habitat. Killer whale cohesion was examined in an effort to determine what might be affecting transitions from one cohesion state to another.

The SRKW summer core critical habitat seasonally receives heavy vessel traffic, including commercial and recreational whale watching (ecotourism), recreational and commercial fishing, passenger ferries, cruise ships, and shipping traffic. Before 1984, commercial whale watching in the SRKW critical habitat area was extremely limited; however, beginning in 1984, the industry saw unprecedented annual growth that peaked in 2001 with a total of 81 Canadian and U.S. commercial whale watching (CWW) vessels. At the end of this study in 2008, the active U.S. and Canadian commercial fleet comprised 37 companies with a total of 76 vessels (Koski 2009). Private whale watching vessels and kayaks have also increased since the 1980s with private vessels making up roughly 30% of all vessels watching whales during the summer months. Extensive daily and seasonal vessel exposure periods occur with whale watching and other recreational boating activities occurring as early as 0600 hr to as late as 2100 hr (dusk during June and July) and from early April through October (Koski 2009). Opportunistic whale viewing from commercial and private boats has also increased throughout the winter months as the use of social media to relay whale sightings has increased (personal observations).

The objectives of this research were to examine changes in cohesion of SRKW groups in response to varying vessel composition including vessel density, distances, and modes of

operation near whales. Whale group cohesion, the average distance between group members (contact, tight, loose, spread), is a spatial and temporal assertion of social structure (Mann 2000). Group behavior states (clustered behavioral attributes or dimensions), are functional definitions of biologically significant activities (specifically foraging, traveling, resting, and socializing/play). The southern resident killer whales are highly social (Hoelzel and Osborne 1986; Heimlich-Boran, S.L. 1986; Parsons et al. 2009; Pilot et al. 2010); and have been documented hunting cooperatively (Hoelzel 1993) and sharing food (Ford and Ellis 2006). When whale group cohesion and/or behavior are disrupted, their ability to communicate, forage, and move through their environment may be impaired, thus limiting their overall fitness and survivability. Previous vessel impact studies show that both southern and northern resident (most often observed near the northern tip of Vancouver Canada, B.C.) killer whale populations demonstrate behavioral responses to vessel presence and activities (Noren et al. 2009; Lusseau et al. 2009; and Williams et al. 2009).

The information collected for this research allowed for sophisticated spatial analyses of the complex interactions between whales and anthropogenic variables (vessel density, distance, and mode of operation) and ecological variables, such as bathymetry in different geographic regions and at different spatial and temporal scales. Results from this study were considered when developing vessel regulations that went into effect in May 2011 (Giles and Cendak, 2010). Additional spatio-temporal research, utilizing methods and materials described here, would be useful to identify additional geographic regions used by the southern resident killer whales for biologically significant behavior.

METHODS AND MATERIALS

Study Area

This research was conducted from June 1 through October 31, 2007 and June 7 through October 31, 2008 in waters surrounding the United States San Juan Islands and the Canadian Gulf Islands which constitute a portion of the international waters officially known as the Salish Sea. The geographic coordinates for the research area are between 48°12′ to 49° N latitude by 122°43′ to 123°50′ W longitude (Figure 3-1). Data were collected in Beaufort sea state ≤ 3 between 0730 hr and 2100 hr as visibility and weather conditions allowed. Southern resident killer whales were located each day by monitoring sightings report transmitted on VHF radio, direct observation, or via communication with CWW vessel operators who shared whale locations. In 2007, we also utilized the Pager Network, a spotting effort established by participating whale watching companies (for additional information in this spotting effort, see Hauser et al. 2006); this effort was discontinued before 2008.

Sampling protocols

Data were collected from one of two research vessels, a 7.3 meter Proline fiberglass powerboat (R/V Scordino, NOAA/NWFSC) with a 200 horsepower Honda four-stroke outboard motor, and a 6.4 meter Munson metal flat-bottom powerboat (R/V Buzzard, The Whale Museum) with twin 50 horsepower Honda four-stroke outboard motors. The research vessel was oriented parallel to whales, typically as far away as the whale watching fleet (> 100 yards), with

rare close approaches within 50 yards for whale identification confirmation conducted under ESA/MMPA Permit for Scientific Research No. 781-1824(01), and/or Canadian Marine Mammal/SARA Scientific License Nos. 2007-08/SARA-68 and 2008-06/SARA-86. Regionally accepted "best-practices" Be Whale Wise guidelines were adhered to in order to minimize effects of the research vessel on the behavior of other vessel operators or whales.

Equipment

Novel research equipment used for this study made it possible to observe and collect data on whales throughout their summer range at distances greater than the voluntary distance guidelines, 100 yards at that time, and farther from whales than the CWW fleet and private vessels observing whales. Consequently, the effects of the research vessel were minimized and the quantity and quality of geographical, spatial, and behavioral data were maximized. This study utilized two integrated equipment packages or laser positioning systems (LPS); each package consisted of a global positioning system receiver (GPS receiver: GeoExplorer GeoXH, GeoXT, Trimble MFG., Sunnyvale, CA) with built-in data collector to record attribute data (e.g. whale identification, group size, and behaviors), a laser rangefinder (Impulse 200 XL, Laser Technologies Inc., Englewood, CO) to determine distance, and a digital compass (MapStar Compass Module II, Laser Technologies Inc., Englewood, CO) for azimuth measurements. All components of the LPS were cable connected and synchronized via two built-in RS232 serial ports to communicate as one unit and generate geo-referenced data points with the push of one button. All package components were mounted on a monopod for maneuverability and secured to the researcher via a custom harness. One LPS was used to collect latitude and longitude and

whale attribute data on focal whales and the other LPS was used to collect similar information on vessels in the vicinity of a focal whale group. Chapter 2 (Giles, 2013a) of this dissertation on methods and materials provides a full description of each component of the LPS.

Data Post-processing

At the end of each day, whale and vessel location and attribute data were downloaded from the two laser positioning system GPS receivers onto a desktop computer running Pathfinder Office software (Trimble Mfg., Sunnyvale, CA) and differentially corrected using nearby reference stations. Differential correction substantially increases the positional accuracy of GPS location information, thus increasing the accuracy of the latitude and longitude recorded for each whale and vessel. After differential correction, all whale and vessel tracks were transferred to a custom software program developed for this project that calculated the distance between each vessel and the nearest whale in time, thus producing the most accurate vessel-to-whale distance measurements. Specifically, it was important to ensure distances between each vessel and the focal whale were as accurate as possible. Given that the objects (whales and vessels), as well as the data collectors were all on/in the water and often moving, only vessel locations that were paired with whale locations within 3 seconds were considered to be accurately measured. All other vessel and whale distance measurements were excluded from analysis.

Whale Behavioral Data

Location and behavior data were collected for whale groups in close proximity to varying numbers of vessels, including situations when the research vessel was the only vessel present within 1,000 yards. When the only vessel present the research vessel maintained a distance greater than 100 yards, as required by state law at that time, to minimize the possibility that the research vessel would alter group cohesion. To limit inter-observer error, only the lead researcher collected data on whales. I utilized a laser positioning system package (LPS) to record whale data using an individual-follow protocol, and both predominant group activity and scan sampling methods were used during focal follows (Altmann 1974; Mann 1999). A focal whale was chosen and subsequent attribute data (Table 3-1) were documented based on the position and behavior of the focal whale in relation to other whales nearby and/or whales engaged in similar behaviors. If the focal animal left a group, the research vessel remained with that animal for the duration of the focal follow with notes marking the transition to a new group. Behavioral assessments of the focal animal and predominant group activity were made at 5 minute fixed intervals during 15-60 minute sampling tracks. Tracks were limited to 60 minutes per individual whale per day to reduce impacts to individual whales. Tracks that were less than 15 minutes were deemed unsuitable for statistical analysis. Scan sampling (Mann 1999) was used to record the gross behavioral activity state (resting, foraging, socializing, and traveling) in which the focal whale and most other group members were engaged. Additional whale group attributes, (see Table 1 for fine-scale definitions), were documented including: cohesion, orientation, speed, and directionality. These whale attribute data were coded using a behavioral sampling methodology developed by participants in a SRKW Behavior Coding Workshop held

in Seattle in 2004 (NOAA 2004). Scan sampling was also used to record focal group size, pod identity, identity of non-focal group whales/sub-pods in area, and approximate total number of whales in the area. Whale swim speed was assumed to equal that of the research vessel, which attempted to parallel the focal whale during follows. This provided a detailed record of the actions of the vessel and the behavior of whales for analysis.

Vessel Data

While I collected whale location and behavior data, a research assistant used a second laser positioning system to recorded geo-referenced vessel latitude and longitude locations and vessel attributes relative to the focal whale using scan sampling techniques in 5-minute intervals simultaneous to the corresponding 15-60 minute whale sampling track. The vessel attribute data (see Table 3-2 for fine-scale descriptions) included: vessel class, vessel activity, vessel type, vessel speed, vessel placement relative to focal whale/group (inshore, in path, offshore), vessel position relative to focal whale/whale group (parallel, bow-in perpendicular, bow-out perpendicular), and location of vessel relative to focal whale/group swim direction (in front, to the side, on top of, or behind). These vessel attributes provided a detailed record of vessel distance, density and actions near focal whale groups.

Statistical Analysis

Model Fitting Through Regression and Analysis of Variance (ANOVA)

Cohesion state transition analysis

Killer whale cohesion was examined in an effort to determine if vessel mode of operation, distance and or density might drive transitions from one killer whale cohesion state to another. Data were queried for the observed transitions from one cohesion state to another; then, a log-linear model was fit to the data to study the possible dependence of transitions on vessel density. A "transition" was defined as the collective data from two consecutive 5-minute time intervals. For each transition, the cohesion state ('contact', 'tight <10m', 'loose 10-100m'), or not-cohesive ('spread >100m') for the first interval, the cohesion state for the second interval, and the vessel density were noted.

Vessel density was defined as 'low' if there were 5 or less vessels present within 1,000 yards of the focal whale in both intervals making up the transition and was defined as 'high' otherwise. The cut-off for high and low vessel density was chosen as 5 vessels after studying the distribution of the number of vessels within 1,000 yards of the focal group for all observed transitions; both the mean and the median for the distribution were around 5 vessels. The research vessel from which these data were collected was included in these analyses. Categorizing the data in this way resulted in a three-way contingency table with factors: 'current cohesion state', 'succeeding cohesion state', and 'vessel density'. It should be noted that although some transitions between cohesion states occurred more frequently than others, it is

certainly possible for transitions between all cohesion states to occur. That is, there is no physical/biological constraint preventing the whales from switching between any of the four possible cohesion states.

Using the information from the three-way contingency table, the proportion of observations that southern resident killer whales were engaged in the four distinct cohesion states were calculated for the combined 2007-2008 data sets in order to investigate for differences in cohesion depending on vessel density within 1,000 yards of the focal whale. Next, I examined the effect of vessel density on the probability that the whales would remain in a given cohesion state by plotting the effect size of vessel density.

Lastly, a log-linear analysis was conducted using SAS 9.1 to test the independence of transitions in cohesion state on vessel density for the combined 2007 and 2008 data set. Analysis considered models that included the main effects of each factor (current cohesion state, succeeding cohesion state, and vessel density) and added two-way interactions separately at first and then jointly. Due to sample size constraints, it was not possible to include other candidate independent variables, such as behavior state, for this dataset in this model. Doing so would have stratified the data to such an extent as to violate the requirements of the log-linear model. Specifically, several estimated cell counts would have been less than 1 and many other estimated cell counts would have been less than 5, well below the minimum requirement of 6, based on the number of cells in the analysis.

Results from the log-linear analysis showed that overall three models were found to best explain the variance in the data: 1) the model considering main effects and the interactions between current and succeeding cohesion state and between current cohesion state and vessel density: 2) the model considering main effects and the interactions between current and succeeding cohesion state and between succeeding cohesion state and vessel density: 3) the model considering main effects and the interactions between current and succeeding cohesion states, between current cohesion state and vessel density, and between succeeding cohesion state and vessel density.

A comparison of the three models (named A, B, and C for ease of discussion) including each model's: likelihood ratio test statistic (G^2) and degrees of freedom, its p-value, and its Akaike's Information Criterion (AIC) value, determined which model best explained the variance in the data.

RESULTS

Effort Summary Statistics

In 2007, between June 1 and October 31, location and behavior data were collected on southern resident killer whales and vessels on 41 days, during which time 93 focal follows were conducted, resulting in 5,434 geo-referenced data points to be used for analysis. In 2008, similar whale and vessel data were collected on 57 days between 7 and October 31, during which 127 usable focal follows were conducted, resulting in an estimated 11,079 geo-referenced data points including behavioral attributes of vessels and whales used for analysis.

Whale Summary Statistics

For 2007 and 2008 combined (Figure 3-2) there were 4,803 whale data points collected and used for analysis. The behavioral budget for both years combined showed whales traveling 56% (n=2,652), foraging 17% (n=833), socializing 9% (n=477) and resting 7% (n=332) of the time observed. In 2007, some whale locations were recorded without comment on behavior state; these locations represent 11%, (n=539) of the total whale locations recorded for both 2007 and 2008 combined (Table 3-3).

Vessel Summary Statistics

For 2007 and 2008 combined, (Table 3-4) there were 11,710 vessel data points collected and used for analysis. It is important to note that data on the same vessel may have been recorded more than once if it remained in the vicinity of the focal whale group for more than one 5-minute data sampling interval during any given focal follow. For both years combined (Figure 3-3), CWW vessels represented the majority of all vessels recorded; 49%, (n=5,643). Private vessels made up the next most observed vessel class with 28% (n=3229). A summary of all vessel distances to the focal whale were summarized by vessel type (Table 3-5).

The proportion of all observations for commercial whale watching vessels and private vessels were stratified into separate distance bins (Figure 3-4) to investigate vessel behavior near whales. The majority of the vessel distances recorded for both vessel types were between 400-799.99 yards from the focal whale (CWW 46.5%, Private 47.6%), followed by the 200-399.99 yard

distance bin in which the proportion of observations for both vessel types was 28.6%. There were more CWW (14.6%) and private vessels (13.5%) observed being between 800-999.99 yards from the nearest focal whale compared to those observed between 100-199.99 yards away from the focal: CWW (8.4%), and private (8.0%). Notably, the distance bin with the fewest observations for both vessel types was that nearest to the focal whale, between 0-99.99 yards: CWW vessels (1.8%) and private vessels (2.3%).

Cohesion state transition analysis

The purpose of this analysis was to investigate how cohesion, as defined by the distance between group members (contact, tight, loose, or spread) of southern resident killer whales changed in response to vessel mode of operation, distance and/or density. In 2007 and 2008, 1616 cohesion state transitions were observed, with 777 (48.08%) occurring in low vessel density and 839 (51.92%) occurring in high vessel density (Table 3-6).

The proportion of observations that killer whales were engaged in the four distinct cohesion states were calculated for the combined 2007-2008 data sets using the information from the three-way contingency table. This analysis was to investigate the differences in cohesion depending on vessel density within 1,000 yards of the focal whale.

In this study, whales tended to be in tight cohesion (<10 m) significantly more often in high vessel density situations than in low vessel density situations (Figure 3-5) and tended to be non-cohesively spread (>100 m) significantly more often in low vessel density situations than in high

vessel density situations. Additionally, the analysis of the combined data set demonstrated that the whales tended to be in contact significantly more often in low vessel density than in high vessel density (Figure 3-5).

Next, I examined and plotted the effect size of vessel density on the likelihood that the whales would remain in a given cohesion state during low and high vessel density situations (Figure 3-6). Vessel density appeared to be significant both when the whales were tight and when they were spread: the whales were significantly less likely to remain tight in low vessel density situations than in high vessel density situations and the whales were significantly more likely to remain spread in low vessel density than in high vessel density situations.

Log-linear regression analysis was used to test independence of current and succeeding cohesion states on vessel density (Table 3-7). Based on the likelihood ratio test statistic, the p-value, and AIC, the best model to select would be model C which contains the three main effects (the main effects of current state, succeeding state, and vessel density) and all two-way interactions. The likelihood ratio test statistic for model C was the lowest of the three, as was its AIC value which assigns increasing penalty to models with increasing number of parameters (i.e. it penalizes models that are more complicated). Also, the p-value for model C was much higher than those of the other models, indicating a better fit. However, when a hypothesis test was conducted at the $\alpha = 0.05$ level for each simpler model against model C based on the likelihood ratio test statistics, it becomes evident that it is not possible to reject either of the simpler models as adequately fitting the data (p-values 0.1531 and 0.0697 for the tests of model A vs. model C and model B vs. model C, respectively). Nonetheless, the best fitting models included an interaction

between vessel density and at least one cohesion state, indicating that vessel density cannot be overlooked as a factor that is related to whale cohesion.

DISCUSSION

From an examination of distances between all vessels to the nearest focal whale in time, it is evident that in 2007 and 2008, most vessels of all classes (private, commercial, research, etc.,) far exceeded the 100 yard viewing distance laws. Indeed, 56% of all vessel locations were greater than 400 yards away from the focal whale. Based on these data, Federal regulations passed in 2011, which doubled the whale viewing distance for vessels from 100 yards to 200 yards in U.S. waters, will likely be observed by the majority of both commercial and private whale watching vessels.

Across studies, the proportion of time southern resident killer whales have been documented traveling has varied widely, from as little as 4% (Ford, 1989) to as much 70% (Noren et al. 2009). While some of the variance between this and past research may be due to differences in sampling methods and/or subjective interpretation of killer whale behavior state by different researchers, there remains the possibility that the whales are in fact traveling considerably more than in the past.

Rest is another behavior state that warrants comment. Past research documented SRKW engaged in resting behavior during 25% of all observations (Heimlich-Boran, S.L, 1988), and another study reported resting behavior during 13% of observations (Osborne 1999). More

recent research on SRKW behavioral budgets found the whales resting 7% of the time during observations made between 2005-2006 (Noren et al. 2009), and also between 2007-2008 (Giles and Cendak, 2010), and another study documented resting during 8% of the time for observations from 2006 alone (Ashe and Williams, 2009). These findings support the suggestion that southern resident killer whales are becoming more diurnal over time (R. Osborne, personal communication).

Beyond documenting whale and vessel locations and behavioral attributes that can be used for comparison to other studies, the overarching purpose of this analysis was to determine if group cohesion, as defined by the distance between group members (contact, tight, loose, or spread) of SRKW changed in response to vessel operator modes of operation, distance and/or density.

Log linear analysis has been used previously to investigate whether boat presence influences changes in behavioral states in other delphinids. For example, log-linear analysis was used to show that boat presence affected changes in activity state for southern resident killer whales (Lusseau 2009; Bain et al. 2006). Additionally, Williams et al. (2006) used log-linear analysis to show that boat presence had a strong effect on the probability of change in activity state for northern resident killer whales. And log linear analysis was used to show that boat interactions affected the probability of transitions in activity state for bottlenose dolphins (Lusseau 2003).

For this study, an analysis of changes in cohesion state depending on boat density within 1000 yards of the focal whale indicate that whales tended to be in tight cohesion (<10 m) significantly more often in high boat density situations than in low boat density situations. These finding

suggest that southern resident killer whales respond to high boat density situations by grouping together. Other researchers have found that swimming paths of northern resident killer whales become more direct in Johnstone Strait, B.C., Canada when vessel density is high (Williams and Ashe, 2007). Alternatively, boats that are viewing whales that are less cohesive could simply be spread over a larger area, resulting in lower boat densities. Boat operator behavior could be dictated by whale cohesion state; when whales are spread or in small groups, it could be deemed a better whale watching experience, (when only a few boats are viewing a few whales). Consequently, boat operators avoid high vessel densities when whales are spread. Similarly, when all of the whales are closely grouped the only option for all of the boat operators in the area is to view the same whales, resulting in high boat densities. Additional investigation is needed to resolve the competing hypotheses.

Results from this study also show that whales tended to be non-cohesively spread (>100 m) significantly more often in low boat density situations than in high boat density situations. These finding suggests the possibility that the whales engage in foraging more often in low vessel density situations compared to high vessel density situations. Past research has demonstrated that these whales cooperatively hunt by spreading apart from one another, often more than 200-meters apart, in order to scan large areas for fish (Hoelzel 1993; Ford and Ellis, 2006); therefore, if the whales group up with increasing numbers of vessels in close proximity, then it is probable that foraging is diminished. Previous studies on resident killer whales have found that foraging is reduced when vessels are present (Lusseau et al. 2009; Williams et al. 2006).

Further, results from the combined data for 2007-2008 indicate that southern resident killer whales tend to be in contact (whales touching) significantly more often in low boat density than in high boat density. Research on the effects of dolphin watching vessels in Bay of Islands, New Zealand has shown that bottlenose (*Tursiops truncates*) dolphin resting behavior decreases as vessels increase (Constantine, et al. 2004). If SRKW are more likely to be in contact cohesion in low vessel density situations, it is possible that high numbers of vessels lessen the probability that whales will engage in the biologically significant behavior of resting.

Lastly, an examination of the effect size of boat density on the likelihood that the whales would remain in a given cohesion state in low versus high density situations found that the whales were significantly less likely to remain in tight cohesion (<10 m) when in low vessel density situations and were significantly more likely to remain spread out (>100 m) in low vessel density situations. These findings suggest that whales may be more likely to initiate and/or continue foraging (e.g., in spread cohesion state) when the number of vessels is low.

To investigate changes in group cohesion in response to vessels, I collected whale and vessel geo-referenced data points and behavioral attributes throughout the southern resident killer whale's critical habitat. Results from this study are similar to findings from two land-based studies which suggest that foraging behavior of fish eating southern resident killer whales may be the most impacted behavior from high numbers of vessels (Lusseau 2009, Williams et al. 2006). Future studies would benefit from using the equipment and methods described in this paper to collect geo-referenced locations and behavior attribute data on cetaceans throughout their ranges.

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Table 3-1. Definitions of whale attribute data observed in 2007-2008 based on Southern Resident Killer Whale Coding Workshop, Seattle WA (2004). Whale Attribute Data recorded every 5 min during sampling.

Behavior / Activity State	
Travel	any orientation, any cohesion, slow to porpoising speed, directional, often synchronous
Forage*	any orientation, any cohesion, slow to fast speed, directional or non-directional
Socialize/Play	any orientation, any cohesion, any speed. Social play (touching, percussives), solitary play with objects (kelp, floats, prey)
Rest**	flank or non-linear orientation, contact or tight cohesion, stationary to medium speed,* directional
Milling***	non-linear orientation, any cohesion, any speed, non-directional
	** Foraging behavior was coded with sub-activities whenever possible. For example, forage-search might be coded when the whales were seen to be both foraging and traveling and forage-prey would be coded when the whales were seen eating prey. However, all foraging activity states were counted together for statistical analysis*
	*** Resting whales traveling at medium speed were likely being carried by water currents*
	**** Milling was often coded as an intermittent sub-activity during any of the primary behavior states or as a speed*
Spatial Arrangement / Cohesion	
Contact: physical contact	
Tight: (<10 meters)	
Loose: (10-100 meters)	
Spread: (>100 meters)	
Orientation	
Flank: side-to-side	
Linear: head-to-tail	
Non-linear: no orientation detected	
Speed	
Stationary: 0 knots, logging, hanging	
Slow: < 2 knots, jerky, less smooth surfacing	
Medium: 2-6 knots, slow roll	
Fast: 6-10 knots, fast roll	
Porpoising: >10 knots, part of body out of water	
Directionality	
Directional: < 90° change in direction from previous surfacing	
Non-directional: > 90° change in direction from previous surfacing	

Table 3-2. Definitions of vessel attribute data observed in 2007-2008. Vessel attribute data recorded every 5 min during sampling.

Vessel Class*	
	Private
	Commercial
	Research
	Enforcement
	Monitoring
	Kayak
	Ferry
	Shipping
Vessel Activity	
	Whale Watching
	Fishing
	Non-Whale Oriented
	Transiting: vessels were coded as transiting when moving from one group of whales to another, usually > 400 yards from any whale
Vessel Type	
	Inflatable
	Sailboat (any size)
	Small Hard Bottom
	Medium Hard Bottom
	Large Hard Bottom
Vessel Speed**	
	Stationary
	Slow 0-2 knots
	Medium 3-4 knots
	Fast 5-6 knots
	Very Fast 7+ knots
Vessel Placement	
	Inshore of Whales: vessel between focal whale and shoreline
	In Path: vessel in the path of approaching focal whale
	Offshore of Whales: vessel on the offshore side of focal whale
Vessel Position	
	Parallel to Whales: vessel oriented with port or starboard closest to focal whale
	Bow In-Perpendicular to Whales: vessel bow pointing toward focal whale
	Bow Out-Perpendicular to Whales: vessel motor(s) pointing toward focal whale
Vessel Location Relative to Focal Whale Swim Direction	
	Front of Whales: vessel in front of approaching whales
	Side of Whales: vessel is to the side or abreast of focal whale
	Behind Whales: vessel is behind whale in relation to whale swim direction
	On Top of Whales: vessel within one body length of surfaced focal whale

* All vessels were identified by name or unique feature in order to identify repeated measures during analysis

** Vessel speed most often based on research vessel speed. Occasionally, vessel speed was estimated based on water displacement at the bow and/or spray from a motor

Table 3-3. Summary of all killer whale attribute data collected in 2007-2008 combined.

Whale Attribute Data	TRAVEL N=2652 56%	FORAGE N=833 17%	SOCIAL N=447 9%	REST N=332 7%	UNCODED N=539 11%	TOTAL N=4803 100%
Spatial Arrangement (Cohesion)						
Contact	3.5%	1.6%	36.0%	19.0%	2.2%	343
Tight 0-10m	53.7%	27.7%	55.3%	78.0%	59.0%	2480
Loose 10-100m	21.5%	28.5%	7.4%	1.2%	13.4%	917
Spread >100m	21.2%	42.1%	1.3%	1.8%	16.5%	1014
Uncoded (2007)	0	0.1%	0.0%	0.0%	8.9%	49
Orientation						
Flank	64.6%	33.6%	40.3%	88.6%	69.6%	2841
Linear	15.0%	2.5%	7.2%	1.5%	5.2%	485
Non-linear	20.4%	63.5%	52.6%	9.9%	15.2%	1420
Uncoded (2007)	0.0%	0.4%	0.0%	0.0%	10.0%	57
Speed						
Stationary	0.0%	0.0%	2.0%	9.9%	0.9%	47
Milling	0.0%	28.9%	28.9%	5.1%	8.7%	434
Slow	29.1%	42.7%	50.1%	77.1%	45.8%	1854
Medium	52.5%	21.7%	17.9%	7.8%	33.2%	1858
Fast	16.2%	6.6%	1.1%	0.0%	1.7%	499
Porpoising	2.2%	0.0%	0.0%	0.0%	0.0%	59
Uncoded (2007)	0.0%	0.0%	0.0%	0.0%	9.6%	52
Directionality						
Directional	92.3%	38.9%	64.7%	97.0%	64.7%	3733
Non-Directional	1.3%	58.8%	33.8%	2.4%	8.3%	728
Uncoded (2007)	6.4%	2.3%	1.6%	0.6%	26.9%	342

Table 3-4. Summary of all vessels sampled 2007-2008.

Size/type	Commercial Whale Watch	Private	Research	Monitoring	Enforcement	Kayaks	Ferry	Shipping	Totals
Inflatable	1676	56	85	411	0	0	0	0	2228
Small Hard-Bottom	884	1688	2134	0	18	55	0	0	4779
Medium Hard-Bottom	1834	945	60	0	32	0	0	0	2871
Large Hard-Bottom	1236	515	0	0	0	0	21	22	1794
Uncoded	13	25	0	0	0	0	0	0	38
Totals	5643	3229	2279	411	50	55	21	22	11,710

Data on the same vessel may have been recorded more than once if it remained in the vicinity of the focal whale group for more than one 5-minute data sampling interval during any given focal follow.

Table 3-5. Summary of all vessel distances to whales recorded in 2007-2008 combined.

Distance from boats to whales in yards	Commercial Whale Watch	Private	Research	Monitoring	Enforcement	Kayaks	Ferry	Shipping	Totals
0-99.99	92	66	71	1	0	8	0	0	238
100-199.99	418	233	1038	8	0	11	2	1	1711
200-399.99	1432	835	763	86	14	23	5	1	3159
400-799.99	2327	1389	328	212	22	13	4	2	4297
800-999.99	731	395	49	61	10	0	2	4	1252
> 1000	643	311	30	43	4	0	8	14	1053
Totals	5643	3229	2279	411	50	55	21	22	11,710

Data on the same vessel may have been recorded more than once if it remained in the vicinity of the focal whale group for more than one 5-minute data sampling interval during any given focal follow.

Table 3-6. Three-way contingency table for cohesion states for 2007 and 2008 data.

First Cohesion State	Low Vessel Density Succeeding Behavior State				High Vessel Density Succeeding Behavior State			
	Contact	Tight	Loose	Spread	Contact	Tight	Loose	Spread
Contact	23	24	5	0	15	21	1	0
Tight <10 m	26	282	48	14	19	389	50	21
Loose 10-100 m	1	41	95	26	3	43	88	31
Spread > 100 m	3	15	23	151	0	16	24	118

Table 3-7. Model selection for testing the independence of transitions in killer whale cohesion state on vessel density for 2007-2008 data.

Model	G^2	df	p-value	AIC
A: main effects, current X succeeding, current X boat density	14.65	12	0.2612	26.65
B: main effects, current X succeeding, succeeding X boat density	16.45	12	0.1713	28.45
C: main effects, current X succeeding, current X boat density, succeeding X boat density	9.38	9	0.4028	23.88

FIGURE CAPTIONS

Figure 3-1. Regional map of Northwest Washington State and Southeast British Columbia, Canada with study area outlined. Map used with permission from The SeaDoc Society.

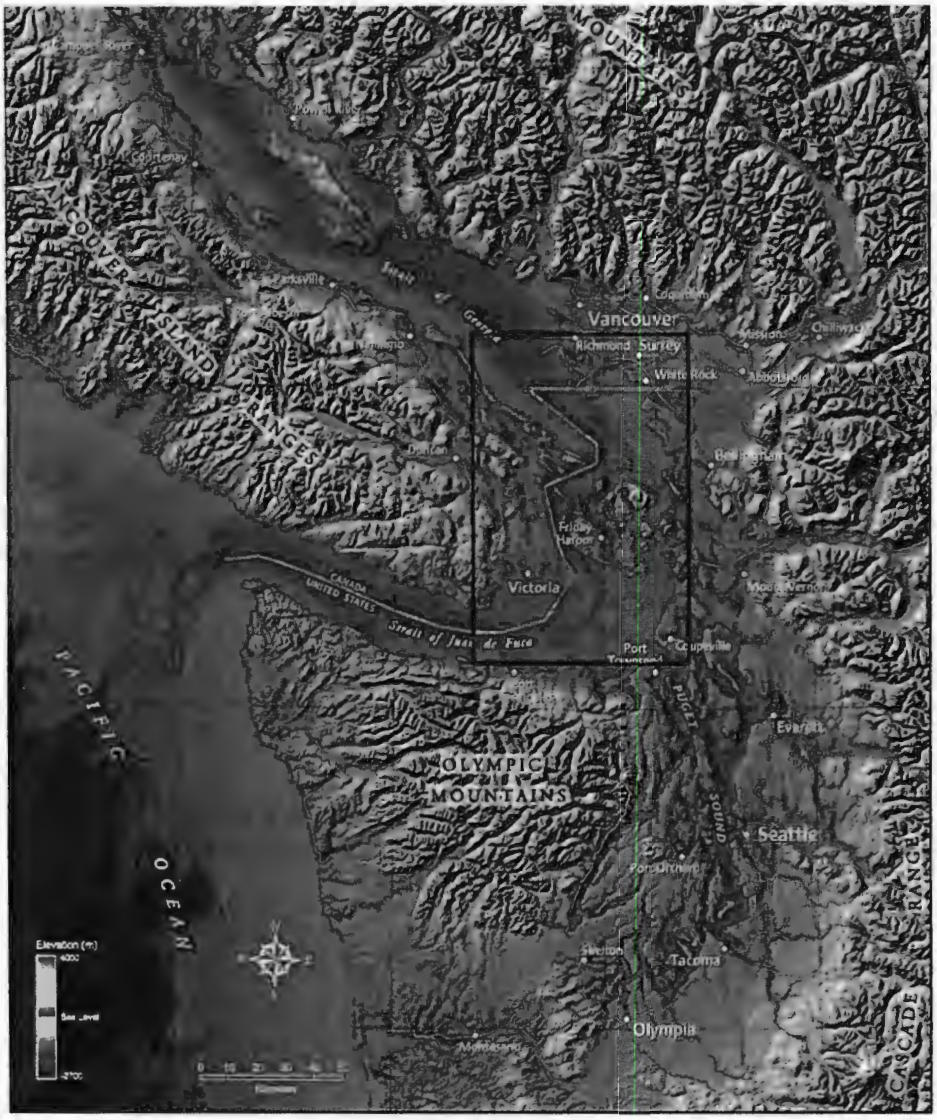
Figure 3-2. Proportion of southern resident killer whale behavior states recorded in 5 min intervals during 15-60 min focal follow tracks in 2007-2008.

Figure 3-3. Proportion of vessel classes from which attribute data were collected in 2007-2008, with ferry and shipping vessel types combined.

Figure 3-4. Proportion of all observations of commercial whale watching and private vessels between 0-999.99 yards, in 2007 and 2008 combined. Due to the disparity in sample sizes for the two vessel types, percentage of total boats represented in each distance bin for each vessel type (commercial or private) are also presented.

Figure 3-5. Cohesion state as a function of vessel density within 1000 yards of whales in 2007 and 2008. The proportion of time focal killer whale spent in each cohesion state in low and high vessel density in 2007 and 2008 (data combined).

Figure 3-6. Difference in likelihood that whales will remain in a given cohesion state as a function of vessel density within 1000 yards for 2007 and 2008 data combined.



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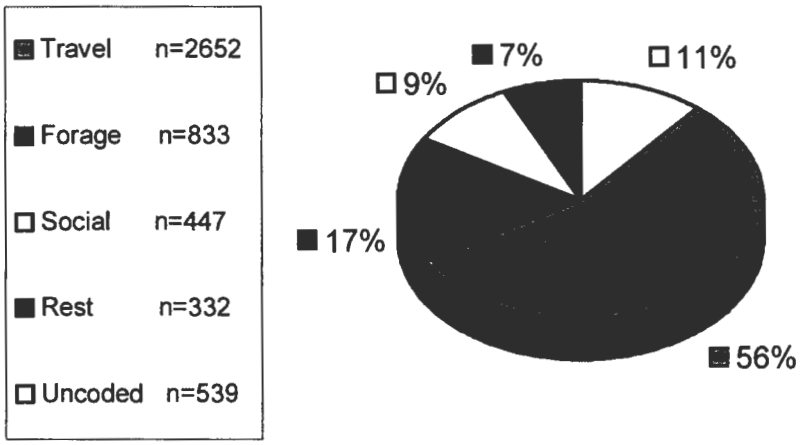

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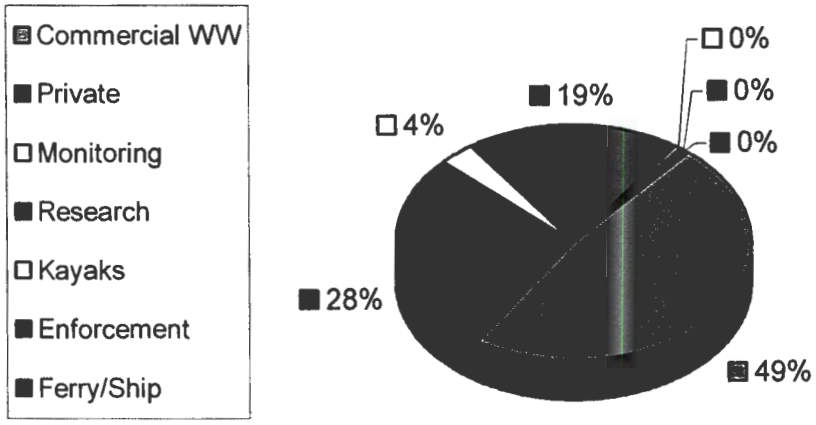

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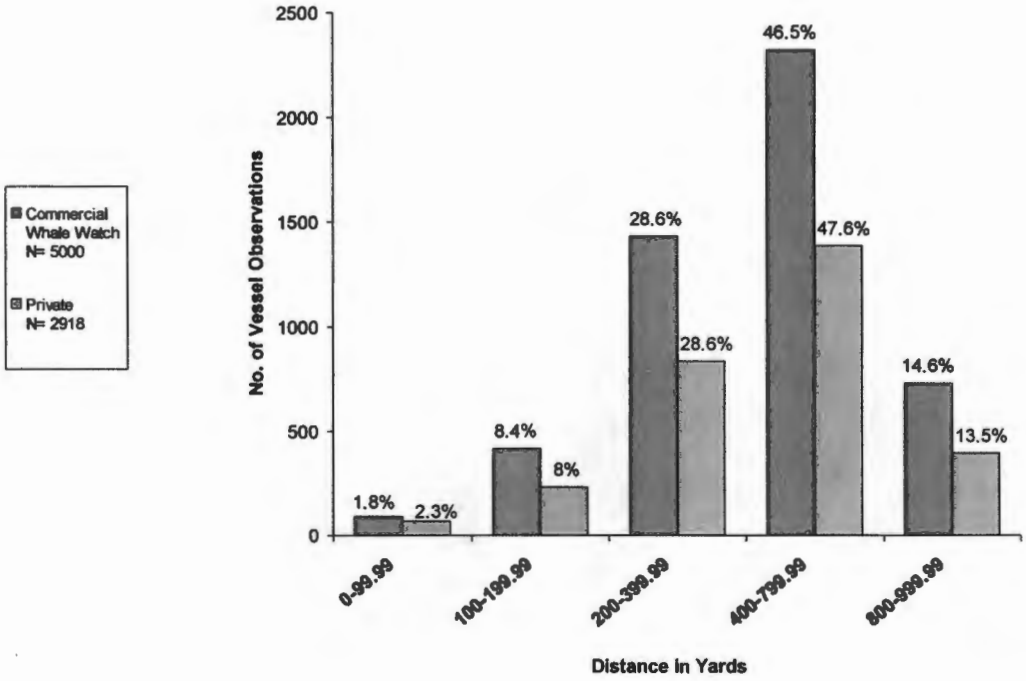

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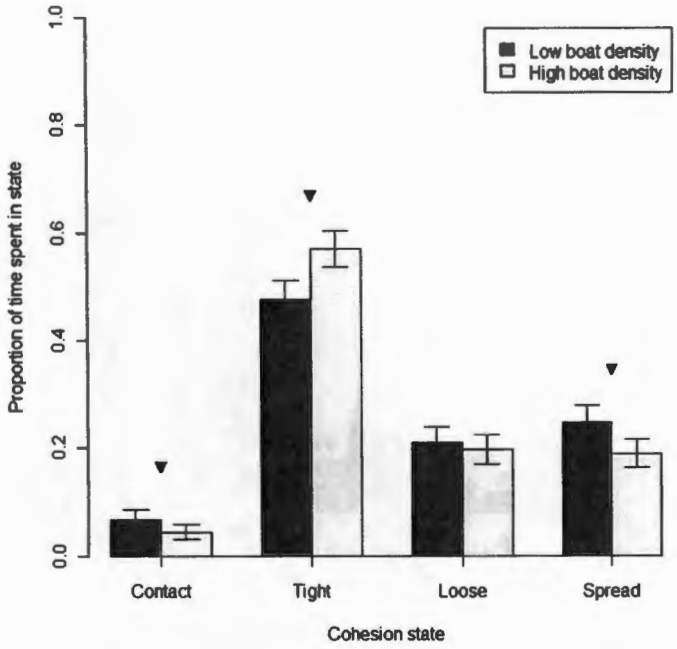

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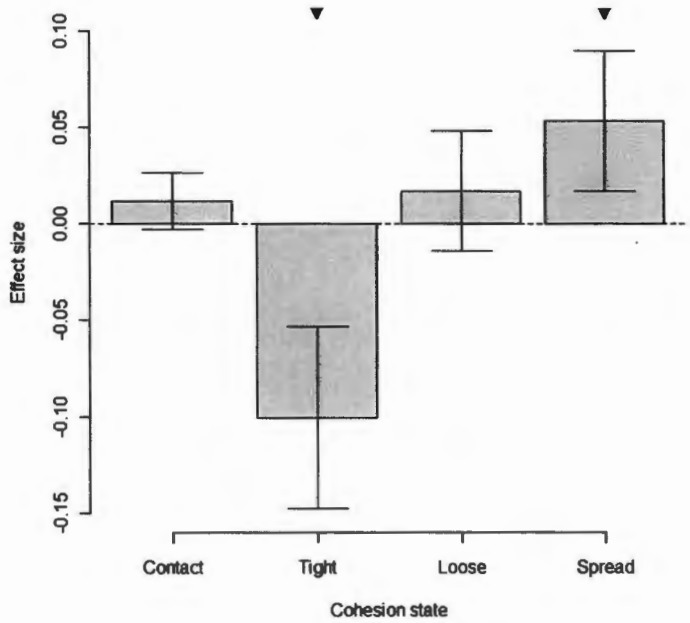

Figure 3-6. Difference in likelihood that whales will remain in a given cohesion state as a function of vessel density within 1000 yards for 2007 and 2008 data combined. Error bars indicate 95% confidence intervals and triangles indicate significant differences at the 95% level.

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Close approaches by vessels elicit surface active behaviors by southern resident killer whales

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ABSTRACT: Vessel disturbance is one potential risk factor to the endangered population of southern resident killer whales *Orcinus orca*. This study was conducted to determine if southern resident killer whales perform surface active behaviors (SABs) in response to close approaches by vessels. Data were collected in the San Juan Islands, USA, and Gulf Islands, Canada, from May through September 2005 and 2006. Continuous behavioral data, including the performance of SABs (e.g. spy hops, breaches, tail slaps, pectoral fin slaps), were recorded from southern resident killer whales using a focal follow approach. Distances between the focal whale and nearby vessels were systematically measured throughout each focal follow. In addition, the distance between the nearest vessel and the focal whale was recorded each time the whale performed an SAB. Tail slaps were the most frequently performed SAB. The highest frequency of SABs occurred when the nearest vessel was within 75 to 99 m and 125 to 149 m of the focal whale in 2005 and 2006, respectively. Approximately 70% of SABs occurred when the closest vessel was within 224 m of the whale. Furthermore, a significantly greater proportion of SABs occurred when vessels closely approached whales. Finally, there was a significant temporal relationship between close approaches and the occurrence of SABs; most SABs were performed near the time of the closest approach by a vessel. These results suggest that close approaches by vessels elicit behavioral responses in southern resident killer whales and that the minimum approach distance of 100 m in whale-watching guidelines may be insufficient in preventing behavioral responses from whales.

KEY WORDS: Behavior · Boat · Cetacean · Disturbance · Guidelines · Killer whale · *Orcinus orca*

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INTRODUCTION

Whale-watching has become increasingly popular over the last 2 decades. Since many targeted species are classified as endangered or threatened, the whale-watching industry is also a potential medium for addressing conservation issues through experiential educational opportunities (Orams 2000, Luck 2003, Corkeron 2004). However, while there are many benefits associated with whale-watching, increased boat traffic and noise levels may affect marine mammals by increasing physiological indicators of stress (Romano et al. 2004), increasing daily energetic costs (Williams et al. 2006) and/or inhibiting important behaviors necessary for survival (Williams et al. 2006, Hodgson & Marsh 2007, Lusseau et al. 2009).

Southern resident killer whales *Orcinus orca* are piscivorous whales that spend the majority of the summer months (May to September) in the US San Juan Islands and neighboring Canadian Gulf islands (Bigg 1982, Krahn et al. 2002). The whales' predictable presence makes the islands an ideal location for commercial whale-watching enterprises and private recreational whale-watching. Vessel-based whale-watching in the San Juan Islands has increased significantly since the late 1980s for both private and commercial boats (Duffus & Baird 1995). For example, the number of vessels in the commercial whale-watch fleet in-

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creased from approximately 10 in 1985 to nearly 80 in 1997 (Koski 2004). In recent years (2000 to 2006), the number of vessels in the fleet has remained fairly stable at approximately 75 (Koski 2007). Moreover, from 1998 to 2006, southern resident killer whales consistently had an average of nearly 20 vessels (private, commercial, kayak, research, etc.) within a half-mile of their location between 09:00 and 18:00 h from May through September (Koski 2007). For this same time frame, maximum boat counts within a half-mile of the whales ranged from 69 to 120 vessels (Koski 2007).

Increased vessel activity near southern resident killer whales is a concern because this distinct population segment (DPS) experienced a 20% population decline from 1996 to 2001 (Krahn et al. 2002). The precipitous decline from 97 to 78 individuals in this small DPS resulted in a 'depleted' listing under the US Marine Mammal Protection Act (MMPA) and 'endangered' listings under the US Endangered Species Act (ESA) and the Canadian Species at Risk Act (SARA). Because a large number of vessels are often in the immediate vicinity of these whales during the summer months, vessel disturbance was identified as one of the potential risk factors associated with their decline (Krahn et al. 2002). Other risk factors include reduced prey availability and quality as well as high levels of persistent contaminants (Krahn et al. 2002).

It is evident that southern resident killer whales are exposed to multiple vessels daily during their residence in the San Juan Island region. This is a concern because vessel presence may elicit long- and short-term behavioral changes in delphinids. These include: decreased use of primary habitats (Allen & Read 2000, Lusseau 2005), altered spatial distribution among individuals (Au & Perryman 1982, Bejder et al. 1999, 2006, Nowacek et al. 2001, Jelinski et al. 2002), altered behavioral budgets (Chilvers et al. 2003, Coscarella et al. 2003, Lusseau 2003a, 2004, Constantine et al. 2004, King & Heinen 2004, Lemon et al. 2006, Williams et al. 2006, Hodgson & Marsh 2007, Lusseau et al. 2009), changed swimming speed or direction (Au & Perryman 1982, Kruse 1991, Au & Green 2000, Nowacek et al. 2001, Williams et al. 2002a,b, Jahoda et al. 2003, Lusseau 2003b, Ng & Leung 2003, Bejder et al. 2006, Lemon et al. 2006, Williams & Ashe 2007) and altered surface and dive durations (Janik & Thompson 1996, Au & Green 2000, Jahoda et al. 2003, Lusseau 2003a, b, Ng & Leung 2003). Surface active behaviors (SABs), such as tail slaps, pectoral fin slaps, leaps and jumps, may also be displayed in response to approaching vessels (Weinrich et al. 2001, Williams et al. 2002a, Coscarella et al. 2003, Danil et al. 2005, Lusseau 2006a).

Though previous studies on southern resident killer whales have shown that vessel presence can have acoustic (Erbe 2002, Foote et al. 2004, Holt et al. 2009) and behavioral impacts (Lusseau et al. 2009, Williams et al. 2009), it is also important to determine whether these whales perform SABs in response to approaching vessels. This is because the performance of these behaviors can be energetically costly (Yazdi et al. 1999), and energetic impacts are of particular concern for these killer whales, which may be food limited (Ford et al. 2005).

The present study aimed to determine whether endangered southern resident killer whales display SABs when closely approached by vessels. Specifically, whale and vessel behaviors were recorded to assess the relationships between vessel distance and mode of operation and the performance of SABs by southern resident killer whales.

MATERIALS AND METHODS

Study area. Research was conducted in nearshore waters off the San Juan Islands, USA, and off the east coast of Vancouver Island and the southern Gulf Islands, Canada (approximate range of study area: 48° 15′ N to 49° N, 122° 35′ W to 123° 30′ W), from early June through mid-September 2005 and mid-May through early August 2006. Data were collected only in Beaufort sea states ≤3, between 07:00 and 18:00 h and while visibility conditions were adequate for locating and following killer whales. Southern resident killer whales were located each day by searching areas they frequent and by monitoring the VHF radio channel and pager system used by commercial whale-watchers.

Behavioral data. Behavioral data from individually identified southern resident killer whales were collected continuously using a focal follow approach. Data were collected from a research vessel (7.9 m aluminum boat with a 225 hp 4-stroke outboard motor) that was operated according to strict adherence to voluntary guidelines for watching southern resident killer whales (http://www.bewhalewise.org/bewhalewise.pdf). Specifically, the research vessel slowly approached each focal killer whale from behind and parallel to the whale's swimming path. Data were collected while the vessel traveled at a slow speed in parallel with the focal whale at a distance ≥100 m. These procedures are identical to those followed by commercial whale-watch operators in the region, although the research vessel usually paralleled whales at distances that were well beyond 100 m. The average (±SE) operating distance between the research vessel and focal whale was 199.8 ± 6.0 m in 2005 and 224.5 ± 4.4 m in 2006. These operating distances were somewhat dictated by the behavior of other boats in the area, and the increase in operating distance between

the 2 years was due to a difference in the mode of whale-watch vessel operation between the 2 years. Specifically, there was an increased presence of enforcement officials on the water, and the guidelines also changed in 2006. Dissimilar to guidelines in 2005, those in 2006 stated that vessel operators were to move their vessels away from oncoming whales in order to minimize the likelihood that vessels would ever be within 100 m of whales, even if the whales approached the vessels. It is important to note, though, that in practice, the research vessel followed the 2006 guidelines during both years in order to perpetually maintain a distance of >100 m from focal whales during data collection.

Data from a single southern resident killer whale, readily identified by unique markings on its dorsal fin and the grey saddle patch at the base of the dorsal fin (van Ginneken et al. 2005, Ellifrit et al. 2006), were recorded during each focal follow. A previous study on the effects of vessel presence on southern resident killer whales (Williams et al. 2009) found that the performance of SAB bouts was not influenced by sex or age but that younger animals tended to perform more individual SABs within bouts. Thus, for the present study, focal follows were only conducted on older animals to minimize the variability in responses due to age. With the exception of one focal follow of a 10 yr old male in 2005, data were only collected from adult females and adolescent and adult males. Otherwise, focal animals were selected in the field at random, with an overall goal to collect data from several different individuals from all 3 pods. However, accessibility to whales did depend on the locations of other whales, boats and land.

The time of occurrence for every SAB (defined in Table 1) performed by the focal whale was recorded on a handheld PDA (Palm IIIxe, Palm) using Event 3.0 Software (program designed by J. Ha, Department of Psychology, University of Washington). Occurrences of every dive initiation, dive termination and respiration, as well as swimming speed were concurrently recorded on the same handheld PDA (these results will be presented elsewhere). Data (number of whales, pod identification, activity state, directionality, configuration and spatial arrangement) from the group of killer whales that the focal animal associated with were also collected every 10 min via instantaneous scan sampling from a second handheld PDA during focal fol-

Table 1. *Orcinus orca*. Definition of surface active behaviors performed by southern resident killer whales

Surface active behavior	Description
Breach	The body of the whale clears the water completely and then lands on the lateral or ventral side, generating a large splash.
Cartwheel	The whale performs an exaggerated tail slap by hurling the posterior portion of the body, from the dorsal fin to the tail, out of the water and over its head. The entire posterior end of the whale (dorsal, lateral or ventral side up) lands, generating a large splash.
Dorsal slap	The whale slaps the water with its dorsal fin by rolling onto its side with force, generating a splash.
Half breach	One half to two-thirds of the anterior portion of the whale clears the water and then lands on the lateral or ventral side, generating a large splash.
Pectoral fin slap	The whale slaps one or both pectoral fins (ventral or lateral side up), generating a splash.
Spyhop	The whale rises vertically out of the water so that both eyes are exposed. The pectoral fins can either be in or out of the water.
Tail slap	The whale slaps its tail (dorsal or ventral side up) on the surface of the water, generating a splash.

Table 2. *Orcinus orca*. Definition of activity states observed in southern resident killer whales based on Ford (1989)

Activity state	Description
Forage	Searching and/or locating food indicated by arch dives, non-directional swimming and lunges at the surface. Often includes long duration dives.
Rest	Swimming at speeds of less than 2 knots or completely stationary with respiratory synchrony and tight spatial associations among whales.
Social	Interacting with other members of the pod, members of other pods or with inanimate objects. Can include sexual and surface active behaviors.
Travel	Directional movement at a steady pace, often with coordination of the entire group.

lows. The data on activity state (Table 2, based on Ford 1989) were used to determine if SABs occurred preferentially during particular states. Focal follows were terminated whenever a surfacing event was missed by the observer, other vessels obstructed observations or after approximately 40 min of continuous data collection.

To minimize pseudoreplication and further eliminate the bias of age on the rate of SABs (Williams et al. 2009), SAB bouts, rather than every individual SAB, were included in the analysis. We defined an SAB bout as a series of one or more SABs performed sequentially with ≤1 min lapsing between the execution of each successive behavior. We deemed this to be a robust approach because 67% of SABs were performed within ≤1 min of the preceding SAB when multiple SABs were performed during a focal follow. For the remaining 33% of these cases, individual SABs were separated in time by 65 sec to 25 min, with over 50% of these separated by ≥5 min.

Vessel data. Distances between the research vessel and the focal whale and between the research vessel and the 2 vessels closest to the focal whale (identified as commercial, private, kayak, research or unknown) were measured using a laser range finder (Yardage Pro 1000, Bushnell) at least every 10 min in 2005 and every 5 min in 2006. Schematic drawings, indicating positions, distances, and estimated angles (in 5° increments), were also made for each set of measurements. Additionally, in 2006 these measurements and drawings were made and the behavior (idling stationary, shut-down stationary or moving under motor) of the vessels were recorded every time the focal whale performed an SAB. Although distances were not always recorded when focal whales performed SABs in 2005, a sufficient sample of distances measured during SABs existed in the data set to warrant inclusion in the analysis.

The schematic drawings were used to determine the distance of the closest vessel to the focal whale for each set of measurements taken. The distance between the focal whale and the closest vessel was calculated using simple subtraction and addition when the placement of the focal whale and the vessels was linear, and trigonometrically when the vessels and the whale were in a triangular configuration. Similar calculation methods were used by Suryan & Harvey (1999).

Distances for the point of closest approach (POCA) by a vessel during each focal follow and for the nearest vessel during each SAB bout were included in the analysis. The POCA for each focal follow was defined as the shortest distance between any vessel and the focal whale recorded during the entire focal follow. The distance of the nearest vessel during an SAB bout was defined as the distance between the focal whale and the closest vessel when the first SAB within the bout occurred. Distances between the research vessel and focal killer whales were included in all analyses because the research vessel followed killer whales in a manner similar to private and commercial whale-watch boats and was thus considered to be part of the collective whale-watching fleet.

Finally, because the commercial and private boats found in the study area were so numerous and diverse, it was not possible to assess whether specific vessel or motor types were more likely to elicit behavioral responses from killer whales. For example, there were 74 and 76 active commercial whale-watch vessels from 39 and 41 companies in 2005 (Koski 2006) and 2006 (Koski 2007), respectively.

Data analysis. The small size of the southern resident killer whale DPS precluded the selection of only one focal follow per individual for the analysis. However, we presumed each focal follow was an independent sample because data were collected from individuals at different time periods during the day, on different days spanning several months over 2 yr and across a wide range of vessel traffic conditions. Data from males and females were pooled because Williams et al. (2009) found no sex-specific differences in the performance or rate of SABs in southern resident killer whales.

Because of the previously described differences in data collection and whale-watch vessel operation between the 2 years, Kolmogorov-Smirnov 2-sample tests were first used to compare the distributions of data (POCA distances, nearest vessel during SAB distances, temporal differences between the POCA and SABs, etc.) collected in 2005 and 2006. Data were only combined if the distributions did not differ significantly.

The Shapiro-Wilks test was used to determine whether distance data were normally distributed. Because the data were not normally distributed, Mann-Whitney rank sum tests and Kruskal-Wallis 1-way ANOVAs on ranks were used to determine significant differences between POCA distances. Kolmogorov-Smirnov tests were also used to compare distributions of data to defined distributions. Parameters in some distributions were estimated using the maximum likelihood method. Chi-squared tests were used to compare the proportion of SAB bouts performed when POCA distances were 'close' and 'far'. Fisher's exact tests were used to compare the number of SABs performed in a bout relative to vessel operation mode. All means are presented ±1 SE. Results were significant at $p < 0.05$. All graphical and statistical analyses were conducted using SigmaPlot 11.0, SYSTAT 12.0 and SigmaStat 3.5 Software (SYSTAT Software).

RESULTS

Killer whale behavior

Data were collected from southern resident killer whales during 39 and 37 d on the water in 2005 and 2006, respectively. This effort resulted in a total of 174 focal follows of 36 individual killer whales (72% of all adults in the population) in 2005 and 193 focal follows of 30 individual killer whales (56% of all adults in the population) in 2006 (Table 3). On average, 5 focal follows of individual southern resident killer whales were conducted per day (2005: 4.5 ± 0.4 focal follows d^{-1}; 2006: 5.2 ± 0.4 focal follows d^{-1}). Data were collected continuously during focal follows for an average duration of 17.2 ± 0.9 min in 2005 and 20.1 ± 0.8 min in 2006, totaling 49.9 and 64.8 h of data collected, respectively.

Table 3. *Orcinus orca*. Summary of focal follows conducted on southern resident killer whales that did (with) and did not (without) include the performance of surface active behaviors (SABs). Individual whales are identified by a letter and a number. The letter (J, K, or L) designates the pod of which the individual is a member

ID	Birth year	2005 focal follows			2006 focal follows		
		With SABs	Without SABs	Total	With SABs	Without SABs	Total
Females							
J002	1911	2	7	9	5	11	16
J008	1933	2	0	2	2	2	4
J011	1972	0	4	4	2	1	3
J014	1974	1	0	1	0	2	2
J016	1972	0	2	2	0	1	1
J017	1977	0	3	3	3	2	5
J019	1979	0	1	1	1	3	4
J022	1985	1	3	4	0	0	0
J028	1993	0	2	2	0	4	4
K007	1910	1	4	5	2	13	15
K011	1933	0	5	5	1	6	7
K012	1972	0	3	3	1	0	1
K013	1972	0	1	1	0	0	0
K014	1977	0	0	0	0	2	2
K016	1985	0	1	1	0	0	0
K020	1986	1	1	2	0	4	4
K022	1987	1	4	5	0	2	2
K040	1963	1	6	7	2	5	7
L002	1960	0	1	1	0	0	0
L007	1961	1	0	1	0	0	0
L012	1933	1	0	1	0	3	3
L022	1971	2	3	5	0	0	0
L025	1928	1	3	4	2	0	2
L026	1956	0	0	0	0	1	1
L043	1972	0	1	1	0	0	0
L054	1977	0	1	1	0	0	0
L067	1985	0	2	2	0	0	0
L072	1986	0	0	0	0	1	1
L077	1987	1	3	4	0	0	0
Males							
J001	1951	5	24	29	9	22	31
J026	1991	1	2	3	2	13	15
J027	1991	0	0	0	2	12	14
J030	1995	1	0	1	0	0	0
K021	1986	2	14	16	3	12	15
K026	1993	0	0	0	2	9	11
L041	1977	4	9	13	0	8	8
L057	1977	0	7	7	0	6	6
L071	1986	0	2	2	0	0	0
L073	1986	0	0	0	0	2	2
L074	1986	0	2	2	0	0	0
L078	1989	1	6	7	0	0	0
L079	1989	0	17	17	2	2	4
L085	1991	0	0	0	0	2	2
L087	1992	0	0	0	0	1	1

SABs were performed by both male and female killer whales and occurred during 17.2 and 21.2% of focal follows in 2005 and 2006, respectively (Table 3). For both years combined, SABs were performed during 15.4% of focal follows conducted on males and 20.0% of those conducted on females (Table 3). When SABs did occur, a variety of 7 distinct behavior types (see Table 1) were performed in bouts lasting 1 to 78 sec in duration and consisting of 1 to 9 behaviors executed within 1 to 60 sec of the preceding behavior. Tail slaps were the most frequently performed behavior, representing 66% of the total number of SABs observed in both 2005 and 2006 (Table 4).

Focal killer whales performed SABs during all activity states (rest, forage, travel and social) in 2005 and during travel and forage in 2006. Because the activity state data were primarily collected for another study in 2005 (Marsh 2008), these data did not always temporally match the data collected for the present study. Thus, additional analyses on relationships between the performance of SABs during specific activity states were not possible for data collected in 2005. The data collected in 2006 suggest that SABs were not preferentially performed during particular activity states. Specifically, 71% of all SAB bouts were performed during travel, which represented 70% of all activity state observations in 2006. Similarly, 29% of all SAB bouts were performed during forage, and this activity represented 21% of all activity state observations. Unlike in 2005, no SAB bouts were performed by focal whales during rest (7% of observations) and social (2% of observations) activity states in 2006; however, SABs were performed by other non-focal individuals during these activity states. Lack of observations of focal whales performing SABs during rest and social activity states is likely an artifact of the rare occurrence of these activity states, rather than an indication that killer whales do not perform SABs during these states. This supposition is particularly supported for the case of socializing whales, which often perform SABs (Ford 1989, see Table 2).

Distance between vessels and killer whales

The distribution of POCA distances differed significantly between the 2 years (Kolmogorov-Smirnov [K-S] test, $D = 0.190$, $p = 0.004$). In addition, POCA distances for all vessel types combined in 2005 (median = 92 m, mean = 111.1 ± 7.4 m) were significantly closer (Mann-Whitney, $T = 28\,695.5$, $p = 0.001$) than those in 2006 (median = 114 m, mean = 131.7 ± 6.5 m). However, data collection protocols were identical for both years. Thus, POCA distances for the research vessel alone did not differ significantly ($T = 13\,272$, $p = 0.072$) between 2005 (median = 117 m, mean = 146.1 ± 9.1 m) and 2006 (median = 131 m, mean = 156.9 ± 8.0 m) (Fig. 1). In contrast, for all other vessel types combined, excluding the research vessel, the increase in POCA

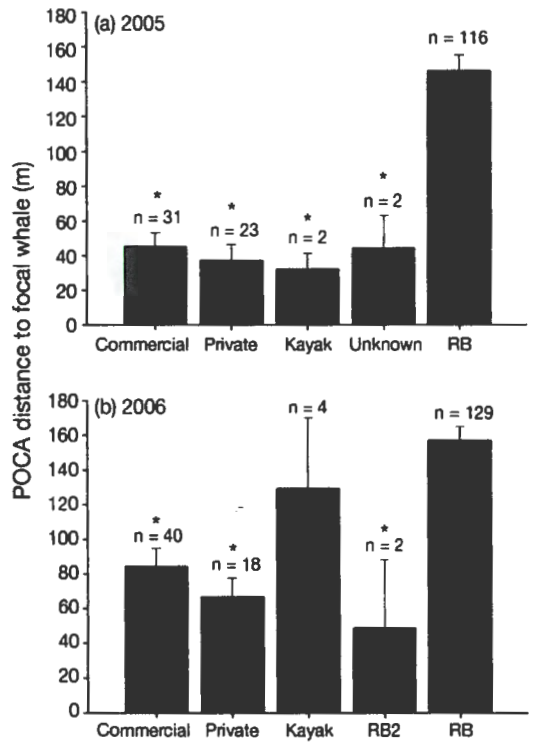

Fig. 1. Point of closest approach (POCA) distances to southern resident killler whales *Orcinus orca*, characterized by vessel type in (a) 2005 and (b) 2006. Mean POCA distances for commercial, private, kayak, unknown (2005 only), research boat (RB; present study) and other research boat (RB2; conducting non-related study, 2006 only) are presented with +1 SE bars. n: number of times each vessel type was the vessel with the POCA. *: the POCA distance was significantly less than that of the RB

Table 4. *Orcinus orca*. Percent occurrence of all surface active behaviors (see Table 1 for details) performed by focal southern resident killer whales

Year	Dorsal slap (%)	Pectoral fin slap (%)	Tail slap (%)	Cartwheel (%)	Breach (%)	Half breach (%)	Spyhop (%)
2005	0	12	66	3	13	0	6
2006	2	7	66	11	7	2	5

distances from 2005 (median = 25 m, mean = 41.2 ± 5.8 m) to 2006 (median = 85.5 m, mean = 90.0 ± 7.9 m) was highly significant (T = 2714.5, $p < 0.001$) (Fig. 1). Finally, of all POCAs by vessels other than the research vessel, 91 and 65% were ≤100 m from focal whales in 2005 and 2006, respectively. This result shows that commercial whale-watching and private boats were often within 0 to 100 m of whales, which contravenes the local voluntary guidelines for watching southern resident killer whales.

The POCA distances by vessel type were significantly distinct (Kruskal-Wallis 1-way ANOVA, 2005: H = 73.6, df = 4, $p < 0.001$; 2006: H = 49.2, df = 4, $p < 0.001$) (Fig. 1). Furthermore, POCA distances for the research boat were significantly farther away from focal whales than POCA distances for both commercial whale-watching and private boats in 2005 and 2006 (all $p < 0.001$) (Fig. 1). The POCA distances for commercial whale-watching and private boats were not discernibly different in either year ($p > 0.05$).

Relationship between killer whale SABs and close approaches by vessels

The distributions of POCA distances measured during focal follows with SABs differed from those measured during focal follows without SABs in 2005 and 2006 (K-S test, 2005: D = 0.800, $p < 0.001$; 2006: D = 0.707, $p < 0.001$) (Fig. 2). These distributions were best fit by Gumbel distributions. The modes for the estimated distributions of POCA distances measured during focal follows with SABs (2005: 61.6 m; 2006: 84.6 m) were closer than those meaured during focal follows without SABs (2005: 68.8 m, 2006: 93.9 m). POCA distances for focal follows with SABs also tended to be more narrowly distributed than those without SABs. Seventy-five percent of POCA distances for focal follows with SABs were ≤129 m in 2005 and ≤141 m in 2006 (Fig. 2). In contrast, 75% of POCA distances for focal follows without SABS were ≤139 m in 2005 and ≤163 m in 2006 (Fig. 2).

The performance of SABs by killer whales tended to be associated with close approaches by vessels (Fig. 3). Distributions of time differentials between the occurrence of the closest approach and the performance of SAB bouts during focal follows were not significantly different between the 2 years (K-S test, D = 0.183, p = 0.356), thus the data were combined for analysis. The distribution of time differentials differed significantly from a uniform distribution (D = 0.249, $p < 0.0001$); instead, a normal distribution best fit the data. For both years combined, the distribution did not significantly differ from normal with a mode of −0.5 min and an SD of 6 (D = 0.109, p = 0.185). This implies that the majority of SABs were performed 30 s after the point of closest approach by a vessel, and that the performance of SABs was more likely to occur near the time of the POCA during a focal follow (Fig. 3). For the 2 years combined, the highest frequency (21%) of SAB bouts occurred during and within 2 min following (time = 0 to −2) the POCA, and the second highest frequency (10%) of SAB bouts occurred within 2 min prior to the POCA. Furthermore, approximately half (46%) of the 100 total SAB bouts were observed within ±4 min of the POCA.

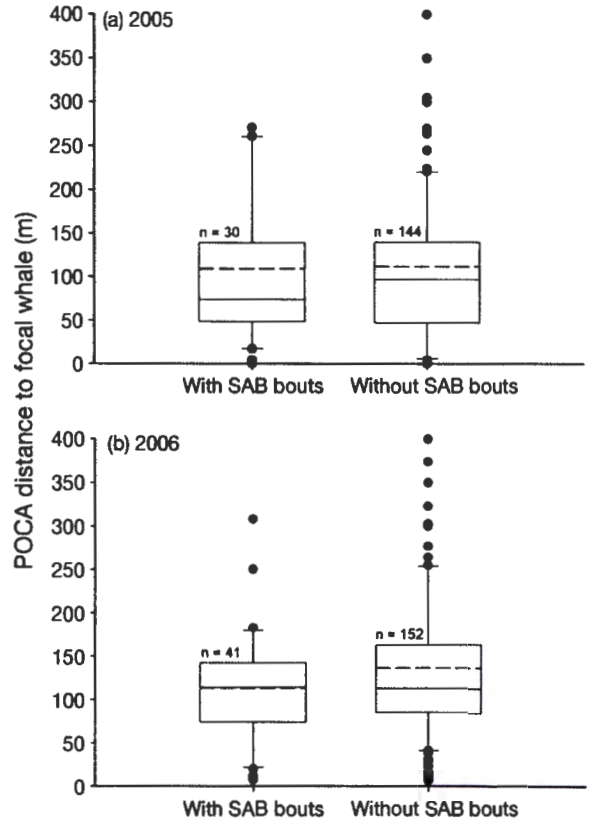

Fig. 2. *Orcinus orca*. Point of closest approach (POCA) distances during focal follows with and without surface active behavior (SAB) bouts for (a) 2005 and (b) 2006. Box plots are presented with the dashed and solid lines within the boxes representing the mean and median values, respectively. Box boundaries indicate the 25th and 75th percentiles, error bars indicate the 10th and 90th percentiles and all outlying data are designated by filled circles. Numbers indicate the sample size for each box plot

Relationship between killer whale SABs and vessel distance and behavior

The distributions of distances between the nearest vessel and the focal whale during SAB bouts were best

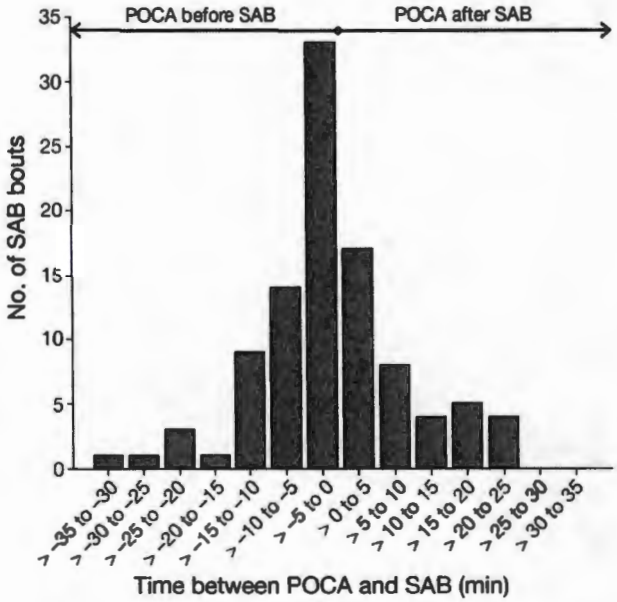

Fig. 3. *Orcinus orca*. Number of surface active behavior (SAB) bouts in relation to the time elapsed between the occurrence of the point of closest approach (POCA) and the SAB bout (2005 and 2006 data are combined). Time elapsed is presented in 5 min bins. Negative, zero and positive time values indicate POCAs that occurred prior to, simultaneous to and after SAB bouts, respectively

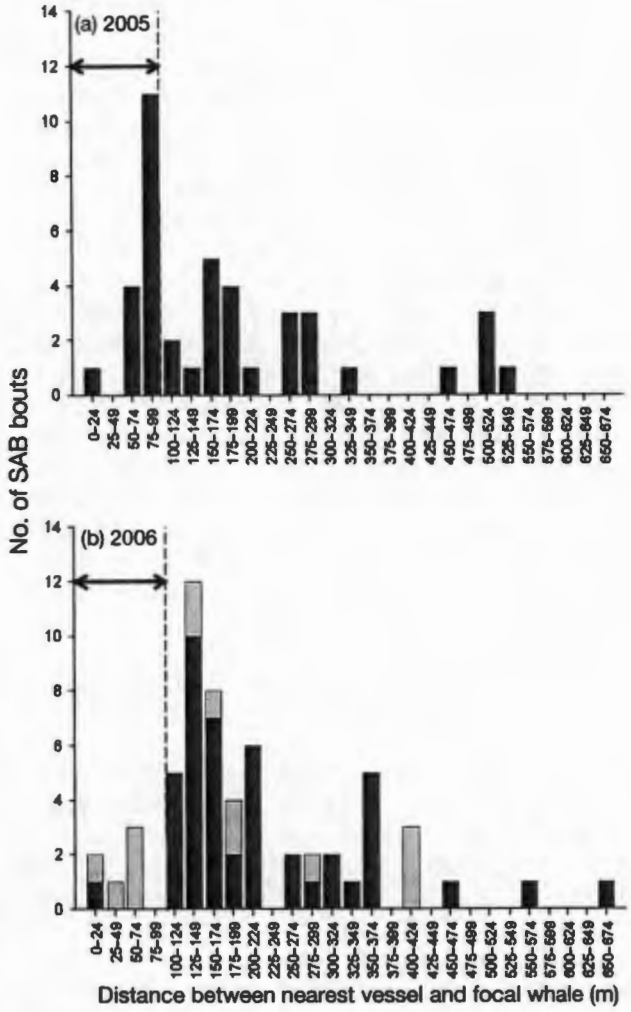

Fig. 4. *Orcinus orca*. Number of surface active behavior (SAB) bouts in relation to the distance between the focal whale and the nearest vessel during the SAB bout in (a) 2005 and (b) 2006. Distance data are presented in 25 m bins. In 2006, the SAB bouts are presented as stacked bars, with motoring vessels designated by black bars and stationary vessels (idling or shut-down) designated by grey bars. The 100 m 'no go' zone, in which boats are discouraged from approaching southern resident killer whales by guidelines (http://www.bewhalewise.org/bewhalewise.pdf), is shown by the dashed line and double-ended arrow for both years

fit by Gumbel distributions, but these distributions differed significantly between the 2 years (K-S test, D = 0.320, p = 0.011). Similar to data for the POCA, the mode for the estimated distribution of nearest vessel distances during SAB bouts in 2005 (128.0 m) was approximately 25 m closer than the estimated mode in 2006 (153.2 m).

The majority of SAB bouts were displayed while vessels were relatively close to the focal whale (Fig. 4). For both years, 70% of SAB bouts occurred when the nearest vessel was within 224 m of the focal whale. The highest number of SAB bouts occurred when the nearest vessel was between 75 and 99 m from the focal whale in 2005 (27%, 11 of 41 total SAB bouts) and between 125 and 149 m from the focal whale in 2006 (20%, 12 of 59 total SAB bouts) (Fig. 4a,b). Furthermore, in 2006, 70% of the SAB bouts that were performed at distances of ≤149 m from the nearest vessel occurred while the nearest vessel was motoring (Fig. 4b).

SAB bouts were more likely to occur during focal follows when whales were approached closely. For the purpose of this analysis, the break point between the 2 distance categories ('close' and 'far') for each year is the average POCA (2005: 111.1 ± 7.4 m, 2006: 131.7 ± 6.5 m) rounded to the nearest 50 m because 50 m distance increments are likely practical for management purposes. In 2005, a significantly higher proportion of SAB bouts occurred during focal follows with 'close' (0 to 99 m) compared to 'far' (≥100 m) POCAs (χ^2 = 5.3, p = 0.02) (Table 5). In 2006, a higher proportion of SAB bouts occurred during focal follows with 'close' (0 to 149 m) compared to 'far' (≥150 m) POCAs, though this difference was not significant at the level of p = 0.05 (χ^2 = 2.6, p = 0.10) (Table 5). However, the power of the test for the 2006 data was low because of the small sample size for 'far' POCAs. Consequently, the beta probability (probability of accepting a false null hypothesis, Zar 1996) was high (β = 0.65), and a sample size

Table 5. *Orcinus orca*. Number of focal follows with 'close' and 'far' point of closest approach (POCA) distances during which focal whales did and did not perform surface active behavior (SAB) bouts in 2005 and 2006. Distance bins represent 'close' (2005: 0–99 m, 2006: 0–149 m) and 'far' POCA distances (2005: ≥100 m, 2006: ≥150 m)

POCA distance (m)	No. of focal follows with SAB bouts	No. of focal follows without SAB bouts
2005		
0–99	30	74
≥100	11	70
2006		
0–149	48	105
≥150	11	47

of 436 focal follows (316 with POCAs ≤149 m and 120 with POCAs ≥150 m) is required to conclude that the difference is significant at the level of $p = 0.05$ and power = 0.80.

The number of behaviors within an SAB bout tended to differ with vessel behavior and distance to the whale. In 2006, most SAB bouts consisted of only 1 to 2 SABs, yet SAB bouts consisting of 3 to 8 behaviors were performed when the nearest vessel was motoring. In contrast, only 1 to 2 SABs were performed in bouts when the nearest vessel was stationary (Fig. 5a). However, the proportions of SAB bouts consisting of 1 to 2 and ≥3 behaviors were not significantly different between the 2 vessel operation modes (Fisher's exact test, $p = 0.33$). Furthermore, the majority of SAB bouts consisting of ≥3 SABs were performed at 'close' distances (2005: ≤100 m; 2006: ≤149 m), yet, for both 2005 and 2006, the proportion of SAB bouts with ≥3 SABs did not significantly differ between these and greater distances (Fisher's exact test, 2005: $p = 0.36$; 2006: $p = 0.37$). Still, the sample size of SAB bouts with ≥3 behaviors was small for both years, so additional data are needed to determine if vessel operation mode and distance to the whale are related to the number of SABs performed in a bout. Finally, tail slaps occurred more frequently than any other behavior (Table 4) regardless of whether the nearest vessel was stationary or motoring (Fig. 5b).

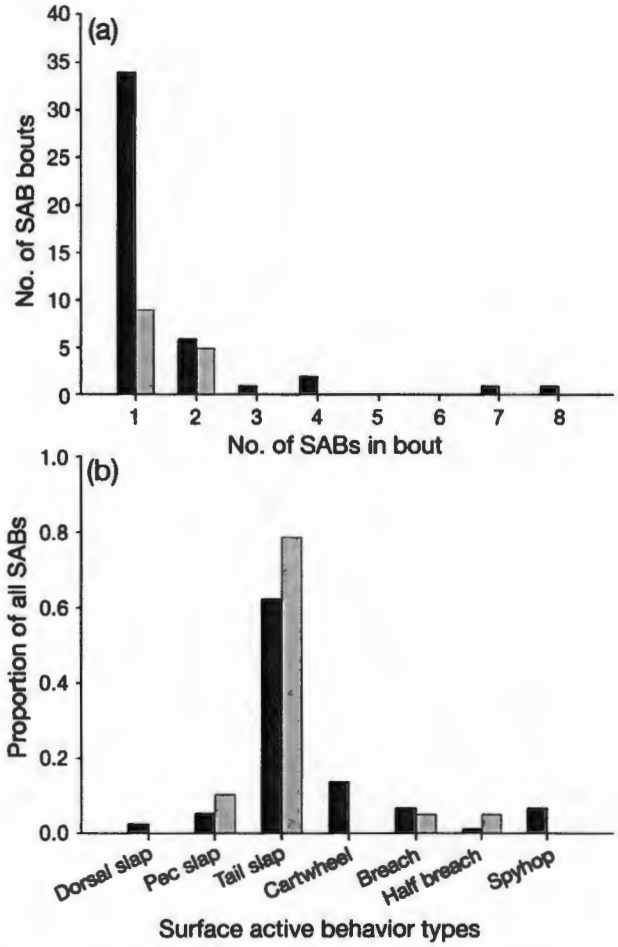

Fig. 5. *Orcinus orca*. Number of surface active behavior (SAB) bouts performed in 2006 in relation to the number of SABs performed within a bout (a) and the proportion of each SAB type performed in all SAB bouts (b) when the nearest vessel was motoring (black bars) or stationary (idling or shut-down; grey bars)

DISCUSSION

The results from the present study demonstrate that southern resident killer whales perform SABs during all activity states. Although killer whales likely perform SABs for several reasons, it is probable that the performance of some is in response to the presence of vessels. The data from the present study and field observations suggest that killer whales may perform SABs in response to close approaches by vessels. Furthermore, these whales may react more often to vessels moving under motor power compared to stationary (idling or shut-down) vessels.

In the present study, killer whales performed SABs during all activity states (rest, forage, travel and social). Because SABs were predominantly performed during travel, which was also the predominant activity state observed, it is likely that activity state was not the only factor influencing the performance of SABs by southern resident killer whales. Indeed, the finding that proportionally more SABs were performed during focal follows with close approaches and the significant temporal relationship between the POCA and the performance of SABs are indicative of killer whales responding to close approaches by vessels, rather than a consequence of collecting data during certain activity states. In previous studies, the performance of SABs by

killer whales (Duffus & Baird 1995) and dolphins (Lusseau 2006a) have also been linked to vessel approaches. For example, sideflops were most often observed when powerboats traveled at fast speed and passed within 50 m of bottlenose dolphins *Tursiops* sp. (Lusseau 2006a). Williams et al. (2009) also found that SABs were more likely to occur as boats got closer to southern resident killer whales, but the authors did not report the approach distances. Thus, it is not possible to compare the relationships between SABs and POCA distances in the study by Williams et al. (2009) and the present study on southern resident killer whales.

If the voluntary whale-watching guidelines in the area (http://www.bewhalewise.org/bewhalewise.pdf), which suggest vessels avoid approaching southern resident killer whales within <100 m, were not regularly observed by the whale-watching fleet, the peak frequencies for SAB bouts would likely occur at distances that are closer than we observed. Indeed, the increased distance for the peak frequency of SAB bouts from 2005 to 2006 was most likely attributed to changes in approach distances of private and commercial vessels. This change is evident in the mean POCA distances for the 2 years, particularly for the commercial vessels (Fig. 1). There were a few factors that contributed to this change in behavior. Mainly, in 2006 there was an increased presence of enforcement officials on the water and the guidelines also changed. Vessel operators were expected to move their vessels away from oncoming whales in order to minimize the likelihood that vessels would ever be within 100 m of whales, even if the whales approached the vessels.

Although several SAB bouts appeared to be linked to close approaches by vessels, SAB bouts also occurred at distances that were quite far from vessels (e.g. >500 m). This demonstrates that SABs are performed during several contexts and thus may serve many purposes. Indeed, surface active behaviors have been linked to feeding (*Orcinus orca*, Similä & Ugarte 1993), social (*Physeter macrocephalus*, Waters & Whitehead 1990; *Orcinus orca*, Ford et al. 2000) and sexual and aggressive (*Cephalorhynchus hectori*, Slooten 1994) behaviors in cetaceans. Several studies have also shown that cetaceans perform SABs in response to disturbance. The performance of SABs are common reactions to biopsy sampling (Weinrich et al. 1992, Clapham & Mattila 1993, Brown et al. 1994, Gauthier & Sears 1999, Hooker et al. 2001) and approaches by vessels and swimmers (Weinrich et al. 2001, Williams et al. 2002a,b, Coscarella et al. 2003, Danil et al. 2005, Lusseau 2006a). Similarly, the findings in the present study that more SABs were performed when vessels approached whales closely and that the majority of SAB bouts were performed near the time of the POCA suggest that close approaches and/or changes in vessel behavior or distance may elicit SAB performance in southern resident killer whales.

Likewise, temporal patterns in behavioral changes by bottlenose dolphins have been linked to close approaches by vessels. For example, Buckstaff (2004) found that whistle rates were significantly greater within 1 min prior to vessel approach, followed by a significant decline as vessels passed (Buckstaff 2004). Similarly, Miller et al. (2008) found that several behavioral changes occurred within the first minute following the passing of high-speed personal watercraft within 100 m.

The function of performing SABs will never be known for certain, yet it is feasible that southern resident killer whales perform SABs as a form of communication while in close proximity to vessels. These signals could serve to promote group coordination, warn conspecifics of a vessel's presence or alert vessels to the whales' presence. Because SABs provide a visual as well as an acoustic cue, these behaviors may aid killer whale communication when ambient noise is elevated, as is the case when several vessels are present (Holt et al. 2009). The observations that SAB bouts tended to consist of more SABs when the nearest vessel was motoring and when vessels were very close provides additional evidence to support the hypothesis that SABs can be performed in response to vessel disturbance. Williams et al. (2002a) also found that male northern resident killer whales tended to increase rates of SABs in response to leapfrogging vessels. Similarly, dolphins increased the number of whistles produced in response to transiting vessels (Van Parijs & Corkeron 2001, Buckstaff 2004).

Southern resident killer whales tended to perform tail slaps more often than other SABs. Tail slaps allow for both visual and acoustic communication and may be performed by killer whales when disturbed (Ford et al. 2000). This preference for performing tail slaps is similar to the northern resident killer whale population (Williams et al. 2002a,b), whose male members tend to increase rates of SABs as the number of whale-oriented vessels increase (Williams et al. 2002b). Similarly, spinner dolphins were observed to repeatedly tail slap near swimmers and kayakers that were following the group (Courbis & Timmel 2009). These behaviors may carry motivational or intentional information (Lusseau 2006b). Individuals may be able to transfer information non-vocally about the direction to take (Lusseau 2006b), or designate the location of a vessel (present study), by attracting the attention of others that can observe the direction and location of the tail slapping animal (Lusseau 2006b). The use of this particular behavior is likely a cost-effective method for combined visual and acoustic communication in killer whales. Although most surface active behaviors are

easily seen and heard, tail slaps are far less energetically expensive to perform than breaches (Waters & Whitehead 1990, D. Noren unpubl. data). Indeed, visual displays involving tail movements are commonly used by organisms across several taxa to deter predators and/or potentially alarm conspecifics (Hersek & Owings 1993, 1994, Brown et al. 1999, Cooper 2001, Langkilde et al. 2004, Alvarez et al. 2006, Murphy 2007).

While there are several variables that likely determine whether vessel presence will elicit a response, it was not feasible to address them all in the present study. The performance of SABs was relatively rare (20% of all focal follows conducted in 2005 and 2006) and thus it is clear that these whales do not always respond to vessels by performing these behaviors. However, the results from the present study suggest that a significant portion (approximately 50%) of SAB bouts that were performed by southern resident killer whales may be related to vessel distance and behavior. Reactions may be more likely to occur under particular conditions, such as when vessels approach whales at exceptionally close distances or when there are several boats nearby simultaneously operating in potentially harmful modes. Unfortunately, due to the high level of traffic and diversity of vessel types in the area, it was not possible to include additional vessel characteristics (e.g. size, motor type, trajectory) in the analysis.

The performance of SABs is likely to have a relatively minor energetic impact compared to other previously documented responses of resident killer whales to vessels. This is because these behaviors do not constitute a substantial portion of southern resident killer whales' daily energy budgets due to the rarity of their occurrence and the preferential performance of tail slaps over other SABs. As mentioned previously, tail slaps have a relatively low energetic cost (D. Noren unpubl. data). Instead, decreased energy consumption in response to vessel traffic may be of greater concern for resident killer whales. Previous studies on northern (Williams et al. 2006) and southern (Lusseau et al. 2009) resident killer whales have found that whales spend less time feeding and more time traveling while in the presence of vessels. These activity budget changes were estimated to increase energy demand by approximately 3% while they more substantially decrease energy gain by approximately 28% in northern resident killer whales (Williams et al. 2006). Thus, increased energy expenditure by either increasing travel (Williams et al. 2006, Lusseau et al. 2009) or increasing SAB rates (Williams et al. 2002a,b, present study) is expected to have a relatively minimal energetic impact compared to reduced prey acquisition (Williams et al. 2006, Lusseau et al. 2009) in response to vessels.

However, because food resources of southern resident killer whales may be limited (Ford et al. 2005), vessel guidelines that minimize impacts which increase energy expenditure and/or decrease energy acquisition will likely be important to the recovery of this population. Indeed, without the voluntary guidelines, it is possible that the number of very close approaches (<100 m) by vessels would have been greater than what was observed during the present study. If the linkage between the performance of some SABs and close approaches is valid, then it is likely that SAB rates could increase if the number of close approaches by vessels increases. This increase in SAB rate may potentially increase the daily energy expenditure of killer whales. Thus, guidelines that prohibit close approaches by vessels could be important in reducing the energetic impacts of vessel disturbance.

The results from the present study and future research could be used to update and modify the voluntary guidelines and/or inform decisions on regulations for vessels in the vicinity of southern resident killer whales. The existing voluntary guidelines request that vessels do not approach whales within a 100 m radius and that they slow down to <7 knots within a 400 m radius. However, results from the present study as well as previous studies on killer whales (Erbe 2002, Williams et al. 2002a,b, 2006, Williams & Ashe 2007) and dolphins (Van Parijs & Corkeron 2001, Kreb & Rahadi 2004) demonstrate that vessels can affect cetacean behavior at distances ≥100 m. Furthermore, motoring vessels, even when transiting well beyond 100 m from cetaceans, can cause behavioral impacts (Van Parijs & Corkeron 2001, Erbe 2002, Goodwin & Cotton 2004, Kreb & Rahadi 2004, present study). Thus, it appears that the current guidelines may not adequately prevent southern resident killer whale behavioral responses to vessels. Furthermore, data from the present study also demonstrate that vessels routinely violated the current 100 m 'no-go zone'. At the very minimum, increasing the minimum approach distance to >100 m will provide the whales with a larger buffer zone from boats. This would thereby reduce the number of vessels that approach killer whales within ≤100 m, thus reducing acoustic impacts (Erbe 2002) and behavioral responses (Erbe 2002, Williams et al. 2002a,b, present study).

Finally, minimizing disturbance is important because short-term behavioral responses to disturbance from whale-watching can have long-term consequences for individuals and populations (Lusseau & Bejder 2007). Furthermore, species that do not avoid disturbance may be most adversely affected by it (Gill et al. 2001). For example, southern resident killer whales stay in the area of disturbance because they consume mobile and highly aggregated prey that are localized in the

San Juan Island region during the summer, and are thus forced to tolerate disturbance, which may impact their population (Gill et al. 2001). Because of this, it is particularly critical to fully understand and minimize the cumulative effects of vessel disturbance and other anthropogenic impacts on this endangered population.

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Vessel traffic disrupts the foraging behavior of southern resident killer whales *Orcinus orca*

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ABSTRACT: Vessel traffic may have contributed to southern resident killer whales *Orcinus orca* becoming endangered. To determine the importance of this threat, we measured the behavior of southern residents in the presence and absence of vessels from 2003 to 2005 at 2 different sites along San Juan Island, Washington, USA. We observed activity states of killer whale schools using scan sampling and collected information on the number of vessels present at various distances from those. We use first-order, time-discrete Markov chains to estimate state-transition probability matrices under varying boat exposure conditions. Transition probabilities between activity states were significantly affected by vessel traffic. In addition, there was a reduction in time spent foraging, as estimated from the stationary state budget from the Markov chains, confirming an effect also previously observed in northern resident killer whales. If reduced foraging effort results in reduced prey capture, this would result in decreased energy acquisition. Each school was within 400 m of a vessel most of the time during daylight hours from May through September. The high proportion of time southern resident killer whales spend in proximity to vessels raises the possibility that the short-term behavioral changes reported here can lead to biologically significant consequences.

KEY WORDS: Whale watching · Killer whale · Disturbance · Behavioral disruption · Foraging

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INTRODUCTION

The eastern North Pacific southern resident stock of killer whales *Orcinus orca* declined to fewer than 80 individuals in 2001, resulting in their listing as 'depleted' under the Marine Mammal Protection Act and 'endangered' under the United States and Washington State Endangered Species Acts, and Canada's Species at Risk Act. The causes of this decline are uncertain, but many scientists consider a combination of reduction in prey resources, toxic chemicals, disturbance from vessel traffic, and other factors to have contributed (Krahn et al. 2004, Wiles 2004, Killer Whale Recovery Team 2005).

Krahn et al. (2004) noted that the southern resident killer whale population increased at an normal rate in the late 1980s (~3% yr^{-1}). Growth began to slow in the early 1990s and was followed by a decline of 20% from 1996 to 2001. This stock is composed of 3 social units (pods). J and K pods exhibited little change in number during this period, in contrast to the expected growth. In contrast, the L pod not only failed to grow, but it declined, and this decline resulted in the decline in number of the entire population. Factors in the inshore waters of Washington and British Columbia, such as declines in prey abundance, toxins, and vessel traffic may be responsible for the lack of growth in all 3 pods. Differences in usage patterns of the inshore waters

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among the different pods (Bigg et al. 1990, Olesiuk et al. 1990, Osborne 1999, Hauser et al. 2006) may account for some of the additional decline experienced by the L pod alone, but factors external to these waters are likely to be of similar importance to factors in inshore waters (regional differences in prey abundance [Protected Resources Division 2004], perhaps entanglement, and exposure to oil, among others).

Vessel traffic may have contributed to the decline through a variety of mechanisms. Collisions between vessels and killer whales occur occasionally in residents, including southern residents, and other killer whales and result in injury or death (Ford et al. 2000, G. M. Ellis pers. comm.). Unburned fuel and exhaust from vessels may contribute to toxin load. The presence of noise from vessels may contribute to stress (Romano et al. 2004). Noise from vessel traffic may mask echolocation signals (Bain & Dahlheim 1994, Erbe 2002), reducing foraging efficiency. Behavioral responses may result in increased energy expenditure, or disrupt feeding activity, which may reduce energy acquisition (Bain 2002, Williams et al. 2006). Energetic mechanisms for impact are of particular concern, since southern resident killer whales may be food limited.

Repeated disturbance of wild animals is implicated as a factor reducing the quality of life, foraging efficiency, fitness, or reproductive success of individual animals. Studies link anthropogenic disturbance to changes in foraging behavior (e.g. Galicia & Baldassare 1997), reproductive success (e.g. Safina & Burger 1983), and mating system and social structure (e.g. Lacy & Martins 2003). These, in turn, either singly or synergistically, can influence population dynamics and viability (Lusseau et al. 2006). Effects of vessel traffic have been studied in a range of cetacean species. Effects vary within and between species, and included changes in respiration patterns, surface active behaviors, swimming velocity, vocal behavior, activity state, inter-individual spacing, wake riding, approach and avoidance, and displacement from habitat. Williams et al. (2006) found northern residents were less likely to forage in the presence vessels. Vessel traffic can also displace bottlenose dolphins (Lusseau 2005, Bejder et al. 2006) and significantly alter their behavioral budget (Lusseau 2004).

In the San Juan and Gulf Islands region, the commercial whale-watching day runs from about 09:00 to 21:00 h in summer, and until sunset in spring and early fall. In addition to commercial whale-watching vessels, other vessels are also in contact with whales throughout the day. These include recreational and research vessels, cruise ships, sport and professional fishing vessels, and intermittently commercial freight ships. Due to the variety of vessels observed in the presence of whales, the term whale watching as used in the present paper refers to all whale-oriented vessel traffic, regardless of whether the vessels are commercial whale-watching vessels or not. Because these whales are in the presence of vessels during much of the day, the potential for cumulative effects makes it important to investigate whether the behavior of killer whales is altered in the presence of vessels.

Assessing variation in behavior under different conditions is difficult, due to the inherent temporal dynamics of activity states, as they tend to occur in bouts. We used Markov chains to quantify this temporal dependence and assess how exposure conditions changed it (Cane 1959, Lusseau 2003). The same temporal biases inherent to behavioral data mean that simple tallies of state samples observed under different boat conditions will not represent the true behavioral budget of the population under these exposure conditions (Guttorp 1995, Lusseau 2003). However, we can infer these budgets from the stationary behavior of the Markov chains developed for each exposure condition.

Here, we assess whether boat traffic affects the behavioral dynamics and behavioral budget of this population of killer whales. Given the importance of food limitation on the dynamics of this population, we particularly determined whether they disrupt foraging activities and the range of influence of vessels (the maximum distance between whales and boats eliciting disruptions).

MATERIALS AND METHODS

Study areas. From 28 July to 30 September 2003, 1 May to 31 August 2004, and 15 May to 31 July 2005, a land-based team of observers monitored behavior of whales and activity of boats from 2 study sites on the west coast of San Juan Island, WA, USA. One site (hereafter referred to as the north site) was located at 48° 30.561′ N, 123° 8.494′ W (near Lime Kiln State Park) at an altitude of approximately 99 m above mean lower low water. The south site was located on Mt. Finlayson (48° 27.421′ N, 122° 59.401′ W) at a height of 72 m, and the view of the eastern portion of Juan de Fuca Strait was unobstructed. Whales have been reported to use this area heavily for foraging, whereas the north site appeared to be used primarily for travel and socializing (Heimlich-Boran 1988, Felleman et al. 1991, Hoelzel 1993). Together, these sites were chosen to maximize sample size and to allow the behavioral observations to include the entire repertoire of the population.

Behavioral sampling. During the study periods, 238 d were spent on effort, of which 128 d were spent with whales. During that time scan sampling was conducted at 15 min intervals to characterize subgroup size (ranging from 1, to the size of the school in the

study area), activity state, and the number of vessels within 100, 400, and 1000 m of whales. The activity state subcategories (1 to 8; Table 1) were combined to match the categories described by Ford et al. (2000). The resulting activity states were cumulatively inclusive and mutually exclusive. A scanned group was defined as animals within 10 body lengths of one another at the time of a scan-sample observation, using a chain rule (Connor et al. 2000). The identity of group members was recorded, but when individuals were too far away to be identified, their identity was assigned to categories based on size (e.g. calf, juvenile, medium-sized whales [large juveniles or adult females], subadult male, adult male). Sequential observation of focal groups allowed estimating the probability of animals' switching from one activity state to another as a function of vessel traffic.

Vessel traffic sampling. Vessels were counted separately depending on whether or not they were engaged in whale watching, although commercial and recreational whale-watching boats were not distinguished in scan-sample counts. Distances were visually estimated, and, in most instances, the distances were confirmed using coordinates of whales and boats taken using a theodolite. These theodolite-based Quality Assurance and Control (QA/QC) measurements were made continuously throughout the study to insure observer reliability and consistency (Williams et al. 2009). Observer errors never exceeded 10%. Since our analyses are not based on the exact distance between boats and whales, but on the number of boats present within 100, 400, and 1000 m of the whales, such errors where adequate.

Analyzing scan-sampling data from focal groups. Understanding the recurrence of activity states allows one to understand the likelihood that a state will be disrupted by, in our case, boat presence. The data were a series of scan samples of a focal group that were treated as samples of activity-state sequences. A sequence stopped when sampling stopped on a given day or when a focal group ceased to exist due to changes in group membership (through fission or fusion with other individuals), or because they left the study area. For the purposes of the present study, we were only interested in understanding the change in the likelihood that when a group was in State A they would be in State B 15 min later (i.e. at the next scan). These are called first-order transitions in activity. This sequence of discrete time samples could be treated as a Markov chain (Lusseau 2003, 2004) because it was ergodic. A time series is ergodic when transitions between all states are possible; in the present study a group could be involved in a transition from any state to another (there was no biological constraint preventing whales from switching between one state and the others). We then assessed whether our first-order assumption was warranted. That is, we assessed whether the assumption that a state was only dependent on the immediately preceding sample best explained sequences by comparing the Bayes information criterion (BIC) for first-order chains to BIC for zero-order chains and second-order chains (Guttorp 1995, Lusseau 2003). BIC provides a consistent estimate of the order of a Markov chain. The higher the BIC, the more information the order provides on the sequences. A BIC difference of 9.2 is sufficient to determine the best-fitting order (Guttorp 1995).

Table 1. *Orcinus orca*. Definition of activity states used in the present study

Activity state	Subcategory	Definition
Rest		Characterized by prolonged surfacing in contrast to the rolling motion typically observed during travel
	1	Deep rest, hanging, logging: whales do not progress through the water
	2	Resting travel, slow travel: whales progress through the water, although they may not make forward progress over the ground
Travel		Characterized by a rolling motion at the surface, progress through the water, and membership in a subgroup of >4 individuals
	3	Moderate travel, medium travel: travel in which whales do not porpoise
	4	Fast travel: travel which includes porpoising
Forage		Characterized by progress through the water by lone individuals or while a member of a subgroup of 4 or fewer individuals
	5	Dispersed travel: foraging in a directional manner
	6	Milling, feeding, pursuit of prey: foraging involving changes in direction
Socialize		Interaction with other whales, or other species in a non-predator–prey context
	7	Tactile interactions: socializing that involves touching another whale, such as petting or nudging
	8	Display: socializing that does not involve touching, but may include behaviors such as spy hops, tail slaps and breaches

To understand the effect of boat interactions on the state transitions, the number of vessels in the field of view was counted, as these vessels may have contributed to ambient noise in the area (Bain pers. obs.). The number of vessels within 100, 400, and 1000 m of subgroups were also counted. The numbers within specific distances were used as candidate explanatory covariates, to assess whether the probability of animals switching among activity states varied as a function of boat traffic. We therefore constructed a transition matrix, representing the probabilities for whales to be observed in state i at time t and subsequently in state j at the next sampling event (t + 15 min):

$$p_{ij} = \frac{e_{ij}}{\sum_k e_{ik}} \quad (1)$$

where e_{ij} is the total number of times the transition was observed and $\sum_k e_{ik}$ is the total number of time state i was observed as the starting state.

Analyzing the influence of vessel traffic and other factors on behavior. We were able to explore the effects of several parameters on the likelihood to go from one state to another by comparing the behavioral contingency tables (preceding to succeeding states) obtained for different levels of different factors (Lusseau 2003). Using these multidimensional contingency tables, we used general log-linear analyses (SPSS algorithm), to test whether site (north/south), year (2003/2004/2005), pod (J, K, and L), or vessel traffic (boat present/absent within 100, 400, and 1000 m) affected transitions in activity states, which was the likelihood that focal groups went from a preceding behavior (state at time t) to a succeeding behavior (state at time t + 15 min). Log-linear analyses can be thought of as generalized linear models for categorical data (with a Poisson distribution and log link). This technique is described in more detail by Lusseau (2003, 2004). The response variable in these analyses was the succeeding behavior (S), and we estimated whether the observed count of succeeding behavior was influenced by the preceding behavior (P), the year (Y), boat presence (B), and/or location (L). Given that we estimated the behavioral sequences using first-order Markov chains, we were assuming that the interaction PS was significant. Given that sampling was based on observational data, we could not control sample size for each factor, and therefore the count of preceding behavior was influenced by other factors (Caswell 2001). The log-linear analysis fits a saturated model to the dataset, i.e. a model that considers all interactions, indicated by $BLYPS$ in the first analysis. The effects of the different factors can be tested by comparing different fitted models using likelihood ratio tests. Here, the null hypothesis is that succeeding behaviors are independent of boat presence, year, and location, given preceding behaviors. This null hypothesis corresponds to the null model $PS + LBYP$. The influence of factors was assessed in 2 manners. First, we estimated the Akaike information criterion (AIC) for each model, and the best fitting model minimized AIC. Secondly, we assessed whether the presence of a factor in the log-linear model added a significant contribution to explaining the data's variance using likelihood ratio tests. For example, the effect of boat presence in the first analysis can be evaluated by comparing the null model and $BPS + LBYP$ because adding the terms BS and BPS, which correspond to a boat presence effect on the observed count of succeeding behaviors, to the null model results in the model $BPS + LBYP$. The significance of the boat presence effect can then be tested by comparing the goodness-of-fit of both models. The difference in goodness-of-fit ($\Delta G^2 = G^2_{BPS,LBYP} - G^2_{PS,LBYP}$) is the likelihood ratio testing the significance of the addition of terms BS and BPS with degrees of freedom equal to the difference in the degrees of freedom for the 2 models. The effect of the various factors can be tested at various stages by adding the effect to different models that already consider other factors (Fig. 1). We tested the interactions between year, site, and boat presence and their influences on behavioral transitions.

Influence of pod identity. We then tested whether the pod identity of the focal whales influenced the previous analysis. For this analysis we only retained focal schools that were composed exclusively of members of 1 pod. Due to sample size constraints the latter analysis was carried out on only 2 behavioral states (foraging or not foraging), while the former was carried out on all states.

Influence of distance between boats and whales. To assess whether distance to boats influenced the behavior of killer whales, we calculated the likelihood that whales that were foraging stayed foraging when boats interacted with them at distances of 100, 400, and 1000 m. We also looked at the effect of boat presence on the likelihood that whales that were foraging would stay foraging by comparing control situations (no boats within the given distance band) to impact ones. In all these analyses, foraging was selected because recent studies show that northern resident killer whales were more likely to switch activity states when boats approached foraging whales than when whales were engaged in other activity states. Furthermore, alteration to this state is likely to carry larger energetic consequences for killer whales, because it has the potential not only to increase energetic expenditure, but also to reduce acquisition (Williams et al. 2006).

We analyzed the scans containing distances between vessels and groups to determine mean and maximum

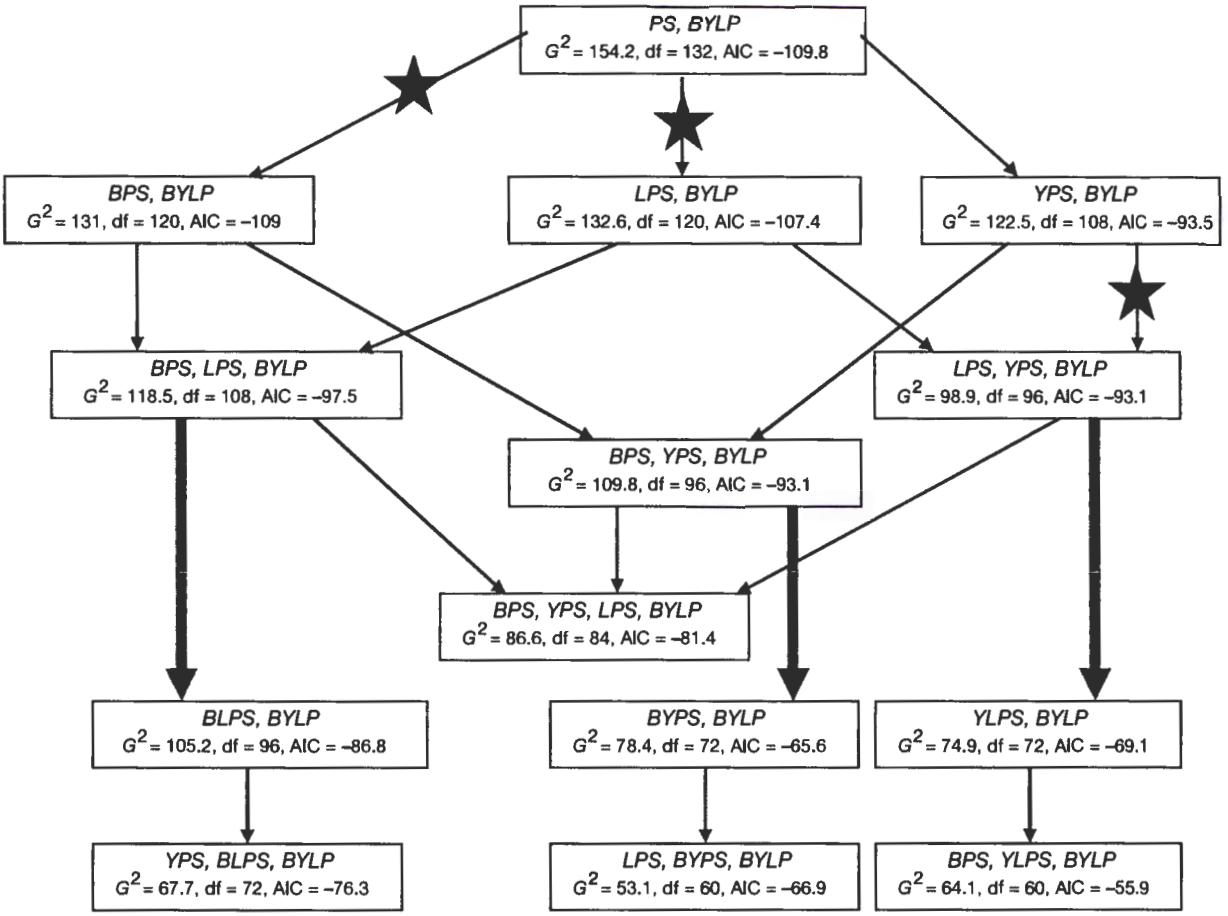

Fig. 1. Tests of boat presence within 100 m (*B*), site (*L* for location to avoid confusion in abbreviations), and year of sampling (*Y*) effects on behavior transitions (*PS*) using log-linear analyses. Models and their respective goodness-of-fit G^2 statistics, degrees of freedom, and Akaike information criterion (AIC) values are shown in the boxes (adapted from Caswell 2001). Terms added are color coded. Blue arrows represent the addition of a site effect (*LS*, *LPS* terms added to the previous model), red arrows represent the addition of a boat effect (*BS*, *BPS*), and green arrows represent the addition of a year effect (*YS*, *YPS*). To those terms correspond an increment in G^2 and degrees of freedom, which are used to test for the significance of the term addition. Arrows are marked with a star when the term addition is significant ($p < 0.05$). The top left star indicates a significant boat effect; the center and right stars indicate significant site effects. Year effects were non-significant

vessel counts along with the proportion of time groups spent within 100, 400, or 1000 m of the nearest vessel (e.g. proportion of time within 100 m equals the number of scans with boats within 100 m divided by the number of scans in which vessel distances were recorded).

Behavioral budget variations. Finally, we assessed variation in behavioral budget under different conditions. We estimated budgets using the long-term behavior of the transition matrices. Transition matrices are based on ergodic time series, which means that eigenanalysis of this matrix reveals several properties of activity states. Applying the Perron-Frobenius theorem we show that the transition matrix of long-term behavior, i.e. the amount of time that the whales spent in each activity state, can be approximated by the left eigenvector of the dominant eigenvalue of the matrix (Lusseau 2003). Ultimately, this approach can be used to calculate stable, unbiased activity budgets in contrast with budgets obtained from sample tallies that can be influenced by autocorrelation issues. Further, reliance on transitions rather than individual scans helped control for possible effects of whale behavior on vessel behavior.

RESULTS

Over the 3 field seasons we observed 593 behavioral transitions in *Orcinus orca* (135 in 2003, 217 in 2004, and 251 in 2005 out of 373, 1058, and 770 scans, respectively; Table 2). The first-order Markov chain was deemed the

Table 2. *Orcinus orca*. Number of activity state transitions observed in the presence/absence of boats within 100 m

Site	2003		2004		2005	
	No boat	Boat	No boat	Boat	No boat	Boat
North	49	30	121	30	111	52
South	45	11	46	20	40	48

more appropriate way to estimate the behavioral sequences because it provided more information than zero-order or second-order Markov chains ($BIC_{0\text{-order}} = -357.5$, $BIC_{1\text{-order}} = -262.8$, $BIC_{2\text{-order}} = -293.8$). We assessed the effects of year (2003/2004/2005), site (north/south), and vessel traffic (no boat within 100 m, boat present within 100 m) on first-order behavioral transitions using a 5-way, log-linear analysis (LLA). Due to small sample size the full interaction of the 3 independent variables could not be quantified (Table 2). This analysis reveals that 3 models provided more information on the data's variance (Fig. 1). The null model, i.e. no effects from independent variables (*PS*, *BYLP*), the model considering a site effect (*LPS*, *BYLP*), and the model considering a boat effect (*BPS*, *BYLP*), all had lower AIC values than the other models (Table 3), indicating that each of the null, site effect, and boat effect models were plausible. In addition, adding a boat and site effect to the model provided significantly more explanation of the data variance (significant effects represented by stars on Fig. 1, see also Table 3), the site effect still being significant after the year effect has been taken into consideration. Significance of the terms were derived from the likelihood ratio tests as described in 'Materials and methods'. From this analysis, we can conclude both that boat presence within 100 m of the focal whales affected their behavioral transitions and that the whales behaved differently at the 2 sites, in contrast to the null model that was not rejected when considering the AIC value alone. The introduction of a boat effect explains significantly more variation in the dataset than the null model alone (as shown by the red star in Fig. 1). We can therefore conclude that while intrinsic behavioral processes and data structure (the null model) as well as site explain some of the variation in the dataset, a boat effect cannot be excluded (because of the AIC weights) and should be included as well (because this parameter provides significantly more information than the null model alone).

Table 3. Information theoretic approach used to select models, from Fig. 1, providing the most parsimonious explanation for the variation in the scan-sample dataset. The selection is based on the Akaike information criterion (AIC). The models are described in Fig. 1. The difference between the best fitting model and the other models, ΔAIC, helps in defining models that are less plausible (usually ΔAIC > 4 to 8). The likelihood of the model given the data can be approximated using an exponential transformation of ΔAIC: $\ell(\text{model}_i|\text{data})=e^{(-0.5\Delta AIC_i)}$. The weight of evidence provided by each model can be obtained by normalizing these likelihoods so that they sum to 1

Model	AIC	ΔAIC	Weight
Null model	−109.8	0	0.507
Boat	−109.0	0.8	0.340
Site	−107.4	2.4	0.153
Year	−93.5	16.3	0.0001
Boat + Site	−97.5	12.3	0.001
Site + Year	−93.1	16.7	<0.0001
Boat + Year	−82.2	27.6	<0.0001
Boat + Year + Site	−81.4	28.4	<0.0001
Boat × Site	−86.8	23.0	<0.0001
Boat × Year	−65.6	44.2	<0.0001
Year × Site	−69.1	40.7	<0.0001
Year + (Boat × Site)	−76.3	33.5	<0.0001
Site + (Boat × Year)	−66.9	42.9	<0.0001
Boat + (Year × Site)	−55.9	53.9	<0.0001

Influence of pod identity

The southern resident community of killer whales is composed of 3 pods (J, K, and L), which do not spend the same amount of time within Puget Sound (Olesiuk et al. 1990, Ford et al. 2000). This may result in differences in the cumulative exposure of each pod to whale watching and therefore may lead to variation in the way these pods respond to boat presence. We therefore assessed whether the identity of the focal whales affected the behavioral response observed in relation with boat presence. To do so, we conducted a log-linear analysis including pod identity and boat presence within 100 m as independent variables (Table 4). The log-linear analysis showed that there does not appear to be any variation in the way that whales responded to boat presence depending on their pod, because there was no interaction between the pod and boat effect (Table 5). The analysis shows that while the best model was the null model, both pod effect and boat effect could not be discounted (ΔAIC < 2; Table 5). This highlights that potentially the site effect we observed in the previous analysis (Fig. 1) may just be a reflection of the

Table 4. *Orcinus orca*. Number of activity state transitions observed with and without boats present within 100 m of subgroups for each pod for both sites in all years (considering only schools composed solely of members of 1 pod)

Pod	No boat present	Boat present
J	158	35
K	21	21
L	99	47

Table 5. Information theoretic approach used to select models, from the log-linear analysis considering pod identity, site, and boat presence, providing the most parsimonious explanation for the variation in the scan-sample dataset. The difference between the best fitting model and the other models, ΔAIC, helps in defining models that are less plausible (usually ΔAIC > 4 to 8). The likelihood of the model given the data can be approximated using an exponential transformation of ΔAIC: $\ell(\text{model}_i|\text{data}) = e^{(-0.5\Delta AIC_i)}$. The weight of evidence provided by each model can be obtained by normalizing these likelihoods so that they sum to 1. mle: maximum likelihood estimate

Model	mle	df	AIC	ΔAIC	Weight
Null	21.43	22	−22.57	0	0.378
Pod	14.43	18	−21.57	1	0.229
Boat	19.22	20	−20.78	1.79	0.154
Site	20.97	20	−19.03	3.54	0.064
Boat + Site	18.89	18	−17.11	5.46	0.025
Boat + Pod	13.42	16	−18.58	3.99	0.051
Site + Pod	12.44	16	−19.56	3.01	0.084
Site × Pod	8.66	12	−15.34	7.23	0.010
Site × Boat	18.21	16	−13.79	8.78	0.005
Boat × Pod	48.79	12	24.79	47.36	<0.0001
Boat × Pod × Site	0	0	0	22.57	<0.001

difference in use of the 2 sites by the 3 pods (Figs. 2 & 3). J pod seemed to be the pod most likely to be foraging, and, interestingly, they seemed to be more likely to be foraging at the south site, while K and L were equally likely to forage at both sites (Fig. 3).

Influence of distance between focal school and boats

While an effect of boat presence was apparent when boats were within 100 m of the focal subgroup, we

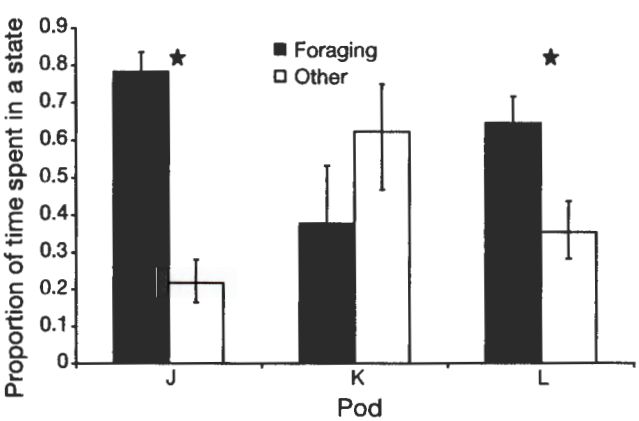

Fig. 2. *Orcinus orca*. Proportion of time focal killer whales spent in each activity state (their activity budget) depending on the pod membership of the focal school. Data from both sites are combined. Error bars are 95% confidence intervals. Black stars indicate differences that are significant at the 0.05 level

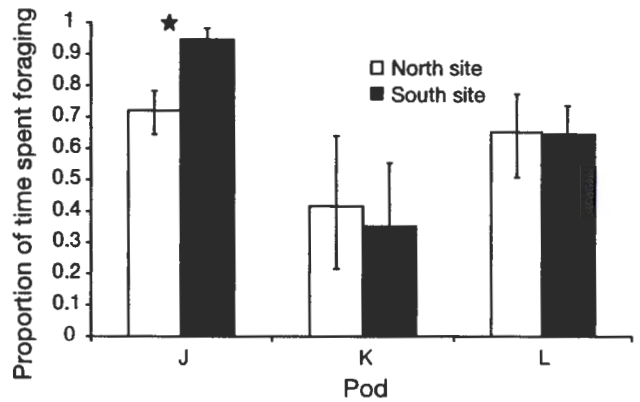

Fig. 3. *Orcinus orca*. Proportion of time focal killer whales spent foraging depending on the pod membership of the focal school and the site at which they were observed. Error bars are 95% confidence intervals. Black star indicates difference that is significant at the 0.05 level

wanted to assess whether more distant boats also influenced the activity states of the whales. Control samples are more difficult to obtain when considering boat presence at distances of 400 and 1000 m, because boat traffic around the 2 sampling sites is consistently high. For this reason the current samples available did not allow us to assess the site effect in relation to boat presence within 400 m of the whales. Similarly, we could not assess the effects of boats within 1000 m of the whales because of the lack of a minimum amount of control samples. Therefore, we present only the results of the log-linear analysis assessing the effects of boat presence within 400 m of the whales without considering the other potential effects (i.e. merging samples obtained during all years and at both sites). Given that the site effect (or potentially the pod effect) was found to affect the activity budget in previous analyses, the following results need to be interpreted with caution. As in previous models, we compared the model, obtained from log-linear analyses, containing all 2-way interactions, to the fully saturated model to assess the effect of boat presence on behavioral transitions (Lusseau 2003). This comparison, based on the difference in maximum-likelihood estimates of both models using G^2 statistics, did not reveal an effect of boat presence within 400 m on behavioral transitions (ΔG^2 = 11.0, Δdf = 9, p = 0.28).

We then assessed the effect of boat presence within 100, 400, and 1000 m on the probability to continue foraging when foraging. The effect size of boat presence, i.e. the difference in the likelihood to continue foraging when foraging between control and impact situation (vessels present within the specified distance), decreased with the distance between whales and boats increasing (Fig. 4a). The effect of boat presence appeared to be only significant when boats were

within 100 and 400 m (Fig. 4a, note the star and the confidence intervals), yet sample size might have prevented the detection of smaller effect size for the other treatment (1000 m; Fig. 4a). In addition, the likelihood to continue foraging when foraging increased as the distance between the focal group and boats present in the study area increased, but not significantly (Fig. 4b).

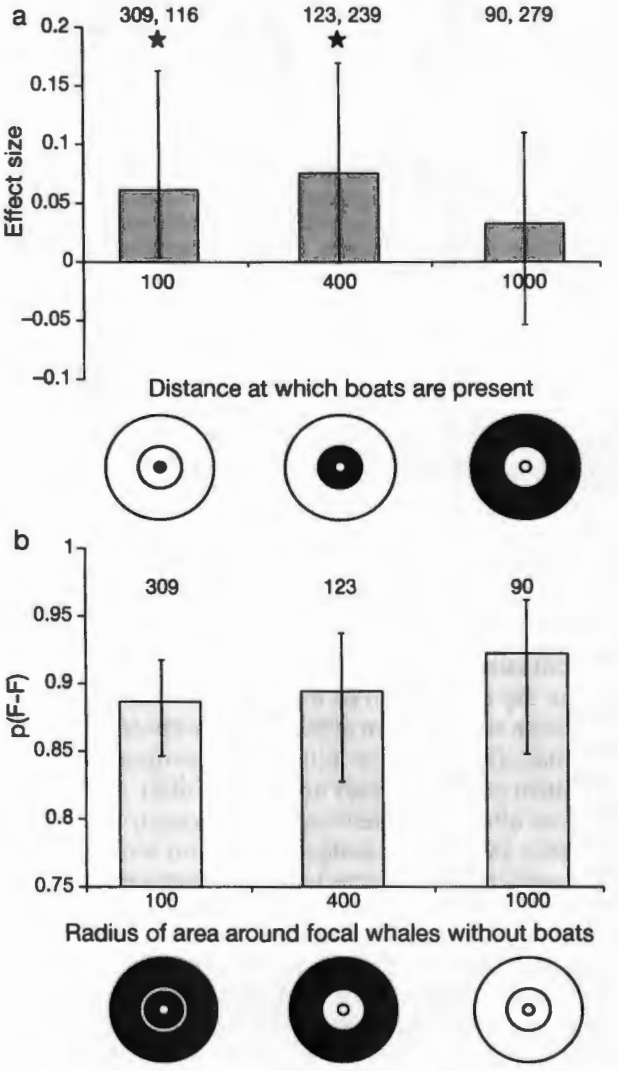

Fig. 4. *Orcinus orca*. Difference in the likelihood to continue foraging when foraging ($p_{F\to F}$) between control and impact situations ($p_{control} - p_{impact}$), i.e. effect size: (a) depending whether some boats were present within 100, 400, or 1000 m of the focal whales and (b) when there is no boat present within 100, 400, or 1000 m of the focal school. The diagrams describe these 3 treatments: the focal group is at the center of the concentric doughnuts (100, 400, and 1000 m radii) and boat exposure is represented in black. In order to test the effect of distance to boats, this analysis only takes into consideration samples when boats were present at the given distance. Error bars are 95% confidence intervals for the difference. If the interval includes 0, the difference is not significant at $p < 0.05$ (indicated by a star). The number of transitions observed is given above each bar ($n_{control}$, n_{impact})

Behavioral budget variations

We calculated the activity budgets of the whales at both sites, as well as in the presence and absence of boats. Whales tended to spend significantly more time traveling and less time foraging when boats were present within 100 m than when they were absent within 100 m (all data pooled with site effect ignored; Fig. 5a). The difference in activity budgets between both sites only involved socializing (all data pooled with boat effect ignored; Fig. 5b). Whales spent significantly more time socializing at the north site. While boat effect was not significant at 400 m, trends in behavioral budgets depending on boat presence within 400 m were in the same direction as those when boats were within 100 m (Figs. 5a & 6), with whales spending significantly more time traveling and significantly less time foraging.

DISCUSSION

Behavioral sequences of *Orcinus orca* varied significantly between locations, as expected. They also differed significantly with the presence of vessels. It is

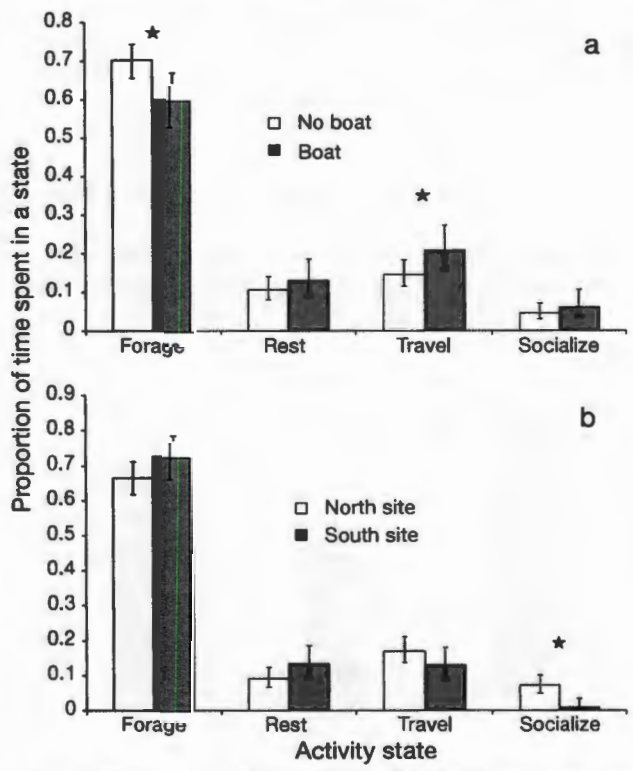

Fig. 5. *Orcinus orca*. Proportion of time focal killer whales spent in each activity state (their activity budget) depending on (a) the presence of boats within 100 m of them and (b) the site sampled. Data from all 3 pods at both study sites are combined. Error bars are 95% confidence intervals. Black stars indicate differences that are significant at the 0.05 level

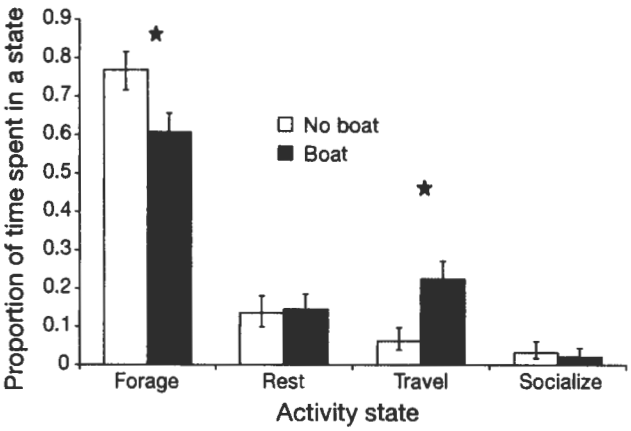

Fig. 6. *Orcinus orca*. Proportion of time focal killer whales spent in each activity state (their activity budget) depending on the presence of boats within 400 m of them, pooling across years and sites. Error bars are 95% confidence intervals. Black stars indicate differences that are significant at the 0.05 level

possible that the observed difference between locations is actually related to pods using the 2 sites with different intensity and some differences in behavioral sequences existing between pods. J pod was more likely to be observed at the north site, while L pod was more likely to be at the south site. Similarly, schools composed of members of all 3 pods were more likely to be observed at the north site. However, boats operating close to whales (within 100 m) also affected their activity budget in a similar fashion at both sites. Whales were significantly less likely to be foraging and significantly more likely to be traveling when boats were around. This finding is in agreement with previous studies of the northern resident killer whale population (Williams et al. 2006). This effect raises concerns about the implications of this short-term displacement for the ability of individuals to acquire prey and the potential for long-term repercussions at the population level, especially in the light of the level of whale-watching activities carried out with southern resident whales. Vessel activity is also believed to reduce foraging success in other species (*Tursiops*; Allen & Read 2000). After controlling for effects of site and boats, there was no significant difference in the data between years. Additional years of study will be needed to determine whether the 3 different years happened to be similar in factors that vary on an annual time scale (e.g. prey abundance), or if our results will be robust across a range of conditions. The present study shows that whales are displaced short distances by the presence of vessels. Thus, whales may be displaced from optimal foraging routes. Further, Bain & Dahlheim (1994) suggested noise would mask echolocation signals and reduce foraging efficiency. These data are also consistent with observations of northern resident whales (Williams et al. 2006). Thus, we would encourage further study to determine how noise and proximity interact to reduce foraging effort.

Influence of pod identity

Boat interactions appear to have the same effect on all 3 pods, yet more sampling is required to fully understand the interaction between the composition of focal groups and the influence of boats on their activity state. Since pods appear to use certain areas preferentially (Hauser et al. 2006), and whales use both study sites differently, it was not surprising to see that the site effect observed earlier may actually relate to a pod effect. J pod, which spends the most time in Puget Sound, was more likely to be observed foraging than the 2 other pods. That pod was also significantly more likely to be foraging at the south site than at the north site, while the 2 other pods foraged similarly at both sites.

Influence of distance between focal school and boats

Boats within 100 m clearly have a significant effect on whale behavior. Boats between 100 and 400 m also have a significant effect, although we cannot say whether boats throughout this range cause effects, or the significance is due to the effects of vessels just over 100 m away. More spatial resolution in the data collection protocol would have been needed to address this issue. Similar but smaller differences were observed when the closest vessels were between 400 and 1000 m away. However, a larger sample would be needed to determine whether effects extend beyond 400 m. These results suggest the zone of influence of vessels in this area exceeds the 100 m radius in current guidelines, and that more extensive guidelines such as those developed by the Whale Watch Operators Association Northwest (2003), or those proposed by Orca Relief Citizens Alliance (2005) will be necessary to completely prevent behavioral changes caused by vessels, and more data will be needed to determine appropriate guidelines.

One potential explanation for these results is that noise impairs the ability to forage using echolocation (Aguilar Soto et al. 2006). Although Bain (2002) and Au et al. (2004) suggested whales would be able to detect prey directly in their path despite vessel noise, their ability to detect prey off to the side of their path would be impaired, as the active acoustic foraging range would be reduced by masking vessel noise (Bain & Dahlheim 1994, Erbe 2002). Since received noise levels typically decline with distance, the closer the boats are, the more the echolocation range is reduced (Bain 2002,

Williams et al. 2002a), potentially leading to foraging disruption, as suspected here. To test this hypothesis, acoustic monitoring would be required, as noise produced varies with engine type and the speed at which boats operate. These data were beyond the scope of the present study.

CONCLUSIONS

In this study, we found evidence consistent with changes in behavior in the presence of vessels. These effects support the development and enforcement of regulations for whale watchers, both recreational and commercial. Future research could address whether different approaches to whale watching have different degrees of impact (as paralleling and leap-frogging were compared by Williams et al. 2002a,b), and whether changes in behavior are more pronounced in some parts of the range than in others. However, since it has proven difficult to demonstrate significant differences in behavioral responses to currently accepted practices, it could be expected to take carefully controlled experiments or many years of observation to compare the implications of proposed guidelines to current guidelines. Future research could also attempt further elucidation of age, sex, pod, and individual differences in responses to vessels. Strong behavioral responses of animals to disturbance do not always indicate population-level effects. Indeed, inter-specific variability in site fidelity and availability of alternative suitable habitat make it difficult to infer population-level consequences from inter-specific variability in sensitivity to disturbance (Gill et al. 2001). Thus, it will be important to develop the link between short-term behavioral effects and population dynamics (see Bain 2002).

The present study echoes findings with northern resident killer whales: the presence of vessels inhibits the foraging behavior of fish-eating killer whales. This may lead to a reduction in energy acquisition, and a priority field research area would be to address whether prey capture actually is affected by vessel presence. In addition, modeling exercises should be carried out to identify potential mechanisms and the biological significance of any effects found.

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Killer whale evasive tactics vary with boat number

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Abstract

Controlled exposure experiments that measure animal response to vessels can inform relevant wildlife-viewing guidelines and reveal how they make decisions about changes in their environment. Previous experimental studies documented stereotyped avoidance responses by killer whales to boats. Additional observations collected during these studies showed an apparent shift in avoidance behaviour at high traffic levels. Our study tested experimentally whether whales did respond differently to approach by few (1–3) versus many (>3) vessels. Data were collected in summer 2004 in Johnstone Strait, British Columbia, using a theodolite to track the positions of boats and individually identifiable focal whales during control and treatment (few vs. many boats) phases. The responses of 16 adult male killer whales differed significantly between treatment levels (Wilcoxon's test, $P = 0.0148$). Swimming paths became more tortuous when few boats approached whales, but straighter as many boats approached. Pooling treatments would have masked significant responses with high statistical confidence (Wilcoxon's test, $P > 0.999$), falsely suggesting that boat presence had no effect. The division between few and many boats was supported by 140 opportunistic observations on 26 whales from a population of 216. We used generalized additive models to control for the effects of confounding variables, detected a non-linear relationship between number of boats and whales' swimming path directness and confirmed an inflection point at approximately three boats within 1000 m. We urge caution when designing controlled exposure assessments that rely on a simple absence–presence framework, which can mask multivariate or non-linear responses. Experimental design, coupled with analytical techniques incorporating statistical power and appropriateness of treatments and response variables, must be considered when interpreting the biological significance of null findings from impact assessments. Our study provides new information about levels of habitat degradation that this marine apex predator can tolerate.

Introduction

A number of studies have examined the impacts of human activities on behaviour, energetics and reproductive success of a variety of wildlife taxa. These studies demonstrate that there is an observer effect in wildlife viewing, such that our presence may disrupt the activities of the animals we watch. In some cases, these effects are striking, and obvious both to tourists and to researchers and managers aiming to reduce tourism impacts. Birdwatchers know this, and curtail their movements to reduce their influence, but also simply to prevent birds from fleeing. In the coastal environment, an approaching boat can cause hauled-out seals to enter the water (Suryan & Harvey, 1999). Diving seals make for poorer viewing than those ashore, so it is in both the animals' and the tourists' best interests that guidelines reduce the probability of such a startle response. An extremely subtle example is our disruption of wary predators when we are not physically there. Human-built trails and roads in Alberta, Canada, have increased the 'tortuosity' of paths followed by wolves *Canis lupus* (Whittington, St Clair & Mercer, 2004). Thus, even without posing absolute barriers, trails and roads altered wolf movement across their territories. Such a finding may seem obvious in hindsight, but it provides a useful mechanism for defining good wolf habitat, identifying how to protect it (i.e. complete closure areas) and linking short-term behavioural responses to fitness. In the bird, seal and wolf examples, avoidance responses range from the overt to the subtle, but they are real, and may carry costs. Human activities that make wolves adopt more circuitous routes to reach a destination can cost them energy if increased travel time replaces time budgeted for resting. The effect is exacerbated if the increased travel time comes at the expense of time budgeted

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for feeding, as may be the case for grizzly bears (White, Kendall & Picton, 1999).

In the marine environment, whalewatching is a growing industry worldwide (Miller, 1993; Hoyt, 1997) and managers have implemented whalewatching guidelines or regulations in many countries (IWC, 2005). Many recommendations came from whalewatchers themselves, who identified that boats influence whale behaviour, and wanted to minimize that this tendency (e.g. JSKWC, 1996). Anthropogenic activity is a concern for two at-risk killer whale populations in the north-eastern Pacific (Baird, 2001). However, assessing the effects of human presence on cetaceans is difficult. We can expect cetacean avoidance responses to be subtle and difficult to detect, because we observe animals only when they surface to breathe, and because unlike flying birds, whales can rarely move quickly enough to escape people in powerboats. Despite the difficulty in conducting impact assessments on free-ranging cetaceans, studies have quantified the effects of vessel traffic on behaviour (e.g. Williams, Trites & Bain, 2002*b*; Williams *et al.*, 2002*a*; Lusseau, 2003; Scheidat *et al.*, 2004), activity and energetic budgets (Lusseau, 2004; Williams, Lusseau & Hammond, 2006) and habitat use and possibly reproductive success (Bejder, 2005). One feature common to these studies is that they report inconspicuous, stereotyped behavioural cues that cetaceans displayed when approached by boats. The responses of cetaceans to boats are generally small, but real.

The detection of avoidance responses by cetaceans will benefit from carefully designed controlled-exposure experiments, especially by land-based observers. In Johnstone Strait, British Columbia (BC), Canada, research and whalewatch communities work together to draft common-sense guidelines, test efficacy experimentally and update them in an iterative process. Commercial whalewatch operators recommended that boaters approach whales slowly, from the side and to parallel the animals' path at distances no closer than 100 m (JSKWC, 1996). Two experimental studies were begun in 1995 to test the relevance of local whalewatching guidelines. The first measured how whales responded to one boat following the guideline by approaching the animal slowly, from the side, and paralleling the whale's path at a 100 m distance (Williams *et al.*, 2002*b*). The second measured how whales responded to one boat violating local whalewatching guidelines by 'leapfrogging' – a practice in which boaters speed up when close to whales in order to place their boat in a whale's predicted path (Williams *et al.*, 2002*a*). Both studies revealed that whales, on average, attempted to increase their distance from boats by increasing their path tortuosity, that is, by deviating from the more predictable path that they were following immediately before the experimental approaches. Opportunistic observations revealed that the magnitude of this horizontal avoidance response increased as a boat approached closer than 100 m.

The consistency between these experimental and opportunistic studies suggests that, for northern resident killer whales, summary statistics describing the tortuosity of swimming paths can be considered a suitable response variable to describe an animal's tolerance for various approach distances and activities. Previous experiments, though, measured how whales responded to the activities of a single boat, while killer whales are often approached by more than one boat. In order to test the effects of higher-traffic conditions, hypotheses can be generated from correlations between boat number and whale behaviour measured under opportunistic conditions, and then tested experimentally. One such comparison was reported from opportunistic data by Williams *et al.* (2002*b*), who found an inconsistency between whale response to boat number and proximity. Whales in that study showed a decrease in path directness as boats approached more closely, but an increase in path directness as boat number increased. The findings suggested that killer whales responded differently to a few boats than to many, occurring when approximately three boats approached within 1000 m of the whale. The authors hypothesized that:

> An irregular path may be a useful avoidance tactic with a single boat, but ineffective with more than one. In a multiple-vessel scenario, a dive that takes a whale farther from one boat may bring it closer to another. . . . This compromise deserves further attention in the form of a multiple-vessel experiment (Williams *et al.*, 2002*b*).

Here, we report on results from that multiple-vessel experiment. Studies on other species show a shift in dolphin avoidance strategies depending on the number of boats present (Bejder, 2005; Lusseau, 2005), ranging from short-term evasion to long-term area avoidance. The at-risk status of killer whales (Baird, 2001), and the increasing level of boat traffic around them (Foote, Osborne & Hoelzel, 2004) create an urgent need for science to inform management of boat number around killer whales. In the case of the endangered southern resident killer whale population, there are more whalewatching boats than whales to watch (Koski, 2004).

The primary goal of our study was to test whether northern resident killer whales responded differently to an experimental approach by few boats than to many. Our secondary goal was to provide a quantitative description of whale behavioural data collected across a wider range of traffic conditions (boat number) and with a larger sample of individuals than could be obtained practically using experimental approaches. We use these results to generate hypotheses to be tested in future on the adjacent, but endangered southern resident population.

Methods

Field methods

We collected data from a cliff opposite Robson Bight–Michael Bigg Ecological Reserve (Johnstone Strait, BC, Canada, 50°30′N, 126°30′W), from 1 July through 11 September 2004. We used an electronic theodolite to record locations of boats and whales via a laptop computer

equipped with custom software (THEOPROG: see Williams 2002*a*,*b*).

As whales entered the study area, we selected a focal whale. We identified individual whales by referencing photo-identification catalogues (Ford, Ellis & Balcomb, 2000) and choosing a distinctive focal animal that could be tracked continuously for at least 15 min. Once a focal whale was chosen, we used the theodolite to 'mark', or record, the position of the focal at each surfacing (i.e. the time and position of each breath was recorded). We recorded vessel positions as frequently as possible to plot its trajectory with respect to that of the focal animal. We subsequently refer to each record of at least 20 min of observation of a focal animal as a 'track'. We summarized boat and whale data such that each track was represented only once in the analyses.

Experimental trials versus opportunistic observations

The local whalewatchers had agreed to participate in experiments before the beginning of our study. At the outset of each experimental trial, we requested whalewatchers' cooperation in creating an experimental control phase by remaining farther than 1000 m from the focal whale for *c.* 20 min, and an experimental treatment phase by approaching the focal for a typical whalewatching session for an additional 20 min. The control section referred to the data collected over a continuous 20-min period during which no boat approached the focal whale within 1000 m. The treatment section referred to the 20-min minimum period immediately following this control period in which at least one experimental vessel approached within 1000 m of the same focal animal. Each animal served as its own control, and the control phase always preceded the treatment.

We summarized boat traffic variables for every experimental trial for *post-hoc* categorization into one of two treatment levels based on the number of boats that approached the whale during the experimental section: approach by *few* (1–3) versus *many* (>3) boats (based on the hypothesis generated in Williams *et al.*, 2002*b*).

On most occasions, however, conditions prevented us from manipulating traffic around the focal animal, so-called opportunistic observations. On these occasions, we selected focal animals and measured whale behaviour and boat activity in the same way as described for the experimental trials.

Analysis methods

For each track, we interpolated the number of boats within 100, 400 and 1000 m of the focal whale at the time of each surfacing. Then, we recorded the maximum, inclusive count for each of these radii for each track (called MAX100, MAX400 and MAX1000). Similarly, we recorded the minimum distance ever observed between the focal whale and any boat, referred to subsequently as the point of closest approach (PCA).

We calculated the response variable, the *directness index*, using the methods described in earlier experimental studies published on this population (Williams *et al.*, 2002*a*,*b*). The directness index measures path predictability, and is generated by dividing the distance between end-points of a path by the cumulative surface distance covered during all dives and multiplying by 100. The directness index is a ratio of the diameter of a circuitous path to its perimeter, and ranges from zero (a circular path, where the whale ends up exactly where it started) to 100 (a straight line).

We analysed our data in three ways:

1. *Categorical analysis of experimental data with two treatment levels: few versus many boats:* We used paired, non-parametric tests to assess the significance of behavioural responses of whales to our experimental treatments. For each trial, we calculated the whale's response to the experimental approach. The response data were then placed in two categories: a sample of responses of whales exposed to approach by few (1–3) boats, and a second sample of responses of whales to many (>3) boats approaching. We used the Mann–Whitney *U*-test (Zar, 1996) to assess whether the treatment variable influenced the ranking of each observation of whale behavioural response.
2. *Analysis of experimental trials with one treatment level: boat presence:* We then reran the analyses ignoring the boat number grouping variable, thereby pooling data in an absence–presence framework. We used the Wilcoxon matched-pairs signed-ranks test.
3. *Descriptive analysis of opportunistic data:* We used generalized additive models (GAMs) to describe variation in whale swimming path directness as linear or non-linear functions of both traffic-related and non-traffic-related candidate predictor variables, using a set of objective criteria for adding or dropping terms. GAMs use splines for interpolating between observed data by placing 'knots' automatically at observed data. We used package mgcv for *R* to determine the shape of the relationships between predictors and response using thin-plate regression splines (Wood, 2001). The optimal degree of flexibility that can be justified by the data is estimated in a maximum likelihood framework, while penalizing the model for overparameterization or oversmoothing (Wood, 2001). The higher the estimated degrees of freedom (edf) given to any term in the model, the more flexible that relationship was estimated to be.

We considered the following potential explanatory variables for inclusion in the model: month, time, age, sex, PCA, MAX100, MAX400 and MAX1000. Factor variables were entered as linear or grouping terms. Continuous variables were entered as candidates for smoothing [$s(x)$] by mgcv.

The following summarizes our backward stepwise model specification procedure, which followed the framework proposed by Wood (2001):

1. We fitted a fully saturated model to the data: {DI~month + time + s(age) + sex + s(PCA) + s(MAX100)- s(MAX400) + s(MAX1000)} with the default degree of smoothing (10 knots, 9 edf).
2. We assessed model fit in mgcv, to show coefficients, GCV score, explanatory power (deviance explained) and fit

(residual plots). Term-wise P-values for each coefficient presuppose that the other terms are in the model.

3. For each linear term, we examined whether the parameter coefficient (slope) was near 0 and the significance term near 1. If so, we removed the term to see whether the GCV score decreased and the explanatory power of the model increased. If so, we dropped the term from the model. If no marked improvement was detected by removing the term (or if dropping a term led to a worse fit), then we retained the term in the model.

4. For each smooth model term, we examined whether the estimated number of degrees of freedom was near 1. We evaluated whether the 95% confidence intervals for that term included zero across the range of observations. If so, we dropped the term temporarily, to see whether the GCV score dropped and the explanatory power of the model increased.

5. We dropped a term from the final model if it satisfied all three of the conditions in step 4. If the first criterion was met (edf $\approx$ 1) without satisfying the other two, then we replaced the smooth term with a linear one. If replacing the smooth term with a linear one reduced the model's explanatory power, then we retained it as a smooth term with edf $\approx$ 1.

Finally, we looked at the relationship between the animals' path directness and the number of boats. We conditioned on the selected model describing variation in path directness index, but placed knots manually along the x-axis describing variation in boat number. This allowed us to assess objectively where the curve changed shape, by using Akaike information criterion (AIC) to determine objectively where a node ought to be placed.

Results

Effort and sample size

We collected data on 72 of the 73 days between 1 July and 11 September 2004, representing 792 h of search effort. Whales were present for at least part of the day on 60 of these 73 days. In total, our study represents 73.8 h of continuous observation (i.e. of tracks >20 min in length) of focal animals using the theodolite. We conducted a total of 16 experimental trials. Despite good cooperation from whalewatchers, non-whale-oriented traffic (particularly during a 10-day commercial fishing opening) disrupted dozens of otherwise-suitable control data collection periods. Opportunities to conduct experimental approaches became rare enough that we decided to restrict our trials to males, and excluded one experimental approach of a female from the analyses. We collected a total of 140 opportunistic tracks on 26 focal whales. Of the 16 experimental trials, focal animals were approached (within 1000 m) on eight occasions by 1–3 boats, and by 4–17 boats on the remaining eight occasions.

Responses of whales to experimental approach by few versus many boats

Figure 1 shows the distribution of the response variable during the experimental trials; however, our statistical analyses used non-parametric tests based on ranks, rather than raw data. Whales approached within 1000 m by few (1–3) boats decreased their index of path directness by 14.0 points relative to that observed during preceding, control conditions (from a mean of 82 to a mean of 67.9). Those approached within 1000 m by many (4–17) boats actually increased the directness of their paths on average by 12.9 points than during control conditions (from a mean of 70.9 to a mean of 83.8). These responses differed significantly between treatment levels (Mann–Whitney U test, two-tailed $P = 0.0148$).

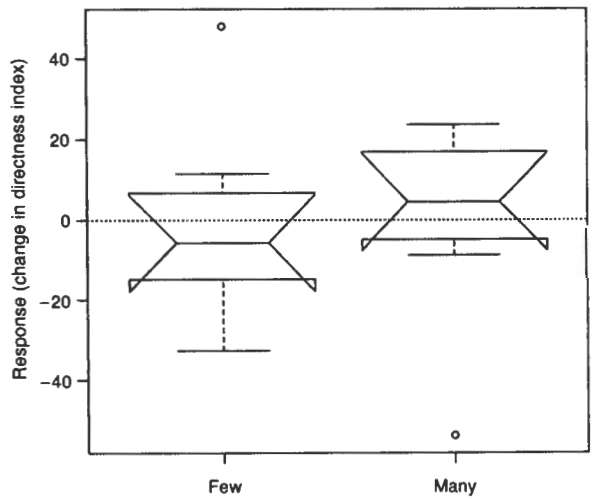

Figure 1 Response (difference in path directness index between the treatment and control phase) by focal male killer whales to experimental approach by few (1–3) versus many (4–17) boats within 1000 m.

We used these data and rearranged the formula for calculating directness index to estimate the distance a whale would have to travel along a circuitous route to cover 100 m of a straight-line distance. In the absence of boats (i.e. a whale displaying a path directness index of 82), a whale would have to swim 122 m (i.e. 100/0.82) along a circuitous path to cover the straight-line distance of 100 m. The same whale, adopting a mean swimming path directness index of 67.9, would have to swim 147 m along a circuitous path to cover the 100 m straight-line distance. The total distance a whale would have to travel in the presence of 1–3 boats represents a 20.7% increase over the total distance it would swim to cover the same ground in the absence of boats. Whales approached by 4–17 boats would actually increase the efficiency of their paths: from 141 m (control) to 119 m (treatment) required to make 100 m of headway.

Responses of whales to experimental approach by any number of boats (i.e. contrasting whale behaviour during absence and presence of boats)

For illustrative purposes, we contrasted behaviour in a simple presence–absence framework by pooling the two

experimental treatment levels. In the absence of boats, the mean path directness index of focal whales was 76.4. When approached by boats (from 1 to 17 boats), the mean directness index was 75.8. This difference was not statistically significant (Wilcoxon's matched-pairs signed-ranks test, two-tailed $P > 0.9999$).

Results of GAM fitting

The model described variability in whale behaviour best as a function of two boat traffic-related (MAX400 and MAX1000) and two traffic-unrelated (month and age) variables (Table 1). The explanatory power of the selected model was good: the model explained 67.7% of the deviance (i.e. residual sums of squares, Wood, 2001). In general, paths became more direct as the season progressed, and as the number of boats within 400 m increased. Age and number of boats within 1000 m entered the selected model as smooth terms, and Fig. 2 shows how directness index related to the smoothed components of these two variables.

The *P*-values listed are approximate, and should be interpreted with caution (Wood, 2001), because they are conditional on all other terms being in the model, the accuracy of the smoothing parameters and any scale parameter estimate. As a result, some model terms were retained even though their *P*-values were >0.05, for the reasons outlined in 'Methods'. Note that a poor model fit was found (as evidenced by patterns in residual plots) when specifying a quasi or gamma distribution in path directness data on a 0–100 scale. This was addressed by standardizing the data – expressing them as a proportion by dividing by 100, so that 0 represented a circular path and 1 a straight line. The response was then modelled in a quasibinomial (maximum likelihood) framework with a logit (1/0) link, which alleviated the patterns that were previously evident in the residual plots.

Table 1 Summary of the selected generalized additive model describing variation in directness index

Family: quasibinomial
Link function: logit
Formula: DI~month + *s*(age) + MAX400 + *s*(MAX1000) − 1

	Parametric coefficients			
	Estimate	SE	*t* ratio	Pr(>|t|)
Month	0.15381	0.01857	8.281	1.1382e–13
MAX400	0.084724	0.09028	0.9384	0.34972
	Approximate significance of smooth terms			
	edf	χ^2	*P*-value	
s(age)	2.04	3.0592	0.22666	
s(MAX1000)	2.784	5.1208	0.14729	
Deviance explained =67.7%			*n*=140	

The terms dropped from the model included sex, time, PCA and MAX100, as well as the intercept.
edf, estimated degrees of freedom.

Using B splines to verify the node between 'few' and 'many' boats

We conditioned on the selected model describing variation in path directness index, but manually placed knots at every observed value of MAX1000. A plot of AIC of the model describing path directness index against the knot position is shown (Fig. 3). AIC was the lowest when the knot was placed at MAX1000 = 3. This provides an objective identification of the optimal placement of the node separating few from many boats.

Discussion

Our study demonstrates a non-linear relationship between the number of boats and the tortuosity of killer whale swimming paths, and confirms an inflection point at approximately three boats approaching a whale within 1000 m. We interpret this as evidence that the whales have identified a way to evade few boats, but abandon that tactic when crowded by multiple boats. These results make sense in the context of turning gambits used by prey to evade faster predators; whales followed the stereotyped evasive tactics around boats that prey species use under predation risk when space is unrestricted, and in which there is nowhere to hide (see Frid & Dill, 2002; Williams *et al.*, 2002*b*). Carefully designed studies are needed to measure how whales interact with their environment, and to quantify the effects of habitat degradation on their viability. Our study offers guidance for design of appropriate vessel impact assessments for southern resident killer whales, for example, and provides, for the first time, an estimate of the number of boats at which northern resident whales shifted avoidance strategies. Here, we show that this effect starts at a relatively low level of traffic – only three boats within 1000 m.

We hypothesize that the behaviour of southern resident killer whales under extremely high traffic conditions will appear similar to that under no-boat conditions, because increasing path tortuosity will cease to be an effective evasive manoeuvre beyond some traffic saturation point. Assessing the role of boat traffic on southern residents directly is problematic, primarily because there are too many boats to allow experimental control over studies. Even if an experiment on southern residents were possible, a variety of factors could lead to a null finding. When we contrasted the path directness under no-boat conditions with those under all boat-present conditions (i.e. conducting a binary analysis by pooling treatment levels), the average response did not differ significantly from zero (Wilcoxon's matched-pairs signed-ranks test, two-tailed $P > 0.9999$). Ignoring the complexity of responses might have led to a false conclusion that boats do not alter the behaviour of killer whales, when in fact, boats altered behaviour in at least two opposing ways. Unfortunately, the complexity and subtlety of demonstrated avoidance responses may require researchers to collect large (and logistically and financially challenging) sample sizes to detect those real effects. Collecting a large sample size on free-ranging cetaceans will be

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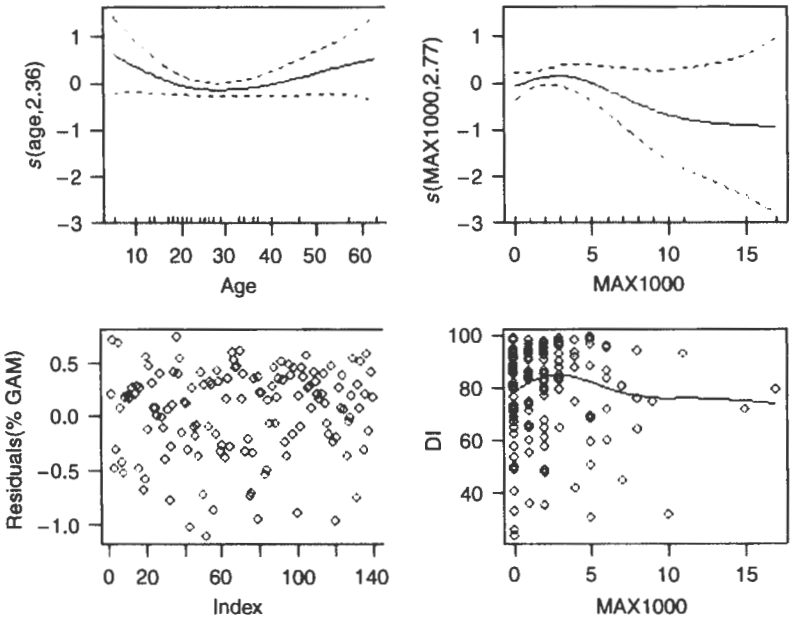

Figure 2 Smooth terms in the selected generalized additive model (GAM; top), residuals (lower left) and the raw data for boat number and directness index (lower right).

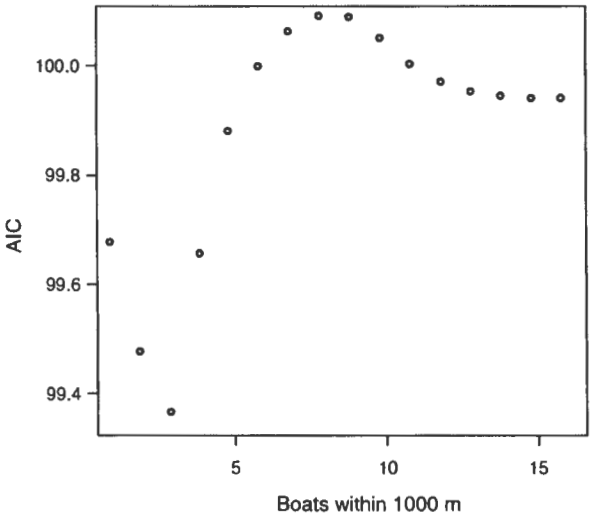

Figure 3 The *x*-axis represents the point at which a knot was placed manually, when fitting a B spline through the opportunistic data, conditional on the selected model (Table 1 and Fig. 2). The *y*-axis represents the Akaike information criterion (AIC) value of that model. AIC was the lowest when a knot was placed manually at MAX1000 = 3.

difficult, so we encourage complementing small experimental datasets with larger opportunistic ones using appropriate statistical modelling methods to control for confounding effects.

Our results also have implications for mitigating the impact of habitat degradation on valued marine predators. One way to alleviate effects is to identify areas of demonstrated importance to the whales, and to close these areas to boats altogether (Lusseau & Higham, 2004). In addition, one will need sensible guidelines for managing whalewatching outside protected areas, and our results suggest that those guidelines should also aim to reduce crowding. In future, we may be able to combine recommendations on approach distance and boat number in the same guideline. Beale & Monaghan (2004) present a model in which cliff-nesting birds perceive people as 'predation-free predators', whereby the perception of predation risk is a function of both the number and proximity of observers. The authors suggest that setting one approach distance is insufficient when the number of visitors is variable. They recommend that large groups of people be kept farther from nesting areas of vulnerable species than small groups, or that approach distances be determined for the largest group of people who are likely to visit the site. Studies on terrestrial mammals have also shown that predator group size may be a good predictor of the behaviour of prey species. The flight initiation distance of Thomson's gazelle was related to the number of predators approaching: gazelles were likely to flee from packs of hyenas at a much larger distance than they did from a solitary predator (Walther, 1969). In the killer whale case, one might design whalewatching guidelines to have different approach distances for different numbers of boats, or to set the overarching set-back distance to the one we would wish all boaters to keep when 120 boats are trying to approach a whale at once.

The risk of predation, whether perceived or actual, strongly influences prey behaviour. These behaviourally mediated, non-lethal or predation-risk effects can form a so-called 'ecology of fear' (Brown, Laundre & Gurung, 1999; Ripple & Beschta, 2004). In the marine environment,

boats may be thought of as introducing artificial habitat structures (albeit temporary, ephemeral ones) into killer whale habitat that may impede locomotion, or increase perceived risk associated with locomotion by making whales more conspicuous to human, predation-free predators. The resulting behaviour becomes a balancing act between what the animals want to do (e.g. evade boats, minimize received noise level from outboard motors; Williams *et al.*, 2002*a*) and what they need to do in this important habitat (e.g. mate or feed; Ford *et al.*, 2000; Williams *et al.*, 2006). Understanding how foraging animals make decisions about their movement patterns will assist us in assessing the consequences of habitat degradation or fragmentation.

Often, when predators and prey are both relatively mobile and there is no spatial refuge for the prey, no clear pattern of relative spatial distribution of predators to prey will result overall (Formanowicz & Bobka, 1989). However, interruptions to the activities of individual animals in terms of increased vigilance can carry costs. Flexible movement patterns can provide animals with adaptive predator responses. For example, small rodents adopted straighter paths in the presence of predators than in their absence (Lagos *et al.*, 1995); subsequent simulations suggested that the information that these animals had about predation risk and the availability of alternative habitat would influence their movement patterns, overall abundance and distribution (Russell, Swihart & Feng, 2003). While individual animals may have options in terms of behavioural plasticity, the decisions that they make about locomotion will affect their fitness. Consequently, summary statistics about swimming paths of killer whales can be informative insofar as they tell us something about how whales cope with disturbance while maximizing their fitness. Recent analyses suggest that these vessel-avoidance activities of killer whales may carry energetic costs (Williams *et al.*, 2006). When exposed to much higher levels of anthropogenic habitat degradation in the form of acoustic harassment devices, resident killer whales abandoned a part of their historic range altogether (Morton & Symonds, 2002). The present study reminds us that habitat degradation is a continuum. Animals make decisions along the way between dealing with small consequences of repeated disturbance (in terms of disrupting prey acquisition in a well-known foraging area, e.g.), to abandoning preferred habitat. Measuring reference points between individual-level disturbance and displacement will help to ensure that population-level effects are mitigated before they occur.

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Effects of vessels on behaviour patterns of individual southern resident killer whales *Orcinus orca*

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ABSTRACT: Southern resident killer whales numbered only 84 ind. in 2004. Disturbance by vessels may be a factor in the population's endangered status. To determine the importance of this factor, we compared behaviour in the presence and absence of vessels from 2003 to 2005 at 2 different sites along San Juan Island, Washington State, USA. Theodolite tracks were summarised in terms of swimming path directness and deviation indices, travel speed, and rates of respiration and surface active display behaviours. Vessel number and proximity were used in a generalised additive modelling framework as candidate explanatory variables for differences in whale behaviour, along with natural factors. Path directness varied with number of vessels and proximity to vessels. The increased distance that whales travelled in the presence of vessels could have resulted in increased energy expenditure relative to whales that could rest while waiting for affected whales to catch up. The likelihood and rate of surface active behaviour varied with number of vessels. Number and proximity of vessels were also related to variability in respiratory intervals, path deviation index and swimming speed. The high proportion of time that southern resident killer whales spend during summer in proximity to vessels raises the possibility that the short-term behavioural changes reported here may have biologically significant consequences.

KEY WORDS: Whale watching · Killer whale · Disturbance · Behavioural disruption · Ecotourism

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INTRODUCTION

The eastern North Pacific 'southern resident' stock of killer whales *Orcinus orca* declined to a low of 79 individuals in 2001 (van Ginneken et al. 2002). The population experienced a 20% decline between 1996 and 2001, which resulted in their listing as 'depleted' under the US Marine Mammal Protection Act, and 'Endangered' under the US and Washington State Endangered Species Acts and Canada's Species at Risk Act (Krahn et al. 2004, Wiles 2004, US Fish and Wildlife Service 2005, Fisheries and Oceans Canada 2008). The causes of this decline are uncertain, but candidate explanations include reduction in prey resources, presence of toxic chemicals and disturbance from vessel traffic. Vessel traffic may have contributed to the decline through a variety of mechanisms, including collisions, toxins from unburned fuel and exhaust, stress, and reduced foraging efficiency due to masking of echolocation signals. Short-term behavioural responses by whales to boats may result in increased energy expenditure, or disrupt feeding activity, which may reduce energy acquisition (Williams et al. 2006, Lusseau et al. 2009). Energetic mechanisms for impact

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are of particular concern because southern resident killer whales may be food-limited (Fisheries and Oceans Canada 2008).

Behavioural responses of cetaceans to vessel traffic vary within and between species, and include changes in respiration patterns, surface active behaviours, swimming velocity, vocal behaviour, activity state, inter-individual spacing, wake riding, approach and avoidance, and displacement from habitat. Studies on killer whales have shown that boats can elicit a number of short-term behavioural responses. Experiments conducted on the adjacent northern resident killer whale population showed that whales adopted less predictable paths in the presence of vessels than they were following before the boat arrived (Williams et al. 2002a,b). For southern resident killer whales, even subtle behavioural responses to boats have not been reported in the primary literature. This is a critical area of study because the San Juan and Gulf Island waters have high levels of vessel traffic and these whales are in the presence of vessels (including those not focused on whale watching) during much of the day. In terms of the candidate explanations for the decline, vessel traffic is a priority research topic because it is the factor that lends itself most readily to management and mitigation. This study addresses relationships between vessel activity and southern resident killer whale behaviour.

MATERIALS AND METHODS

Field methods. From 28 July to 30 September 2003, 1 May to 31 August 2004, and 15 May to 31 July 2005, a land-based team of observers monitored behaviour of whales and activity of boats from 2 study sites (Fig. 1). The 'North Site' was located at 48° 30.561′ N, 123° 8.494′ W at an altitude of approximately 99 m above mean lower low water. The 'South Site' was located at Mt. Finlayson (48° 27.421′ N, 122° 59.401′ W), near the southeast tip of San Juan Island. The South Site was located at a height of 72 m and the view of the eastern portion of Juan de Fuca Strait was unobstructed. The theodolite height was determined using the method of Williams et al. (2002a,b). We chose the combination of these 2 sites so as maximize sample size. For the 3 study periods combined, data were obtained on 128 d over approximately 9 mo in the field.

Theodolite tracking of focal individuals and boats. Two land-based teams of observers were established between the 2 study sites to maximise sample size. The teams recorded boat and whale positions and activity using a Pentax ETH-10D theodolite interfaced to a personal computer running Theoprog (Williams et al. 2002a,b, Williams & Ashe 2007), a Bushnell 40× spotting scope, binoculars, and a mini-DV camera (DeNardo et al. 2001).

As whales entered the field of view from a study site, a focal individual was selected and indentified by comparing natural markings identified to a published photo-identification catalogue compiled by the Center for Whale Research (e.g. van Ginneken et al. 2002, with annual updates). Whales were tracked for at least 800 s because short observation sessions have been shown to yield biased estimates of respiration rate (Kriete 1995). After a tracking session was completed, a new focal individual was selected, when possible. Individuals were selected haphazardly, but were drawn as evenly as practicable from all pods, age, and sex classes. Observers chose individuals that would not be confused with other individuals nearby and that were sufficiently close to shore to be accurately identified (typically within 3 km). The theodolite was used to record position of the focal individual at the time of every surfacing. The spotting scope and computer operators, who had a wider field of view, watched for surfacings missed by the theodolite operator, to ensure an accurate record of respiration rate and surface active behaviour. While the focal whale appeared to be on a long dive, the theodolite operator recorded vessel positions. During periods of intense vessel activity, a second theodolite team tracked only vessels, so that the primary theodolite operator could focus solely on measuring whale behaviour (the top priority). While the theodolite operator recorded the position of boats, the spotting scope operator scanned for the whale; the probability of missing a surfacing was expected to be low overall, but did not vary with traffic level.

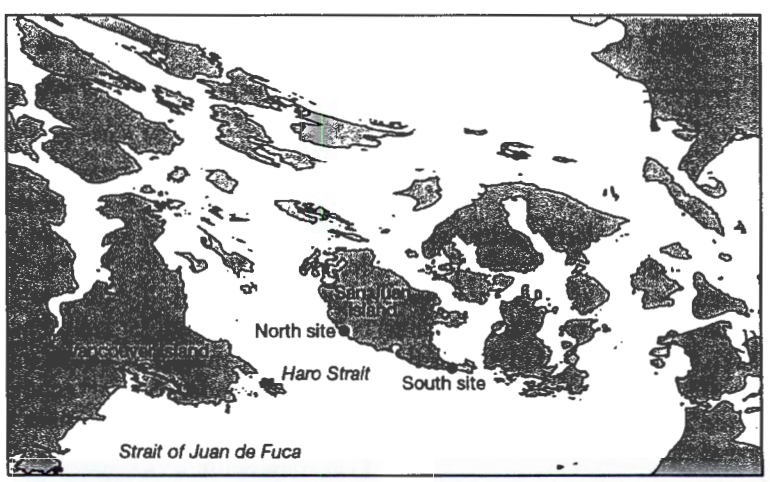

Fig. 1. Study area showing the North and South theodolite sites (●)

In addition to recording positions of boats and whales, activity states, behavioural events (e.g. respirations and surface active behaviours such as breaches) and other notes about data entry errors or boat and whale activities were recorded (Williams et al. 2002a,b). Boat and whale data were summarised for each track so that each track was represented only once in the analyses.

Statistical analysis. Independent variables included those related to: Time (YEAR, MONTH); Location (SITE); Oceanographic Conditions (tide height, TIDE) and magnitude and direction of current (CURRENT); Focal Animal (AGE, SEX, POD); and Vessel Traffic (Point of Closest Approach [PoCA], Overall Boat Count within the field of view [BOATS]); number of boats within 100, 400 and 1000 m of the focal whale (SUM100, SUM400 and SUM1000, respectively). These variables are largely self-explanatory, but calculation of vessel-related candidate explanatory variables is described in greater detail in Williams et al. (2002a,b) and Williams & Ashe (2007). The terms YEAR and SUM100 entered the model as factors, because relatively few levels of the variables were observed. Other factors in the model included SITE, SEX and POD. All other terms entered the model as continuous covariates.

Dependent (i.e. whale response) variables were calculated using methods described previously (Williams et al. 2002a,b, Williams & Ashe 2007) and included: (1) Inter-breath interval or dive time, respiration analysis (RESP) — a mean time between breaths was calculated (in s) for each track. Only tracks lasting more than 800 s were included in the analysis to ensure the data reliably reflected the ongoing breathing pattern (Bain 1986, Kriete 1995); (2) Swimming speed (SPEED): The average swimming speed (reported in km h^{-1}) of the whale was obtained by dividing the total surface distance travelled by the duration of the tracking session.

Two measures of path predictability were calculated: a directness index (DI) and a deviation index (DEV). DI estimates path tortuosity (or its inverse, linearity) on the scale of an entire tracking session, and is generated by dividing the distance between end points of a path (i.e. crow's flight distance) by the cumulative surface distance covered during all dives and multiplying by 100. DI is the ratio of the diameter of a path to its perimeter, and ranges from zero (a circular path) to 100 (a straight line). DEV estimates path tortuosity (or its inverse, smoothness) on the scale of adjacent surfacings. For each surfacing in a track, we calculated the angle between the path taken during a dive and the straight-line path predicted by the dive before it. DEV is the mean of the absolute value of these discrepancies in degrees (potentially ranging from 0 to 180), during the entire track.

Surface active behaviour (SAB) was modelled in 2 ways: the rate at which bouts occurred, and the probability that a bout would occur in a track. The rate of SAB was determined by recording each time that surface-active events such as spy-hopping, tail-slapping or breaching occurred, and presenting this as an average rate of events expected per hour. The occurrence of SAB (SAB.1.0) was determined by recording each time that surface-active events occurred and presenting this as a binary (yes-no) response variable.

Analysis of theodolite data from focal individuals. We modelled whale behaviour using generalised additive models (GAMs) in the multiple generalised cross-validation package (mgcv) for program R (Wood 2001, 2006). The GAM framework was chosen because it allowed us to incorporate continuous and categorical explanatory variables, response variables from non-normal distributions, and because some of the relationships between explanatory and response variables were expected to be non-linear (Williams & Ashe 2007). The mgcv package allows GAMs to be fitted in R using regression splines for the smooth terms of each explanatory variable, with each spline carrying a penalty for excessive flexibility (Wood 2001, 2006). All models were fitted using the cubic regression spline basis, which is recommended for cases where the ratio of variables to observations is large or where convergence problems are expected (Wood 2006). Flexibility was determined by the number of 'knots' (approximately one higher than the estimated degrees of freedom, edf) for each model term, between which the functional, or smoothed, relationship was modelled. The amount of flexibility given to any model term was determined by minimising the generalised cross-validation (GCV) score of the whole model (i.e. given the other terms in the model). The GCV score penalises models for being over-parameterised.

The default smoothing value used for splines was the default value set by package mgcv, 10 knots in each spline, corresponding to 9 df (Wood 2001), with an additional penalty (gamma = 1.4) to prevent oversmoothing, which is recommended in cases with relatively few observations per variable (Wood 2006). The shape of the smooth terms in the GAM was solved as a likelihood maximisation problem using penalised iteratively reweighted least squares (Wood 2006). In the case of cubic regression splines, knots are placed evenly throughout the covariate values, with values connected between knots by sections of cubic polynomials.

Histograms of the response variables were used to determine the appropriate family distribution and link function. All response variables were bounded by zero (i.e. subject to the constraint that they could not be negative) and most showed evidence of skew. Given that some were derived variables so that their underly-

ing distributions were unknown, the models were fitted using quasi frameworks which estimated the dispersion parameter in a maximum likelihood framework (in contrast to the degree of smoothing, which was estimated using penalised iterative least squares). The following summarises our model specification procedure adopted for each of the response variables, *Y*, during this study, using the framework proposed by Wood (2001):

(1) A fully saturated model was fitted to the data: Y ~ YEAR + s(MONTH) + SITE + POD + s(AGE) + SEX + s(TIDE) + s(CURRENT) + s(PoCA) + s(BOATS) + SUM100 + s(SUM400) + s(SUM1000), with the default degree of smoothing (10 knots, 9 df).

(2) Model fit was assessed using the summary.gam and plot.gam functions in mgcv, which showed coefficients, GCV score, explanatory power (deviance explained) and fit (residual plots).

(3) For each linear term, we examined the parameter coefficient (slope) to see whether it was near 0 and the significance term to see whether it was near 1. If so, the term was removed to see whether the GCV score decreased and the explanatory power of the model increased. If both criteria were fulfilled, the term was dropped from the model. If no improvement was detected by removing the term, then it remained in the model.

(4) For each smooth model term, the estimated number of df was examined to see if it was near 1. We examined the 95% CIs for that term to see whether they included 0 across the range of observations. If so, the term was dropped temporarily, to see whether the GCV score dropped and the explanatory power of the model increased.

(5) A term was dropped from the final model if it satisfied all 3 of the conditions in Step 4 (i.e. edf ≈ 1; 95% CIs include 0 across range of *x*; and dropping the term decreased the GCV score and increased the deviance explained). If the first criterion was met (edf ≈ 1), but not the other 2, then the smooth term was replaced by a linear term.

These guidelines for including or dropping terms are particularly well suited for cases in which multicollinearity in explanatory variables is suspected (Wood 2001). Correlations between explanatory variables require that the evaluation of whether to drop a model term (Step 5) be conducted one at a time, starting with the variable that has least support from the data for inclusion in the model (i.e. p nearest 1). We did explore the use of generalised additive mixed-effects models (GAMMs, Wood 2006) in which individual identity was treated as a random effect, but in all cases explanatory power (deviance explained) of any given model was approximately an order of magnitude lower than it was for its GAM counterpart. In other words, there was evidence from the data that substantial within-individual variability existed and insufficient support from the data to justify including individual identity as a covariate.

Plots were produced for all selected models (see Figs. 2 to 7) using the plot.gam function in mgcv. The *x*-axis for each plot contains a rugplot, in which small ticks mark locations of observations. On the *y*-axis 0 corresponds to no effect of the covariate on the estimated response, values above 0 indicate positive correlation, while values below 0 indicate negative correlation. The *y*-axis is labelled *s*(covariate name, estimated df) indicating that the curve is smoothed. The dashed lines represent ±2 SE, or roughly 95% CI.

RESULTS

Theodolite tracking of focal individuals

We collected 42 tracks in 2003, 77 tracks in 2004, and 67 tracks in 2005 that were of sufficient quality and duration to use in the analysis (Table 1). Roughly 50% of the individuals in the population were sampled at least once during the 3 seasons. Whales were tracked for an average of 25.2 min over 2.6 km. Only 25 tracks met the criteria for no-boat observations (2 in 2003, 19 in 2004 and 4 in 2005, Table 1).

Results of GAM-based analyses of focal animal behaviour

RESP. The model that fitted the respiration data best included 2 vessel traffic variables (SUM400 and BOATS) and 1 whale-related variable (AGE) (Table 2, Fig. 2). The model described the variation in mean respiratory interval reasonably well, in that it was able to account for 25.7% of the deviance. One traffic variable (SUM400) entered the model as a smooth term, while the other (BOATS) entered the model as a linear term.

As the number of boats increased, the inter-breath interval showed a significant tendency to decrease (Table 2). Note that coefficients for linear terms are on the scale of the units of the original variables, so it is not possible to compare the magnitude of the effect of boat number and proximity by comparing the magnitudes of coefficients in Table 2 (because the former is measured in counts, while the latter is measured in m).

Dive times tended to be shorter when few boats were present within 400 m of the focal whale, and increased as number of boats increased (Fig. 2). When >8 boats were present within 400 m, mean inter-breath interval declined, but this relationship became non-significant (i.e. CIs comfortably spanned 0) with large numbers of boats (8 to 14).

Table 1. *Orcinus orca*. Sample size of theodolite tracks

Parameter	Sample size (no. of tracks) 2003	2004	2005	Total
Study site				
North	28	52	47	127
South	14	25	20	59
Month				
May	0	33	14	47
June	0	13	27	40
July	4	19	26	49
August	16	12	0	28
September	22	0	0	22
Track duration (min)				
13.3–20	15	27	16	58
>20	27	50	51	128
Sex of focal animal				
Female	7	39	16	62
Male	27	38	41	106
Unknown	8	0	10	18
Pod of focal animal				
J	8	44	19	71
K	4	9	11	24
L	21	24	26	71
Unknown	9	0	11	20
Traffic (no. of unique boats in theodolite track)				
0	2	19	4	25
1	2	2	10	14
2	0	4	2	6
3	3	6	3	12
4	1	6	2	9
5	6	2	2	10
6–10	17	15	13	45
11–15	6	11	16	33
16–20	1	3	4	8
21–25	2	2	9	13
26–30	2	3	1	6
31–35	0	1	0	1
36–40	0	1	1	2
41–45	0	2	0	2
Minimum no. of focal individuals sampled[a]	13	34	24	45
Total	42	77	67	186

[a]ignoring unknowns

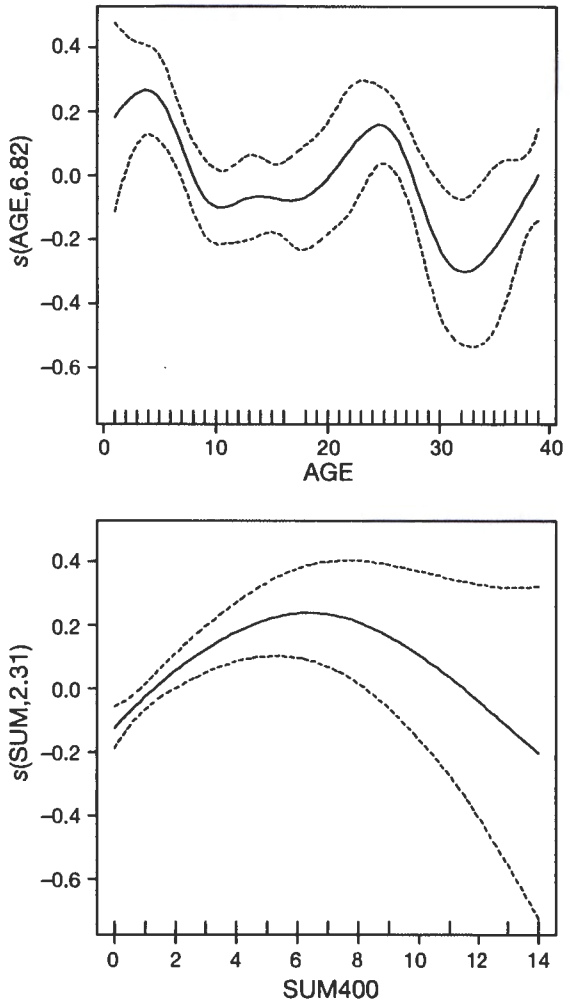

Fig. 2. Relationships between smoothed component (solid line) of the explanatory variables (*x*-axis) used in the fitted generalised additive model and the response variable, mean-time between breaths (RESP). The *x*-axis for each plot contains a rugplot, in which small ticks mark locations of observations. On the *y*-axis, 0 corresponds to no effect of the covariate on the estimated response, values >0 indicate positive correlation, while values <0 indicate negative correlation. The *y*-axis is labelled *s*(covariate name, estimated df) indicating that the curve is smoothed. SUM400: number of boats within 400 m of the focal whale. Dashed lines: ±2 SE, or roughly 95% CI

SPEED. The selected model included only the maximum number of boats within 400 m of the focal animal (Table 2, Fig. 3). The model was able to account for only 7.3% of the deviance. The non-linear relationship between swimming speed and MAX400 was fairly flat until the number of boats within 400 m reached approximately 8, at which point swimming speed increased (Fig. 3).

DI. The model that fitted the path DI data best included 2 vessel-related variables (PoCA and BOATS), as well as AGE (Table 2, Fig. 4). The model demonstrated weak power to describe variation in DI, amounting to only 5.8% of the deviance explained. The variables BOATS and PoCA entered the model as linear terms with positive slope. Fig. 4 shows the non-linear relationship between AGE and DI. While the CIs span 0 across the range of AGE, model fit was improved by retaining this term.

DEV. The model that fitted the path DEV data best included 1 boat-related variable (BOATS), 1 whale-related variable (AGE), and 1 environmental variable (TIDE). Model fit was improved by dropping the intercept term. The model demonstrated weak power to describe variation in DEV, amounting to only 6.6% of

Table 2. *Orcinus orca*. Summary of selected models describing whale behaviour as linear and smooth functions of covariates. Model terms are described in 'Materials and methods.' Each row represents a candidate explanatory variable, and each column represents a response variable. The value in each cell represents the slope of linear terms (numbers) or the degree of smoothing (*s*[estimated degrees of freedom]) for smooth terms that were included in the model. Note that coefficients for linear terms are on the scale of the units of the original variables. Significance of each model term: •••p = 0–0.001; ••p = 0.001–0.01; •p = 0.01–0.05; p = 0.05–0.1; no symbol, p > 0.1; (–) term dropped from the model; N: sample size for the model

	RESP	SPEED	DI	DEV	SAB	SAB.1.0
Intercept	4.04 •••	1.85 •••	–0.38 •••	–	–	–
YEAR	–	–	–	–	–	–
SITE	–	–	–	–	–	–
MONTH	–	–	–	–	0.181 •••	–
POD	–	–	–	–	–	–
SEX	–	–	–	–	–	–
AGE	*s*(6.82) •••	–	*s*(1.72)	*s*(1.96) •	–0.027 •	–
TIDE	–	–	–	–0.001 •	*s*(3.41) ••	–
CURRENT	–	–	–	–	–	*s*(7.64)
SUM100	–	–	–	–	–	–
SUM400	*s*(2.31) •••	*s*(4.75) •	–	–	*s*(2.66)	*s*(2.69)
SUM1000	–	–	–	–	–	–
PoCA	–	–	3.6e–5 •	–	–	–0.003 •
BOATS	–0.0132 ••	–	0.0068 •	–0.01 •	–	–0.065 ••
Family	Quasi	Quasi	Quasi	Quasi	Quasipoisson	Quasibinomial
Link function	Log	Log	Log	Log	Log	Logit
Deviance explained (%)	25.7	7.30	5.80	6.60	20.20	14.30
N	153	153	185	186	153	153

the deviance explained. BOATS entered the model as a linear term with negative slope, indicating that whales exhibited relatively smooth paths when few boats were observed close to the whale and more erratic paths when many boats were present (Table 2). The effect of TIDE on path deviation suggests that there may be something of ecological importance (perhaps foraging activity) reflected in these data and warrants further attention.

The smooth term relating DEV to AGE in the selected model is shown in Fig. 5. The spline shows weak evidence that swimming paths showed a non-linear relationship with AGE; however the CIs span 0 across a wide range of AGE. The term was retained because dropping it increased the GCV score and reduced the model's explanatory power.

Rate of SAB. The results for SAB are shown in Table 2 and Fig. 6. The model that best fitted the SAB

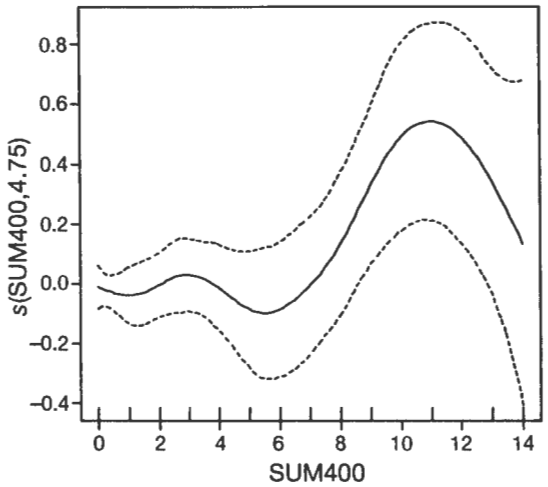

Fig. 3. Relationship between smoothed component (solid line) of the explanatory variable (*x*-axis) used in the fitted generalised additive model and the response variable, swimming speed (SPEED). SUM400: number of boats within 400 m of the focal whale. Dashed lines: ±2 SE (roughly 95% CI). For further information see Fig. 2

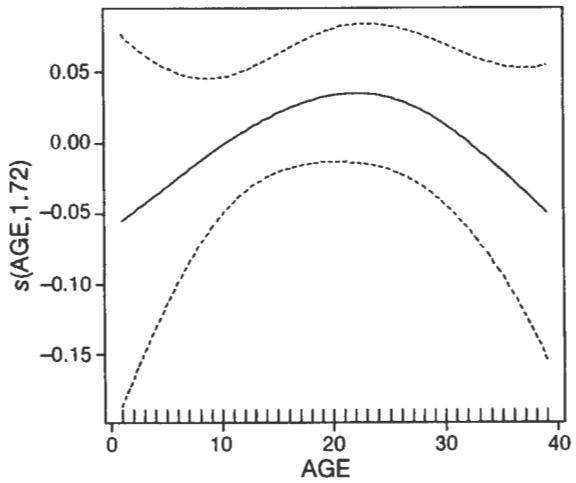

Fig. 4. Relationships between smoothed component (solid line) of the explanatory variable (*x*-axis) used in the fitted generalised additive model and the response variable, path directness index (DI). AGE: age of the focal whale. Dashed lines: ±2 SE (roughly 95% CI). For further information see Fig. 2

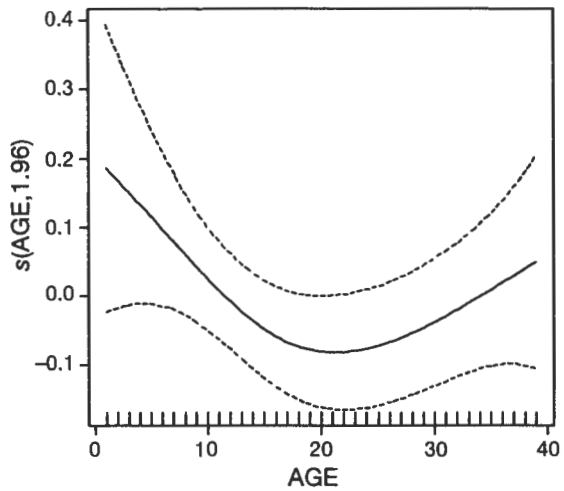

Fig. 5. Relationship between smoothed component (solid line) of the explanatory variable (*x*-axis) used in the fitted generalised additive model and the response variable, path deviation index (DEV). AGE: age of the focal whale. Dashed lines: ±2 SE (roughly 95% CI). For further information see Fig. 2

data included only 1 vessel traffic variable (SUM400), but also TIDE, MONTH and AGE (Table 2, Fig. 6). Model fit was improved by dropping the intercept term. The model demonstrated modest power to describe variation in rates of SAB, amounting to 20.2% of the deviance explained. Analysis suggests that rates of SAB declined with AGE, but increased as the season progressed (MONTH). The effect of boats (SUM400, Fig. 6) was non-linear; SAB was highest when boats were absent, low when intermediate numbers of boats approached the whale within 400 m (SUM400), and higher again with large numbers of boats. Note, however, that the CIs spanned 0 across much of the range (Fig. 6). The non-linear effect of TIDE on rate of SAB suggests that there may be something of ecological importance (perhaps foraging activity) reflected in these data (with very high rates of SAB observed at the highest tides) and warrants further attention.

SAB.1.0. The results for SAB.1.0 are shown in Table 2 and Fig. 6. Model fit was improved by dropping the intercept term. The model demonstrated modest power to describe variation in the probability that a bout of SAB would or would not occur, amounting to 14.3% of the deviance explained. The analysis of SAB.1.0 suggests surface active events were most likely to occur when the number of boats within 400 m of the whale was small (SUM400; Fig. 7), although the CIs spanned 0 across much of the range. The probability of bouts of SAB occurring was negatively related to both PoCA and BOATS, indicating that surface active events were less likely to occur as boat number increased, but more likely to occur as boats got closer to the whale.

The non-linear effect of CURRENT on the SAB.1.0 suggests that there may be something of ecological importance (perhaps foraging activity) reflected in these data (with very high probability of SAB occurring observed at the strongest ebb current) and warrants further attention.

Age was not a factor in SAB.1.0, perhaps suggesting that the probability of engaging in SAB is equal for all age classes, but that younger animals tend to be more active once they get started. Similarly, pods may be equal in their probability of initiating a bout of SAB, but differ in the number of events performed once a bout is initiated.

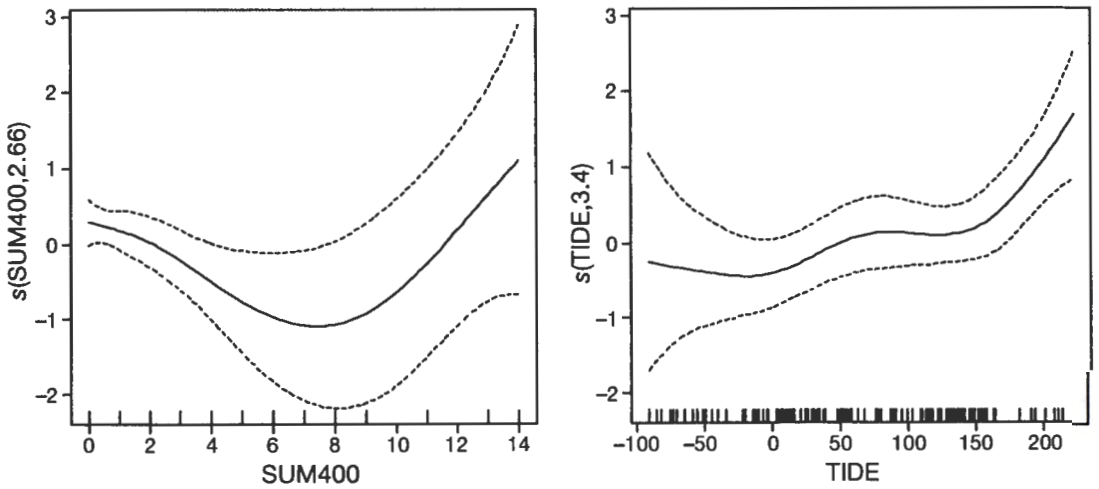

Fig. 6. Relationships between smoothed components (solid line) of the explanatory variables (*x*-axis) used in the fitted generalised additive model and the response variable, rate of surface active behaviour (SAB). SUM400: number of boats within 400 m of the focal whale. TIDE: tide height. Dashed lines: ±2 SE (roughly 95% CI). For further information see Fig. 2

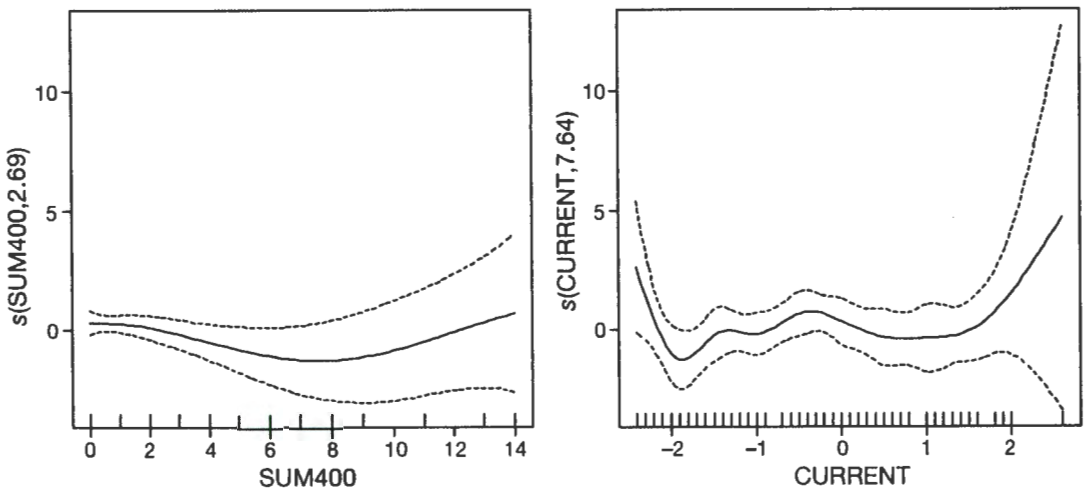

Fig. 7. Relationships between smoothed components (solid line) of the explanatory variables (*x*-axis) used in the fitted generalised additive model and the response variable, probability of a bout of surface active event occurring (SAB.1.0). SUM400: number of boats within 400 m of the focal whale. CURRENT: direction of current. Dashed lines: ±2 SE (roughly 95% CI). For further information see Fig. 2

DISCUSSION

Despite a model specification approach that penalised over-parameterisation, all 6 models fitted the killer whale behaviour data better with boat variables included than when boat variables were excluded. The models lend support to the conclusion that boats exerted a small but significant effect on behaviour of southern resident killer whales in 2003 to 2005, and that the relationships were complex and often non-linear.

Williams et al. (2002b) and Williams & Ashe (2007) suggested that vessel number and vessel proximity were different dimensions of vessel traffic, and that a killer whale's response to changes in vessel number is likely to occur independently of its response to changes in proximity, and vice versa. As such, an increase in proximity need not have the same effect as an increase in number. This study supports that suggestion. In all 6 cases, SUM100 and SUM1000 were dropped from the models, while SUM400 was retained in 4 of 6 cases. Similarly, PoCA was retained in only 2 of 6 models, but in both cases in which the term was retained, it offered little explanatory power (Table 2).

We also observed several non-linear effects of boat traffic on whale behaviour. Qualitatively, it appeared there was a baseline distribution of behaviour when boats were absent, a trend with intermediate numbers of boats (from 1 to about 3 vessels), and the opposite trend when the number of vessels was large (>10).

The complexities described above may account for inconsistencies among studies, many of which simply compared a vessel-present to a vessel-absent condition. Williams & Ashe (2007) demonstrated experimentally that the response of northern residents to approach by few (1 to 3) boats was opposite to that of many (4 to 17) boats, and that the average of these opposing responses would be statistically indistinguishable from no response. In southern residents, our results suggest that the number of boats within 400 m of the focal whale helped explain much of the variability in whale behaviour (SUM400 appeared in 4 of our 6 models), but current guidelines for this population focus more on proximity than crowding (although proximity appeared in only 2 of our 6 models).

The relationships between path directness and vessel traffic have appeared consistently in studies such as the present one (Williams et al. 2002a,b, Williams & Ashe 2007). These patterns are consistent with whales making concerted efforts to evade boats: swimming paths became less direct as boats approached close to the whales, but more direct as number of boats increased (Table 2). Our analyses confirmed that both vessel number and proximity were significant factors, even after taking natural factors into account. Altering swimming paths may lead to an increase in energy expenditure if the decreased DI results in an overall increase in time spent travelling over time spent resting (Williams et al. 2006).

The path DEV decreased as the number of boats increased (Table 2). This is consistent with previous multiple-vessel experiments that demonstrated that avoidance responses which are effective with few boats may not be effective with many boats (Williams & Ashe 2007). The DEV would be expected to be relatively high during socialising and foraging, and TIDE was a natural factor correlated with DEV. Felleman et

al. (1991) suggested that foraging strategies of whales should take into account current-related movements of their salmonid prey. This relationship merits additional investigation.

Reported changes in breathing patterns as a function of boats have been inconsistent. The GAM analysis suggests that inter-breath interval increases with increasing vessel number when the number of vessels is small (from 1 to about 6 vessels), but decreases when the number of vessels is large (up to 12 vessels). This U-shaped response pattern may account for the inconsistent results reported in various studies. There may be alternative tactics employed that vary depending on vessel number and proximity (Williams & Ashe 2007). Vessel proximity did not enter directly as a factor, although boat counts at different distances entered separately, suggesting that proximity has some relevance. It is possible that this index is more sensitive to distances throughout the track relative to brief close approaches than other indices are, or that respiration rate (as a physiological variable) may be more strongly related to swimming speed and activity level than boat traffic. Additional data will be needed to confirm whether the result reported here is robust in a wider range of conditions.

Changes in SAB have been significant in many studies, although the direction of the change varies from one study to another. Our results suggest the inconsistency may be due to differences in methodology. For example, our work and that of Williams et al. (2002b) suggest that SAB is maximised when 1 or a small number of boats approach closely, but SAB may be inhibited by other configurations of vessels. Data collected when boats are primarily in an inhibitory configuration may find that vessels reduce rates of SAB. Alternatively, studies that pool all configurations may find no effect (Williams & Ashe 2007).

The analysis is further complicated by the relationship between track duration and measured values. Analysis of rates may need to be limited to longer tracks than some of those used here. Longer tracks would also be helpful for one-zero sampling, as that would allow the subdivision of tracks into multiple short segments. The tendency of SAB to occur in bouts, along with the fact that SAB is a somewhat artificial class composed of behaviour patterns (breaching, spyhopping, tail-slapping, etc.) with a wide-range of functions, make it difficult to address these behaviour patterns with statistical rigour. Nonetheless, the increased probability of SAB occurring in the presence of vessels appears robust, as the effect is large and present in numerous datasets.

One could speculate that threat displays consisting of SABs such as breaches, slaps, and fluke lifts (Tavolga 1966, Norris et al. 1994, Lusseau 2006a,b) increased when vessels were close but not close enough to trigger an escape response. At greater distances, SAB could be reduced to avoid attracting the attention of vessel operators. Baseline rates would reflect the use of SAB for purposes independent of vessels such as communication, foraging, and non-communicative behaviour. Some SABs, such as breaching, require increased energy expenditure, so this variable should be considered when calculating cumulative effects.

The trend in swimming speed with respect to vessel traffic has been inconsistent across studies (e.g. contrast Kruse 1991 with Williams et al. 2002b). The GAM analysis suggested that the number of boats within 400 m could be important. Given the potential for changes in swimming speed to carry energetic costs to whales, as well as reflecting their physical condition, the factors influencing swimming speed deserve more careful assessment.

Felleman et al. (1991) found that resident killer whales were approximately equally likely to be oriented with, against or non-oriented with respect to tidal currents. However, killer whales were found to change their direction of travel most often near slack tide; they were 7 times more likely to change direction within an hour of slack tide than one would expect from chance (Felleman et al. 1991). Although TIDE and CURRENT were dropped from our models of RESP, SPEED and DI, these oceanographic variables were included in models describing variability in DEV and SAB. One interpretation of this finding is that SABs vary inconsistently with boat traffic, but play an important role in foraging ecology of resident killer whales.

The results reported here exhibit similarities and differences with other species. Variation in behavioural responses with boat proximity appears to be relatively common (Nowacek et al. 2001). Increases in travel and SAB are also commonly found. In contrast, measures of swimming speed have varied among species and among studies within species, with some studies reporting increases (*Orcinus orca*: Kruse 1991; *Tursiops truncatus*: Nowacek et al. 2001), some reporting no change (*O. orca*: present study; *Globicephala macrorhynchus*, *Stenella coeruleoalba*, *Steno bredanensis*: Ritter 2003), and some reporting both increases and decreases depending on vessel speed (*Stenella frontalis*, *T. truncatus*: Ritter 2003). Some species show increased dive times as reported here (e.g. *Eschrichtius* sp.: Sumich 1983), while other species shorten dives in the presence of boats. Some species are displaced from regions by vessels (e.g. *Tursiops* spp.: Allen & Read 2000, Bejder et al. 2006), in contrast to resident killer whales, which continued to use the same range in the presence of vessels.

The present study found evidence of small but statistically significant changes in behaviour in the pres-

ence of vessels. At first glance, these findings raise philosophical questions about the use of advanced statistics in detecting disturbance. If the detection of vessel effects requires such delicate methodology, are these effects really worth mitigating against? In practice, scientists and managers would be more comfortable if management decisions were based on the results of experiments conducted on northern residents. However, this system is now so heavily saturated by boats (Table 1) that experiments are all but impossible, and relatively sophisticated modelling frameworks were required to cope with confounding effects and estimate partial contribution of boat traffic to describing whale behaviour. The fact that models fitted the data better with boat variables than without, despite penalties for over-parameterisation, indicates that such anthropogenic impacts are real. It remains a management decision to evaluate whether effect sizes are large enough to warrant regulations for vessel operation near killer whales. Given the small population size, the endangered status of the population, and the suggestion that boat traffic can disrupt feeding activities of resident killer whales (Williams et al. 2006, Lusseau et al. 2009), it seems reasonable to us to err on the side of caution when managing boat traffic around southern resident killer whales. Given suggestions that this population may be food-limited (Fisheries and Oceans Canada 2008), minimising boat traffic around whales may also improve foraging efficiency by reducing masking effects of boat noise on echolocation (Bain & Dahlheim 1994). Clearly, managing boat traffic around whales does not address prey limitation or toxic contamination, but unlike these potentially larger problems, boat traffic is a demonstrated threat that lends itself to immediate mitigation.

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FRIENDS
OF THE SAN JUANS

Protecting the San Juans since 1979

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

By E-mail

September 20, 2017

Ms. Julie Thompson
San Juan County Community Development and Planning Department
P.O. Box 947
Friday Harbor, WA 98250
JulieT@sanjuanco.com

Re: Shoreline Substantial Development Permit PSJ000-17-0003
SEPA Comments on Mitigated Determination of Non-Significance for Dock and Desalination Facility

Dear Ms. Thompson:

Friends of the San Juans ("Friends") respectfully submits the following comments to request that San Juan County ("County") withdraw the Mitigated Determination of Non-Significance ("MDNS") that it issued for the third version of a dock proposal and first request for desalination permit, Shoreline Substantial Development Permit No. PSJ000-17-0003 ("Application"). The third version of the Application seeks: (1) a larger dock than the second version, at 260 feet in length and 1,729.8 square feet in overwater coverage; (2) a navigational warning buoy; and (3) a desalination facility that would withdraw up to 12,068 gallons of seawater per day and discharge over 9,000 gallons of brine per day. Like the 2014 and 2015 applications for the dock, the Application offers ample text about the project, but also like those applications, it fails to adequately analyze the potential impacts that the project would cause, instead concluding summarily that it would not result in significant adverse impacts.

Although the MDNS proposes several conditions that might prevent the project from maximizing its impacts, those measures expressly apply to just the

construction of the facilities, and do not protect against operational impacts.[1] It is puzzling that the MDNS issued in the absence of information to address several of the omissions that the County identified when it withdrew its MDNS for the 2015 application of a smaller dock, including:

- Lack of monitoring and mitigation plan for eelgrass impacts from prop scour, as recommended by the Washington Department of Fish and Wildlife ("WDFW");
- Long-term impacts to kelp and other large plants, the pocket beach, the marine reserve, and the need to protect and repair the infrastructure;
- Oil spill dispersal patterns into False Bay; and
- Methods to protect the dock and boats from storm events.[2]

In addition to these omissions, the MDNS could not have fully considered the project's impacts because the Application continues to either omit information about or inadequately evaluate: (1) impacts to possible nearby seal haul-out rocks; (2) navigation impacts; (3) aesthetic impacts of a lighted, 15-foot-high dock against a recently-cleared shoreline; (4) cumulative impacts associated with approving the first dock within a 15-20-mile stretch; (5) feasible alternatives for the dock; (6) impacts associated with attaching a buoy to a rock outcropping; (7) impacts of seawater intake and brine discharge for the Reverse Osmosis ("RO") system; and (8) energy use for the RO system.

The MDNS falls short of the full consideration of environmental impacts that Washington's State Environmental Policy Act ("SEPA") promises. Just as the County withdrew its DNS in 2014 and 2015 due to inadequate information and analysis, it should withdraw the current MDNS.

I. BACKGROUND.

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[1] San Juan County, Mitigated Determination of Nonsignificance for Shoreline Permit Application for Orca Dreams LLC Four-slip dock and RO Desalination System, San Jan Island (Sept. 6, 2017).

[2] San Juan County, Letter to Law Office of Stephanie Johnson O'Day re: Orca Dreams Dock MDNS withdrawal (Oct. 30, 2015).

A. **Project Details.**

The Application proposes to construct a substantial dock, navigational buoy, and RO system adjacent to the False Bay Marine Preserve on the southwestern shores of San Juan Island. Although a single applicant has requested the dock, the Application characterizes it as a joint-use community dock ("Dock"). The Dock would extend approximately 260 feet west from the shoreline and would cover 1729.8 square feet of tidelands and bedlands.[3] The dock float would span 480 square feet, measuring 8 feet X 60 feet.[4] The significant length of the Dock, spanning more than 80% of the length of a football field, is due at least in part to the shallow depth of the water offshore of the site's pocket beach.[5] The Waterfront Construction document titled Dive Survey shows the Dock stretching over a seabed that slopes gently to just -7 feet MLLW by the end of the Dock.[6] This length of pier, ramp, and float would require the driving of twelve new galvanized steel pilings into the seafloor.[7] The Elevation View indicates that the pilings would extend over 15 feet above MLLW.[8] In exchange, the applicants have pledged to remove the unburied portions of existing creosote pilings.[9] The Application proposes to attach the Dock to a concrete abutment and a derelict block of timbers bound by rusted metal that it calls a "wooden pier head shore mount."[10] It does not evaluate the potential impacts to beach spawning fish

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[3] SEPA Environmental Checklist ("SEPA Checklist"), 3-4 (May 2017).

[4] SEPA Checklist, at 4.

[5] *See* Waterfront Construction Inc., Dive Survey (revised 5-17-17).

[6] *Id.*

[7] SEPA Checklist, at 4.

[8] Waterfront Construction, Inc., Elevation View (revised 5-17-17).

[9] Waterfront Construction, Inc., Detail View (revised 5-17-17) (showing two pilings). Although the Application suggests that eight creosote pilings will be removed, the Detail View reveals only two existing pilings and the Application does not provide any photographs or other visual identification of the six other suggested pilings.

[10] SEPA Checklist, at 4. Photos attached to the 2014 application show this object, which does not appear to have been used for a dock since at least 1977 based on Washington Coastal Atlas aerial photographs of the site available at https://fortress.wa.gov/ecy/coastalatlas/tools/ShorePhotos.aspx.

of using that structure.

The Application does not evaluate the shading impacts of the Dock. It states that the Dock will be grated with 46% open area that allows 69.9% of available light to penetrate to 18 inches below each panel and 86.2% of available light measured 5 feet below the panel.[11] The Application does not evaluate the shading effects of placing electrical and water utility lines under the Dock.[12] Nor does the Application evaluate the shading effects of the float tubs underneath the float. The Application also attaches a light study for grated decking but does not evaluate the impacts that grated docks cause on underlying aquatic vegetation.[13]

The Dock would be used for summer recreation.[14] The Application estimates that the Dock would generate up to 736 one-way trips annually.[15] The Application states that the ramp and float would be removed from November to May.[16] The Application states that four boats ranging in size from 18 to 35 feet would be moored at the boat, but does not specify the size of the individual boats or identify the owners of those boats.[17]

The desalination portion of the project would remove terrestrial and aquatic vegetation.[18] The SEPA Checklist states that "[n]ative grasses, shrubbery and marine algaes will be removed in the area where the RO desalination system utility trench will be excavated."[19] The SEPA Checklist states that once the desalination utility trenches are backfilled, exposed soils will be seeded with

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[11] SEPA Checklist, at 4.

[12] SEPA Checklist, at 21 (noting that "[e]lectrical and water lines will be placed in a conduit attached to the side of or under dock decking until reaching the float where they will connect with a hose bib(s) and electrical outlet(s) for use by boat owners.").

[13] *See* Fairbanks Environmental Services, Orca Dreams LLC, Biological Assessment (revised Feb. 24, 2017), at Appendix A, Light Availability Test, SunWalk Decking.

[14] Orca Dreams Dock/Desal SSDP, Detailed Project Data, Description, and Regulatory Analysis, 1 (revised May 2017) ("Project Description").

[15] SEPA Checklist, at 30-31.

[16] *Id.*

[17] *Id.* at 3.

[18] SEPA Checklist, at 21.

[19] *Id.*

native grasses.[20] The SEPA Checklist does not identify methods for restoring shrubbery and marine algae.

B. <u>The Dock Would Intrude Into Ecologically Rich Surroundings</u>.

The Dock would be constructed within a rich ecological setting that includes a marine preserve, underlying kelp and nearby eelgrass, suitable forage fish spawning habitat, and critical habitat for threatened juvenile Chinook salmon and endangered Southern Resident Killer Whales. This section identifies these areas and explains their ecological significance.

1. False Bay Marine Preserve.

The False Bay Marine Preserve ("Preserve") lies just to the west of the area proposed for the dock.[21] In 1990, WDFW established the Preserve in conjunction with the University of Washington's Friday Harbor Laboratories ("FHL") so that researchers could study marine organisms in a natural condition.[22] The primary goals of the Preserve are to: (1) foster stewardship of unique or important resources or habitats; (2) provide research and education areas; and (3) provide baseline areas or reference sites.[23] As a result, fishing is restricted within the Preserve. The bay and outer reaches of the Preserve host wildlife like invertebrate species studied by FHL students and researchers, harbor seals, and orca whales, and may serve as important shorebird habitat during migration.[24] Photographs of the Preserve at the mouth of False Bay from the shoreline opposite the location proposed for the Dock suggest that the Dock would figure prominently in views of the Preserve from western shores.[25]

The Application does not evaluate the impacts of the Dock on FHL

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[20] *Id.*

[21] *See* Attachment A (WDFW map of False Bay Marine Preserve).

[22] *See* WDFW, Marine Protect Areas within Puget Sound: False Bay marine Preserve, *available at* http://wdfw.wa.gov/fishing/mpa/false_bay.html (last visited Sept. 20, 2017).

[23] *See id.*

[24] *See id.*

[25] *See, e.g.*, Attachment B.

research projects, including its continued viability as a site for studying organisms in a natural condition.

2. Pocket Beach Importance for Forage Fish and Migrating Salmon.

The Dock would likely impact potential beach spawning habitat and juvenile salmon. The pocket beach on the shoreline proposed for the Dock hosts potential forage fish spawning habitat.[26] The Application's Biological Assessment did not evaluate impacts to potential forage fish spawning habitat, concluding that the project would not have an impact on that habitat because forage fish spawning had not been observed there during a survey by Friends in 2004.[27] The Biological Assessment does not note the limited nature of the 2004 sampling effort, or the fact that limited surveys may not find spawning forage fish that can spawn at any time of year in the San Juans.[28]

To the extent that the Dock's pier would connect to bound timbers on that beach, it could interfere with that spawning habitat by directly covering it. The nearshore area along the pocket beach also serves as an area where juvenile Chinook salmon, listed as threatened under the federal Endangered Species Act, juvenile Chum salmon, and Pacific sand lance are more likely to be found, and in greater numbers.[29] Pacific sand lance have been documented to spawn at the head of False Bay, less than a mile from the proposed development.[30]

The Dock and RO system could cause significant unevaluated impacts to salmon and sand lance. To the extent that the Dock would cast shade that created a sharp light contrast, it could result in the following effects: (1) migration delays

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[26] *See* Attachment C (map showing documented and potential forage fish spawning habitat in the False Bay Region, San Juan Island, prepared by Friends of the San Juans). That beach has experienced very limited forage fish spawn sampling.

[27] Biological Assessment, at 37.

[28] *Id.*

[29] *See* Attachment D (maps of juvenile Chinook salmon, chum salmon, and Pacific sand lance presence probability from Eric Beamer & Kurt Fresh, *Juvenile Salmon and Forage Fish Presence and Abundance in Shoreline Habitats of the San Juan Islands, 2008-2009: Map Applications for Selected Fish Species* (Dec. 2012)).

[30] *See* Attachment C.

due to disorientation; (2) loss of schooling in refugia due to fish school dispersal under light-limited conditions; and (3) increased size-selective predation risk as salmon move to deeper water to avoid the dock.[31]

Depending on the scale of shrub removal, the upland vegetation clearing could also cause the following impacts:[32]

- Vegetation removal/reduction, soil compaction, and grading cause changes in the loading of nutrients, organic matter, and sediment, and reduces the capacity of riparian areas to filter and absorb pollutants, as well as increased sediment loading;
- The creation of impervious surfaces, vegetation removal, and soil compaction cause surface water to increase in volume and magnitude, decreasing the ability of soils and vegetation to infiltrate and intercept pollutants;
- Removal of vegetation near the water's edge reduces shade and species diversity and abundance;
- Increased light levels in the upper intertidal zone result in higher levels of mortality and dessication of insects, invertebrates, and eggs of beach spawning fish;
- Vegetation removal and cutting impacts slope stability;
- Future requests for armoring for the access trail could lead to:
    - Lower levels of Large Woody Debris and organic litter;
    - Wildlife habitat loss, reduction, or alteration;
    - Lowered bird diversity;
    - Altered food webs and benthic community composition;
    - Barriers to passage for salmon and fragmented habitat connectivity;

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[31] Nightingale and Simenstad, *Overwater Structures: Marine Issues*, White Paper for Research Project T1803, Task 35, 43 (June 2001), *available at: http://www.wsdot.wa.gov/research/reports/fullreports/508.1.pdf* (last visited June 3, 2014).

[32] *See* Jim Brennan, et al., *Protection of Marine Riparian Functions in Puget Sound, Washington*, prepared for Washington Department of Fish and Wildlife, WDFW Agreement 08-1185 (June 15, 2009) (Appendix E, summarizing the impacts of residential development is attached hereto as Attachment E).

- Lowered abundance of wildlife that can harm upper trophic levels like salmon.

Vegetation removal would uniquely impact threatened juvenile Chinook salmon by decreasing the amount of their preferred insect prey.[33] Insects compose a dominant portion of juvenile Chinook salmon diets in nearshore waters of the northern Puget Sound, like those along the property.[34] As Duffy et al. conclude, "the importance of insects as high-quality prey highlighted the terrestrial link to the marine feeding of Chinook salmon and suggests that shoreline development and land use changes will affect feeding opportunities for these fish in Puget Sound."[35] Neither the Application nor the MDNS studied these impacts.

Notably, although the Biological Assessment ("BA") confirms that the impacts identified above could result from the Dock, it summarily determines that the project would not result in a significant adverse impact.[36] For example, the BA agrees that the following factors have led to the decline of Puget Sound Chinook salmon populations:

- Degradation of spawning and rearing habitat due to human activities;
- Loss of riparian vegetation and soils that alter hydrologic and erosion rates; and
- Increased sedimentation.[37]

Yet the BA's exposure matrix does not evaluate any of these long-term impacts from the project, or the direct and indirect shading impacts to the salmon and the kelp.[38] Instead, and notwithstanding its acknowledgment that "[a] dense band of the algae *Laminaria* [brown kelp] and *Ulva* were observed from MLLW to -7 feet

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[33] *See* Attachment F (Duffy et al., *Ontogenetic Diet Shifts of Juvenile Chinook Salmon in Nearshore and Offshore Habitats of Puget Sound*, Transactions of the American Fisheries Society 139:803-823, 903 (March 25, 2010).

[34] *Id.*

[35] *Id.*

[36] Biological Assessment, at 33-38.

[37] Biological Assessment, at 24.

[38] BA, at 42-44.

MLL in the area of the proposed dock," the BA concludes that the dock "will be built with light permeable grating and placed in an area with sparse marine algae; impacts due to shading from the dock will be minimal."[39] The BA does not evaluate the effectiveness of grating or the amount of light that will be blocked by the floats and other under-decking infrastructure. The BA also states that "[b]oats moored to the dock will be in deeper water and will not likely contact the seafloor," but does not compare the float depths with boat draws.[40] The Dive Survey indicates that the float would extend over seafloor from about -5 MLLW to -7 MLLW. Given the low tide identified by the BA for summer 2017, at -3.4 feet, any boats with a draw greater than 1.6 feet would have grounded out on the seafloor at some point this summer.[41] The absence of an analysis that reviews the likely effects of the Dock and vegetation removal and their impacts to salmon habitat or fish needs cannot support the MDNS.

3. The Dock Would Shade Kelp and Invite Boats to Approach It Through Eelgrass and Bull Kelp.

The Application suggests that the Dock would impact critical areas by shading an underlying kelp bed and potentially causing propeller scour of eelgrass and bull kelp.[42] Although the Project Description claims that "[t]his location is ideal from a habitat perspective because...it avoids location over any eelgrass or kelp beds," the August 20, 2014 dive survey by Wells Construction shows 90% laminaria (kelp) lying in the vicinity of the proposed Dock.[43] In

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[39] *Compare* Biological Assessment, at 37 *with* Biological Assessment, at 32.

[40] Biological Assessment, at 37.

[41] *Compare* Dive Survey *with* BA, at 37.

[42] Wells Construction, Preliminary Eelgrass Survey (Aug. 20, 2014) (showing 90% Laminaria along the 0 transect), BA, at 20 (image showing abundant bull kelp along southern approach to Dock).

[43] *Compare* Project Description, at 12 *with* Aug. 20, 2014 Preliminary Eelgrass Survey. The Project Description also asserts without explanation that "[t]he limited amount of kelp present in this area does not warrant the description of these areas as 'beds.'" At 40. Statements such as this suggest that the author incorrectly relied upon a previous macroalgae survey that the applicants had inappropriately conducted in late winter. *See* Wells Construction dive survey map dated March 8, 2014. That survey found only trace amounts of kelp near the proposed dock site, which reinforces the appropriateness of conducting dive surveys during the summer growing season.

addition, an earlier submitted preliminary survey from March 8, 2014 and the Detail View show eelgrass to the south and the Wells Construction dive survey shows a patch of eelgrass directly to the north of the proposed float.[44] This eelgrass lies at a depth of -5 to -7 feet MLLW in the path of boats that would approach the Dock. Notwithstanding the location of these critical areas under and surrounding the Dock float, the Application materials do not evaluate the likely shading impacts in favor of an assertion that the decking material will avoid those impacts and they declare that boating activity will avoid scouring the eelgrass with propeller wash.

As an initial matter, the Application omits a proper macroalgae survey conducted pursuant to WDFW standards. The Application offers three documents that may purport to be such a survey: a Waterfront Construction document titled Dive Survey with an initial date of 3-31-14, something titled a Preliminary Eelgrass Survey from August 20, 2014, and a Video and Dive Survey from February 2016. Two of these surveys fall well outside the summer growing season timeframe that state agencies apply for surveys to adequately assess the existence of important plants. WDFW regulations state that "[s]eagrass and macroalgae surveys must be conducted between June 1 and October 1 because the full extent of seagrass and macroalgae distribution can be more accurately mapped."[45] In addition, densities must be identified so that impacts can be quantified.[46] The hand-drawn picture from August 20, 2014, while purporting to reflect a survey taken at the right time of year, does not offer sufficient densities to comprehend the impact. It also does not explain where the Dock would be located in relation to the widely-spaced transects used.

State agencies have designated eelgrass and kelp as saltwater habitats of special concern in recognition of their importance in providing a number of

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[44] Although rocks beyond the end of the Dock direct access to either a route to the north or a route to the south, dive surveys do not appear to have been conducted for macroalgae in the shallower waters in those directions.

[45] WAC 220-660-350(3)(c).

[46] WAC 220-660-350(3)(e).

functions and values in the marine environment.[47] Likewise, San Juan County has designated eelgrass and kelp as critical areas that must be avoided where possible.[48] Eelgrass serves essential functions as a carbon-fixing primary producer and in the developmental life history of fish and shellfish, such as refugia and shelter for fish and invertebrates, food for marine animals and birds, habitat for red algae and other marine plants, and spawning habitat for Pacific herring.[49] Eelgrass also provides physical stabilization for the nearshore area by baffling wave and tidal energy, protecting subtidal sediments and shorelines from erosion.[50]

Eelgrass is particularly important in Washington State.[51] Washington protects eelgrass largely due to its many ecological services, such as habitat for spawning Pacific herring, out-migrating corridors for juvenile salmon, and foraging grounds for Great Blue Heron and other avians.[52] Because of these functions, eelgrass also provides significant economic benefits to the state.

Although the Application states that the pier, ramp, and float would be grated, it overstates the benefit of that grating by omitting reference to the opaque float tubs and float boarders that would block a substantial amount of the light striking the surface of the float.[53] Thus, although the SEPA Checklist states that the Dock will be constructed of Sun Walk grating that will allow 69.9% of light to pass through to 18 inches and 86.2% to five feet, it does not account for the float tubs and framing that directly block a substantial amount of light.[54] Even if the grated portion of the float allowed the 70% of light transmission claimed, the total amount of light reaching beneath the float would fall under

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[47] WAC 220-110-250.

[48] SJCC 18.35.130.G.1.b.i.

[49] *Kelp and Eelgrass in Puget Sound*, at 1-2.

[50] *Id.*

[51] S. Wyllie-Echeverria, *et al.*, *Z. marina* Declines in San Juan County, WA, 2 (2003) (hereafter "Eelgrass Declines").

[52] *Kelp and Eelgrass in Puget Sound*, at 1-2.

[53] *See* Waterfront Construction Inc., Float Tub Layout (revised 5-17-17).

[54] SEPA Checklist, at 4.

45% of the light that would otherwise reach the intertidal area. In addition, the combination of the Dock's east-west orientation and the 20-inch depth of the floats would result in the Dock's casting significant shadows at any time of day during any season when the sun did not shine from directly above the Dock. Thus, the Dock float would block at least 55% of the light that currently reaches the intertidal area below its proposed location. Moored boats would block 100% of the light.

Furthermore, field studies of dock grating indicate that constructing fixed piers with grating does not ameliorate the impacts of dock shading and installation.[55] A study of seagrasses in Australia found that aluminum mesh decking reduced the reduction in seagrass biomass caused by docks, but did not eliminate it. By 26 months after installation, seagrass biomass had declined by 90% under those docks, including impacts from shading and installation.[56] Although the setting there appears to have included a smaller tidal variation than in the San Juans, the structures were typically 2-3 feet above the water and only 3-4 feet wide.[57]

The cumulative impacts of docks on macroalgae, while difficult to quantify, can also be significant, and are not limited to impacts from shading.[58] These impacts include litter, toxic materials associated with boating, toxic metals that can leach from treated woods approved for marine construction, alterations in sediment deposition regimes along the shore, propeller wash impacts, addition of shell debris to sediments, and increased habitat for predatory organisms such as crabs and seastars that otherwise would not have such access to eelgrass beds.[59] In addition, some floating docks exhibit a halo effect – an area bereft of

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[55] *E.g.*, William Gladstone and Glenn Courtenay, *Impacts of docks on seagrass and effects of management practices to ameliorate these impacts*, Estuarine, Coastal and Shelf Science 136, 53-60 (2014) (Attachment G).

[56] *Id.* at 59.

[57] *Id.* at 54.

[58] Nightingale and Simenstad, at 79, 88-91.

[59] Nightingale and Simenstad, at 51-62.

eelgrass larger than the footprint of the dock.

Because the Application assumes that shading will not occur and that the band of kelp under the Dock does not qualify as a kelp bed, it omits an analysis of impacts to the kelp and species like rockfish that rely upon it.[60] The Biological Assessment also does not evaluate the impact of 736 potential boat trips through the bull kelp to the south of the Dock based on the assumption that boat operators will stay in a deeper channel clear of bull kelp and will operate at slow speeds.[61] The BA does not evaluate the surface area that could be covered by fast-growing bull kelp or explain how boats will be guaranteed to use an exacting route at a slow speed. In addition, although the BA states that a 25-foot radius around the Dock will allow boats to maneuver near the Dock without scouring eelgrass, it does not evaluate scouring impacts to eelgrass to the north of the Dock as boats approach and depart it.[62]

4. Unexplored Impacts of RO System.

As an initial matter, because the RO discharge and intake lines would extend several hundred feet from seaward of the shoreline,[63] the Application needs to include visuals that show the extent of the RO System components on the seafloor in relation to sensitive habitats like kelp and eelgrass. In addition, the Application must evaluate the impacts of algae removal to accommodate that trenching. Neither the BA nor the SEPA Checklist do so.

5. The Dock Could Interfere with Seal Haul-Outs.

Seals reportedly use rocks in the vicinity of the Dock for haul-out spots. Neither of the BA nor the SEPA Checklist address this potential impact.

C. <u>Inadequately Evaluated Visual Impacts</u>.

The Dock would impose a substantial visual intrusion. The pier and its

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[60] *Compare* BA, at 32 *with* BA, at 26-28 (noting that rockfish utilize nearshore kelp beds and that "Puget Sound kelp beds have been impacted by shoreline development, industrial development and water quality degradation."

[61] BA, at 37.

[62] BA, at 37.

[63] SEPA Checklist, at 10.

railings would extend approximately 20 feet in height above extreme low tide, and would be composed of reflective materials like aluminum and galvanized steel.[64] The Dock would also extend 80% of the length of a football field out from its pocket beach, impacting shoreline views from the north and west and a broad range of marine views, including those from the Preserve. The impacts to views from the north and west would be exacerbated by an unpermitted clearcut on the shoreline to the southeast that would form its backdrop. The Application suggests that the dock may be lighted; although the SEPA Checklist states that "[n]o lighting fixtures are proposed as part of the dock or stairs construction," the Project Description notes that electricity will extend to the float and that the applicants agree to comply with dock lighting requirements.[65]

Neither the Application nor the MDNS evaluate the impacts of the potential light pollution on False Bay neighbors or the marine habitat.[66] With regard to visual impacts generally, the Application states that "[a]lthough this will be the only dock along this length of shoreline, it is low in profile and set against a fully vegetated high-bank waterfront which allows the dock to blend in with the surroundings."[67] However, many of the trees and shrubs that would have provided a background for the Dock will be unable to serve that function because the shoreline suffered an unpermitted clearcut. The SEPA Checklist also asserts that the Dock would not create a significant fixture as viewed from the abutting property to the north because that property is located 300 feet away but fails to note that the Dock itself extends 260 feet in length at nearly a horizontal angle to that property, and thus would impose a significant visual intrusion.

The Dock would also intrude upon a 15-20 mile stretch along the west coast of San Juan Island that offers the largest stretch of shoreline in San Juan County unbroken by a dock.[68] Several factors may account the absence of such a

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[64] *See* Waterfront Construction Inc., Elevation View (revised 5-17-17); Project Description, at 22.

[65] SEPA Checklist, at 28; Project Description, at 21.

[66] SEPA Checklist, at 28.

[67] Project Description, at 15.

[68] *See* Attachment H, map of docks in San Juan County (displaying results of 2009 Shoreline Modification Inventory conducted by Friends of the San Juans).

dock, including the shoreline's high banks, as well as its exposure to winds and waves from the west. In addition, the absence of docks in the vicinity of False Bay suggests that the surrounding neighborhood shares a stewardship ethic that appreciates the natural character of the shoreline.

The Application inappropriately relies upon *Inskeep v. San Juan County* for the suggestion that the proposed Dock would blend in with high bank waterfront. In that decision, a majority of the Shorelines Hearings Board panel found that high banks behind the proposed location and on either end of the aptly titled Horseshoe Bay would allow the dock to blend into its surroundings.[69] Unlike the deeper cove in *Inskeep*, the Dock would extend from a shallower shoreline, and when viewed from properties and the water to the northwest, would be framed against a recently clearcut shoreline.

D. The Dock Would Interfere with Public Recreation and Navigation.

Neither of the Biological Assessment nor the SEPA Checklist evaluate the impacts of the Dock on local kayaking in the environs of the Preserve. The SEPA Checklist fails to acknowledge that the publicly-owned waters in this vicinity are available for use regardless of the title to the underlying tidelands and thus fails to assess the impact that the 260-foot-long Dock would impose on community members who kayak or otherwise boat along the shoreline there. Particularly given the proposal to extend the Dock nearly to rock outcroppings, and to install anchor lines that attach near those rocks, the environmental analysis should evaluate the navigational impediment created by the Dock.[70]

E. The DNS Was Not Based on Full Information About Alternatives.

The Application confirms that the property enjoys several alternatives for shoreline access and boat moorage, including a mooring buoy and marina facilities.[71] As a threshold matter, the Application does not identify the boats that

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[69] SHB No. 98-033, Final Findings of Fact, Conclusions of Law and Order, FOF No. X (April 16, 1999)

[70] Waterfront Construction, Inc., Detail View.

[71] Project Description, at 18.

would actually be moored, thus precluding an adequate alternatives analysis. However, even given the range proposed of 4 boats sized between 18 feet and 35 feet, moorage appears to exist.

First, the applicants contacted several marinas to seek moorage for four unidentified boats and learned from the Port of Friday Harbor that they had moorage available.[72] Jensen's shipyard had one covered space available for a boat up to 25', and possibly an unspecified amount of noncovered moorage.[73] The Port of Friday Harbor likewise had suitable moorage for 20' and 40' boats.[74] Snug Harbor has space for 2 of the boats at up to 28' sizes.[75] Thus, between the available marinas, moorage exists for the unspecified boats. Second, the Application does not support the need for moorage for four boats, and thus does not demonstrate that alternative moorage for fewer than four boats would be inadequate or infeasible.

In addition to the availability of moorage at island marinas, a mooring buoy would provide a feasible alternative for summer boating purposes and would provide safer moorage in the event of the "extreme wave action" predicted by the Application. A mooring buoy provides safer moorage in stormy weather because it allows the boat to swing to face the wind, decreasing the force of wind and waves against the boat, and because the boat will not crash into the side of a dock in those situations. Furthermore, the Application's assumption that four mooring buoys would be required, and that those mooring buoys would require an acre, leads to its assumption that the shoreline waters do not offer space for buoys.[76] As an initial matter, the Application does not explain why it needs to provide four spaces for moorage because it has not identified the boats for moorage. In addition, the Application suggests that it would be necessary to clear

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[72] Project Description, at 18.

[73] *Id.*

[74] *Id.*

[75] *Id.*

[76] Project Description, at 14-15.

and grade space for dinghies without explaining why it would not be feasible to store a dinghy above extreme high water on the wood block proposed for attaching the pier head or on the driftwood along the shoreline, similar to other dinghy storage used in the San Juans.[77] Consequently, because the SEPA review presumably assumed the necessity of up to four mooring buoys, the SEPA review did not adequately evaluate a mooring buoy as an alternative.

II. DISCUSSION

The MDNS should be withdrawn because the County issued it in the absence of information about the Dock's RO System's probable significant adverse impacts and alternatives. An MDNS can be overturned where: (1) a project would cause unmitigated probable significant adverse impacts; or (2) where the SEPA official did not adequately review environmental factors.[78] The Dock's aesthetic impacts, unevaluated macroalgae and other ecological impacts, and inadequately evaluated alternatives demonstrate that the MDNS issued prematurely. Consistent with SEPA's basic purpose to consider environmental and ecological factors as fully as possible, the County should withdraw the MDNS and formulate a revised threshold determination that incorporates that information.

A. The MDNS Should Be Withdrawn to Allow for Adequate Environmental Review.

In 1971, the State legislature enacted SEPA with the following four basic purposes: (1) to declare a state policy that encourages productive and enjoyable harmony between humankind and the environment; (2) to promote efforts that will prevent or eliminate damage to the environment and biosphere; (3) to stimulate the human health and welfare; and (4) to enrich the understanding of ecological systems and natural resources important to the state and nation.[79]

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[77] Project Description, at 14.

[78] WAC 173-11-340

[79] RCW 43.21C.010.

SEPA expressly incorporates the legislative recognition that "each person has a fundamental and inalienable right to a healthful environment" and "each person has a responsibility to contribute to the preservation and enhancement of the environment."[80] To carry out SEPA's environmental protection policies, governmental entities must use all practicable means to, among other responsibilities, "[a]ssure for all people of Washington safe, healthful, productive, and aesthetically and culturally pleasing surroundings."[81] In adopting SEPA, the legislature decreed that other policies, regulations, and laws of the state must be interpreted and administered in accordance with SEPA's policies.[82]

In addition to these policies and directives, SEPA's basic purpose is to "require local government agencies, including counties, to consider total environmental and ecological factors to the fullest extent when taking 'major actions significantly affecting the quality of the environment.'"[83] To determine whether an environmental impact statement will be required, the government must perform a threshold determination that assesses whether: (1) a major action has been proposed; (2) that will significantly affect the quality of the environment.[84]

The proposed shoreline substantial development is a major action.[85] "[A] governmental agency's approval of private projects by the granting of permits constitutes an 'action' within the meaning of SEPA."[86] In addition, the issuance of a shoreline substantial development permit is generally deemed a major action.[87]

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[80] RCW 43.21C.020(3).

[81] RCW 43.21C.020(2)(b).

[82] RCW 43.21C.030(1).

[83] *Sisley v. San Juan County*, 89 Wn.2d 78, 82, 569 P.2d 712 (1977) (citing RCW 43.21C.030(2)(c)).

[84] *Id.*

[85] *Id.* at 83.

[86] *Id.*

[87] *See, e.g.*, *id.* ("[i]ssuance of a substantial development permit under SMA will thus most often require an assessment of the environmental effects of the project"); *Merkel v. Port of Brownsville*, 8 Wn. App. 844, 850-51, 509 P.2d 390 (1973).

To reach a threshold determination that a proposal will not significantly affect the quality of the environment, the County "must consider the various environmental factors even it if concludes that the action does not significantly affect the environment and therefore does not require an EIS."[88] Washington courts have stressed the importance of the initial threshold determination -- an incorrect threshold determination, made in the absence of complete information, thwarts the SEPA purpose to ensure that the full disclosure of environmental information informs the government's decision-making process.[89] Consequently, an agency that issues a threshold decision must demonstrate "that environmental factors were considered in a manner sufficient to amount to prima facie compliance with the procedural requirements of SEPA."[90] In *Sisley*, the County Planning Department's failure to conduct a field investigation or gather information concerning impacts of a proposed marina on water pollution, shellfish and bird life, traffic, and aesthetics demonstrated that it had incorrectly issued a DNS.[91]

Here, the County erred when it issued an MDNS without adequately evaluating the potential aesthetic and ecological impacts of the Dock and RO System. As explained above, while the County received some information from the applicants, it did not conduct an independent assessment of the proposal's aesthetic impacts, did not evaluate impacts to the Preserve (including those that would interfere with its use for scientific research), did not review kelp shading or eelgrass or bull kelp scouring impacts from a substantial amount of boating traffic, did not evaluate the impacts of vegetation removal on juvenile Chinook salmon feeding, did not evaluate impacts to nearby seal haul-out rocks, did not evaluate the impacts to macroalgae from installing RO lines on the seafloor, and failed to evaluate impacts to local recreation and navigation, thus erring in

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[88] *Sisley*, 89 Wn.2d at 83.

[89] *See id.* at 84.

[90] *Juanita Bay Valley Cmty. Ass'n v. Kirkland*, 9 Wn. App. 59, 73, 510 P.2d 1140 (1973).

[91] *Sisley*, 89 Wn.2d at 87.

issuing the DNS.

The County also erred in failing to fully assess reasonable alternatives. SEPA directs implementing agencies to assess alternatives. For example, the SEPA rules direct agencies to "emphasize important environmental impacts and alternatives."[92] The SEPA rules also direct agencies to "identify, evaluate, and require or implement, where required by the act and these rules, reasonable alternatives that would mitigate adverse effects of proposed actions on the environment."[93] Consequently, an environmental review that does not emphasize and evaluate alternatives, particularly those that would mitigate impacts, falls short of compliance with SEPA.

Here, the use of moorage facilities at Jensen's, the Port of Friday Harbor or Snug Harbor marina would eliminate visual and ecological impacts near the False Bay Marine Preserve. Similarly, moorage at a properly designed and installed mooring buoy would impose far less upon the viewshed from and around False Bay, would avoid larger navigational impacts, and would eliminate a significant amount of shading that the Dock would cause. Both of these alternatives would improve boat safety during storms, as well, by offering either sheltered harbors or a system that turned into the wind and waves.

B. To the Extent That the MDNS Failed to Evaluate the Project's Cumulative Impacts, It Does Not Satisfy SEPA.

Environmental review under SEPA must include a proposal's direct, indirect, and cumulative impacts.[94] The SEPA rules note that impacts include "the likelihood that the present proposal will serve as a precedent for future actions."[95] Similarly, in reviewing an appeal of a shoreline permit, the Shorelines Hearings Board stated in *Bishop v. San Juan County* that "[i]n considering any shoreline development, particularly a dock or pier, it is essential to evaluate the

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[92] WAC 197-11-030(2)(b).

[93] WAC 197-11-030(2)(g).

[94] WAC 197-11-060(4)(d), (e).

[95] WAC 197-11-060(4)(d).

cumulative impacts of similar proposals."[96]

Both of the Dock and RO System would contribute to unevaluated cumulative impacts. Authorizing the first dock on the western side of San Juan Island, particularly given the existence of reasonable alternatives for boat moorage, could lay the foundation for significant cumulative impacts. The County's file does not contain an analysis of the number of docks that such a decision likely would encourage along the western shores, including those along privately-owned pocket beaches. The MDNS must be withdrawn to allow for an analysis of the project's cumulative impacts.

C. The MDNS Issued Without Requiring a Showing That the Dock and RO System Complies with Critical Areas Ordinance Provisions for Avoiding Impacts Where Possible and Achieving No Net Loss.

The Critical Areas Ordinance ("CAO") that the County adopted in 2012 requires applicants to show that: (1) avoidance of impacts to critical salt water habitats like kelp by an alternative alignment or location is not feasible; and (2) the project will result in no net loss of ecological functions associated with critical saltwater habitat.[97] Rather than evaluating whether the Dock can avoid specific critical areas like kelp, the Project Description states that all salt water in San Juan County is critical habitat. Consequently, the Application and MDNS improperly decline to evaluate whether the Dock construction can avoid the kelp bed. In addition, the MDNS and its focus on construction impacts does not evaluate whether the project will result in long-term net loss to critical shoreline species and habitat.

III. CONCLUSION

San Juan County issued the MDNS without fully considering the ecological and aesthetic impacts of a 260-foot dock and RO System adjacent to the False

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[96] SHB No. 99-034 (May 16, 2000) (Final Findings of Fact Conclusions of Law, and Order (Corrected)) (citing *Hayes v.* Yount, 87 Wn.2d 280, 287, 552 P.2d 1038 (1976) for the determination that "[l]ogic and common sense suggest that numerous projects, each having no significant effect individually, may well have very significant effects when taken together.").

[97] SJCC 18.35.130.G.1.b.i.

Bay Marine Preserve. Friends respectfully requests that the County withdraw that MDNS to allow for an adequate environmental review of the likely impacts identified above.

Respectfully submitted,

Kyle A. Loring
Staff Attorney

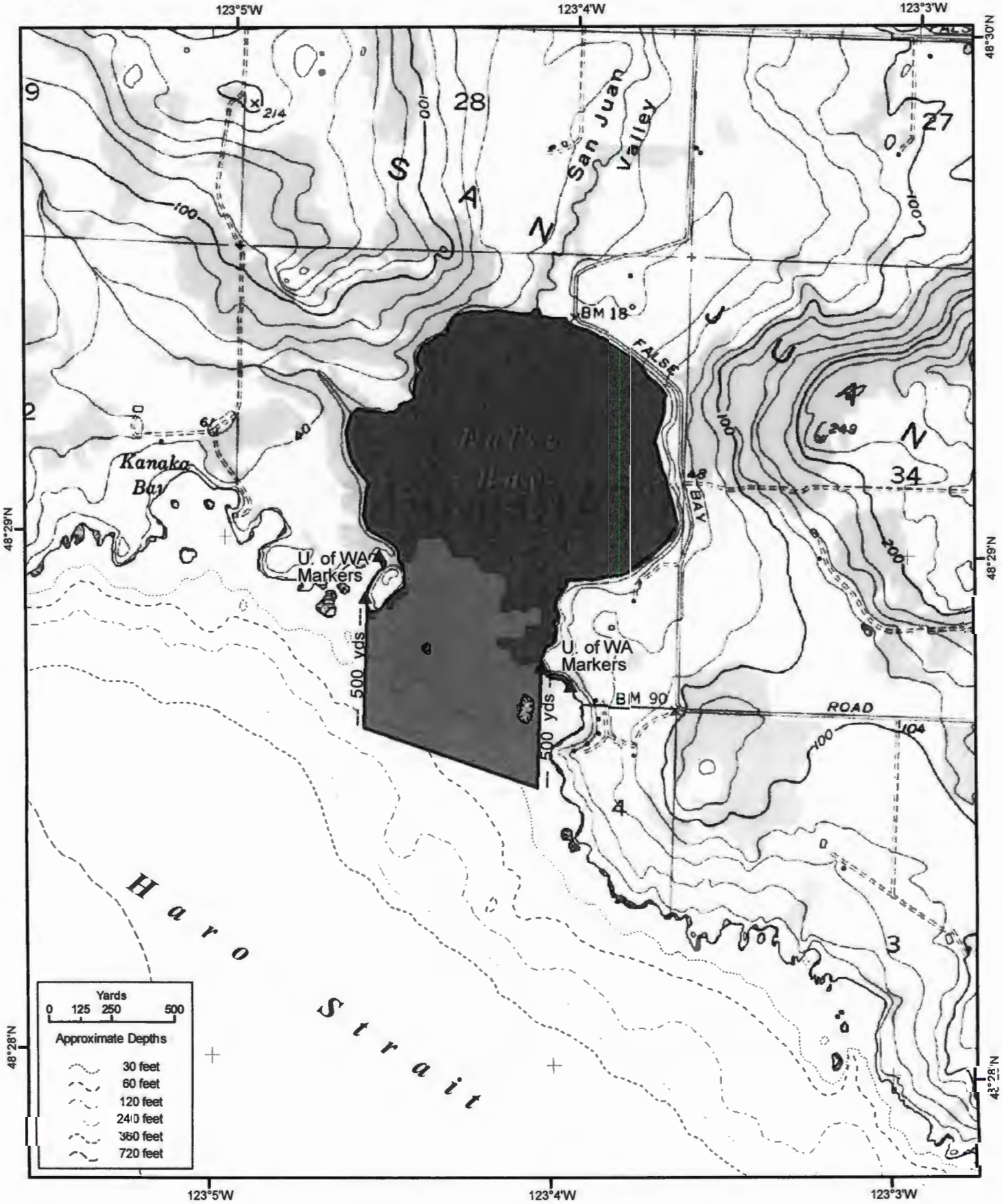
encls.

ATTACHMENT A

Washington Department of FISH and WILDLIFE

False Bay
Marine Preserve

WAC 220-16-440(1)



ATTACHMENT B

ATTACHMENT C

False Bay Region, San Juan Island

Legend

- documented forage fish spawn habitat (FSJ and WDFW 2004)
- potential forage fish spawn habitat (FSJ and WDFW 2004)

0 625 1,250 2,500 Feet

FRIENDS OF THE SAN JUANS

ATTACHMENT D

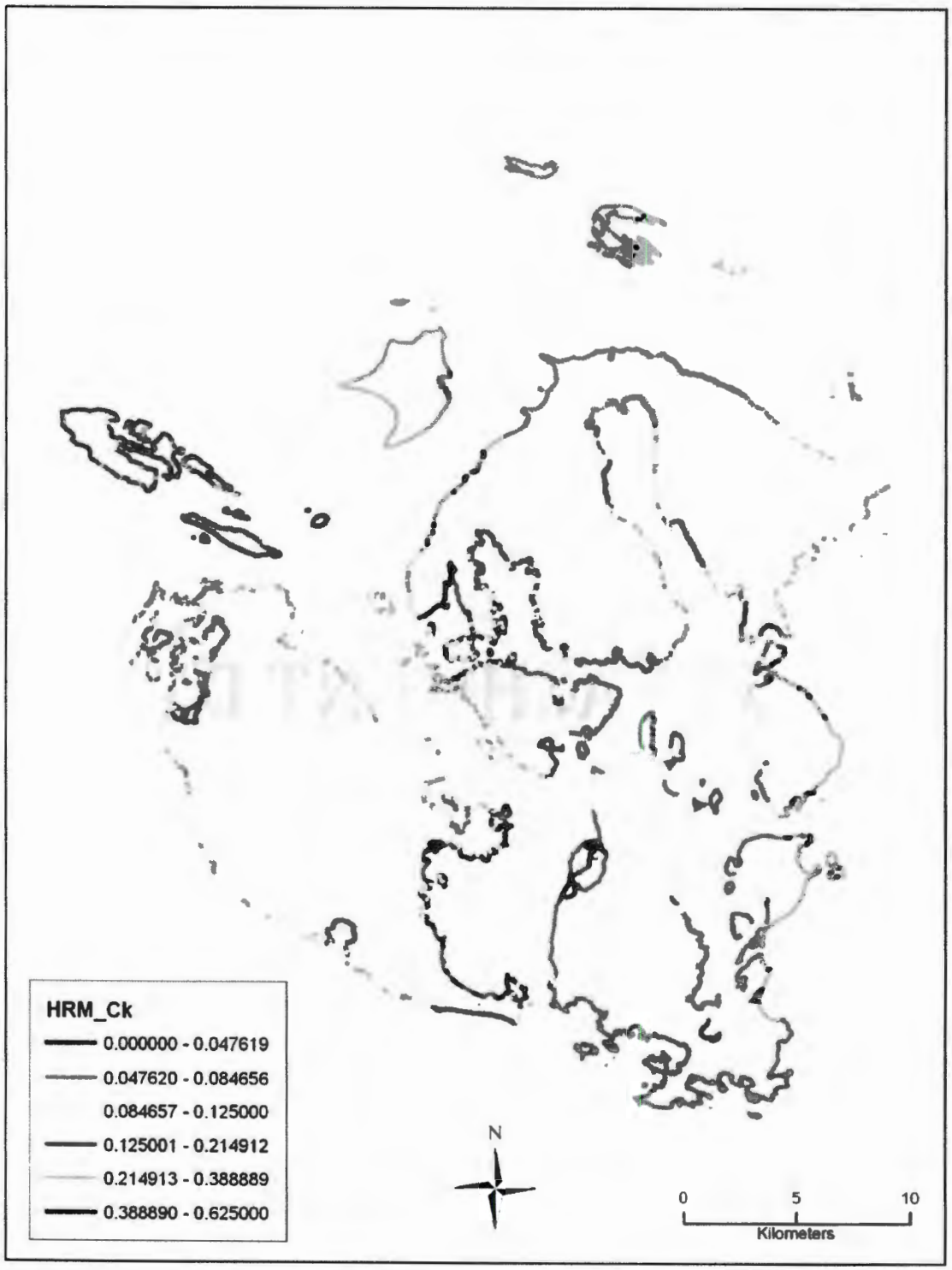


Figure 28. Fish presence probability for wild (unmarked) juvenile Chinook salmon for shoreline habitats (high resolution model).

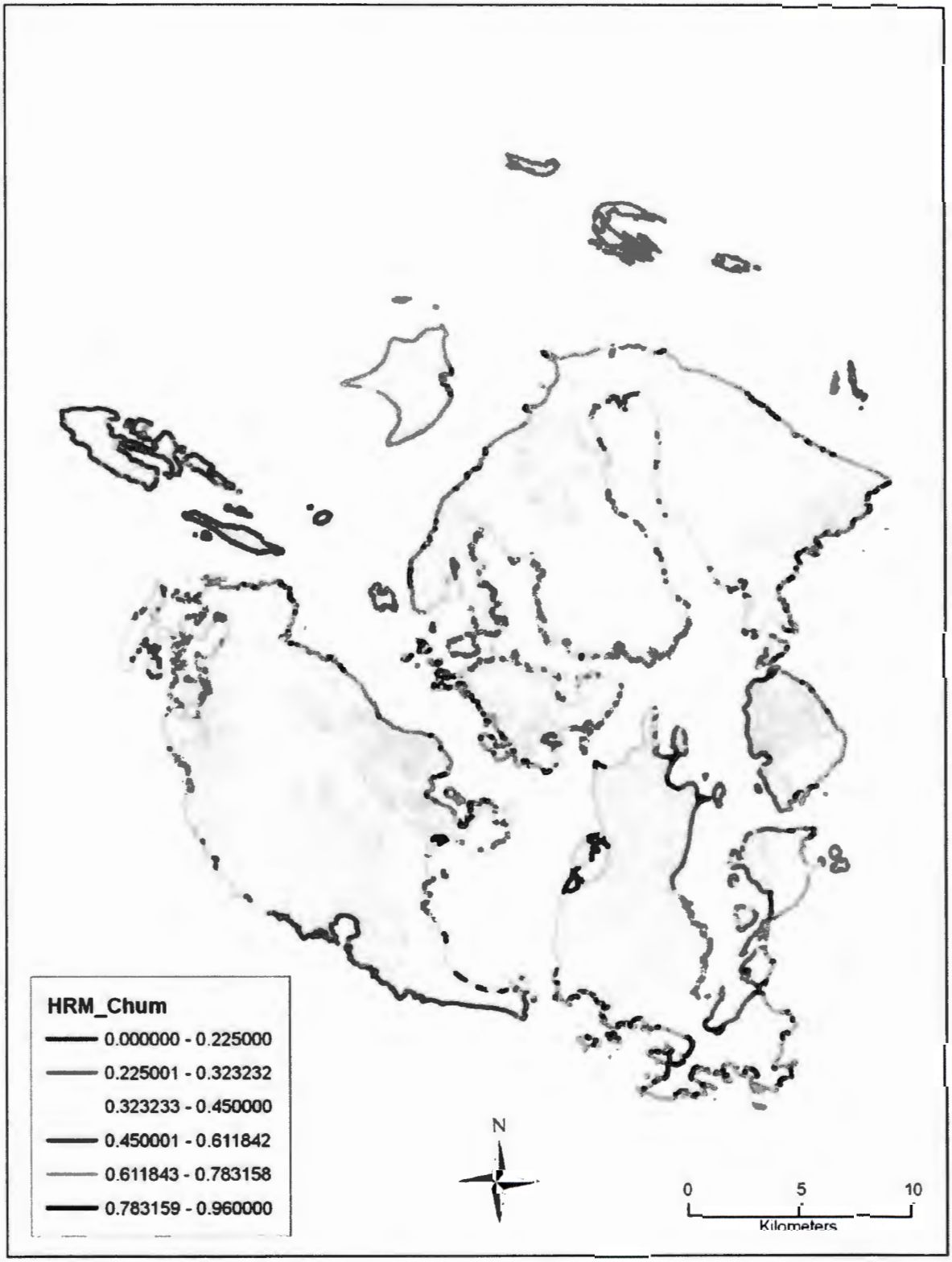


Figure 30. Fish presence probability for juvenile chum salmon for shoreline habitats (high resolution model).

Figure 38. Fish presence probability for juvenile Pacific sand lance for shoreline habitats (high resolution model).

ATTACHMENT E

APPENDIX E: Literature summary documenting the impacts of development, agriculture and forest practices on riparian functions

Land use impacts on riparian function (Development, Agriculture and Forestry)

Land use	Riparian function impaired							Specific activities associated with land use category	Impact findings on function	Literature cited
	Water Quality	Shade/Microclimate	LWD	Litter fall	Fine sediment control	Wildlife	Hydrology/slope stability			
Development	X	X	X	X	X	X	X	Clearing and grading/vegetation removal Construction of homes, buildings, roads/Impervious surfaces Shoreline armoring (docks, bulkheads, etc.) Landscaping (non-native plants) Recreational activities (hiking, biking, beachcombing, etc.)	Riparian areas are more highly altered in developed landscapes than in agricultural and forested landscapes	Booth 1991 (*in* Everest and Reeves 2006)
									Direct alteration within the riparian area (vegetation removal/reduction, soil compaction, grading) causes changes in loading of nutrients, organic matter and sediments; reduces capacity of riparian area to filter/absorb pollutants; increases sediment loading	Valiela et al 1992; Wahl et al. 1997; Jones et al. 2000; Jordan et al. 2003 (*in* Hale et al. 2004)
									Creation of impervious surfaces (e.g., parking lots, paved streets, sidewalks, roads), vegetation removal, and soil compaction cause surface water to increase in volume and magnitude. Increased runoff decreases the ability of soils and vegetation to infiltrate and intercept pollutants , increases flooding potential.	Knutson and Naef 1997; Montgomery et al. 2000 (*in* Johannessen and MacLennan 2007); Glasoe and Christy 2005; Hashim and Bresler 2005; Ekness and Randhir 2007; Schiff and Benoit 2007
									Construction of boat landings, docks, and piers creates increased slopes, causing increased and concentrated water flows; construction of domestic, residential and industrial facilities and utilities in and near riparian areas can result in altered topography, removal of vegetation, and rerouting of surface and groundwater flows	Knutson and Naef 1997; NRC 2002; Ekness and Randhir 2007; Schiff and Benoit 2007
									Construction close to the water's edge (bulkheads, docks, etc.) reduce shade as well as species diversity and abundance	Sobocinski et al. 2003; Rice 2006
									Areas with high levels of impervious surface coverage (>50%) correlated with low macrobenthic diversity and abundances	Lerbert et al. 2000
									Vegetation removal causes decreased shade and increased temperatures	Beschta et al. 1987; Macdonald et al. 1994; 1995; Thom et al. 1994; Penttila 1996; Williams and Thom 2001; Bereitschaft 2007
									Removal of vegetation cover also reduces LWD and canopy cover, which serve to dissipate flow energy and control temperature by shading	Booth et al. 2006
									Increases of light levels in the upper intertidal zone results in higher levels of mortality and dessication of insects, invertebrates, and the eggs of intertidal spawning fish like Pacific sand lance and surf smelt.	Pentilla 1996, 2000; Rice 2006
									Low levels of organic litter and LWD have been found on armored beaches	Sobocinski et al. 2003; Dugan and Hubbard 2006; Defeo et al. 2009
									Increased surface runoff of toxins Toxins can affect wildlife through physiological and behavior changes,	Klapproth and Johnson 2000; Krebs and Bums 1977; Krebs and Valiela 1978; Moore et al. 1979

									reduced density and species richness	(*in* Adamus et al. 1991); Firehock and Doherty 1995 (*in* Klapproth and Johnson 2000); Hashim and Bresler 2005; PSAT 2007
									Vegetation is a critical component in maintaining stable slopes. Roots anchor thin layers of soil to the bedrock or provide lateral stability through intertwined roots.	Morgan and Rickson 1995 (*in* Parker and Hamilton DATE); Sidle et al. 1985 and Chatwin et al. 1994 (*in* Stanley et al. 2005).
									Decreased wood abundance and elevated beach temperatures have been documented in several studies around Puget Sound.	Higgens et al. 2005; Rice 2006; Tonnes 2008
									Low levels of LWD and organic litter have been found on armored beaches as compared with unaltered beaches	Sobocinski et al. 2003; Dugan and Hubbard 2006; Defeo et al. 2009
									Dams and other water control structures have caused changes in nutrient cycling	Knutson and Naef 1997
									Offshore structures (e.g., breakwaters, jetties) can cause increased deposition of beachwrack.	Martin et al. 2005 *in* Defeo et al. 2009
									Shoreline modifications result in 1. wildlife habitat loss, reduction, and or alteration 2. lowered bird biodiversity 3. altered food webs and benthic community composition 4. creation of passage barriers for salmon and fragmented habitat connectivity 5. lowered abundance of wildlife which can cause harm to upper trophic levels, like Pacific salmon	1. Paulson 1992; Levings and Thom 1994; Williams and Thom 2001; Toft et al. 2004; Griggs 2005 2. Donnelley and Marzluff 2004 3. (Dauer et al. 2000; Lerberg et al. 2000 *in* Hale et al. 2004), 4. Williams and Thom 2001). 5. Sobocinski et al. 2003; Johannessen and MacLennan 2007; Defeo et al. 2009
									Habitat alteration can cause increased loading of contaminants and pathogens	Siewicki 1997; Inglis and Kross 2000; Mallin et al. 2000 (*in* Hale et al. 2004)
									Habitat alteration can cause changes in water flow	Hopkinson and Vallino 1995; Jones et al. 2000 (*in* Hale et al. 2004)
									Clearing of land for development produces the largest amount of sediment to aquatic resources; developed areas can produce 50-100 times more sediment than agricultural areas	U.S. EPA 1993 (*in* Stanley et al. 2005); Jones and Gordon 2000 (*in* Stanley et al. 2005
Agriculture	X		X		X	X	X	Clearing and grading/vegetation removal Application of pesticides/fertilizers Tillage/irrigation practices	Loss of native vegetation and LWD, bank instability and loss of floodplain function	Spence et al. 1996 (*in* Everest and Reeves 2006)
									Increased phosphorus and nitrogen levels in soils and surface runoff; 40 times the amount of nitrogen in agricultural land than forested areas and two times the nitrogen levels of urban areas in Puget Sound	Carpenter et al. 1998 (*in* Stanley et al. 2005); Ebbert et al. 2000 (*in* Stanley et al. 2005
									Excessive fertilizer use has led to increased nutrient levels in aquatic environments, causing algal blooms and eutrophication	Caffrey et al. 2007
									Activities can cause soil loss and erosion	Hashim and Bresler 2005
									Loss of vegetation cover, changes in hydrology cause altered flow regimes; increased sedimentation	Seddell and Froggatt 1984 (*in* Everest and Reeves 2006)
									Activities within riparian areas have simplified aquatic and riparian habitats	Spence et al. 1996 (*in* Everest and Reeves 2006)

									Direct alteration can cause increased loading of contaminants and pathogens	Inglis and Kross 2000 *(in* Hale et al. 2004)
									Conversion of riparian areas to cropland can decrease the infiltration potential of riparian soils	NRC 2002
Forestry	X	X			X	X	X	Introduction of pesticides and fertilizers Impervious surfaces (roads etc) Vegetation removal (timber harvesting)	Timber harvesting within riparian areas reduces shade	Hashim and Bresler 2005
									Timber harvesting within riparian areas increases sedimentation	Everest and Reeves 2006
									Timber harvesting within riparian areas reduces bank stability	Everest and Reeves 2006
									Road construction and maintenance activities can increase fine sediment loads and mass wasting processes, and can reduce bank stability	Hashim and Bresler 2005; Everest and Reeves 2006
									Forestry practices can cause changes in the abundance and diversity of wildlife in riparian areas. This occurs through the loss of LWD, canopy and shrub cover, interior forest habitat within and adjacent to the riparian zone, sedimentation of the aquatic habitat, and habitat fragmentation.	Knutson and Naef 1997
									Removal of trees within marine riparian reduces available shade (thereby increasing water temperatures); temperature changes affect water quality and changes in fish/wildlife behavior, structure, and composition.	Hashim and Bresler 2005 Vigil 2003; Everest and Reeves 2006
									Forestry practices, including use of fertilizers and pesticides, timber harvesting, and road construction and maintenance, degrade water quality and can cause extensive changes in hydrology and riparian vegetation	Jones et al. 2000

Impact of specific activities on riparian function

Specific activities	Typically associated with land use	Riparian function impaired							Finding	Literature cited
		Water quality	Shade/Microclimate	LWD	Litter fall	Fine sediment control	Wildlife	Hydrology/slope stability		
Clearing and grading/ vegetation removal (including timber harvesting)	Development Agriculture Forestry	X	X	X		X	X	X	Can lead to an increase in contaminated runoff	Ekness and Randhir 2007
									Common development practices can result in conditions that produce unhealthy plants that require excessive fertilizers and pesticides	WDOE 2007
									The reduction or removal of slope vegetation can result in either increased rates of soil erosion or higher frequencies of slope failure.	OSB 2007
									Permanent loss of vegetation cover or replacement by ineffective vegetation increases soil saturation and surface water runoff. Disturbed or degraded sites undergo continual erosion and may not establish an effective cover.	Menashe 2001
									Vegetation removal decreases shade, leading to increased temperatures that can impact wildlife survival	Macdonald et al. 1994; Thom et al. 1994; Macdonald 1995; Penttila 1996, 2000; Williams and Thom 2001; Rice 2006; Bereitschaft 2007
									Can cause extensive changes in hydrology and riparian vegetation.	Jones et al. 2000
									Timber harvesting within riparian areas reduces shade; agricultural activities can degrade water quality by increasing fecal coliform levels, temperatures and nutrient/pesticide loading.	Hashim and Bresler 2005
									Timber harvesting within riparian areas reduces bank stability	Everest and Reeves 2006
									Agricultural activities within riparian zones have resulted in a loss of native vegetation and LWD, bank instability, and loss of floodplain function.	Spence et al. 1996 (*in* Everest and Reeves 2006)
									Agricultural activities within riparian areas have simplified aquatic and riparian habitats	Spence et al. 1996 (*in* Everest and Reeves 2006)
Construction and maintenance of impervious surfaces (e.g. roads, homes and buildings)	Development Agriculture Forestry	X				X	X	X	Can lead to an increase in contaminated runoff	Ekness and Randhir 2007
									Can degrade water quality (including increased temperatures) and cause extensive changes in hydrology	Jones et al. 2000
									Direct alteration can cause increased loading of contaminants and pathogens	Mallin et al. 2000 (*in* Hale et al 2004)
									Can increase fine sediment loads and mass wasting processes, which can cause erosion.	Hashim and Bresler 2005
									Direct alteration within the riparian area causes changes in loading of nutrients, organic matter and sediments	Valiela et al 1992; Wahl et al. 1997; Jones et al. 2000; Jordan et al. 2003 (*in* Hale et al. 2004)
									Areas with high levels of impervious surface coverage (>50%) correlated with low macrobenthic diversity and abundances.	Lerbert et al. 2000

									Impervious surfaces cause increased volume and magnitude of surface water runoff, decreasing the ability of soil and vegetation to absorb/intercept pollutants	Montgomery et al. 2000 (*in* Johannessen and MacLennan 2007)
									Impervious surfaces increase flooding potential	Glasoe and Christy 2005
									Increased sedimentation has also been shown to affect juvenile and filter-feeding fish.	Williams and Thom 2001
Shoreline armoring (e.g. docks, bulkheads, etc)	Development	X					X		The construction of boat landings, docks, and piers often creates increased slopes, which causes increased and concentrated water flows. Shoreline armoring structures, such as rip-rap, concrete, and bulkheads, can require the removal of vegetation and can also impede the movement of wildlife that utilize the shoreline as migration corridors.	NRC 2002
									The installation of shoreline armoring structures reduces beach width, resulting in the loss of wildlife habitat (in upper intertidal areas)	Griggs 2005
									Associated with low levels of organic litter and LWD	Sobocinski et al. 2003; Dugan and Hubbard 2006; Defeo et al. 2009
									Alters hydrologic processes, which affects sand transport rates, erosion and beach accretion processes	Defeo et al. 2009
									Shoreline modifications result in habitat loss, reduction, and or alteration* lowered bird biodiversity** (altered food webs and benthic community composition*** creation of passage barriers for salmon and fragmented habitat connectivity****	*Paulson 1992; Levings and Thom 1994; Williams and Thom 2001; Toft et al. 2004 ** Donnelley and Marzluff 2004 ***Dauer et al. 2000; Lerberg et al. 2000 *in* Hale et al. 2004 ****Williams and Thom 2001
Construction and maintenance of impervious surfaces (e.g. roads, homes and buildings)	Development Agriculture Forestry	X				X	X	X	Can lead to an increase in contaminated runoff	Ekness and Randhir 2007
									Can degrade water quality (including increased temperatures) and cause extensive changes in hydrology	Jones et al. 2000
									Direct alteration can cause increased loading of contaminants and pathogens	Mallin et al. 2000 (*in* Hale et al 2004)
									Can increase fine sediment loads and mass wasting processes, which can cause erosion.	Hashim and Bresler 2005
									Direct alteration within the riparian area causes changes in loading of nutrients, organic matter and sediments	Valiela et al 1992; Wahl et al. 1997; Jones et al. 2000; Jordan et al. 2003 (*in* Hale et al. 2004)
									Areas with high levels of impervious surface coverage (>50%) correlated with low macrobenthic diversity and abundances.	Lerbert et al. 2000
									Impervious surfaces cause increased volume and magnitude of surface water runoff, decreasing the ability of soil and vegetation to absorb/intercept pollutants	Montgomery et al. 2000 (*in* Johannessen and MacLennan 2007)
									Impervious surfaces increase flooding potential	Glasoe and Christy 2005
									Increased sedimentation has also been shown to affect juvenile and filter-feeding fish.	Williams and Thom 2001
Shoreline armoring (e.g. docks, bulkheads, etc)	Development	X					X		The construction of boat landings, docks, and piers often creates increased slopes, which causes increased and concentrated water flows. Shoreline armoring structures, such as rip-rap, concrete, and bulkheads, can require the removal of vegetation and can also impede the movement of wildlife that utilize the shoreline as migration corridors.	NRC 2002

									The installation of shoreline armoring structures reduces beach width, resulting in the loss of wildlife habitat (in upper intertidal areas)	Griggs 2005
									Associated with low levels of organic litter and LWD	Sobocinski et al. 2003; Dugan and Hubbard 2006; Defeo et al. 2009
									Alters hydrologic processes, which affects sand transport rates, erosion and beach accretion processes	Defeo et al. 2009
									Shoreline modifications result in habitat loss, reduction, and or alteration* lowered bird biodiversity** (altered food webs and benthic community composition*** creation of passage barriers for salmon and fragmented habitat connectivity****	*Paulson 1992; Levings and Thom 1994; Williams and Thom 2001; Toft et al. 2004 ** Donnelley and Marzluff 2004 ***Dauer et al. 2000; Lerberg et al. 2000 *in* Hale et al. 2004 ****Williams and Thom 2001
Tillage and irrigation practices	Agriculture	X							Can result in soil loss and erosion as well as the transport of pesticides and fertilizers to surface and groundwater	Hashim and Bresler 2005
Introduction of pesticides and fertilizers	Development Agriculture Forestry	X							Can degrade water quality and cause extensive changes in hydrology and riparian vegetation	Jones et al. 2000
									Agricultural activities result in fecal coliform pollution, and nutrient and pesticide loading	Hashim and Bresler 2005
Recreational activities (trails, etc)	Development							X	Trampling of riparian soils leads to compaction, erosion and the destruction of soil microbial communities	NRC 2002

ATTACHMENT F

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[Article]

Ontogenetic Diet Shifts of Juvenile Chinook Salmon in Nearshore and Offshore Habitats of Puget Sound

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Abstract.—Marine growth and survival of juvenile Chinook salmon *Oncorhynchus tshawytscha* depend in part on the quality and quantity of prey consumed during this potentially critical life stage; however, little is known about the early marine diet of these fish or factors that affect the diet's variability. We examined the recent (2001–2007) dietary habits of Puget Sound, Washington, Chinook salmon (listed as threatened under the U.S. Endangered Species Act) during their first marine growing season (April–September). Juvenile Chinook salmon initially fed in nearshore marine habitats and then shifted to feed primarily offshore during July–September. Diet composition varied significantly among sampling regions (northern, central, and southern), habitats (nearshore, offshore), years, months, and fish size-classes. At nearshore sites, insects (all months) and gammarid amphipods (July) were dominant prey sources, whereas in offshore diets decapods (primarily crab larvae; July) and fish (September) were most important. Chinook salmon became increasingly piscivorous as they grew and ate fish with fork lengths up to 51% (nearshore) and 52% (offshore) of predator fork length. At nearshore sites, Chinook salmon fed mainly on larval and juvenile Pacific sand lances *Ammodytes hexapterus*; offshore, they primarily ate juvenile and older Pacific herring *Clupea pallasii*. Overall, Chinook salmon had more diverse diets and ate higher-quality prey (insects) in northern nearshore and central offshore waters, whereas Chinook salmon caught in the southern nearshore and northern offshore waters had a lower proportion of empty stomachs but ate lower-quality prey (crustaceans). Annual variation in the composition of offshore prey appeared to be determined early in the growing season, suggesting that environmental factors (e.g., climate) affecting marine productivity might produce strong interannual trends in marine survival of Puget Sound Chinook salmon. In addition, the importance of insects as high-quality prey highlighted the terrestrial link to the marine feeding of Chinook salmon and suggests that shoreline development and land use changes will affect feeding opportunities for these fish in Puget Sound.

The early marine life stages of Pacific salmon *Oncorhynchus* spp. experience some of the most rapid growth rates (LeBrasseur and Parker 1964; Healey 1979, 1982a; Mortensen et al. 2000) and highest mortality rates (Parker 1962; Royal 1962; Furnell and Brett 1986; Bradford 1995; Willette et al. 2001) compared with most other stages of the life cycle. Estuarine and coastal marine environments provide important foraging and rearing habitat for juvenile Pacific salmon (Shepard 1981; Simenstad et al. 1982; Thorpe 1994; Aitken 1998). Favorable early marine growth conditions are considered crucial as both larger size (Parker 1971; Blackbourn 1976; Healey 1982b; Ward et al. 1989; Henderson and Cass 1991) and faster growth have been associated with elevated overall marine survival for several salmon species (Holtby et al. 1990; Hargreaves 1997; Murphy et al. 1998; Tovey 1999; Beamish et al. 2004a; Moss et al. 2005; Cross et al. 2008). In Puget Sound, Washington, ocean-type Chinook salmon *O. tshawytscha* are currently listed as threatened under the U.S. Endangered Species Act (Myers et al. 1998; NMFS 1999). Poor marine survival

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is one factor contributing to the decline of this stock (Greene et al. 2005). As juveniles, Chinook salmon spend much of their first marine growing season in Puget Sound estuaries and offshore waters (Beamish et al. 1998). Therefore, recent declines in marine survival (Ruggerone and Goetz 2004) could reflect degraded rearing and foraging conditions during early marine life in Puget Sound.

Puget Sound Chinook salmon primarily exhibit an ocean-type life history, migrating to saltwater immediately after emerging from the gravel as fry or after spending up to several months rearing in freshwater. Most of these juveniles enter estuaries and occupy nearshore habitats primarily during the spring and early summer (Stober et al. 1973; Congleton et al. 1982; Simenstad et al. 1982; Brennan et al. 2004; Duffy et al. 2005; Beamer et al. 2006; Toft et al. 2007). By midsummer, most Chinook salmon transition from nearshore waters and are caught in large numbers in offshore habitats, where catches remain high at least through early fall (Beamish et al. 1998). Predation by fish, birds, and marine mammals is hypothesized to be responsible for most of the early marine mortality experienced by juvenile salmon (Parker 1971; Beamish and Mahnken 2001). Size at this stage is critical because it partially determines the level of predation risk posed by the many gape-limited predators (Sogard 1997; Juanes et al. 2002; Duffy and Beauchamp 2008). In addition, smaller fish may suffer higher predation mortality by employing riskier foraging strategies (Biro et al. 2005). Besides buffering the risk of predation, achieving a larger size enables Chinook salmon to begin eating a previously unavailable supply of energy-rich prey fishes. Incorporating high-energy prey into the diet can be critical for achieving the faster growth and increased lipid stores that are essential for surviving the winter (Post and Parkinson 2001; Sutton and Ney 2001; Beauchamp 2009).

Seasonal shifts in prey resources and water temperature can affect the potential growth rates of juvenile salmon. Poor-quality feeding areas, which vary over short and longer time frames, may result in increased susceptibility to predation due to poorer condition and smaller sizes of fish (Brodeur et al. 1992; Perry et al. 1996). The quality of feeding areas can also affect migration rates and residence times as salmon are believed to leave areas of poor food quality faster than when food is abundant (Simenstad and Salo 1980; Healey 1982b; Orsi et al. 2000). In Puget Sound, regional differences in environmental conditions (e.g., turbidity, salinity, and water temperature profiles) could affect the length and quality of early marine rearing of juvenile Chinook salmon, particularly in nearshore environments (Duffy et al. 2005). In addition, when food supply is limited, dietary overlaps among species and between hatchery and wild salmon may result in intra- and interspecific competition that would reduce growth rates and overall fish size (Fisher and Pearcy 1996; Sturdevant 1999).

Information on the diet of juvenile Chinook salmon in nearshore (Conley 1977; Fresh et al. 1978, 1981; Pearce et al. 1982; Parametrix, Inc. 1985; Duffy 2003; Brennan et al. 2004) and offshore (Fresh et al. 1981; Beamish et al. 1998) Puget Sound waters dates mainly to the 1970s, was not always collected or analyzed methodically, and may not represent the current situation. In the late 1970s, juvenile Chinook salmon in nearshore sublittoral waters ate primarily fish (Pacific herring *Clupea pallasii* and Pacific sand lances *Ammodytes hexapterus*) and brachyuran crab larvae during June and July and then consumed fish, insects, and polychaetes later in the summer (August; Fresh et al. 1981). In the late 1970s and 1990s, Chinook salmon became increasingly piscivorous (feeding mainly on Pacific herring) as they grew larger and were caught in offshore waters (Fresh et al. 1981; Beamish et al. 1998). The current status of prey resources in Puget Sound is unknown; however, Puget Sound is facing many of the problems seen in urbanized estuaries throughout the world, including widespread declines in fish, bird, and marine mammal populations (PSAT 2005). Recent declines in some Puget Sound forage fish populations—particularly Pacific herring (PSWQAT 2002)—may indicate a reduction in the supplies of energy-rich fish prey available for Chinook salmon. Similarly, increasing shoreline development and alteration of nearshore habitats may be altering prey abundance, diversity, and adequate feeding opportunities.

Puget Sound encompasses a wide variety of physical and environmental conditions. Localized differences among basins include the size and discharge of associated rivers, the degree of urbanization (e.g., altered habitats, pollutant loads), the magnitude of salmon runs, species composition, and proportion of natural versus hatchery salmon stocks. These differences likely affect the potential role and quality of these areas as rearing environments for juvenile salmon. Specifically, we expected diets of Chinook salmon to differ by (1) habitat (nearshore and offshore), (2) region (northern, central, and southern), (3) season (April–September), (4) year (2001–2007), and (5) fish size-class. Describing the feeding habits of Puget Sound Chinook salmon stocks during early marine life was an initial step towards understanding whether early marine feeding contributed to the recent declines and regional patterns in marine survival of these stocks (Ruggerone and Goetz 2004).

Methods

Study area.—Puget Sound is a deep, elongated glacial fjord composed of underwater valleys, ridges, and basins and has an average depth of 135 m. The maximum depth of 285 m occurs just north of Seattle in the large Main Basin. A shallow sill separates the Main Basin from the Southern Basin near the Tacoma Narrows. The Southern Basin receives less than 10% of the freshwater draining into Puget Sound, primarily from the Nisqually and Deschutes rivers and also from smaller rivers and streams (Burns 1985). Northeast of the Main Basin, the Whidbey Basin includes the waters of Possession Sound, Port Susan, Saratoga Passage, and Skagit Bay (Figure 1). The Whidbey Basin is fed by Puget Sound's two largest rivers, the Skagit and Snohomish rivers, and receives 60% of the freshwater entering Puget Sound (Burns 1985).

For this study, sampling was stratified by region and habitat. Sampling regions were defined as follows: (1) the northern region was north of Edwards Point and included the northern Main Basin, Admiralty Inlet, and southeastern Whidbey Basin; (2) the central region extended in the Main Basin from Edwards Point south to Tacoma Narrows; and (3) the southern region was located south of the Tacoma Narrows sill (Figure 1). These sampling regions included significant saltwater entry points for both wild and hatchery Chinook salmon, major freshwater inflows (Snohomish, Stillaguamish, Puyallup, Green, and Nisqually rivers), and marine rearing and migration corridors. Nearshore and offshore habitat types were defined primarily by the type of sampling gear used. Nearshore sites were sampled by floating beach seines, which cover the upper 2 m from shore out to a distance of approximately 33 m, targeting shallow sublittoral habitats in shoreline zones. Five to six nearshore sites were sampled in the northern and southern regions (Duffy et al. 2005), and 16 nearshore sites were sampled in the central region (Brennan et al. 2004). Open-water offshore sites (bottom depth generally > 30 m) were sampled by midwater rope trawl, which had an effective opening of 14 × 30 m (depth × width) when fishing (Beamish et al. 2000).

Fish sampling.—Field sampling was designed to characterize the timing of nearshore and offshore habitat use, size structure, and diet of juvenile Chinook salmon in Puget Sound. At nearshore sites, we conducted beach seining (2 sets/site) biweekly during April–July and monthly during August and September in 2001 and 2002 at each northern and southern site (Duffy et al. 2005) and each central site (Brennan et al. 2004) using a floating beach seine (37.0 m long × 2.0 m high, with graded mesh from 6 mm at the cod end to 3 cm in the wings) according to standard estuarine fish sampling protocols (Simenstad et al. 1991). Additional beach seining was conducted at nearshore sites in the northern and southern regions during June–September 2003. Midwater trawling was conducted in the northern and central regions during 2-d cruises in July and September 2001–2007 (October was sampled instead of September in 2004 and no offshore sampling was done in 2003). Additional trawls were conducted in the southern region during July 2004 and in Hood Canal during September 2007. On average, 30 trawls were conducted per year. The average tow lasted 20 min at 4.4 knots (8.2 km/h), covering a distance of 1.45 nautical miles (2.69 km). Approximately two-thirds of the trawls sampled the upper 30 m of the water column, with occasional deeper tows ranging between 30 and 120 m. All sampling occurred during daylight hours.

Counts of all fish representing each species were recorded. Hatchery Chinook salmon were identified by adipose fin clips and coded wire tags (CWTs), while unmarked Chinook salmon were assumed to be of natural origin; however, some unknown proportion of these unclipped fish were of hatchery origin due to factors like incomplete tagging. Individual fork lengths (FLs; nearest 1 mm) and wet weights (nearest 0.1 g) were recorded for subsamples (at least 30 fish/species, when available). When possible (primarily in beach seine samples), fish were anesthetized with buffered tricaine methanesulfonate (MS-222), and gut contents were obtained using nonlethal gastric lavage and preserved in 10% buffered formalin or 95% ethanol for subsequent processing in the laboratory. Fish to be processed in the laboratory were first euthanized in an overdose of buffered MS-222 or with a sharp blow to the head and were then frozen.

Diet composition.—Stomach samples from a subset (5–10 fish/set, but all fish with CWTs) of juvenile Chinook salmon (and up to 10 of the larger age-1 and older Chinook salmon) caught at nearshore sites were examined in the laboratory. Under a dissecting microscope, invertebrate prey were separated into broad taxonomic categories, and fish prey were identified to species where possible. Blotted wet weights of individual fish prey and prey categories were recorded to the nearest 0.0001 g using an electronic scale. Stomach samples from offshore fish were processed on the boat immediately after capture. The fundic and cardiac portions of stomachs from all (or up to 30) of the Chinook salmon caught in a given tow were removed and examined by a single experienced individual. Using a 4× magnifying glass, this individual visually estimated the total volume of the stomach contents to the nearest 0.1 cm^3 and the proportional contribution of the major prey types

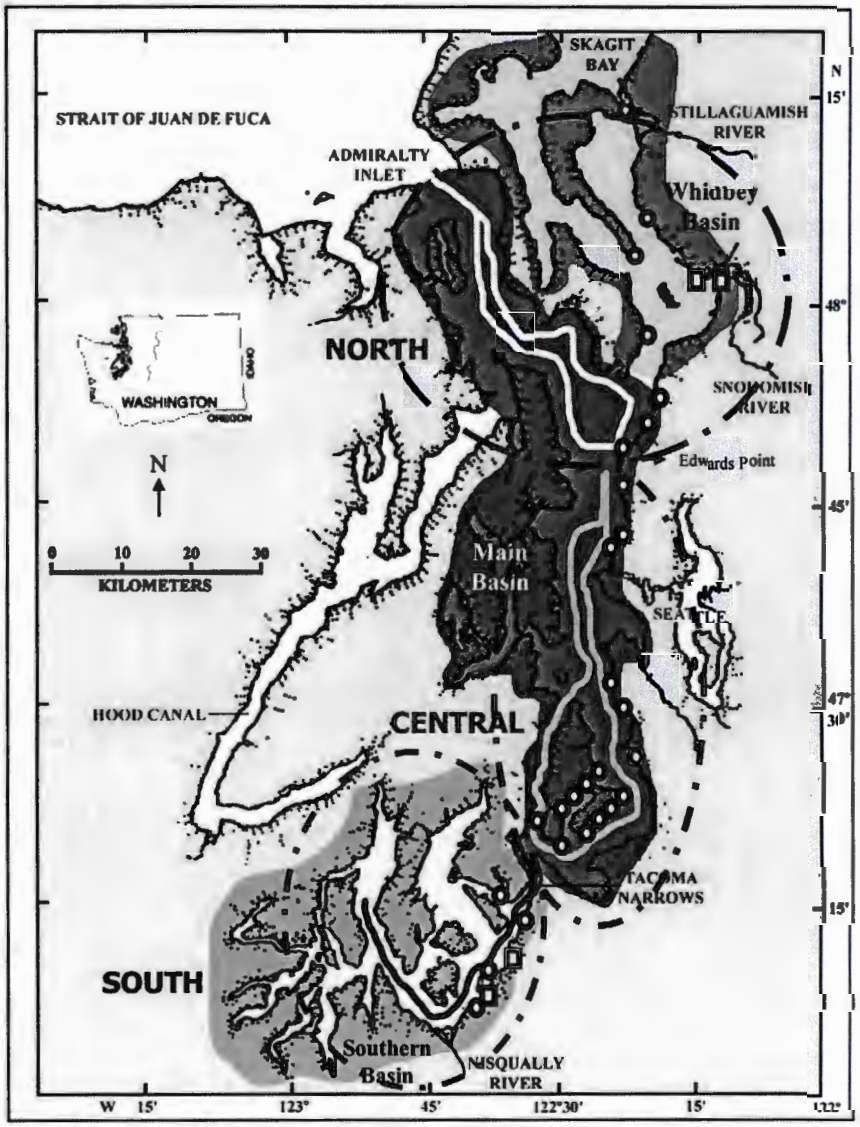

FIGURE 1.—Major basins, sampling regions, and sampling locations for juvenile Chinook salmon studies conducted in Puget Sound, 2001–2007. Shading indicates major basins (dark gray = Main Basin; medium gray = Whidbey Basin; light gray = Southern Basin). Ovals indicate north, central, and south sampling areas. Nearshore sites (circles) were sampled by beach seine during April–September of 2001 and 2002 (and June–September 2003 at northern and southern sites). Solid lines indicate typical routes surveyed by midwater trawl in northern (white line), central (gray line), and southern (black line) regions.

(Beamish et al. 2004b). When possible, individual fish prey lengths (FLs or total lengths depending upon the species) were measured from both nearshore and offshore samples.

Prey were grouped into broad taxonomic categories reflecting the dominant types: copepods (mostly calanoid copepods but also included harpacticoid copepods), decapods (primarily larval crab but also larval and adult shrimp), euphausiids, gammarid amphipods (hereafter, gammarids; both estuarine and marine species), hyperiid amphipods (hereafter, hyperiids), polychaetes (epibenthic and planktonic forms), barnacles (cyprids, nauplii, and exuviae), insects (including both terrestrial and aquatic insects [Insecta]

TABLE 1.—Gross energy density (J/g wet weight [ww]) values for prey eaten by juvenile Chinook salmon in Puget Sound.

Prey group	Energy density J/g (ww)	Sample area	Reference	Comments
Barnacles	2,045	Newport River estuary, North Carolina	Thayer et al. 1973	Barnacle larvae/exuviae
Copepods	2,625	North Pacific and Bering Sea	Davis et al. 1998	*Neocalanus cristatus*
Decapods	2,981	Bristol Bay	Davis 1993[a]	Crab zoea
Euphausiids	3,111	North Pacific and Bering Sea	Davis et al. 1998	*Thysanoessa* spp.
Fish	4,649	Washington; Alaska	Boldt and Haldorson 2002; Duffy 2003	Average of juvenile salmon, Pacific herring, and Pacific sand lance
Gammarids	4,408	Northwest Atlantic	Davis 1993[a]	Average for Gammarids and amphipods
Hyperiids	2,466	Bering Sea	Davis et al. 1998	July 1992–1995
Insects	5,311	Salmon River estuary, Oregon	Duffy 2003	Average of adult insects eaten by salmon
Polychaetes	3,186	Northwest Atlantic	Davis 1993[a]	Mean of two reported values

[a] Literature values are summarized in this reference.

as well as spiders [Arachnida] and water mites [Acari]), other invertebrates (rare and unidentifiable prey), and fish (including larval, juvenile, and adult forms). The proportional wet weight (nearshore; g) or volumetric (offshore; cm^3) contribution of each prey category was calculated individually for all nonempty stomachs. The energy density of each prey group was compiled (summarized from the literature; Table 1) to obtain an indication of prey quality (Armstrong et al. 2008).

Diets of ocean-type juvenile Chinook salmon were the focus of the analysis, and monthly habitat-specific length frequency histograms were used to distinguish the age-0 fish (nearshore: ≤130 mm FL in April–June, ≤200 mm FL in July–September; offshore: ≤230 mm FL in July, ≤300 mm FL in September–October) from older and stream-type Chinook salmon. Summary information was compiled for the age-0 Chinook salmon diet information from nearshore (Table 2) and offshore (Table 3) habitats. We calculated monthly (April–September) average diet proportions for age-0 Chinook salmon by habitat (nearshore and offshore), region (northern, central, southern, and Hood Canal), and year (2001–2007).

Statistical analyses.—We initially used multivariate analysis of variance (multivariate ANOVA) tests (Zar 1999) to determine the effects of factors that were expected to influence (arcsine transformed; Zar 1999) diet proportions of juvenile Chinook salmon. These included temporal factors like year (2001–2007) and month (April–September), spatial factors like region (northern, central, southern) and habitat (nearshore and offshore), and ontogenetic factors like size-class (small, medium, and large). These initial results were screened for only those effects and prey categories that showed significant main effects or interaction terms after Bonferroni correction for multiple comparisons, and subsequent analyses were conducted on each prey category individually by using ANOVA (Zar 1999). All analyses were performed using the Statistical Package for the Social Sciences version 11.5.0 (SPSS, Inc., Chicago, Illinois).

Interhabitat analysis.—To test our hypothesis that diet composition would vary by habitat (nearshore versus offshore) due to ontogenetic shifts in feeding and differences in available prey, we compared diet proportions of Chinook salmon at sizes (small: 70–129 mm FL; large: 130–199 mm FL) that were caught concurrently in both habitats during July and September of 2001 and 2002 in the northern and central regions. We categorized month (July or September) as a covariate to reduce the influence of seasonal variability (Table 4).

Intrahabitat analysis.—We hypothesized that within each habitat, Chinook salmon diet proportions would vary spatially and temporally due to differences in prey composition and would vary with predator size due to prey availability (e.g., ability of the predator to capture the prey). To test this hypothesis, we compared diet proportions at nearshore sites across years (2001, 2002), months (April–September), regions (northern, central, and southern), and size-classes (small: <70 mm FL; medium: 70–129 mm FL; large: 130–199 mm FL). We then compared diet proportions at offshore sites across years (2001–2007 excluding 2003), months (July or September/October), regions (northern, central; northern, central, and southern for July 2004; northern, central, and Hood Canal for September 2007), and size-classes (small: <130 mm FL; medium: 130–199 mm FL; large: 200–299 mm FL; Table 4).

Piscivory.—The proportions of fish in the diets of all sizes of Chinook salmon were pooled over all regions and plotted separately for nearshore and offshore habitats to examine ontogenetic shifts in piscivory. We grouped Chinook salmon into size-classes (<70, 70–129, 130–199, 200–299, 300–399, and ≥400 mm FL) by habitat (nearshore, offshore), and we used one-way ANOVA to examine shifts in piscivory in relation to Chinook salmon size. The FLs of measured prey fish were compared graphically with the FLs of Chinook

TABLE 2.—Summary of diet samples for age-0 Chinook salmon (by month and year) caught by beach seine in nearshore areas of Puget Sound, 2001–2002 (FL = fork length).

		2001						
Region	Variable	Apr	May	Jun	Jul	Aug	Sep	Total
North	Stomachs (*N*)	13	51	19	91	24	8	206
	Percent empty	8	4	0	1	0	0	2
	Percent with fish	0	8	0	7	8	38	7
	Mean FL (mm)	65.1	78.3	85.2	98.5	109.7	152.5	93.5
	Length range	51–81	39–110	61–106	81–150	95–168	123–196	39–196
Central	Stomachs (*N*)		13	89	77	97	38	314
	Percent empty		0	12	5	4	3	6
	Percent with fish		15	2	12	11	11	9
	Mean FL (mm)		83.5	86.3	105.5	124.7	130.6	108.1
	Length range		72–104	70–121	84–148	95–195	110–172	70–195
South	Stomachs (*N*)		85	32	48	5	5	175
	Percent empty		2	0	2	0	0	2
	Percent with fish		4	6	0	0	0	3
	Mean FL (mm)		85.9	90.3	108.7	126.0	128.6	95.3
	Length range		65–115	58–120	80–138	106–177	118–137	58–177

salmon (including fish caught in 2003 and during crepuscular periods in May 2002) to examine size limits (gape limitation) and prey size selectivity.

Diel feeding.—All sampling occurred during daylight hours, which may have caused some gear avoidance and a potential bias in the diet composition. To examine potential diel differences in feeding patterns, we sampled nearshore sites in northern and southern regions over a 24-h sequence during the peak juvenile Chinook salmon migration period in May 2002 (1 d/region; Duffy 2003). To examine diel feeding chronologies, we multiplied the ratio of the wet weight of the gut contents to the whole body weight (less the weight of the gut contents) by 100 to get a measure of feeding intensity (Brodeur et al. 2007).

Results

Diet Composition

Interhabitat analysis.—Chinook salmon at offshore sites were consistently larger than those sampled concurrently at nearshore sites. In 2001–2002, the average FLs of Chinook salmon (with nonempty stomachs) at offshore sites were larger than at nearshore sites by 19–30 mm in July and by 29–44 mm in September (except for northern sites in 2001; Tables 2, 3). In offshore waters, the proportion of Chinook salmon that had eaten fish (5–29%) averaged higher than the proportion at nearshore sites, but the frequency of empty stomachs was also higher offshore (Tables 2, 3).

Seasonal diet composition differed significantly between nearshore and offshore habitats (Table 4), among regions, and among size-classes but did not differ among years (Table 4). Overall, Chinook salmon ate significantly more insects, gammarids, and barnacles at nearshore sites (Figures 2, 3) and more decapods and copepods in offshore habitats (Table 5; Figures 4, 5). Chinook salmon also ate more fish in offshore habitats, particularly during September (Figures 2, 5), although this difference was not statistically significant (Table 5). Adult insects and forage fish (Foy and Paul

TABLE 3.—Summary of diet samples for age-0 Chinook salmon caught by midwater trawl during July and September (*October in 2004) in offshore areas of Puget Sound, 2001–2007 (FL = fork length).

		July						
Region	Variable	2001	2002	2004	2005	2006	2007	Total
North	Stomachs (*N*)	17	28	92	56	30	44	267
	Percent empty	12	18	1	13	13	0	7
	Percent with fish	0	11	10	4	47	11	12
	Mean FL (mm)	127.5	127.2	140.3	147.0	164.5	148.0	143.5
	Length range	113–154	103–179	108–224	109–221	126–226	125–190	103–226
Central	Stomachs (*N*)	17	83	147	174	163	161	745
	Percent empty	0	34	34	35	12	14	24
	Percent with fish	0	1	0	1	19	0	5
	Mean FL (mm)	122.9	114.8	128.0	138.4	146.9	128.6	133.1
	Length range	88–152	86–166	97–230	102–230	94–208	102–207	86–230

TABLE 2.—Extended.

Region	Variable	2002						
		Apr	May	Jun	Jul	Aug	Sep	Total
North	Stomachs (*N*)		31	14	70	16	5	136
	Percent empty		13	0	9	0	0	7
	Percent with fish		3	0	7	19	20	7
	Mean FL (mm)		83.2	74.4	87.4	102.9	132.0	88.5
	Length range		52–128	51–88	60–111	81–119	110–175	51–175
Central	Stomachs (*N*)		35	110	99	72	56	372
	Percent empty		3	4	9	7	5	6
	Percent with fish		20	8	2	7	5	7
	Mean FL (mm)		94.9	93.1	98.5	106.7	121.0	101.54
	Length range		75–115	72–138	80–144	86–162	100–171	72–171
South	Stomachs (*N*)	5	47	42	12	13	6	125
	Percent empty	0	0	2	0	8	0	2
	Percent with fish	40	9	12	8	8	0	10
	Mean FL (mm)	75.4	89.8	90.4	97.3	116.9	138.8	95.3
	Length range	69–88	67–115	76–123	78–120	96–170	112–180	67–180

1999; Table 3) were the highest quality prey eaten by Chinook salmon, with average energy density values close to 5,300 J/g of wet weight—almost double the energy densities of the primary invertebrate prey (planktonic crustaceans like decapods: ~3,000 J/g; Table 1).

Intrahabitat analysis: nearshore.—At nearshore sites (Figures 2, 3), diets consisted primarily of insects, crustaceans, other miscellaneous invertebrates, and fish; diet composition varied significantly among months, sampling regions, and size-classes but not among years (Table 4). Insects (primarily dipterans and hymenopterans, but also lepidopterans, aphids, coleopterans, and trichopterans) and, to a lesser degree, gammarids were a key part of the diet during all months (Figures 2, 3). Hyperiids were significantly more dominant in diets during the summer (August), whereas polychaetes and euphausiids were more prevalent in April–June diets, when the abundance of juvenile Chinook salmon peaked at nearshore sites (Table 5; Figures 2, 3). Rarer prey items (grouped as "other invertebrates") included isopods, cumaceans, ostracods, caprellid amphipods, and molluscs.

Insects were significantly more dominant in diets from the northern and central regions than in southern diets, whereas Chinook salmon in the southern region ate significantly more euphausiids and hyperiids (Table 5) and consistently had the lowest proportion of empty stomachs (<2%; Table 2). Hyperiids were significantly more prominent in diets of Chinook salmon in the southern and central regions, as well as overall in the diets of the largest Chinook salmon (130–199 mm FL; Table 5).

The largest age-0 Chinook salmon also ate significantly more fish (Table 5), but the proportion of the population that had eaten fish was more consistent at northern and central sites (7–9%) than at southern sites (3–10%; Table 2). Chinook salmon fed mainly on larval and juvenile Pacific sand lances, but other fish prey included pink salmon *O. gorbuscha* and chum salmon *O. keta* (at northern and southern sites), surf smelt *Hypomesus pretiosus* (northern), Pacific herring

TABLE 3.—Extended.

Region	Variable	September						
		2001	2002	2004*	2005	2006	2007	Total
North	Stomachs (*N*)	75	105	26	50	30	79	365
	Percent empty	5	10	27	10	53	5	13
	Percent with fish	31	47	23	20	27	13	29
	Mean FL (mm)	154.0	160.7	180.9	195.3	172.8	169.3	168.4
	Mean FL (mm)	96–253	121–250	142–252	165–226	134–221	143–207	96–253
Central	Stomachs (*N*)	87	151	115	171	124	127	775
	Percent empty	10	13	27	11	15	10	14
	Percent with fish	11	15	13	11	28	2	14
	Mean FL (mm)	165.6	165.3	192.8	178.7	189.3	160.1	175.3
	Length range	127–297	123–300	129–282	135–248	126–278	135–190	123–300

TABLE 4.—Results from multivariate analysis of covariance (MANCOVA) and multivariate analysis of variance (MANOVA) tests examining the effects of habitat (nearshore [near]; offshore [off]), sampling region canal (N = north, C = central, S = south, Hd = Hood Canal), years (2001–2007), months (April–September, where 4 = April and 9 = September; 10 = October, for 2004 only), and size-classes (fork length [FL]: sm = small, md = medium, lg = large) on the diet of juvenile Chinook salmon in Puget Sound. Degrees of freedom (df) are listed for both hypothesis (Hyp) and error terms.

Factor	Levels	Hyp df	Error df	Wilks' lambda	*F*	*P*
	Habitat MANCOVA					
Month (covariate)	7, 9	11	844	0.94	5.08	0.00
Habitat	Near, off	11	844	0.82	16.94	0.00
Year	2001, 2002	11	844	0.98	1.63	0.09
Region	N, C	11	844	0.93	5.44	0.00
Size-class	Sm (FL < 130 mm), lg (130–199 mm FL)	11	844	0.94	5.04	0.00
	Nearshore MANOVA					
Year	2001, 2002	9	1,200	0.99	1.85	0.06
Month	4–9	45	5,371	0.91	2.50	0.00
Region	N, C, S	18	2,400	0.96	2.92	0.00
Size-class	Sm (FL < 70 mm), md (70–129 mm FL), lg (130–199 mm FL)	18	2,400	0.98	1.64	0.04
	Offshore MANOVA					
Year	2001–2007 (except 2003)	45	7,728	0.88	4.83	0.00
Month	7, 9 (2004: 7, 10)	18	3,454	0.97	3.26	0.00
Region	N, C (Jul 2004: N, C, S) (Sep 2007: N, C, Hd)	9	1,727	0.97	6.53	0.00
Size-class	Sm (FL < 130 mm), md (130–199 mm FL), lg (200–299 mm FL)	18	844	0.89	11.03	0.00

(central), shiner perch *Cymatogaster aggregata* (northern and central), bay pipefish *Syngnathus leptorhynchus* (northern), and sculpins (Cottidae; northern and southern). Stomachs of Chinook salmon that contained fish averaged (mean ± SE) 1.7 ± 0.5 prey fish/stomach, with a maximum of 20 (larval) fish/stomach.

Intrahabitat analysis: offshore.—Overall, the diets of pelagic Chinook salmon were dominated by crustaceans, insects, and fish (Figures 4, 5), but the relative importance of different prey taxa varied by year, month, sampling region, and size-class (Table 4). Decapods were the most important offshore prey in July (Table 5), particularly during 2001–2004, but they were somewhat less important during 2005–2007 as the contributions of hyperiids, insects, euphausiids, and fish increased (Figure 4). Fish, gammarids, and euphausiids were more important components of offshore diets in September than in July (Table 5). Overall, Chinook salmon in September fed on a more diverse mix of prey types (Figure 5). Decapods, euphausiids, and hyperiids were consistently important, while rarer prey items, including ostracods and larval octopus, occasionally contributed substantially to the diet (Figure 5).

Decapods (almost exclusively crab larvae), euphausiids, and fish were significantly more important prey items in the northern region than in the central region (Table 5; Figures 4, 5), whereas copepods, gammarids, hyperiids, insects, and polychaetes represented a significantly larger proportion of the offshore diet in the central region (Table 5) as well as in the diets of the smaller size-classes of Chinook salmon (Table 5). The proportion of empty stomachs was higher in the central region than in the northern region, particularly during July (Table 3).

Additional spatial variability was found in offshore diets. In July 2004, Chinook salmon caught in the southern region (mean ± SE, 124 ± 4 mm FL; $n = 28$) ate decapods at a proportion similar to that of Chinook salmon in the northern region (and significantly greater than that of Chinook salmon in the central region); Chinook salmon in the southern region consumed a significantly lower proportion of amphipods relative to Chinook salmon in the central region (Table 5). In September 2007, Chinook salmon caught in Hood Canal (164 ± 1 mm FL; $n = 79$) ate a significantly higher proportion of fish and insects and significantly lower proportion of gammarids than did Chinook salmon in the northern and central regions (Table 5).

As in the nearshore habitat, Chinook salmon feeding offshore ate a significantly higher proportion of fish as predator size-class increased (Table 5). Piscivorous Chinook salmon in offshore waters fed mainly on juvenile and older Pacific herring, followed by Pacific sand lances. Other fish prey included surf smelt, bay pipefish, quillfish *Ptilichthys goodei* and larval and juvenile fishes representing various families (Osmeridae, Myctophidae, Agonidae, Cottidae, Sebastidae, and Pleuronectidae). Fish made up the greatest proportion of the July diets in 2006, when Chinook salmon were larger on average than in the other years (Figure 4). Piscivorous Chinook salmon contained an average of 1.21 ± 0.03 fish/stomach (mean ± SE), with a maximum of 4 fish/stomach.

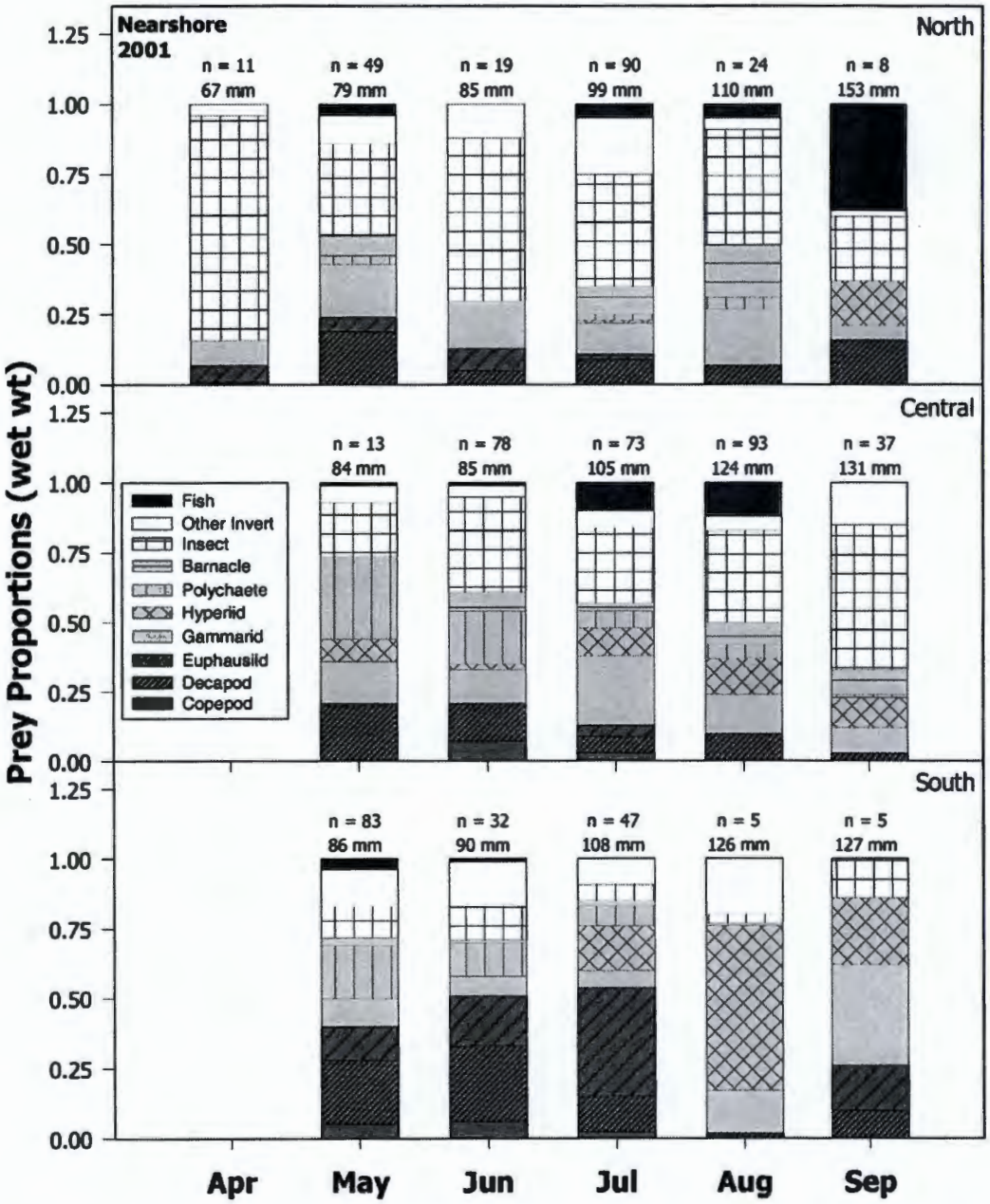

FIGURE 2.—Monthly nearshore marine diet composition (in wet-weight [wt] proportions of each prey category; invert = invertebrate) for age-0 Chinook salmon in northern (upper panel), central (middle panel), and southern (bottom panel) regions of Puget Sound during 2001. Sample size and average fork length are listed above each bar.

Piscivory

There appeared to be a length threshold associated with the onset of piscivory for Chinook salmon in nearshore (70 mm) and offshore (130 mm) habitats (Figure 6); fish that exceeded these thresholds became increasingly piscivorous as they grew larger (Table 6; ANOVA: nearshore $F = 85.02$, $P < 0.01$; offshore $F = 290.02$, $P < 0.01$). Chinook salmon ate fish with FLs

TABLE 5.—Results from analysis of variance (ANOVA) examining the effects of year, month, region, habitat, and size-class on proportions of prey groups in the diet of juvenile Puget Sound Chinook salmon. See Table 4 for definition of codes for levels in each factor (ns = not significant).

		Barnacles		Copepods		Decapods		Euphausiids	
Factor	df	*F*	Relationship	*F*	Relationship	*F*	Relationship	*F*	Relationship
					Habitat				
Habitat	1	9.56[b]	Near > off	6.83[b]	Off > near	137.88[b]	Off > near	0.51	ns
Year	1	0.25	ns	0.02	ns	2.88	ns	0.55	ns
Region	1	0.00	ns	10.05[b]	C > N	9.59[b]	N > C	1.59	ns
Size-class	1	2.05	ns	0.17	ns	7.92[b]	Sm > lg	1.35	ns
Month[c]	1	0.16	ns	2.84	ns	31.19[b]	7 > 9	0.15	ns
					Nearshore				
Year	1	0.04	ns	0.03	ns	0.26	ns	0.43	ns
Month	5	0.45	ns	0.94	ns	0.96	ns	3.70[b]	5 > 8, 9
Region	2	1.21	ns	0.95	ns	1.09	ns	10.06[b]	S > N, C
Size-class	2	0.93	ns	0.44	ns	1.27	ns	2.83	ns
					Offshore				
Year	1	0.36	ns	2.03	ns	3.66[a]	2001 > 2005	4.71[b]	2005 > all years (except 2006)
Month	5	1.39	ns	1.19	ns	59.63[b]	7 > 9, 10	16.34[b]	9 > 7, 10
Region	2	0.94	ns	5.14[a]	C > N	29.24[b]	N > C	4.75[a]	N > C (Sep 2007; N > C, Hd)
						32.79[b]	(Jul 2004; N, S > C)	11.51[b]	
						15.31[b]	(Sep 2007; Hd, N > C)		
Size-class	2	0.32	ns	3.61[a]	Sm > lg	18.39[b]	Sm > md > lg	0.44	ns

[a] $P < 0.05$.
[b] $P < 0.01$.
[c] Covariate.

that were up to 51% (nearshore) and 52% (offshore) of predator FL (Figure 7). At nearshore sites, Chinook salmon fed mainly on larval and juvenile Pacific sand lances (FL was 5–43% of predator FL); offshore, they primarily ate juvenile and older Pacific herring (15–52% of predator FL). Other nearshore fish prey included juvenile pink salmon, chum salmon, and Chinook salmon (5–33% of predator FL), shiner perch (18–34% of predator FL), bay pipefish (32–51% of predator FL), and threespine sticklebacks *Gasterosteus aculeatus* (14–18% of predator FL). Offshore fish prey also included Pacific sand lances (17–43% of predator FL), smaller Chinook salmon (29–42% of predator FL), and other larval and juvenile fishes (estimated as <15% of predator FL).

Diel Feeding

In May 2002, we were able to track the diel feeding chronology of juvenile Chinook salmon at nearshore sites in southern Puget Sound. Gut fullness levels suggest that Chinook salmon fed most actively during mid-day (Figure 8A). Euphausiids were a dominant part of peak daytime diets but were absent from stomach contents at other times. Decapods and copepods were the dominant prey items at dusk and dawn, respectively (Figure 8B).

Discussion

Juvenile Chinook salmon in Puget Sound exhibited diverse diets that varied among habitats, regions, seasons, and years. The current diet composition is similar to what was reported in the late 1970s (Fresh et al. 1981) but indicates an increased importance of insects, especially earlier in the season, and a reduction in the prevalence of fish in the diet, although this may be partly due to differences in study design and reporting. In general, Chinook salmon are opportunistic feeders, taking advantage of the local forage base and availability of prey (Beamish et al. 2003). The consistent appearance of several key prey items in the Puget Sound diets (e.g., insects, Pacific herring, crab larvae) suggests either that these prey were abundant and consistently available or that Chinook salmon have specific dietary preferences. To evaluate the status of foraging conditions for Chinook salmon, we need to examine both the quantity and quality of their historic versus contemporary diets in the context of spatial, temporal, and ontogenetic variability. Feeding intensity and proportion of empty stomachs give us an indication of the quantity of feeding. However, factors including the time of day (particularly for larger fish) and tide (particularly for nearshore fish) can have a large

TABLE 5.—Extended.

Fish		Gammarids		Hyperlids		Insects		Polychaetes	
F	Relationship	*F*	Relationship	*F*	Relationship	*F*	Relationship	*F*	Relationship
				Habitat					
1.91	ns	4.75[a]	Near > off	0.30	ns	49.60[b]	Near > off	0.22	ns
1.15	ns	0.22	ns	0.12	ns	4.71	2002 > 2001	0.01	ns
10.26[b]	N > C	1.55	ns	8.70[b]	N > C	9.92[b]	C > N	4.10[a]	C > N
28.09[b]	Lg > sm	1.26	ns	8.85[b]	Lg > sm	2.05	ns	0.01	ns
1.75	ns	1.32	ns	2.52	ns	13.26[b]	7 > 9	0.23	ns
				Nearshore					
3.51	ns	0.68	ns	8.86[b]	2001 > 2002	0.18	ns	1.08	ns
0.97	ns	2.37[a]	4 > 6, 7	11.41[b]	8 > all months	4.65[b]	7, 9 > 5	2.60[a]	6 > 9
8.97[b]	C > S	2.73	ns	6.68[b]	C, S > N	16.38[b]	N, C > S	0.23	ns
24.00[b]	Lg > sm, md	1.05	ns	4.71[b]	Lg > sm, md	0.08	ns	0.66	ns
				Offshore					
19.42[b]	2006 > all years (except 2002)	2.44[a]	2005 > 2001	9.54[b]	2007 > all years (except 2005)	2.11	ns	0.19	ns
28.64[b]	9 > 7	9.23[b]	9 > 7	1.21	ns	0.29	ns	0.11	ns
13.95[b]	N > C (Sep 2007; Hd > N, C)	10.05[b]	C> N	9.62[b]	C > N	29.13[b]	C > N	21.81[b]	C > N
23.02[b]		8.28[b]	(Jul 2007; C > N, S)	8.77[b]	(Jul 2004; C > N, S)	6.57[b]	(Sep 2007; Hd > N, C)	21.81[b]	C > N
		30.06[b]	(Sep 2007; C, N > Hd)						
118.44[b]	Lg > md > sm	3.08[b]	Md > Sm	6.31[b]	Md < lg	6.27[b]	Sm, md > lg	0.76	ns

influence on the stomach fullness; thus, these metrics should be interpreted cautiously. Specific characteristics of the prey (e.g., nutritional value and handling time) give a measure of the quality of foraging conditions in a particular region or habitat, although this information is not always readily available. We used energy density as an indicator of the relative quality of individual prey items (Table 1). However, these values should also be interpreted cautiously as they were primarily values from the literature and they included prey sampled in different geographical areas or average values from comparable species.

The most striking differences in diet composition and feeding intensity at nearshore sites occurred regionally between the northern and southern Puget Sound sampling sites. The dominance of largely terrestrial insects in diets at northern sites differed markedly from the largely planktonic crustacean-dominated diets at southern sites, while diets at central sites were intermediate between those at northern and southern sites. Adult insects are high-quality prey, with energy densities almost double those of most planktonic crustacean prey (Table 1). Kaczynski et al. (1973) reported a similar regional difference for chum salmon and pink salmon in the early 1970s; diets were more diverse at Port Susan (northern), including insects, mysids, and copepods, whereas diets at Anderson Island (southern) consisted almost entirely of copepods. The greater proportion of neustonic drift insects at northern sites was probably a result of substantially greater freshwater flow into that region, which was apparent in the lower surface salinities at northern sites than at southern sites (Duffy et al. 2005). Other sources of insects that may differ between sampling areas are fallout from riparian habitats (Simenstad et al. 1982) and transportation by wind (Cheng and Birch 1978; Hardy and Cheng 1986; Pathak et al. 1999) from vegetation in wetlands and uplands.

Differences in the proportion of Chinook salmon with empty stomachs may indicate regional differences in prey supply and availability. Chinook salmon in the southern region had the lowest proportion of empty stomachs, suggesting a more constant availability of prey. Annual and seasonal variability in the proportion of empty stomachs was highest in the northern region, which suggests that feeding conditions in this region were highly variable. For Chinook salmon using the nearshore habitat, feeding conditions appeared to be limited by the patchy availability of high-quality prey in the northern region, while at southern sites the fish had access to a lower-quality but more consistent and potentially abundant source of food. Accordingly, prey resources in the northern region are probably linked more to environmental variables (e.g., freshwater flow and wind) and terrestrial factors (e.g., extent of riparian and upland vegetation), whereas the prey resources in

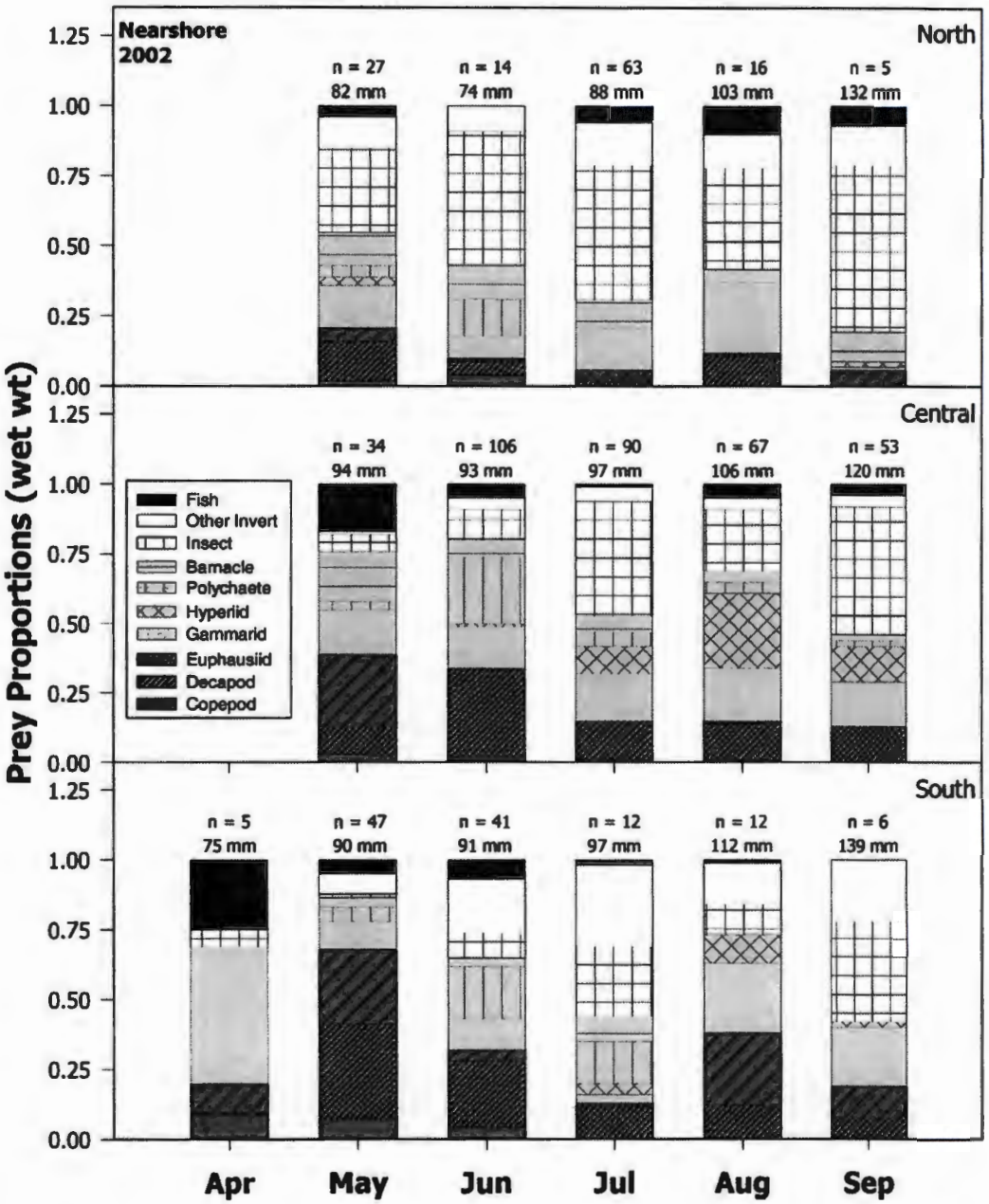

FIGURE 3.—Monthly nearshore marine diet composition (in wet-weight [wt] proportions of each prey category; invert = invertebrate) for age-0 Chinook salmon in northern (upper panel), central (middle panel), and southern (bottom panel) regions of Puget Sound during 2002. Sample size and average fork length are listed above each bar.

the southern region appear to be more marine in origin and are probably linked to environmental variables that control plankton production (e.g., climate).

In the offshore habitat, the diet composition of Chinook salmon was more diverse in fall (September–October) than in summer (July) and was more diverse in the central region than in the northern region. Decapods (primarily brachyuran crab larvae) were the

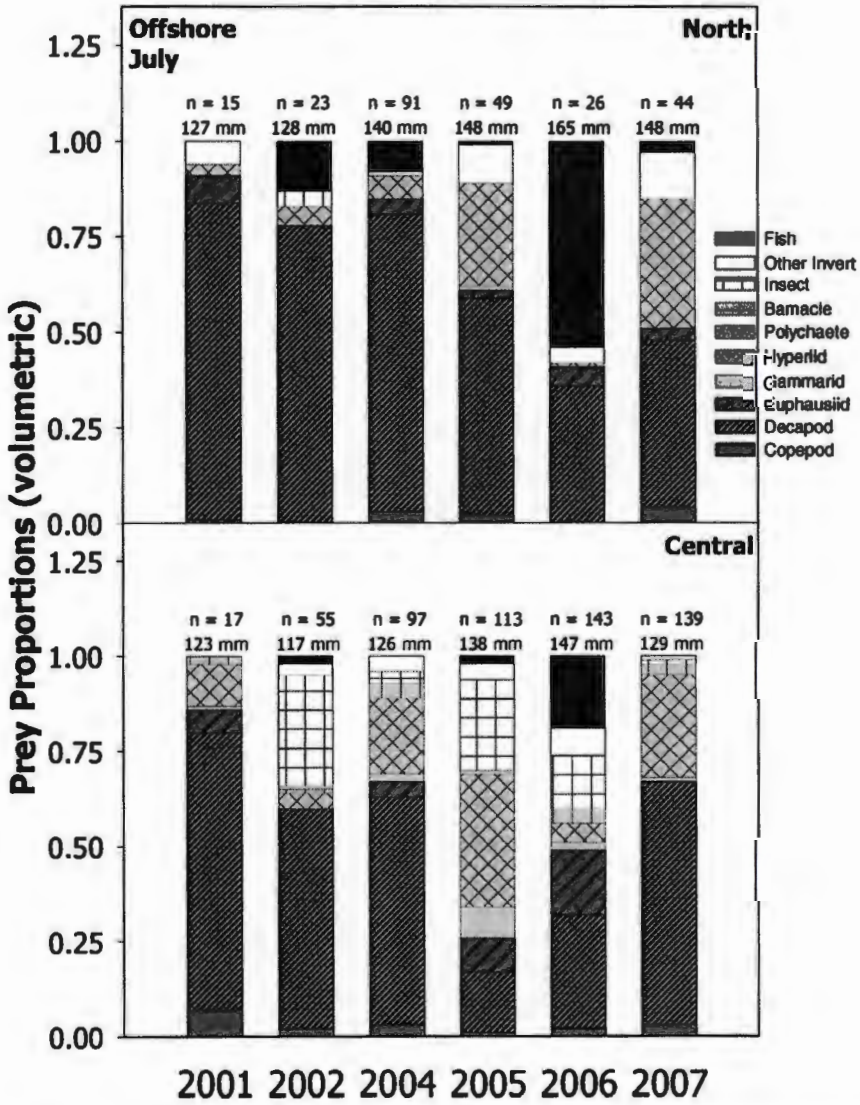

FIGURE 4.—Offshore marine diet composition (in volumetric proportions of each prey category; invert = invertebrate) for age-0 Chinook salmon in northern (upper panel) and central (lower panel) regions of Puget Sound during July 2001–2007. Sample size and average fork length are listed above each bar.

most important component of the diets in both regions during July. Crab larvae were also a major component of the July diets of other juvenile salmon species (in particular, coho salmon *O. kisutch*) and forage fishes (Fresh et al. 1981; R. J. Beamish, unpublished data). The abundance of larval crab prey and the availability of alternative prey resources may substantially affect the quality of summer feeding conditions for juvenile Chinook salmon (and probably coho salmon and forage fishes) in Puget Sound. The lower proportion of crab larvae in 2004–2005 diets and the greater variability in the diet composition at central sites suggest either that larval crab production was lower in those years or that Chinook salmon were opportunistically taking advantage of higher-energy prey items (e.g., insects at central sites in 2001–2004 and fish in 2006) when such items were available. The greater variability in the diet composition at central sites could also suggest that prey resources were more dynamic and unpredictable than in northern offshore waters.

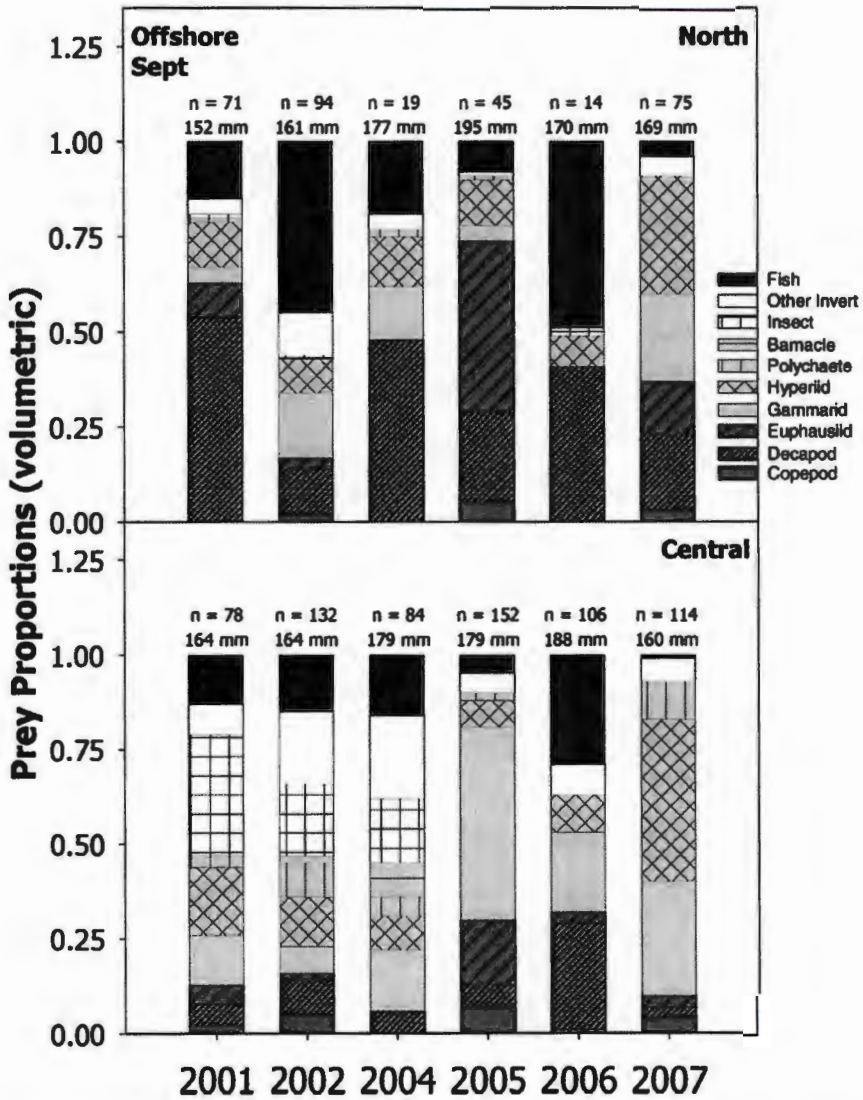

FIGURE 5.—Offshore marine diet composition (in volumetric proportions of each prey category; invert = invertebrate) for age-0 Chinook salmon in northern (upper panel) and central (lower panel) regions of Puget Sound during September 2001–2007 (in 2004, sampling was conducted in October instead of September). Sample size and average fork length are listed above each bar.

Regional differences in feeding intensity were also apparent in the late 1970s, when yearling Chinook salmon caught by purse seine in the central region showed a higher proportion of empty stomachs (36% versus 15%) and lower gut fullness (2.8 versus 3.7 on a qualitative scale, where 1 = empty and 7 = full) than those caught in the southern region (Fresh et al. 1981). Overall, annual shifts in the offshore diets appeared to be consistent among regions and seasons. For instance, in 2002, 2004, and 2006, fish prey made up a higher proportion of the diets in both regions, and this trend persisted between summer and fall (irrespective of size differences among consumers), as did the importance of hyperiids in 2007 diets. This suggests that the composition of prey available offshore in Puget Sound may be established by or before early summer.

It was difficult to separate temporal effects from size- and habitat-based shifts because these factors generally covaried with time. The most apparent size-based dietary shifts related to the onset of piscivory. In

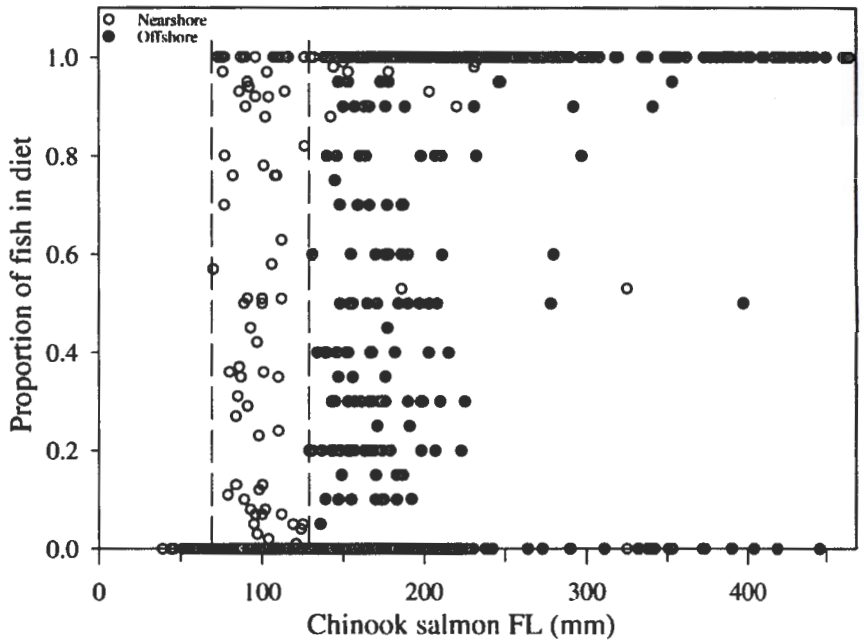

FIGURE 6.—Proportional contribution of fish prey (by wet weight in nearshore samples [open circles] or by volume in offshore samples [gray circles]) to the diets of Puget Sound Chinook salmon in relation to predator fork length (FL). Chinook salmon were collected nearshore by beach seine in 2001–2002 (northern, central, and southern regions: $n = 1{,}354$) and offshore by midwater trawl in 2001–2007 (northern and central regions: $n = 1{,}886$).

all regions and habitats, fish prey appeared in the Chinook salmon diets only above a certain predator size threshold (~70 mm FL nearshore and 130 mm FL offshore) and the proportion of fish in the diet increased as fish grew, which reflects gape limitations, swimming speed, and the size range of available prey. In laboratory conditions, Chinook salmon consumed salmon prey with lengths that were up to 40–47% of predator FL (Pearsons and Fritts 1999). Chinook salmon off the coast of Washington and Oregon consumed fish of lengths that were as much as 50% of predator length, although the average prey fish size was 20% of predator length (Brodeur 1990). In Puget Sound, Chinook salmon at both nearshore and offshore sites ate fish with lengths that were up to 52% of predator FL, and these Chinook salmon tended to have more than one fish in their stomachs (offshore: up to 4 fish/stomach; nearshore: up to 20 fish/stomach).

As in the late 1970s (Fresh et al. 1981), Chinook salmon in our study were highly piscivorous, especially as subadults and adults, and Pacific herring continued to be the predominant prey fish. Chinook salmon also occasionally preyed upon juvenile salmon, including conspecifics. At nearshore sites, juvenile Chinook

TABLE 6.—Mean proportion of fish in the diets of Chinook salmon (based on prey wet weight for nearshore habitat, and prey volume for offshore habitat) caught in Puget Sound by beach seine at nearshore sites (April–September 2001–2002) and by midwater trawl in offshore waters (July, September, and October 2001–2007). Data from all sampling regions are included and organized by size-classes (fork length [FL]; mm) to show ontogenetic shifts in piscivory.

	Nearshore			Offshore		
Size-class (FL, mm)	n	Mean proportion fish	SD	n	Mean proportion fish	SD
<70	42	0.00	0.00			
70–129	1,152	0.03	0.16	356	0.00	0.06
130–199	135	0.24	0.42	1,406	0.10	0.27
200–299	18	0.66	0.48	156	0.62	0.46
300–399	7	0.65	0.47	38	0.75	0.43
≥400				42	0.88	0.33

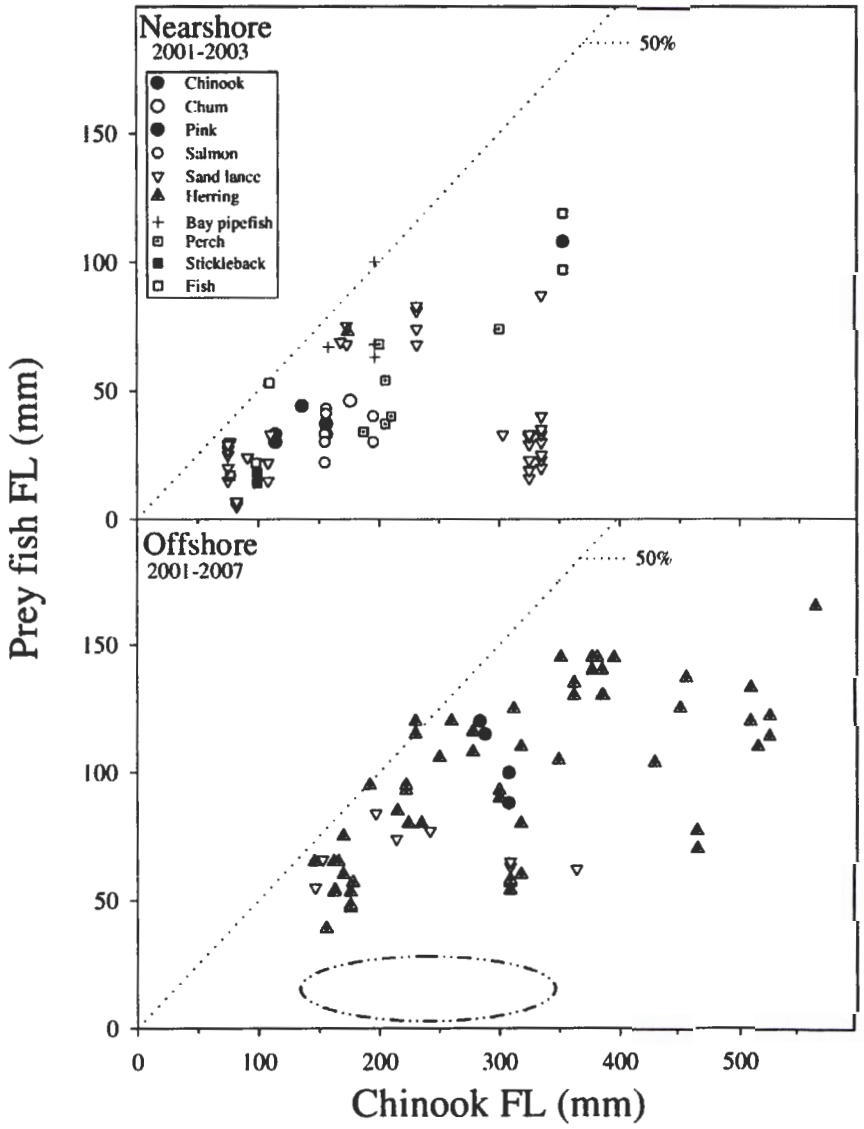

FIGURE 7.—Relation between the fork length (FL) of Puget Sound Chinook salmon (nearshore: $n = 31$ fish; offshore: $n = 34$ fish) and the FLs of consumed fish prey of different species (nearshore: $n = 93$ prey fish; offshore: $n = 73$ prey fish). Chinook salmon were collected nearshore by beach seine in 2001–2003 (northern and southern regions; upper panel) and offshore by midwater trawl in 2001–2007 (northern and central regions; lower panel). The dotted oval represents the likely size distribution of larval fish eaten by Chinook salmon in offshore waters (larval prey fish measurements were not available). Reference lines indicate prey FLs that are 50% (dotted) of predator FL. Prey types depicted are Chinook, chum, and pink salmon; other salmon; Pacific sand lance; Pacific herring; bay pipefish; shiner perch; threespine stickleback; and other fishes.

salmon mainly consumed pink salmon and chum salmon. Offshore, the only salmon species found in the stomachs of larger subadult Chinook salmon were juvenile Chinook salmon. Chinook salmon subadults have also been reported as occasional predators of juvenile salmon in the Pacific Ocean (Fresh et al. 1981; Brodeur 1990). Overall, it appears that Chinook salmon consume the most abundant and available fish prey (within the predator's gape limits and ability to capture; Fresh et al. 1981). While Pacific herring continue to be the most abundant pelagic forage fish in Puget Sound, there have been serious concerns over

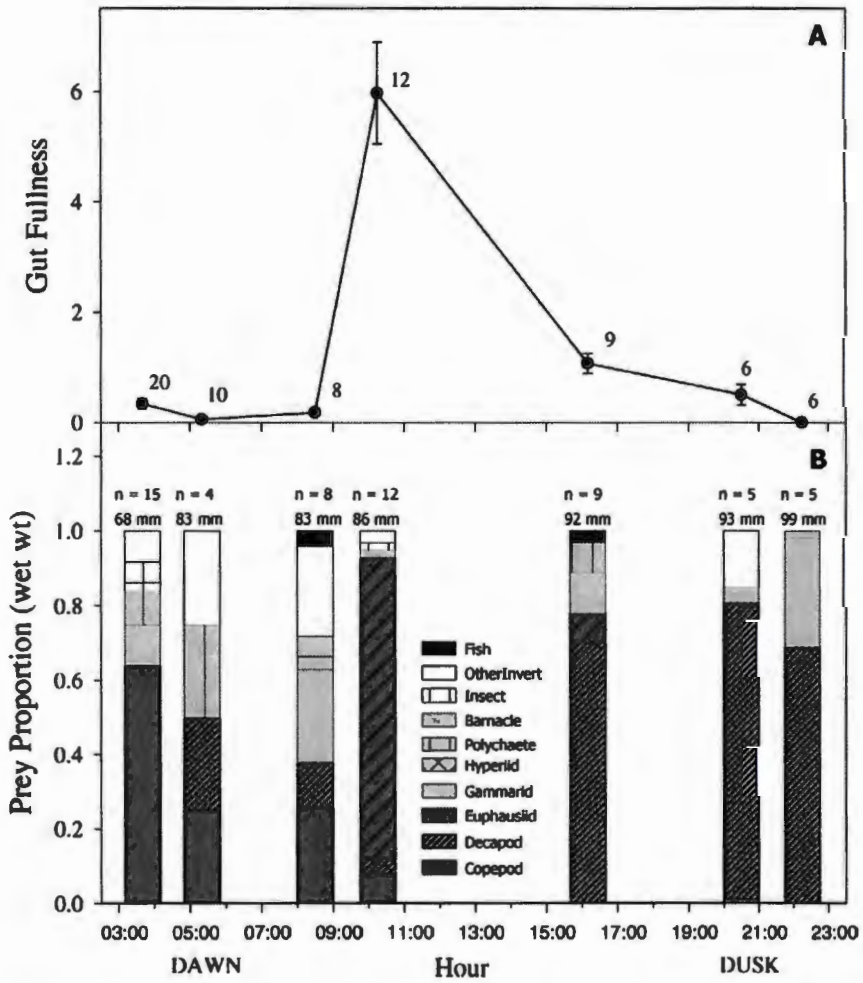

FIGURE 8.—Feeding chronology of age-0 Chinook salmon captured over a 24-h diel sampling period at nearshore sites in southern Puget Sound during May 2002: (A) gut fullness in percent body weight (mean ± SE; sample size is given above each data point) and (B) diet composition in wet weight (wt) proportions of major prey categories (invert = invertebrate; sample size and average predator fork length are indicated above each column).

recent declines in this species (PSWQAT 2002). Declines in Pacific herring stocks may doubly affect Chinook salmon by (1) reducing the quality of feeding conditions in Puget Sound and (2) potentially reducing a species that may act as a buffer to predation by larger salmon and many other species (birds, fish, and marine mammals). Further investigation into the current status of Puget Sound forage fish stocks (especially Pacific herring) and their trophic linkages to Chinook salmon is important for uncovering the mechanisms behind declines in Puget Sound Chinook salmon.

In Puget Sound, recent feeding conditions for juvenile Chinook salmon ranged from high quality yet variable to consistent but lower quality, and these differences were linked to region and habitat. In the northern region, nearshore feeding conditions appear to be more closely linked to terrestrial processes, and Chinook salmon from this region may be more vulnerable to increased shoreline modifications and development-driven loss of vegetation than those from the southern region, where feeding conditions are determined more by marine plankton availability. However, for Chinook salmon in offshore environments, moving into the northern region could provide a more consistent, higher-quality feeding environment than the central region. A northward shift might also encourage earlier migration towards the Pacific Ocean if foraging success at this stage translates to higher

survival. In addition, the present study suggests that annual variation in the composition and quality of prey eaten by juvenile Chinook salmon in Puget Sound is determined early in the growing season, which may translate to strong annual patterns in marine survival. A greater understanding of the mechanisms limiting survival (i.e., predation, starvation, and disease) and the conditions that mediate them (i.e., prey resources and environment) during and subsequent to this critical early marine life history stage is necessary to improve marine survival forecasts and aid recovery plans for Puget Sound Chinook salmon.

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ATTACHMENT G

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Impacts of docks on seagrass and effects of management practices to ameliorate these impacts

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ABSTRACT

Seagrasses have high conservation and human-use values, but around the world they are being damaged by human activities. Compared to the larger spatial scale at which some human activities affect estuaries and their seagrasses (e.g. catchment disturbance, dredging, pollution, trawling), recreational boating and infrastructure of moorings and docks act at smaller scales. However, the cumulative effects contribute to stresses acting on seagrass beds. This study assessed the effects of docks on the native seagrass *Zostera muelleri* subsp. *capricorni* in an estuary in south-east Australia and of current management practices designed to reduce dock impacts on this seagrass. A field survey found that seagrass biomass was significantly reduced below docks, and the effects were not influenced by dock orientation. Management practices requiring the use of a mesh decking to provide greater light penetration reduced, but did not eliminate, the reduction in seagrass biomass caused by docks. A modified beyond BACI experiment provided evidence for a causal link between the installation of wooden or mesh docks and reductions in biomass of seagrass. The reduction in biomass was apparent 6 mo after dock installation, and by 26 mo seagrass biomass had declined by at least 90%. Faced with increasing coastal populations, increases in recreational use, and continued pressures from other human activities, alternative management practices that further minimize the effects of docks are needed.

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1. Introduction

Seagrass beds are productive, shallow-water ecosystems that provide a habitat for a rich and unique faunal biodiversity including the juveniles of many species important for commercial and recreational fishing activities (Waycott et al., 2009; Unsworth and Cullen, 2010). Seagrass beds stabilize sediments and are likely to play an important role in the prevention of coastal erosion. Seagrasses are an important component of estuarine ecological processes due to their high primary productivity, roles in detrital pathways and nutrient cycles, and their export of nutrients and energy to other associated ecosystems (Poiner and Peterken, 1995; Gillanders, 2007). The faunal biodiversity of estuarine seagrass beds is greater than, and different from, nearby unvegetated habitats and seagrass beds therefore represent a substantial component of the overall habitat and species diversity of estuaries (Jenkins and Wheatley, 1998; Rotherham and West, 2002).

Australia has the greatest richness of seagrass species and the largest area of temperate seagrass beds in the world (Gillanders, 2007). Seagrasses within New South Wales (NSW), Australia, have declined in extent and condition as a result of increased turbidity, siltation, erosion from dredging, eutrophication, sea urchin grazing, and trawling (Brodie, 1995; Poiner and Peterken, 1995; Macdonald, 1996; NSW EPA, 2000; ASEC, 2001). The outcome of these pressures on seagrass within NSW was an average 50% loss of seagrass area in estuaries in the period of 1960s-early 1990s (Poiner and Peterken, 1995). Similar, and sometimes greater, losses of seagrass have occurred in other Australian states (Neverauskas, 1987; Preen et al., 1995; Kendrick et al., 2002; Campbell and McKenzie, 2004) and other countries (Delgado et al., 1999; Baden et al., 2003; Hauxwell et al., 2003; Waycott et al. 2009).

Although less dramatic than the losses due to human industry and ecosystem alteration, seagrasses are damaged by recreational activities such as boating (Dunton and Schonberg, 2002; Milazzo et al., 2004), bait collecting (Skilleter et al., 2006), food harvesting (Boese, 2002; Cabaço et al., 2005), trampling (Eckrich and Holmquist, 2000), and the infrastructure installed for recreation such as moorings (Hastings et al., 1995) and docks (Fyfe and Davis, 2007). Seagrasses in NSW estuaries are located in the shallow, nearshore environment and, extending out from the shore for

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distances of 10s to 100s of metres in shallow waters, they are potentially exposed to the impacts of dock construction and use. Current understanding of the impacts of docks on seagrass comes from a small number of studies. Seagrass shoot density was significantly reduced immediately below a dock in Jervis Bay (NSW, Australia), but no impact was detected 5 m away from the dock (Fyfe and Davis, 2007). Two-thirds of docks in Nantucket Harbor and Waquoit Bay (Massachusetts, USA) had no seagrass (*Zostera marina*) below them (Burdick and Short, 1999). Seagrass (*Halodule wrightii*) biomass below docks in Perdido Bay (Alabama, USA) was 67–70% of the values recorded in areas without docks (Shafer, 1999).

Loss of seagrass below docks occurs as a direct result of shading and the indirect impacts of associated boating activities. *Halodule wrightii* were not present under docks where light levels were less than 14% surface irradiance (Shafer, 1999). The effect of shading was greatest between 1000 h and 1500 h, and seagrasses subject to additional shading during the morning and late afternoon due to dock height and orientation were particularly vulnerable to effects of shading (Shafer, 1999). Seagrass and sediment in the vicinity of docks are affected through boat propeller scarring (Shafer, 1999; Burdick and Short, 1999). A cumulative assessment of dock impacts in Waquoit Bay (Massachusetts, USA) found that docks shaded less than 1% of total seagrass area in the Bay. However, seagrass beds in the vicinity of docks were also affected by anchor damage and propeller scarring, and so the areal extent of impact was substantially greater than the area of seagrass directly shaded by docks (Burdick and Short, 1999).

There are large numbers of docks in some estuaries in NSW, including Lake Macquarie (760), Tuggerah Lakes (32), Brisbane Water (≈750), and Pittwater (≈675). Some of these estuaries have lengthy shorelines (e.g. 174 km in Lake Macquarie). However, docks are often concentrated in some areas, reaching densities of 60 docks per km, which is likely to lead to a localization of effects. The effects of docks on seagrass are covered by the NSW by the Fisheries Management Act and its associated Policy and Guidelines for Fish Habitat Conservation and Management (Fairfull, 2013), and implemented by local municipalities. The Policy and Guidelines exclude docks from beds of *Posidonia australis* seagrass (existing as endangered populations in several estuaries), provide guidelines on dock designs, and require a permit for construction of docks over other seagrasses. Construction permits are issued jointly by the NSW Department of Primary Industries (DPI), the Department of Lands, and the local municipality. Guidelines on dock designs include restrictions on the maximum length, minimum water depth, orientation (a north–south orientation is preferred but not mandated), height, and decking materials (e.g. the use of aluminium mesh or translucent PVC to allow greater light penetration). There is, however, no published information on the effects of docks on seagrasses in NSW to inform conservation planning (with the exception of Fyfe and Davis, 2007) or the effects of design options (such as alternative decking materials and orientation) in modifying the impacts of docks on seagrass.

The aims of this study were to quantify the effects of docks on seagrass and evaluate the effects of management options for minimizing their effects, including dock orientation and decking materials. The approaches taken included a series of spatially and temporally replicated mensurative experiments that compared seagrass biomass below wooden or mesh docks with control sites (no docks), and tested the effects of dock orientation on seagrass loss. In order to definitively identify docks as the cause of seagrass loss, a modified beyond BACI (Before-After-Control-Impact) experiment was done to quantify the changes in seagrass following the installation of wooden or mesh docks.

2. Materials and methods

2.1. Study area

This study was undertaken in Lake Macquarie (Fig. 1) between 2006 and 2008. Lake Macquarie is a natural estuarine lagoon with an average depth of 5.7 m, covering an area of about 100 km^2 and surrounded by extensive residential and industrial development. Although seagrass cover has increased in some parts of the lake, the total extent of seagrass has declined since the 1960s (King and Hodgson, 1986). Seagrasses occurring in the shallow (max. depth 1 m) nearshore waters are *Zostera muelleri* subsp. *capricorni*, *Halophila* spp., and *Ruppia megacarpa* (King and Holland, 1986). This study was restricted to an examination of the effects of docks on *Z. muelleri* subsp. *capricorni*. We use the term dock to mean small single wharves installed perpendicular to the shoreline on private property, and distinguish them from public wharves (that may be used mostly for public transport, shipping, commercial fishing operations) and marinas. This study focused on domestic docks (i.e. adjoining privately owned land), which have design constraints imposed by the current policy and guidelines and the local municipality (Lake Macquarie City Council, LMCC). At the time of this study LMCC Development Control Plan 1 Section 3.1.1 (Development Adjoining the Lake and Waterways Zone) required the width of domestic docks to be 900–1200 mm, the height to be 600–750 mm above mean high water mark, and the deck to be constructed from 150 mm × 35 mm hardwood or aluminium mesh (dimensions not specified). Although the gaps between hardwood deck planks, and the dimensions of the openings in the aluminium mesh are not specified, the Plan requires the deck to provide natural light penetration when the dock is situated over seagrass. The locations of all domestic docks were obtained from the LMCC and confirmed by personal visits as part of site selections. Docks were pre-selected to minimize inter-dock variation in dimensions, so their width varied from 900 to 1100 mm and their height above the water varied from 600 to 700 mm. Spring tide range in Lake Macquarie at the study sites is ~120 mm (Nielsen and Gordon, 2008).

2.2. Effects of wooden docks and dock orientation

The null hypotheses that seagrass biomass below wooden docks would not differ from beds without docks, and that dock orientation (i.e. north–south vs east–west) would not affect seagrass biomass, were tested. Samples of *Zostera muelleri* subsp. *capricorni* plants were collected by inserting a 10 cm diameter PVC corer into the sediment to a depth of 10 cm. The corer was withdrawn and the sample washed through a 1 mm sieve to remove adhering sediment. Seagrass samples were returned to the lab and oven-dried at 70 °C until a constant weight was achieved (this usually required 48–72 h). The final dry weight of the seagrass sample was used as an estimate of seagrass biomass (whole plant). The values for seagrass biomass reported hereafter represent dry weight biomass 0.008 m^{-2}. Five replicate cores were collected following the results of an earlier pilot study (authors' unpublished data) that found that this amount of replication provided mean values with an acceptable sampling precision (standard error/mean) of 0.15 (Andrew and Mapstone, 1987).

Sampling was done by laying a tape measure (hereafter called the 'transect') immediately below and along the centreline of a dock and inserting the PVC corer at randomly selected distances (based on a table of random numbers) along the tape measure. Sampling began at least 3 m from the low tide mark on the shore and replicate samples were separated by at least 1.5 m to prevent disturbance during collection of adjacent samples. In seagrass beds

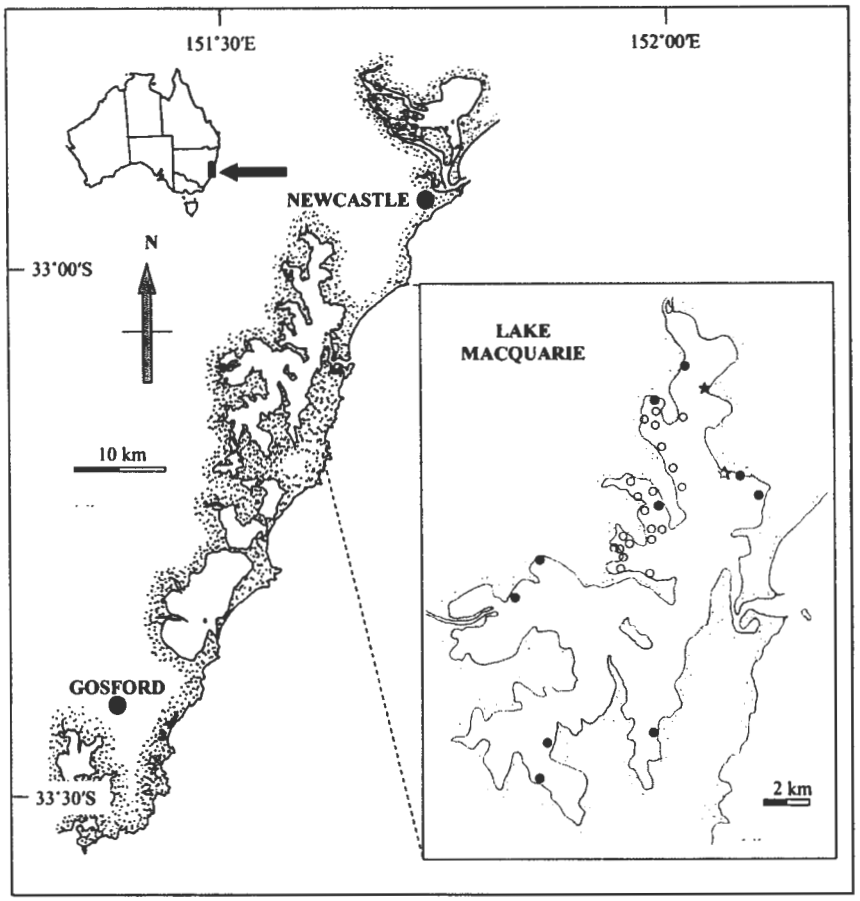

Fig. 1. Locations of study sites in Lake Macquarie used to assess *Zostera muelleri* subsp. *capricorni* for ● effects of dock orientation (each symbol represents 3 docks or 3 seagrass beds without docks), ○ comparison of wooden vs mesh dock study (each symbol represents a single dock or single transect in a seagrass bed without transects), and for BACI study on effects of installation of wooden dock (☆) and mesh dock (★).

without jetties the transects were laid and samples collected using an identical protocol.

A four-factor design was used to test the hypotheses, based on the following model: Treatment (2 levels (dock, no dock), fixed, orthogonal); Orientation (2 levels (north–south, east–west), fixed, orthogonal); Site (3 levels, random, nested in Treatment × Orientation); and Transect (3 levels, random, nested in Site (Treatment × Orientation)). There were $n = 5$ replicate samples per Transect. Three sites of each combination of Treatment and Orientation were randomly selected from amongst the available docks. Replicate sites were at least 1 km apart. Within each site 3 docks or non-dock areas were selected. The orientation of all docks was determined during site visits. The large number of docks in Lake Macquarie meant that it was possible to select docks that were within ±10° of north–south or east–west. Sampling occurred in January–February 2006.

2.3. Effects of wooden and mesh docks

The null hypotheses that seagrass biomass below wooden and mesh docks would not differ, and that seagrass biomass below both types of docks would not differ from seagrass beds without docks, were tested. Preliminary site visits in May 2006 revealed there were insufficient mesh docks to include site as a potential source of variation. Seven mesh docks and 7 wooden docks of the same orientation, length and height on the western side of Lake Macquarie were selected for the comparison. All docks were within the range of allowable width and height specified by LMCC. Gaps between wooden decking planks were 10–12 mm. The decking of all mesh docks was identical and consisted of aluminium expanded mesh, with diamond-shaped openings of length 95 mm, maximum width 32 mm, and mesh thickness 7 mm. Reference transects were positioned in seagrass beds in the same orientation as the dock transects and at least 500 m from the nearest dock. Sampling occurred in June 2006, September 2006, and December 2006. Transects were placed in the same position on each sampling occasion, the positions of samples recorded, and subsequent positions selected to ensure that samples were at least 1.5 m from previous samples.

A three-factor design was used to test the null hypotheses, based on the following model: Time (3 levels (June 2006, September 2006, December 2006), random, orthogonal); Treatment (3 levels (mesh dock, wooden dock, controls i.e. no dock), fixed orthogonal); and Transect (7 levels, random, nested in each level of Treatment). There were $n = 5$ replicate samples per Transect.

2.4. Effects of installation of wooden and mesh docks: BACI test

Although the aforementioned mensurative field experiments provided evidence for an association between docks and seagrass loss (see Results), they do not demonstrate conclusively that docks caused the loss of seagrass. Therefore, a modified beyond BACI field experiment (Underwood, 1992; Glasby, 1997) was used to test whether installation of wooden and mesh docks led to loss of seagrass. The design is 'modified' because only a single example of each dock type was available for testing, and each was compared

with multiple controls. The mesh and wooden docks were installed in May and June 2006 respectively. Sampling associated with the new mesh dock was done 1 week before installation (hereafter called the 'before' sample) and at 6 mo ('after 1') and 26 mo ('after 2') following installation. Sampling associated with the new wooden dock was done 3 mo before installation ('before') and again at 7 mo ('after 1') and 26 mo ('after 2') following installation. The different time periods of the 'before' sample for the two dock types occurred because the installation of the new mesh dock became known to the authors only 1 wk prior to its installation. The effects of dock installation were quantified by comparing the biomass of *Zostera muelleri* subsp. *capricorni* along transects below each new dock with the biomass of *Z. muelleri* subsp. *capricorni* along 6 control transects in each of 3 control sites. Control sites were located from 250 m to 5 km away from the new docks. The selection of multiple control sites, and multiple transects within each control site, addresses the need for impacts to be assessed by accounting for the range in natural variation in seagrass growth that is likely to be occurring (Underwood, 1992). The control transects were the same length and depth as the transects under the new docks.

The null hypothesis that seagrass biomass would not decline after installation of wooden and mesh docks was tested. The model consisted of the following factors: Before vs After (fixed); Dock vs Control (fixed); Sites random and nested in (Dock vs Control) with $n = 1$ site in Dock and $n = 3$ sites in Control; and Transects random and nested in Site (Dock vs Control) with $n = 1$ transect in the Impact site and $n = 6$ transects in the Control sites. There were $n = 5$ replicate samples per transect. As only a single before sample was obtained, separate analyses were done for each dock type for the comparison of before with after 1, and before with after 2. In this asymmetrical design, an effect of dock installation is demonstrated by a significant Before vs After × Dock vs Control interaction and post-hoc pairwise tests that demonstrate significant loss of seagrass below docks, but not control transects, from Before to After.

All hypotheses were tested with permutational multivariate analysis of variance (PERMANOVA) (Anderson, 2001). Univariate asymmetrical PERMANOVAs (Terlizzi et al., 2005; Anderson et al., 2008) were used to compare changes in seagrass biomass from before to after dock installation in transects below new docks and in control transects. Prior to PERMANOVA the raw data were checked for homogeneity of variances and, where necessary, transformed to eliminate heterogeneity. The resemblance measure was Euclidean distance and the analyses were done with PERMANOVA+ for PRIMER software (PRIMER-E Ltd).

3. Results

3.1. Effects of wooden docks and dock orientation

The biomass of seagrass below docks was significantly less than the biomass of seagrass in beds without docks, regardless of their orientation (Table 1, Fig. 2). The average seagrass biomass below docks (3.3 ± 0.85 g) was 25.8% of the average biomass in beds without docks (12.8 ± 1.45 g). The absence of a significant result for Site (Table 1) shows that this difference was spatially consistent throughout Lake Macquarie. The significant result for Transects (Site (Treatment × Orientation)) occurred because there was significant variation in average seagrass biomass among some, but not all, transects in most sites.

3.2. Comparison of wooden and mesh docks

The Ti × Tr interaction occurred because seagrass biomass below mesh docks and in the control sites changed through time but it did not change below wooden docks. The three treatments differed significantly in their seagrass biomass at each sampling time (Table 2, Fig. 3). The average seagrass biomass below wooden docks was 5.2%, 16.9% and 20.9% of the average seagrass biomass in control transects at the three times. The average seagrass biomass below mesh docks was 41.5%, 49.7% and 46.7% of the average seagrass biomass in control transects at the three times. Therefore the null hypothesis that seagrass biomass below wooden and mesh docks would not differ is rejected, and the null hypothesis that seagrass biomass below both types of docks would not differ from seagrass beds without docks is rejected.

The significant Time × Transect (Treatment) interaction occurred because there was inconsistent temporal variation among transects in the three treatments. Average seagrass biomass varied significantly among some transects (not shown in graph) below wooden docks at all sampling times. Seagrass biomass did not vary significantly among mesh docks at any time, whereas it varied among some control transects at some (but not all) times.

Table 1
Summary of results of four-factor PERMANOVA testing for differences in biomass of *Zostera muelleri* subsp. *capricorni* between seagrass beds with and without wooden docks (Treatment) of north–south and east–west orientations (Orientation) in different sites (Sites), and at multiple docks or transects in each site (untransformed data, variances homogeneous, Cochran's $C = 0.12$, $P > 0.05$) ($n = 9999$ permutations of residuals under a reduced model).

Source of variation	df	MS	Pseudo-*F*	*P* (perm)
Treatment: T	1	3912	29.81	0.002
Orientation: O	1	379.90	2.90	0.13
T × O	1	1.55	0.01	0.90
Site (T × O): Si (T × O)	8	131.21	1.48	0.19
Transect (Si (T × O))	24	88.96	5.81	0.0001
Res	144	15.31		

3.3. Effects of dock installation

Seagrass biomass below the wooden dock was not significantly reduced 6 mo after installation, relative to the changes that occurred at transects in the control sites, as shown by the absence of a significant (Before vs After) × (Dock vs Controls) interaction (Table 3a, Fig. 4a). Average seagrass biomass declined significantly in the transect below the new wooden dock but also to varying degrees in many of the transects in each of the control sites, as shown by the significant (Before vs After) × Transect (Site (Dock vs Control)) interaction. It is worth noting that the greatest decline in biomass from Before to After 1 occurred at the dock transect (even

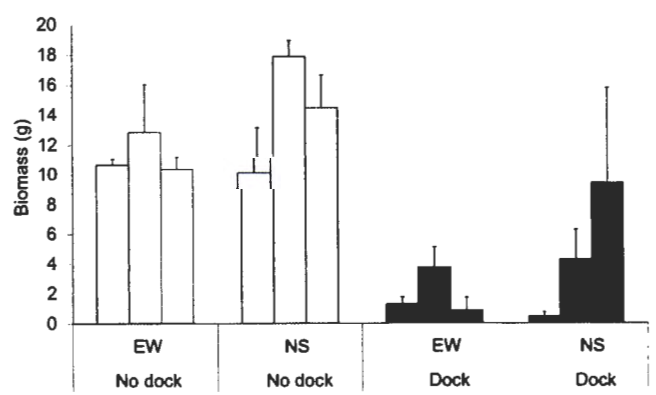

Fig. 2. Biomass of *Zostera muelleri* subsp. *capricorni* in Lake Macquarie in each of 3 sites with no docks (east–west (EW) and north–south (NS) orientations) and 3 sites with wooden docks (EW and NS orientations). Values shown are mean + standard error of 3 transects in each site ($n = 5$ replicate samples per transect).

Table 2
Summary of results of three-factor PERMANOVA testing for differences in biomass of *Zostera muelleri* subsp. *capricorni* at three times (Time) between wooden docks, mesh docks and control seagrass beds without docks (Treatment) and among multiple examples of each Treatment level (Transects). Analyses done on Ln(X + 1.5) transformed data (Cochran's C = 0.07, P > 0.05) and n = 9999 permutations of residuals under a reduced model.

Source of variation	df	MS	Pseudo-F	P (perm)
Time: Ti	2	1.58	22.86	0.0001
Treatment: Tr	2	9.67	12.06	0.0001
Transects (Tr)	18	0.08	1.13	0.38
Ti × Tr	4	0.73	10.54	0.0001
Ti × Transect (Tr)	36	0.07	2.33	0.0002
Res	252	0.03		

though the difference was not significant). Seagrass biomass also varied significantly among the control sites, in a consistent manner among times.

Twenty-six months after installation, the biomass of seagrass below the wooden dock was significantly less than controls, and this temporal decline was greater than the reduction that occurred in the control transects (as shown by the significant (Before vs After) × (Dock vs Control) interaction) (Table 3b). Seagrass biomass below the wooden dock declined significantly from before to after 2 (t = 7.29, P = 0.009) and seagrass biomass in the controls was not significantly different in the after 2 sample (t = 15.20, P = 0.10) (Fig. 4a). Seagrass biomass declined by 96% under the new wooden dock between the before and after 2 samples. There was also significant variation in seagrass biomass among transects in the control sites, and significant variation among the control sites, although this variation was less than the temporal changes below the dock.

Between the before and after 1 sampling associated with the new mesh dock there were significant, but inconsistent, changes in seagrass biomass that were unrelated to the dock installation (Table 4a, Fig. 4b). The significant (Before vs After) × Transect (Site(Dock vs Control)) interaction occurred because seagrass biomass changed in the transect below the new mesh dock, in some transects in two control sites, and in all transects in one control site. Average seagrass biomass also varied significantly among the three control sites.

The (Before vs After) × (Dock vs Control) interaction term for the test of before and after 2 samples was marginally significant

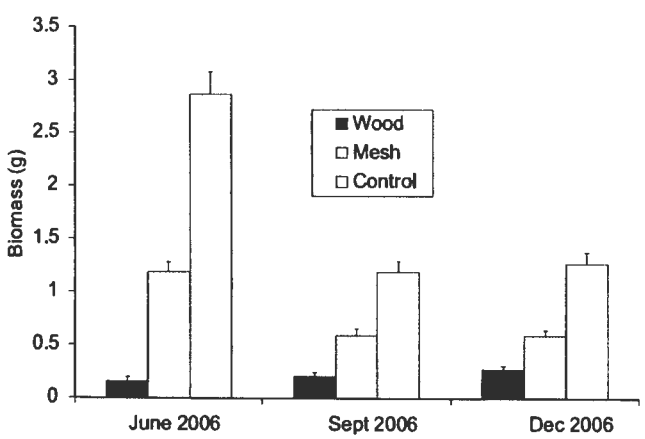

Fig. 3. Biomass of *Zostera muelleri* subsp. *capricorni* seagrass below wooden docks, below mesh docks and in seagrass beds with no docks (i.e. controls). Values shown are mean + standard error from 7 transects in each treatment at each time (n = 5 replicate samples per transect).

Table 3
Summary of asymmetrical PERMANOVA results testing for a change in biomass of *Zostera muelleri* subsp. *capricorni* from (a) before to 7 mo after, and (b) from before to 26 mo after installation of a wooden dock. The change occurring below the newly installed dock was compared with changes among n = 6 transects in each of n = 3 control sites (n = 9999 permutations of residuals under a reduced model).

Source of variation	df	MS	Pseudo-F	P (perm)
(a) Before to 7 mo after installation (Ln(X + 0.1) transformed data, Cochran's C = 0.11, P > 0.05)				
Before vs After: B vs A	1	12.36	38.62	0.002
Dock vs Control: D vs C	1	0.50	0.44	0.54
Site (D vs C): Si (D vs C)	2	3.92	10.29	0.002
(B vs A) × (D vs C)	1	1.12	3.50	0.07
Transect (Site (D vs C)): Tr (Si (D vs C))	15	0.38	1.96	0.02
(B vs A) × Si (D vs C)	2	0.07	0.18	0.83
(B vs A) × Tr (Si (D vs C)	15	0.39	1.99	0.02
Res	152	0.19		
(b) Before to 26 mo after installation (Ln(X + 0.1) transformed data, Cochran's C = 0.07, P > 0.05)				
Before vs After: B vs A	1	35.17	141.08	0.001
Dock vs Control: D vs C	1	2.34	1.64	0.18
Site (D vs C): Si (D vs C)	2	4.97	10.31	0.002
(B vs A) × (D vs C)	1	3.53	14.15	0.007
Transect (Site (D vs C)): Tr (Si (D vs C))	15	0.48	3.22	0.0002
(B vs A) × Si (D vs C)	2	0.34	1.49	0.26
(B vs A) × Tr (Si (D vs C)	15	0.23	1.51	0.11
Res	152	0.15		

(P = 0.05) (Table 4b, Fig. 4b). Pairwise tests showed that seagrass biomass changed significantly below the mesh dock between the before and after 2 samples (t = 4.12, P = 0.008) and did not change in the controls over the same time period (t = 12.05, P = 0.10). Seagrass biomass below the new mesh dock declined by 90% between the before and after 2 samples, compared to 72% decline in the controls. Seagrass biomass varied significantly among transects in two of the three control sites, and among the control sites (Table 4b).

4. Discussion

4.1. Effects of existing wooden docks

Seagrass was present below all wooden docks examined, however, the average seagrass biomass below docks was 25.8% of the average biomass in beds without docks. This loss of seagrass biomass is considerably larger than values reported in Perdido Bay (Alabama USA) (67–70% of the values recorded in areas without docks; Shafer, 1999). However, Burdick and Short (1999) reported that seagrass was absent below two-thirds of the docks examined in two estuaries in Massachusetts (USA).

The distribution, abundance and growth of seagrasses are influenced by a range of physical environmental influences and biological processes. Biological processes influencing the survival of seagrass beds include the distribution of other seagrass plants, productivity of epiphytic algae, grazing and burrowing activity of invertebrates (Edgar, 2001), and algal blooms (Beal and Schmit, 2000). Physical factors influencing seagrass include sediment composition, salinity, nutrients, water depth, turbidity, wave exposure and light (Hillman et al., 1995; Abal and Dennison, 1996; Vermaat et al., 1996; Longstaff and Dennison, 1999; Moore and Wetzel, 2000). Control areas used in this study were selected to be as similar as possible to areas with docks to minimize the potential for other factors to contribute to differences in seagrass biomass. Seagrass below docks in Lake Macquarie was compared with control areas of similar depth and exposure and there is no evidence that the study areas differed in water quality or sediment composition (WBM, 1997).

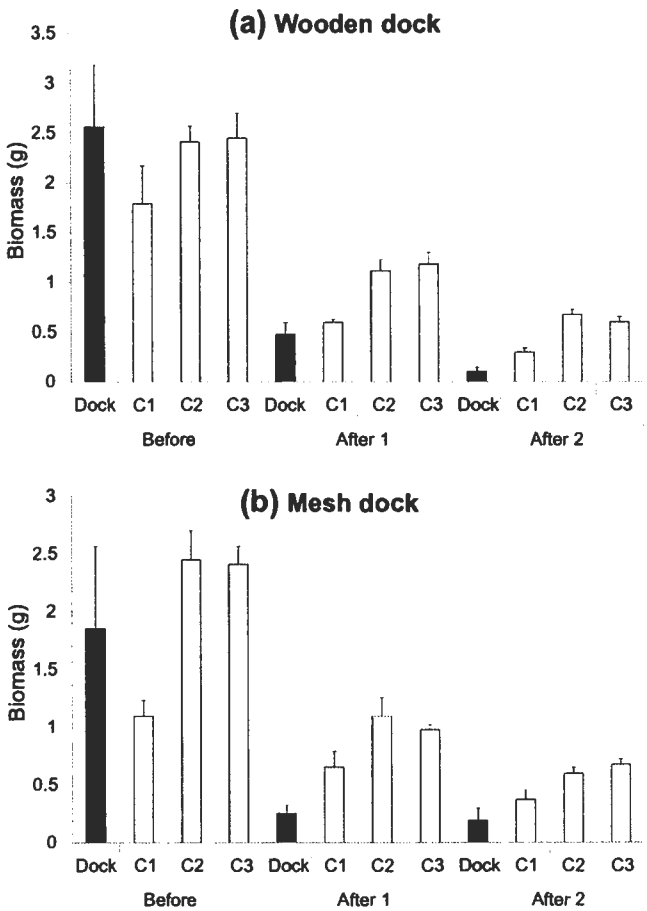

Fig. 4. Changes in biomass of *Zostera muelleri* subsp. *capricorni* seagrass from before to after installation of (a) wooden dock and (b) mesh dock in transects below each dock and in control site (C1–C3). Values shown are mean + SE based on 1 transect below each dock ($n = 5$) and the mean of six transect-level means in each site at each time.

Table 4
Summary of asymmetrical PERMANOVA results testing for a change in biomass of *Zostera muelleri* subsp. *capricorni* from (a) before to 6 mo after, and (b) from before to 26 mo after installation of a mesh dock. The change occurring below the newly installed dock was compared with changes among $n = 6$ transects in each of $n = 3$ control sites ($n = 9999$ permutations of residuals under a reduced model).

Source of variation	df	MS	Pseudo-*F*	*P*(perm)
(a) Before to 6 mo after installation (Ln(X + 0.1) transformed data, Cochran's $C = 0.10$, $P > 0.05$)				
Before vs After: B vs A	1	12.25	22.14	0.002
Dock vs Control: D vs C	1	3.42	1.81	0.15
Site (D vs C): Si (D vs C)	2	7.91	27.06	0.0001
(B vs A) × (D vs C)	1	1.82	3.29	0.09
Transect (Site (D vs C)): Tr (Si (D vs C))	15	0.29	2.01	0.02
(B vs A) × Si (D vs C)	2	0.48	0.83	0.46
(B vs A) × Tr (Si (D vs C)	15	0.57	3.94	0.0001
Res	152	0.15		
(b) Before to 26 mo after installation (Ln(X + 0.1) transformed data, Cochran's $C = 0.08$, $P > 0.05$)				
Before vs After: B vs A	1	21.90	77.16	0.002
Dock vs Control: D vs C	1	2.61	1.15	0.24
Site (D vs C): Si (D vs C)	2	8.54	14.10	0.0004
(B vs A) × (D vs C)	1	1.24	4.38	0.05
Transect (Site (D vs C)): Tr (Si (D vs C))	15	0.61	3.45	0.0001
(B vs A) × Si (D vs C)	2	0.42	1.67	0.22
(B vs A) × Tr (Si (D vs C))	15	0.25	1.42	0.15
Res	152	0.18		

An examination of the impacts of dock shading on the seagrass *Halodule wrightii* in Alabama (USA) quantified the amount of light reduction due to dock shading (Shafer, 1999). The amount of light *H. wrightii* received was critical to seagrass survival: seagrass was not present under docks where light levels were less than 14% surface irradiance. The effect of shading was greatest between 1000 h and 1500 h, and seagrasses subject to additional shading during the morning and late afternoon due to dock height and orientation were particularly vulnerable to effects of shading (Shafer, 1999). The minimum light level below docks needed to support seagrass (i.e. allow for 50% of normal production) has been estimated to be 30% of available light (Burdick and Short, 1999).

Shading seagrass species by experimentally manipulating light levels or exposure to high water turbidity leads to reduced production or death of seagrass plants and seedlings. These impacts are reflected at the habitat scale as reduced density, shoot length, biomass and leaf cover (Gordon et al., 1994; Fitzpatrick and Kirkman, 1995; Grice et al., 1996; Longstaff and Dennison, 1999; Wood and Lavery, 2000; Bintz and Nixon, 2001). Therefore, shading caused by docks is the most likely explanation for the declines in seagrass biomass observed below docks. There is, however, a need for studies to quantify the declines in light levels below wooden and mesh docks (and other potentially suitable decking materials) and to correlate this with seagrass abundance below docks and with features of individual docks (e.g. height, width, water depth). Such studies would be a first step towards determining the threshold for significant shading effects on seagrass and the interactive effects of dock design on this threshold.

Seagrass biomass varied among transects in sites with docks of both orientations and in sites without docks. Variation among transects in sites with docks may have occurred because of variation in the age of docks and therefore the duration of shading of seagrass beds. The observed variation in seagrass biomass among transects and among replicates within transects in seagrass beds without docks is not unusual. Spatial variation (at similar scales used in this study) in seagrass features (biomass, leaf length, shoot density) has been reported in other estuaries in south-east Australia (Bell and Westoby, 1986; Edgar et al., 1994; Fyfe and Davis, 2007).

4.2. Effects of dock orientation

There was no effect of the orientation of docks on seagrass biomass: seagrass was consistently reduced below wooden docks with north–south or east–west orientations. This result contrasts with the only other study of dock orientation (Burdick and Short, 1999) that reported significantly less seagrass below east–west docks than north–south docks. The authors explained that the difference between dock orientations reflected the daily movement of the sun from east to west causing the centres of east–west docks to be shaded for most of the day whereas the centres of north–south docks were shaded only in the middle of the day (Burdick and Short, 1999). The authors therefore recommended that, to minimize impacts on seagrass, docks should be oriented within 10° of the north–south axis. The difference in results between the present study and the study of Burdick and Short (1999) may be attributed to differences in dock widths. The docks studied in Lake Macquarie were 900–1100 mm wide. Docks studied by Burdick and Short (1999) were 0.7–6.9 m wide and 12 of the 21 docks exceeded 1.5 m width. The absence of an effect of dock orientation in Lake Macquarie may reflect the generally narrower width and the change in the angle of the sun throughout the year. At a latitude of 32°S (the approximate position of the study area) in June the sun's altitude will be approximately 33° above the northern horizon and in December its altitude will be approximately 80° (source: http://

wwwphys.murdoch.edu.au/rise/reslab/resfiles/sun/text.html, accessed June 14, 2007). Therefore there would not be many months per year that the area immediately below docks may be shaded for a large part of the day. Additional studies comparing the effects of a range of dock widths and orientations on light availability and seagrass growth may provide more information on the acceptable limits of dock dimensions.

4.3. Comparison of wooden and mesh docks

The use of an aluminium mesh decking reduced the effects of docks on seagrass. Biomass of seagrass below mesh docks was always greater than below wooden docks, although biomass below both dock types was always less than undisturbed seagrass. Although light was not measured in this study, it is likely that the mechanism responsible for the reduced effects of aluminium mesh docks is greater light penetration through the deck compared to wooden docks. The effects of wooden and mesh docks were not compared in another study (Fyfe and Davis, 2007); however, it found a significant effect of a single mesh dock on seagrass (73% decline in shoot density). Other studies evaluating the effectiveness of alternative materials to increase light penetration through docks, such as glass prisms (Steinmetz et al., 2004) and grating (Fresh et al., 2006), also found no measurable benefits.

The comparison of wooden and mesh docks and the assessment of the impacts of dock installation revealed changes in seagrass biomass through time. Although we used a destructive method of sampling seagrass, we attempted to eliminate potentially negative effects of sampling at one time on the plants collected subsequently by ensuring the latter were not collected within the vicinity of previous collections (i.e. within 1.5 m). The inconsistency among treatments in the direction (i.e. increase or decrease) and magnitude of temporal variation in seagrass biomass suggests this risk was minimised by our sampling approach. Temporal variation in seagrass biomass occurred under existing mesh docks as well in seagrass beds with no docks. The major feature of this temporal variation was an autumn–winter decline in seagrass biomass, which was apparent as a decline after March–June 2006. Similar winter die-back of *Zostera muelleri* subsp. *capricorni* has been reported in Port Hacking (Kirkman et al., 1982) and Botany Bay (Larkum et al., 1984) and for *Z. muelleri* subsp. *muelleri* in Port Phillip Bay, Victoria (Kerr and Strother, 1990) and for *Heterozostera tasmanica* in Westernport Bay, Victoria (Bulthuis and Woelkerling, 1983; Edgar et al., 1994). Shoot growth rates of *Z. muelleri* subsp. *capricorni* are also lowest in winter (King and Holland, 1986). The temporal variation in *Z. muelleri* subsp. *capricorni* reported for Lake Macquarie in this study therefore appears to represent a natural phenomenon typical of this species and other related species.

The lack of temporal variation in *Zostera muelleri* subsp. *capricorni* biomass below wooden docks is intriguing. Seasonal declines in *Z. muelleri* subsp. *muelleri* biomass are associated with changes in solar radiation and day length (Kerr and Strother, 1989). The majority of the seasonal change in total plant biomass in *Z. muelleri* subsp. *capricorni* and *Z. muelleri* subsp. *muelleri* is accounted for by changes in leaf biomass (Kirkman et al., 1982; Larkum et al., 1984; Kerr and Strother, 1990). The lack of seasonal variation in seagrass biomass below wooden docks could be due to the absence of a strong seasonal variation in light levels, or the amount of light penetrating below docks may not be sufficient for a significant increase in growth. This explanation is supported by other studies (Shafer, 1999) that have found a greater relative reduction in shoot density than total plant biomass under docks.

A modified beyond BACI experiment confirmed the results of the field surveys and provided evidence that the installation of docks caused a significant decline in seagrass biomass. Although only single examples of each dock type were available for study, the comparison of both dock types with multiple control sites provided a meaningful test of the effects of dock construction. Simultaneous testing of multiple examples of dock construction will improve the generality of this finding. Seagrass biomass below the wooden and mesh docks declined by similar amounts, 96% and 90% respectively, 26 months after dock installation. The experimental design employed in this study cannot distinguish between potential impacts of the installation process (e.g. seagrass destruction resulting from the insertion of pilings into the sediment as the support for the decking) and the combined effects of the installation process and shading from the dock decking. It was not possible to include a control for the installation process (i.e. pilings without decking) therefore the results of this study refer to the combined effects of installation and shading.

The declines in biomass below the new docks were detectable over and above a general decline in seagrass biomass that occurred in all the control sites over the same time period (Fig. 4). Similar dramatic declines in seagrass under new docks and in control sites were also reported in the only other study to assess the impacts of dock construction (Beal and Schmit, 2000). The declines were due to natural processes (i.e. algal bloom) that affected control and treatment sites equally. However, by 33 weeks after construction the cover of seagrass was less under the new docks than control sites.

5. Conclusion

Infrastructure, such as docks, associated with recreational usage of estuaries in south-east Australia is an issue for the long-term conservation of seagrasses. Although the total 'footprint' of ecological effects of docks in estuaries is small relative to other disturbances, they contribute to the total impact of human uses of estuaries. The effects of docks on seagrass were not influenced by the orientation of the docks used in this study, and their effects were reduced when aluminium mesh decking was used in place of wooden decking. Field observations of the effects of docks on seagrass were supported by a modified BACI field experiment involving the installation of wooden-deck and aluminium mesh-deck docks. Alternative controls, such as limits to the total numbers of docks and the use of other construction materials, may have additional conservation benefits.

Acknowledgements

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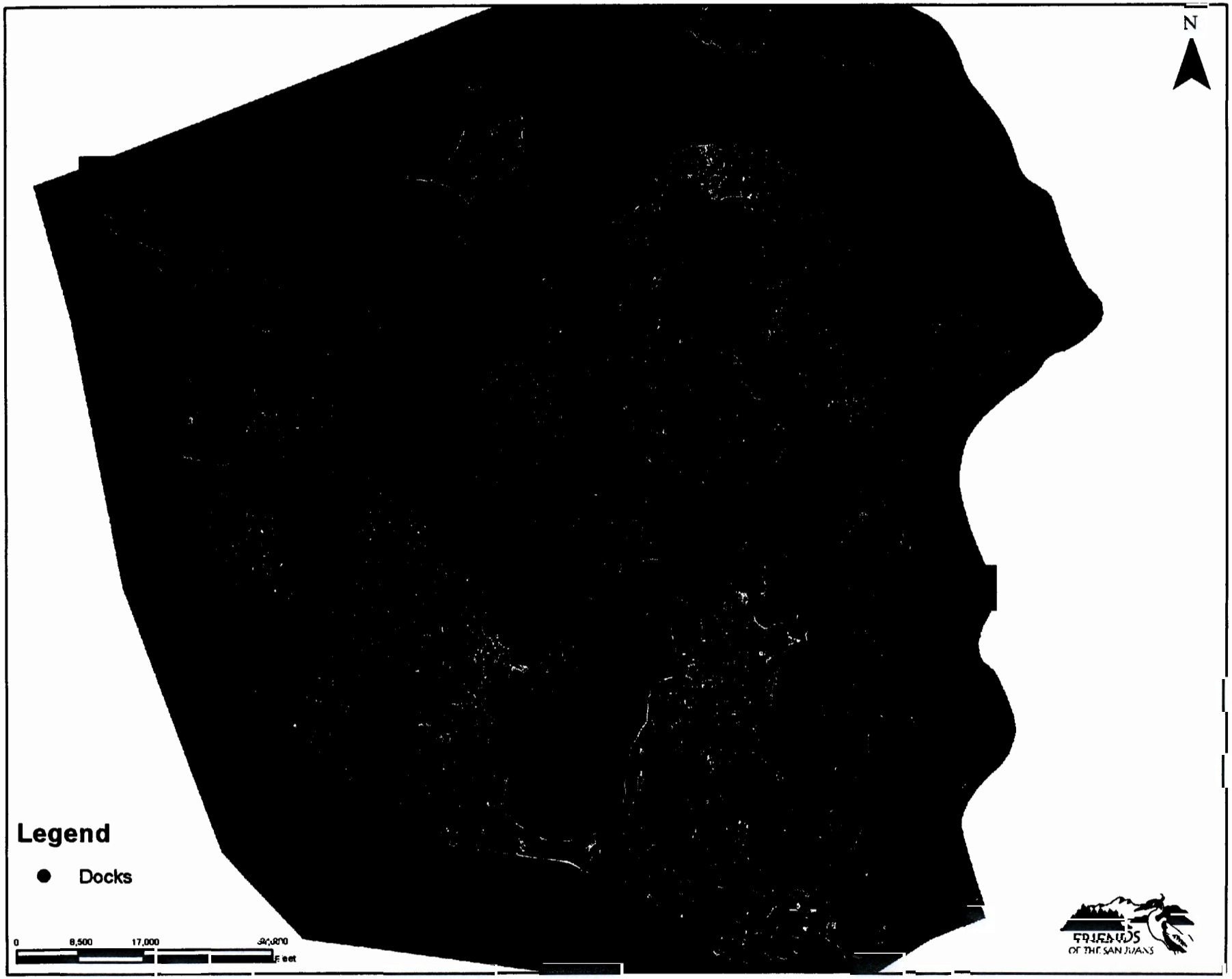
ATTACHMENT H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OF THE SAN JUANS

Julie Thompson

From: Katy Barsamian <katyb@interisland.net>
Sent: Wednesday, September 20, 2017 2:34 PM
To: Julie Thompson
Subject: Permit #PSJ000-17-0003; Project Description: Four-Slip Dock and RO Desalination System

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

September 20, 2017

San Juan County Department of Community Development
Friday Harbor, WA

Re: Permit #PSJ000-17-0003; Project Description: Four-Slip Dock and RO Desalination System

To Whom It May Concern?

I am deeply concerned about the above-referenced project and the County's determination that an Environmental Impact Study is not required for either the construction of the dock or for the desalination system. I am in opposition to this project for many reasons.

I have been a homeowner and resident on the west side of San Juan Island for 29 years. During this time period, I have regularly kayaked on the west side from our local beach in the Hannah Heights neighborhood to False Bay and beyond. I have spent countless hours in my kayak exploring the shoreline, enjoying the varied marine life and floating in the peaceful, protected and pristine environment of False Bay. The abundant and rich marine life, from birds to seals to otters to orcas and more, create a magical environment that is treasured by all and draws many visitors to our islands. Many years ago, I attended a San Juan Nature Institute gathering at the subject beach (formerly Mar Vista Resort) led by Dr. Eugene Kozloff and Dr. Richard Norris, who taught those in attendance about the abundant and fragile life residing in the intertidal zones of this treasured ecosystem. When my son was in Sixth Grade at FHMS, he and his classmates learned about the complexity of the tide pools and their residents. It was fascinating to accompany the students on their tide pool exploration field trip and observe the abundant life hidden under the surf grass, eel grass and kelp and nestled among the exposed rocks at minus tide.

The False Bay Marine Preserve is a treasured marine sanctuary that is an important resource for the University of Washington, as well as a source of enjoyment for islanders. False Bay and its marine residents should be protected from any potential harm. The location of the subject dock and desalination system are just outside the entrance to False Bay and potentially put this marine preserve at risk.

I have first-hand experience with the extreme weather conditions that can unexpectedly arise on the west side of San Juan Island, as well as the intense currents and tidal fluctuations. Many years ago during the summer, I witnessed the Coast Guard rescue a small whale watching boat that was nestled in rocks along the shoreline close to our home because of sudden high winds which prevented the boat from traveling to safety. It was reassuring to observe the efficiency of our Coast

Guard while rescuing multiple people from these hazardous conditions and securing the vulnerable boat to prevent a potential fuel spill and vessel sinking. The passengers were rescued by being lifted in the man basket to the helicopter and transported to land.

Why do the applicant owners feel there is a real need for the construction of a dock when easy access to commercial docks is available, a mere 10-minute drive away? This seems more of a convenience for them to access the west side by boat during the summer months. It is difficult to understand why anyone would want to go to this extreme expense of building a dock on the west side of San Juan Island and expose the area to any kind of a risk. Where will they moor their boats when the dock is pulled/retracted for a portion of the year? Will the residents/owners be present at all times during the period the boats will be moored at the proposed dock (May 1-October 31) in the event of an extreme wind event that could put the boats and surrounding area at risk?

Who will be monitoring the owners and their representatives to ensure that they are following the protocol set out in their proposal to the finest detail and hold them accountable? Who will pay for such monitoring? In the past, the property owners have not demonstrated that they will be careful stewards over the fragile habitat over which they have control; specifically, they failed to supervise contractors who clear cut an extensive area along their property shoreline and were fined by the state after the damage was done.

What about the public tide lands that this project will encroach upon? What is the impact of a desalination system on the marine environment, especially when so close to the False Bay Marine Preserve? What do the scientific experts have to say about the real and potential impacts of such a desalination system in our fragile marine environment? Again, why will there be no Environmental Impact Study?

If this project is allowed to move forward, it will set precedent for the building of docks and large developments on the west side of San Juan Island, where currently no docks exist from Cattle Point to Mitchell Bay.

If NOAA implements a whale protection zone for boats in this area, how will the property owners deal with that potential scenario?

I strongly urge and request San Juan County to require an Environmental Impact Study to fully assess any and all risks and hazards that the proposed dock and desalination system present to the property in question, the surrounding fragile marine environment and life contained therein, and the False Bay Marine Preserve. It seems that logical and responsible action would be for the County to require such a study and analysis. Especially for liability purposes in the event of some future catastrophe should the project be allowed to move forward. The County's responsibility first and foremost is to serve ALL residents and not give priority to the applicant property owners.

Sincerely,

Katy Barsamian

Sharon Grace
175 Gretchen Way
Friday Harbor, WA 98250
360-378-3377
parons@rockisland.com

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

September 20, 2017

By Email: juliet@sanjuanco.com
permits@sanjuanco.com

San Juan County Community Development and Planning Department
PO Box 947
Friday Harbor, WA 98250.

Re: Proposed Dock and Desal Plant at Orca Dreams Property Immediately Adjacent to False Bay Marine and Biological Preserve

Dear Planners:

The short 14 day comment period and the sparse information contained in the MDNS make it difficult to make informed comments. These comments are submitted given this limitation.

There are at least two overall considerations. First, it does not appear that Orca Dreams has addressed the concerns that led to San Juan County's withdrawal of the MDNS for the same, or substantially similar, proposed dock project in 2015. Second, a number of conclusions in Orca Dream's application appear to lack factual support. For example, the applicant states "eelgrass and macroalgae will not be adversely impacted due to any project activities." The proposed activities strongly indicate the opposite is true. The County fails to address the applicant's unsupported conclusions. All such conclusions should be addressed, rather than simply accepting the applicant's word.

An Environmental Review Is Required for the Proposed Dock

Regarding the proposed dock to be located in the pocket beach adjacent to the False Bay preserve, the Department of Planning and Community Development erred in issuing its Mitigated Determination of Nonsignificance under the State Environmental Policy Act. First and foremost, False Bay is a marine and biological preserve. See http://wdfw.wa.gov/fishing/mpa/false_bay.html.[1] The proposed dock that will be

[1] If the links fail to open, please copy and paste into your browser.

located adjacent to the southwest entrance to the False Bay preserve requires an environmental review of the significant individual project impacts to the water, land and air in the adjacent and near areas. The review must also include the potential significant cumulative impacts the project may have, due to the precedent setting effect of building and maintaining docks on the west side of San Juan Island.

To ensure that the proposed dock, among other things, is not likely to adversely impact threatened or endangered species, or destroy or adversely modify their designated critical habitat, I am requesting a public hearing so all interested parties can be fully heard before this application proceeds further.

An Environmental Impact Statement Is Required for the Proposed Dock Adjacent to the False Bay Marine and Biological Preserve, since the Dock Will Have Significant Environmental Impacts

- **The proposed dock will significantly impact threatened and endangered species.** Iconic Northwest endangered animal species that will be impacted are salmon and critically endangered Southern Resident Killer Whales (SRKW'S). The pocket beach is critical habitat for the SRKW'S and Puget Sound Chinook salmon. See http://www.nmfs.noaa.gov/pr/pdfs/criticalhabitat/killerwhale_sr.pdf and http://sanjuanco.com/CDP/docs/CAO_Implementation/CriticalChinookHabitat.pdf. Indeed, although the SRKWs largely have been absent from inland waters throughout most of the summer, in September 2017 members of L Pod have centered on this area for days at a time. The critically endangered marbled murrelets feed in this area. Eelgrass that grows in the area and forage fish that use the eelgrass for cover will be significantly impacted. Further, according to the SeaDoc Society's report published in December 2013, species of concern in the Salish Sea have doubled between 2002 and 2013. See http://www.seadocsociety.org/wp-content/uploads/Salish-Sea-Species-of-Concern-2013-Dec-4-2013.pdf. Many of these species, including the critically endangered SRKWs, have continued to decline during the last four years. Few calves have survived, while many whales have died. The impacts on these species need to be considered in determining environmental effects from the proposed dock.
- **Vessels docked at the proposed dock will significantly impact the environment**. The dock will accommodate 18'-30' vessels. These vessels will leak or spill environmental toxins into the surrounding environment, impacting the soil, air and water. These toxins include oil, fuel, grease, detergents, other cleaners, and waste water. This is in addition to likely catastrophic impacts caused by wave, wind or storm damage to the dock or vessels at the dock.
- **The proposed dock likely will degrade the False Bay Preserve.**

Impacts that immediately present themselves are noise, deteriorated water, soil and air quality, and soil disturbance.

Specific impacts that require evaluation regarding the proposed dock include, without limitation:

- The costs of fuel or oil spill cleanups to taxpayers.
- The impact of construction of the dock and destruction to the dock that may be continual, caused by weather, wind or sea events that occur in all seasons in the Haro Strait, including the impact of habitat destruction or impairment directly caused by the project to plants and animals.
- The impact of sediment on animals and plants, caused by the project.
- The impact of fuel and oil spills locally and in near areas on plants and animals. This will require water current studies, if appropriate studies do not exist, to project how far the damage may go.
- The impact on all threatened and endangered species that may be caused by the project.
- The increased impact of human and boat noise.
- The impact of invasive species that may attach to the outside of vessels or be contained in the ballast of vessels that use the dock.
- The impact of increased marine sound on marine life.
- The impact of interference with marine life movement.
- The impact of vessel strikes on marine mammals that use the near areas.

An Environmental Review Is Required for the Proposed Desalinization Plant

The Department of Planning and Community Development erred in issuing its Mitigated Determination of Nonsignificance under the State Environmental Policy Act, regarding the proposed desalinization plant proposed for the Orca Dreams property. A project that requires an easement from DNR for desalinization lines to be located on state owned tidelines likely has a significant environmental impact. If the "state owned tidelines" refers to the False Bay Marine Preserve, this is a marine protected area that definitionally is an environmentally sensitive area. Washington State and UW have set aside these marine waters for the protection and preservation of species and habitat in the Salish Sea. Among the protections is "[n]o installing of structures (permanent or temporary) except for scientific purposes." See https://fhl.uw.edu/facilities-resources/biological-preserves/management-policy-for-false-bay-argyle-lagoon-and-parks-bay-marine-preserves/.

Loss of shoreline habitat is one of the biggest obstacles to the state's mandate of restoring the health of Puget Sound by the year 2020. Individual property owners do most of the damage to shorelines, according to the Washington Department of Fish and Wildlife.

Specific impacts that require evaluation regarding the proposed desalinization plant include, without limitation:

- The impact of desalinization suction from intake pipes on marine life such as crabs, fish, plankton, fish eggs, fish larvae, and other microbial organisms that constitute the base layer of the marine food chain.
- The impact of salty brine and chemical outflow on bottom-dwelling marine life, plankton, fish eggs, fish larvae and other microbial organisms that constitute the base layer of the marine food chain.
- The impact of salty brine and chemical outflow on eelgrass specifically.
- The thermal impact of salty brine and chemical outflow on bottom-dwelling marine life, plankton, fish eggs, fish larvae, and other microbial organisms that constitute the base layer of the marine food chain.

Project Benefits to the Public

There appear to be none.

The protection and policy behind prohibiting structures in a marine preserve seem to proscribe the precise projects Orca Dreams seeks to construct. It would not be reasonable for San Juan County to permit a private property owner to jeopardize this habitat along with sensitive species, particularly when there is no public benefit involved.

Thank you in advance for your careful consideration of these comments.

Sincerely,

Sharon Grace

Sharon Grace

cc: File

Dear San Juan County Community Planning and Development

S.J.C. DEPARTMENT OF
OCT 20 2017
COMMUNITY DEVELOPMENT

I am writing in opposition to and with comments on the proposed Orca Dreams proposed dock and desalination plant (project file # PSJ000-17-0003). My opposition and comments are based on 4 basic principles, that a precedent setting development such as this should not occur without a thorough Environmental Impact Statement, that the proposal has failed to demonstrate need, that the proposal lacks sufficient protections for the marine and terrestrial environment, and that the proposal is based on the premise that the role of a single stakeholder is not to live within the constraints of the land, but use excess resources to the detriment of other stakeholders.

The proposed dock is the first dock that would be built in that extended region of the west side of the island. While the proposal states that the dock would be sited on the site of an older dock, the original length of the older dock does not appear to be specified in the document. Further, a number of changes in the local environment and improved understanding of the important role of Eelgrass beds has occurred since then. The desalination plant would be the first to service a single landowner rather than a community and would be the first on the west side of the island south of Mitchell Bay, as stated in the proposal. Although the proposal asserts that the dock would serve 3 parcels and 5 existing residences, in the following response the proposal also refers to it as a family compound, which makes it clear that the dock (and desalination plant) is for the purpose of serving a single landowner. At present, this section of the West side of the island has relatively little shoreline development and remains relatively pristine. In past summers the whales have traveled this corridor almost daily.

The proposal has not demonstrated a need for either the dock or the desalination plant. The proposal does not demonstrate that space is unavailable at any of the public docks on San Juan Island. The proposal avoids this issue by referring only to "permanent" mooring. However, the proposal does not specify what is meant by "permanent" mooring. The boats would not in any case be moored over winter when the possibility of high winds might damage boats, as stated in the proposal. The proposed desalination plant is excessive for 5 family dwellings and may not even be necessary. The current well produces 1584 gallons per day. EPA estimates average consumption at 80-100 gallons per family member per day. The USDA estimates average consumption at 300 gallons per day per family. These averages are across the US and do not assume water conservation strategies such as are appropriate for a dry location such as San Juan Island. Therefore, based on these averages, 1500 gallons per day should be sufficient for 5 dwellings even without water conserving strategies. Further, there is a second well, according to the proposal for irrigation purposes. Orca Dreams is proposing a desalination plant that produces up to 3000 gallons/day which in addition to the well water of 1584 gallons/day would be enough water for 15 families.

The proposal lacks sufficient protections for marine and terrestrial environment during construction as well as during proposed use. For the dock for example, during construction while the proposal states that there will be observers during construction who will watch for marine mammals within 200 feet of the site or marbled murrelet within 160 feet of the site. It is not specified who will pay for the observers and more importantly who they are responsible to. If the observers are part of the construction crew there may be substantial conflict of interest, as well as the distraction of construction duties. In

addition it is unreasonable to expect that marine mammals would come within the 200 feet during construction since they would be deterred by the construction noise which travels extremely well under water. For the dock similarly, during use, while the proposal specifies avoiding prop wash and shading in sensitive areas during construction, there is no mechanism for avoiding prop wash and shading during use. Since proposal states that the boundary of the eelgrass bed will be only 25 feet from the dock, this means that when boats are docked the eelgrass bed will be shaded and that the eelgrass beds will undoubtedly be subject to prop wash while docking or leaving dock. Given that Eelgrass beds "really important as fish nurseries for the fish that salmon require, which the killer whales require" (C. Drew Harvell, marine biologist Cornell University) and filter pollutants from sea water this is an area of critical concern. These particular eelgrass beds are already under stress since Eelgrass beds are sensitive to eroded dirt from shore and the Orca Dreams LLC clear cut the shoreline. It has further been shown that Eelgrass beds have disease fighting properties for both marine and human life according to a study published by Joleah B Lamb from Cornell University. Also I note that the starry flounder is not listed under the fish at the site even though this is a signature species in False Bay. The desalination system would "extend over public tidelands and into marine waters" , including the diffuser and intake lines. The proposal statement that the system would "not impede public access to public tidelands or materially interfere with normal public use of waters" is too vague and in no way addresses the fundamental issue of the effect of the system on the diversity of the marine life in those tidelands. In fact, given that False bay is a conservation area, a higher standard of a protection for the marine ecosystem should be applied. Therefore a number of questions should be addressed including: What would be the effect of the excess brine on the marine ecosystem , especially at low tide? Would the intake be screened to prevent the intake and death of larvae or of food web sustaining plankton as well as larger marine life? and How would cleaning chemicals used in cleaning of the desalination plant be controlled and kept out of the terrestrial or marine environment?

Finally, the proposed dock and desalination plant will adversely affect other stakeholders either by decreasing the appearance of the area, increasing boat oil and pollution, potentially decreasing the observable marine wildlife and increasing noise, and impacting research conducted on the preserve by researchers at Friday Harbor Labs both during construction and during use while benefitting a single stake holder.

Sincerely

Laura Derevensky
445 Kilsburrow Rd
Friday Harbor, WA 98250
360-378-4652
and

59 W Corbett Rd.
Montgomery, NY
12549
845-769-7123

Julie Thompson

From: William Cowles <williamscowles@gmail.com>
Sent: Wednesday, September 20, 2017 7:36 PM
To: Julie Thompson
Subject: SEPA Comments for Permit #PSJ 000-17-003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Ms. Thompson,

I strongly oppose the proposed dock and desalination plant on the West Side near False Bay. I am a frequent visitor to the island, and the thing that drew me to it most and keeps me coming back is how unspoiled it is. I grew up in New England, where the islands that I grew up with have become so developed that they are no longer a place to be in touch with nature. Small encroachments on the wildness and unspoiled beauty of the island and the sea add up over time and eventually, the things that we love about the island are all gone.

I believe that this dock and accompanying facility represent major threats to what makes the island so special. They threaten the unspoiled beauty of the Island, as well as the whales that not only make San Juan Island special, but also represent a major source of tourist revenue for the Island.

I strongly oppose it and I believe that it should not be approved.

Thank You,

Willy

--

William S. Cowles
Williamscowles@gmail.com
(860) 670-4734

Julie Thompson

From: Michelangelo von Dassow <mvondass@gmail.com>
Sent: Tuesday, September 19, 2017 11:17 PM
To: Julie Thompson
Subject: Orca Dreams Dock and Plant

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Madam or Sir:

I am writing to you to express opposition to the construction plans of Orca Dreams, LLC. Of particular concern is that Orca Dreams, LLC plans to create a zone of disturbance that cuts substantially across Haro Straight, a major route for orcas that travel regularly up and down the west side. Whale watching is a vital part of the local economy and Orca Dreams' construction could disrupt orca travel along the entire West Side if the whales choose to change routes rather than pass through the action area. This could substantially harm the tourism industry on San Juan Island. I did not see evidence that their plans considered potential costs of disrupting these movements on the San Juan County economy. These potential economic costs to San Juan County residents would be compounded with less tangible costs to island residents who cherish seeing the whales passing, and to the orca populations themselves.

In addition, I urge you to consider that the proposed construction work will take place very near the False Bay Biological Preserve. Please consider the potential impacts on the huge variety of organisms and habitats that make False Bay a unique and valuable resource. Visitors to the bay are often unaware of the treasure trove of life there, because much of it is concentrated at the mouth of the bay on the rocks and seagrass. This is the area nearest the proposed construction and boat traffic. Of particular concern are potential harms from sediment and wakes to the last two remaining seagrass beds in False Bay. These are home to countless species of invertebrates, fish, and algae, and a food source for many large birds such as bald eagles and herons. False Bay has been the source of important scientific findings for many decades, has been a source of joy and wonder for island residents – such as myself – and visitors of all ages.

Finally, it is concerning that the conservation measures that Orca Dreams has proposed to mitigate environmental effects of their "community dock" have no enforcement mechanisms. Because the "community" their dock serves appears to be the owner's family and their guests, there is no evidence to suggest that the users of the dock will actually manage sewage, wakes, and other detrimental activities in accord with what appear to be purely voluntary rules. This is particularly concerning considering that the owner and Orca Dreams, LLC have already violated environmental rules (and been fined for doing so) by illegally, and excessively, clearing land near the shoreline during previous construction. Orca Dreams should demonstrate clear enforcement mechanisms to insure that that the owners, their guests, and their employees follow through on mitigating the detrimental effects of their private dock and desalinization plant.

Thank you for your consideration.

Sincereley,

Mickey von Dassow

Two Barn Farm Ln

San Juan Island, WA 98250

Julie Thompson

From: Yasmin J. von Dassow <yasmin.vondassow@gmail.com>
Sent: Tuesday, September 19, 2017 9:44 PM
To: Julie Thompson
Subject: Orca Dreams construction

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Sir or Madam,

I am writing to you to voice my opposition to the construction plans of Orca Dreams, LLC. I strongly urge you to consider that the proposed construction work will take place only a few yards away from the False Bay Biological Preserve, and frankly, the animals, plants, and sediments do not know or care where the boundaries are. I ask that you thoroughly consider the potential impacts on the huge variety of organisms and habitats that make False Bay a unique and valuable resource—one that will be permanently altered or damaged by the proposed construction. To many people, the bay may look like a vast empty space, but it most certainly is not. Visitors to the bay are often unaware of the treasure trove of life there, because much of it is concentrated at the mouth of the bay on the rocks and seagrass, the very area where the proposed construction would take place.

I am a marine biologist, and I have been working in False Bay for 13 years as a visiting researcher at the Friday Harbor Labs; I am also a San Juan Island resident who lives very close to the preserve. Because I have spent so much time in the bay, I am very familiar with its incredible diversity of living things, including algae, seagrass, bald eagles, wading birds, fish, seals, worms, snails, crabs, sea slugs…the list goes on and on. I am deeply troubled that the proposed construction would take place so close to the last two remaining seagrass beds in False Bay, home to countless species of invertebrates, fish, and algae, and a food source for many large birds (including bald eagles and herons).

The proposed construction projects will, without question, cause disturbances through noise, water pollution, and sediment movement—these simply cannot be avoided in a project of this nature. (I am particularly troubled by the sediment disturbance, as most of the former seagrass beds in False Bay have already been buried by sediment.) When the proposed docks and desalinization equipment are actually used by the owners of Orca Dreams and their associates, all of these disturbances will multiply, and the so-called mitigation measures mentioned in the building plans are not sufficient to prevent lasting damage. Given that Orca Dreams or their associates already destroyed a bald eagle nest and other sensitive habitat, I do not believe that they will take their mitigation measures seriously.

False Bay is a treasure not only to scientists, but also to island residents, visitors, and most importantly, the native flora and fauna. Please help us in preserving this place that has been the source of important scientific findings for many decades, as well as being a source of joy and wonder for all. A dock and desal plant may seem like small construction projects to some, but not to those who know the bay and its inhabitants intimately.

Sincerely,

Yasmin von Dassow, Ph.D.

Two Barn Farm Ln.

Friday Harbor, WA 98250

(951) 897-5994

Julie Thompson

From: staude@u.washington.edu
Sent: Tuesday, September 19, 2017 9:16 PM
To: Julie Thompson
Subject: Comment on Orca Dreams dock and desal application - Craig Staude

Hello Julie,

I came by the Planning Office to deliver my comment letter today at about quarter of 5 and discovered it closed at 3:30. I'm catching an early ferry tomorrow morning so I hope you can accept this digital form of my comments (copied below) on the Orca Dreams dock and desal applications.

Thanks,
Craig Staude

***

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

19 September 2017

To: Julie Thompson, San Juan County Planning Department
Re: Orca Dreams Dock and Desalination Applications

I wish to restate my concern about a proposed dock at Orca Dreams due to its proximity to the University of Washington False Bay Marine Research Preserve on San Juan Island. My previous letter regarding the original dock proposal should be on file from June 2015.

The value of False Bay and its headlands for marine research has been recognized for more than 50 years. In the mid 1960s professors encouraged the UW Administration to purchase the False Bay tidelands to protect it against development, and in 1974 the University obtained ownership. Through the intervening years, this site has been a major study area for classes and independent investigators from the UW Friday Harbor Laboratories. This work has added significantly to our understanding of the biology, ecology, and physiology of marine organisms (e.g., mollusks, crustaceans, polychaetes, seagrass, and microorganisms). I personally have served as a Teaching Assistant for field trips to this rich habitat. In the 1970's and 80's we routinely received permission to park and walk down to the University tidelands through this property, which was then called "Mar Vista Resort" and owned by Mrs. Lee Bave.

The dock that was previously proposed in 2015 was sited immediately adjacent to tidelands owned by the University of Washington. It is not clear to me whether the present proposal has relocated the dock farther east of those UW-owned tidelands. In any case, this project remains very close to those tidelands. I feel strongly that the boundary of the adjacent UW-owned tidelands should be clearly mentioned in the text of the application and be noted on the accompanying charts and drawings. [I can only find the briefest mention in SEPA Checklist 3.a.1 that the project is "outside the False Bay Biological Preserve, and there seems to be no mention of the close proximity of University-owned tidelands.]

I understand that the size of the dock & float is somewhat smaller than the originally proposed (2015) dock, and includes the plan to remove the float and associated boats from November to May to protected the waters of Snug Harbor. This addresses some of my previous concerns, but it does not dismiss them altogether. There will still be the occasional mishap, as occurs around boats, where fuel, paint or solvents will be spilled, bilges will be pumped, and flotsam will be generated. It is also very likely that a boat maneuvering onto the dock will misjudge the turn and drift or be blown on to the shore, possibly over the tideland owned by the University.

I find it hard to believe the statement (SEPA checklist Conservation Measure 10) that "petroleum products will not be transferred on or near the joint use dock." Considering the distance to the nearest fuel dock, there will most certainly be violations to this rule. When boaters misjudge their reserve of fuel they will be forced to replenish their fuel from the dock. SEPA Checklist 3.a.6 acknowledges this "potential for accidental fuel leaks." It further assures that "heads will be pumped... at approved pumpout facilities" but in reality it's a long way to the nearest pumping station.

Regarding the additional application for a desalination plant:

Checklist 3.a.6 states that 9,072 gallons per day of brine will be discharged through a diffuser mounted above the bottom about 56-ft seaward at the -5 tidal elevation. If not properly diluted, this brine can be toxic to marine organisms. Because of its greater density, poorly-mixed brine can pool over depressions and penetrate the sediment, killing sensitive benthic animals.

Permit Drawing Page 6 does not give much information regarding the exact position and mixing pattern of the diffuser. If the scale of the drawing is reliable, it appears that on a -3 ft tide the diffuser may be exposed, and brine would be discharged into extremely shallow water. This would seem insufficient to dilute the brine under low slack conditions. While the Biological Assessment (BA) on page 35 gives assurance that the brine will be thoroughly mixed within 2 to 3 feet of the diffuser, it does not address the condition of very low tides. I would like to see evidence that the brine will be properly dispersed during those periods of low tide. The BA further states that the "sea floor is consistently slopes away from the shoreline" but the aerial photo (Figure 2, page 7) indicates a rocky rise beyond the dock.

The Biological Assessment on page 35 specifies that no chemicals other than brine will be used to clean the desalination system. I question whether this will be adequate to prevent the growth of fouling organisms in the supply/discharge pipes, intake screen, and diffuser. How will fouling organisms be removed should they develop in the system?

I hope these various points will be considered by the reviewers and evaluated for possible significance before the Orca Dreams dock and desalination applications can be approved.

Craig P. Staude, Ph.D.
1273 Three Meadows Lane
Friday Harbor, WA 98250

***

On Fri, 8 Sep 2017, Julie Thompson wrote:

>
> All,
>
> Below are links to the recently submitted Orca Dreams dock and desal
> applications. You are welcome to come look at the file whenever you
> would like, but almost everything is in these two links. The SEPA
> comment period ends Sept. 20; the SEPA appeal period ends October 11. The hearing is scheduled December 27. Project comments are accepted up to the hearing itself, but I would appreciate them earlier so they can be included with the staff report to the hearing examiner.
>
> Please feel free to contact me if you have further questions. These
> links are on the Community Development webpage under "Current Planning Projects".
>
> Julie

Julie Thompson

From: Bill Lewis <billygoat@rockisland.com>
Sent: Tuesday, September 19, 2017 9:33 PM
To: Julie Thompson
Cc: billygoat@rockisland.com
Subject: Permit # PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Julie Thompson,

I live at 426 Mountain Shadows Lane, and we have a clear view from our living room and back deck straight across to the mouth of False Bay.

The proposed dock is not in character with the natural surroundings of this area.

Nor, is it a wise place to put a dock. That shore gets hammered by the winds 9 months out of the year, sometimes year around. If this area or exposure was a good place for docks, you would see a lot more of them around. There are none on the West side of Lopez that are not in protected, lee bays (Barlow, Mackaye, Richardson), same as Snug Harbor on San Juan, OR on the East (lee) side of West side Islands Charles and Long. I am a boater and would not feel comfortable tying up my boat on a dock with such exposure

The public is not allowed to crab or fish there. It is a University of Washington Biological Preserve. How can it be possible that a dock or desalinization plant will not have deleterious impacts to the natural functions of that area? Certainly much greater impacts than crabbing and fishing.

One eyesore is enough. The owners of the property in question illegally cleared their shoreline and built a big house for all to see. How can that affront to the community values, which are encoded in our laws, be rewarded with a special exemption to other equally important development laws?

The owners of this property should not be allowed an exemption for such an intrusion upon the public good when there are two large marinas a ten minute drive away. And, if they want to be on the Westside, they can rent slips or buoys at Snug Harbor or Roche Harbor which are both less than 25 minutes away.

Please decline this permit application.

Sincerely,

Bill Lewis
426 Mountain Shadows Lane
Cell – 360-298-1242

UNIVERSITY *of* WASHINGTON
CAPITAL PLANNING & DEVELOPMENT

September 19, 2017

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Julie Thompson
San Juan County Community Development and Planning
PO Box 947
Friday Harbor, WA 98250

cc: Erika Shook, Director

Re: Orca Dreams 4-Slip Dock, Navigational Buoy and Desalination System #PSJ000-17-0003

Dear Julie,

This letter is to urge San Juan County to issue a Determination of Significance and require the preparation of an Environmental Impact Statement (EIS) for the proposed actions related to Orca Dream LLC's proposed dock, navigational buoy, desalination system and related construction and operations at False Bay (Proposal). The University of Washington believes that the Proposal is likely to have a probable significant adverse environmental impact, even with mitigation measures, and an EIS is required.

False Bay has been owned by the University for many years and has been the site of research conducted since at least 1904. False Bay is a state designated Marine Preserve, part of the San Juan Island Marine Preserve Area set forth in Washington Administrative Code 220-16-440.

False Bay is part of the University's system of biological preserves, which includes Friday Harbor Laboratories and Argyle Lagoon on San Juan Island, and Cedar Rock and Ellis Preserves which are terrestrial properties with waterfront on Shaw Island. The research and graduate, undergraduate, K-12 and community education that takes place at Friday Harbor Laboratories is nationally recognized and is a significant economic force in the San Juan Islands. False Bay is an integral part of the resource base for this research and teaching, and has on-going scientific experiments as described in Dr. Swalla's September 19, 2017 letter to San Juan County. Dr. Swalla points to the potential adverse environmental impacts that should be analyzed in an EIS, in summary here:

- displacement of sea grass habitat
- disturbance of ongoing research
- negative impact on resident Orcas
- impact on Pocket Beach
- impact on marine birds
- impact on sea grass and algae

- impact on Pinto abalone

Box 352205 University Facilities Building Seattle, WA 98195-2205
206.543.5200 fax 206.543.1277 http://pm.uw.edu/cpd/

- impact of desalination system on biological resources and water quality

The University is very concerned with the issuance of a Mitigated Determination of Non-Significance. An EIS is required whenever there is the potential for an adverse environmental impact. The letter from the University's Friday Harbor Laboratories and those letters submitted by others clearly demonstrate that additional analysis is required for the application. The SEPA Guidelines state (WAC 197-11-400) that the primary purpose of an EIS is to ensure that SEPA's policies are an integral part of the actions of state and local government. An EIS provides an impartial discussion of significant environmental impacts and informs decision makers and the public of reasonable alternatives, including mitigation measures that would avoid or minimize adverse environmental impacts or enhance environmental quality (and determine if the Proposal <u>and</u> proposed mitigation would result in an environmental impact). The process enables government agencies and interested citizens to review and comment on proposed projects. The SEPA Guidelines further state that the EIS is more than a disclosure document; it should be used by agency officials in conjunction with other relevant materials and considerations to make decisions.

There are additional potential impacts that I would add to the list that should be analyzed in an EIS. The SEPA Checklist acknowledges that both threatened and endangered species are known to be on or within the vicinity of the project and the marine water fronting the project is a migratory route for Southern Resident killer whale and salmon. The impacts to these threatened and endangered species triggers the need for an EIS. There is little analysis of the impact of the continued existence and use of the facility and no analysis of the proposed desalination system (operations) in this highly sensitive location.

Ecology's direction to local jurisdictions, in light of the citizen referendum creating the Shoreline Management Act, was to provide protections for shoreline natural resources including the land, vegetation and wildlife, and the water of the state and their aquatic life and to ensure no net loss of ecological function. The SEPA Checklist does not adequately assess this loss.

Studies and research that have taken place in False Bay has been of value to the entire state, region and beyond. Impacts will occur from not only dock and desalination system installation, but also from annual removal and reinstallation of the dock and the operations of water craft and the desalination system. The impacts to False Bay will be significant and that will not only impact the immediate area but the critical research that has occurred over the last 100 years. It is also important to note that biological preserves like False Bay are extremely rare and difficult to establish. A primary benefit of False Bay research is that it has occurred over along period of time and has not been subject to spills or other impacts.

Your original MDNS, dated 9/6/17, gave a comment due date of 10/7/17. Yesterday on 9/18/17 you sent a Corrected MDNS that is still dated 9/6/17 but changed the comment due date to 9/20/17. We believe this does not give adequate notice.

Thank you for consideration of our comments on the SEPA determination.

Sincerely,

Julie Blakeslee
Environmental and Land use Compliance Officer
Capital Planning & Development
University of Washington
Phone: 206-543-2425
Email: jblakesl@uw.edu

Cc: Regulatory Branch, US Army Corps of Engineers
Federal Permit Coordinator, Washington Department of Ecology
Doug Thompson, Washington State Department of Fish and Wildlife
Gabriel Harder, Aquatic Lands Manager, Washington State Department of Natural Resources
Dr. Billie Swalla, UW Friday Harbor Laboratories
Jeanette Henderson, UW Real Estate

San Juan County Community Development and Planning Office: Attn: Julie Thompson
Regarding permit application PSJ000-17-0003 for residential dock construction and RO system by Orca Dreams LLC on False Bay, San Juan Island

Comments:
I have been a full-time resident on False Bay, San Juan Island (SJI) for 22 years. My home is very near the project site. I am a retired associate professor in the field of biology. After reviewing the proposal, I have concerns about the long-term effects of such a major shoreline structure and proposed activities for this southern part of False Bay. My comments only pertain to the vessel moorage section of this two-part proposal.

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

I have observed many natural wonders in the two plus decades of living on False Bay. I am concerned and argue that the project being proposed is inappropriate and highly incompatible with protecting the biological resources and unique and fragile, critical ecosystem. As such, I recommend that this project as currently proposed, be denied.

I have spent nearly 100 hours kayaking in and nearby False Bay while living here. The above water rocky areas near this project are frequent haul-out areas for pinnipeds including Harbor Seals, and less frequently, Sea Lions. These pinnipeds are easily disrupted by watercraft and as such, boats entering or exiting from this moorage would consistently cause these mammals and their pups to flee into the water for safety and not be able to rest as needed.

This coastline and the project area are open to Haro Strait and the eastern Strait of Juan de Fuca. Strong wind storms and wave action along this shoreline are common, even in the months of May through July (data available from NOAA weather buoys at Hein Bank). The proposed floats would be highly vulnerable to major damage from these storms. This is the reason there are no moorages on the south west side of SJI. Similar projects in the area have been attempted and failed. Frequent repair and replacement with heavier-duty structures would be inevitable in such a vulnerable location and likely cause more environmental degradation.

Marinas in WA are highly regulated and regularly inspected. This project basically proposes a small, private 'marina' with boats moored for months that could easily discharge (through bilge pumps) oil & fuel, or leak contents of marine heads, as well as sloughing bottom paints, zincs, and materials & solvents etc. from cleaning and/or repairing the boats. There is no plan for county oversight of the project's compliance over time. E.g. no data exists on what the northward rotary current in this part of False Bay might introduce with regard to pollutants into the adjacent False Bay Preserve (UW) Research area.

At least five major marinas exist on SJI including Roche Harbor, Port of Friday Harbor, Shipyard Cove, Jensen's Shipyard and Snug Harbor. Other private, permitted moorages including docks and mooring buoys are available on the island from shoreline owners who no longer use them. I personally have never known any resident boat owner (including myself) of the island who could not find moorage at one of these places by networking and having some degree of patience. These permitted, commercial moorages are much more appropriate for the residents and guests of Orca Dreams LLC to keep their boats available and safe.

The previous owners of this property operated a resort for many years and kept small watercraft on the beach for guests or family to use for recreation. This would be a much more appropriate and less damaging way for the owners and residents of Orca Dreams to explore and enjoy this beautiful area without negatively impacting this amazing and pristine marine environment.

Tom R. Schultz, San Juan Island
September 19, 2017

Julie Thompson

From: Eleanor Hartmann <ehartmann7@gmail.com>
Sent: Tuesday, September 19, 2017 10:57 AM
To: Julie Thompson
Subject: SEPA comment

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

September 18, 2017

To whom it may concern:

I write to express my concern about proposals for a dock and a desalination plant on the Orca Dreams property, formerly Mar Vista, adjacent to False Bay. All development is ruinous to shoreline, near shore, intertidal, and estuarine environments, and projects that impact the delicate intertidal habitat are particularly disastrous, both during construction and in the decades of human impact that follow. The continual injection of brine from the desalination plant would be potentially catastrophic, especially to the biological sanctuary of adjacent False Bay Preserve.

Many of us who are neighbors upland from the shore make every effort to mitigate the effects of our presence on our land, avoiding disruptive construction, landscaping, agricultural disturbances, domestic water use, septic and drainage impacts, and use of harmful home, vehicle, personal care, and gardening products, so that our runoff that ultimately flows down to the sea will minimally harm the microscopic life in our island waters. We regret the actions of shoreline property owners whose lifestyle choices inflict immediate and far-reaching damage on critical natural ecosystems without regard for long-term consequences.

The Salish Sea with its many coves and estuaries is a nursery to the life of the Pacific Ocean. The Orca Dreams Biological Assessment lists species whose critical habitat will be disturbed—birds, mammals, fish, and edible crustaceans, but makes no reference to the nourishment provided by the sediment at the bottom of the food chain and the actual species, including microscopic organisms, upon which shore life and sea life depends, locally and beyond. This information is readily available to those who need to know. This is a time when knowledgeable and caring island residents are removing docks and bulkheads and restoring shorelines. These efforts are applauded.

Thank you for your attention.

Eleanor Hartmann
90 Two Barn Farm Lane
Friday Harbor, WA 98250

Julie Thompson

From: Tom Bosworth <tom@bosworthhoedemaker.com>
Sent: Tuesday, September 19, 2017 10:12 AM
To: Julie Thompson
Cc: gretchen@rockisland.com
Subject: Permit # PSJ000-0003. Project: 260' 4 slip dock and RO desalinization plant

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Julie Thompson,

I wish to strongly urge you to reject the construction of this project, and thereby help all of us, who value and love what still remains of the pristine beauty and natural elegance of our San Juan Island, to save and preserve what is now our responsibility to protect.

A 260' private dock, encroaching on publicly owned tidelands, sticking out from a magnificent extent of unblemished coastline extending from Cattle Point to Mitchell Bay, would irreparably harm and damage what is most special about our most blessed island.

Please say NO!

Sincerely yours,

Thomas L. Bosworth, FAIA
Professor Emeritus of Architecture, University of Washington
90 Mountain Shadows Lane, Friday Harbor, WA 98250

Sent from my iPad

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

September 18, 2017

Permit # PSJ000-17-003
Project Description: 4 slip dock and RO desalination system

Dear Ms. Thompson,

I am writing to once again express my strong opposition to the proposed dock and desalination system at the mouth of False Bay, on San Juan Island. I urge the county to deny the permit outright and put an end to this unnecessarily lengthy and costly process.

My house is on the northwest side of False Bay and looks across the water toward the site of the proposed dock. I am a full time resident of San Juan Island and have lived on the island for about 25 years.

I specifically chose to live around False Bay because of its quiet natural beauty and undisturbed habitat. Most of my fellow neighbors share this sensitivity. Few houses are visible along the shore, and we appreciate that there are often more great blue herons than people present. A large dock would add noise, lights, activity, and disturbance, and degrade the quality of False Bay for myself and my neighbors.

The aesthetics are a compelling argument against this proposed development, but there are many other reasons why it is inappropriate for the county to grant a permit for a large 260' dock in False Bay.

Suitable moorage or dock space is available for boat owners elsewhere at Snug Harbor, Friday Harbor Marina, or Jensen's Cove. Other boat owners in the neighborhood use these facilities, which are protected and convenient, and there is no reason why the owners in question would not use these same facilities.

The weather on the west side of SJI is unsuitable for docks. Winter storms can be fierce, frequent, and ferocious, with prevailing strong southerly winds and high waves coming straight at that coast. While summer storms are less numerous, they too can be dramatic. Giant logs smash around in the waves and eventually pile up along the shores. This is not a protected waterway! I know from sitting in my window seat and looking out at the mouth of False Bay that the cove under consideration can be wild and frothy during these storms. As any boat owner understands, subjecting your boat and equipment to these conditions is risky, and the danger of mishaps real.

Permitting a dock in False Bay would set a dangerous precedent for building fortress like docks on the scenic west side of the island. There are currently no docks along this 14 mile stretch of rugged shoreline, from Mitchell Bay

southeastward to Cape San Juan, and because of this natural beauty, the west side is a favorite destination for tourists and locals and an important attraction for our tourist industry.

A large dock would have an adverse impact on the sensitive ecology of False Bay. The area has been protected as a biological preserve for years by the University of Washington, and its habitat is important to the UW's Friday Harbor Labs for numerous studies by its research scientists. Any activity or use of the bay which would have an adverse impact here is not acceptable.

Serious questions about the effects of the desalination system on the fragile ecosystem in the cove have not been adequately addressed by the applicants.

The proposed dock would also adversely affect the Southern Resident killer whales, an endangered population listed under the Endangered Species Act in 2005. NOAA has spent over $15 millions dollars in the past decade studying ways to support its recovery, and has a clear mandate to protect them from harm.

According to the NOAA report "Southern Resident Killer Whales: 10 Years of Research & Conservation", the three main threats to the survival of the Southern Residents are prey availability, pollution and contaminates, and noise and disturbance from vessels. The report states that"...the west side of San Juan Island is a foraging "hot spot" for Southern Residents during the summer."

The area around the mouth of False Bay is an especially abundant area for salmon. Historically, local tribes established summer fishing camps there, and it's still a popular fishing spot. Killer whales too use this site for fishing, and are often seen (and heard) just beyond the cove where the dock has been sited and directly in the path of the boats which would be entering and leaving through this area as they made their way to open water.

There is no question that the noise and disturbance from the boats will directly affect these feeding whales. NOAA has been concerned about the amount of vessel traffic along the west side of SJI, and has made efforts to work with the county and commercial whale watching boats and kayak tours to mitigate their impacts. For the most part compliance with keeping distances has been a matter of understanding good stewardship, and based on the honor system.

Given the applicant's past history of non compliance with county and state regulations protecting our resources, I see no reason to believe that a system designed to safeguard the whales by requiring the owners to refrain from entering and exiting the cove when the whales are nearby would work.

Based on the accumulation of evidence that strongly suggests there would be a significant adverse impact on the endangered Southern Resident killer whale population from the construction of a large dock at the mouth of False Bay, and the

increased disturbance and traffic of motor boats in and out of this site, there can be no justification for granting this permit. Whale populations have been struggling in the past few years, with a notable drop in sightings this summer. This is not the time to add to their difficulties.

I urge you to deny this permit.

Sincerely,

Martha Scott
264 Mt. Shadow Lane
Friday Harbor, WA 98250
(360) 378-1303

Sept 18, 2017

Re: Permit # PSJ000-17-0003 (4 slip dock and RO desalination system)

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Ms. Thompson:

This letter is being submitted in opposition to the proposed dock and desalination plant at the mouth of False Bay, San Juan Island.

I am a resident of the Kanaka Bay neighborhood, a frequent visitor to the False Bay tidelands, a sea kayaker and wildlife watcher, and a wildlife biologist by profession.

Part of this 260 foot dock will occupy publicly owned tidelands and pose a direct threat to the University of Washington's False Bay Biological Preserve through its construction and ongoing use. The potential for fuel and chemical spills in this relatively pristine section of shoreline will greatly increase. Docks of this size pose a direct threat to fragile eelgrass beds that provide spawning habitat for herring, a prey species for endangered Chinook salmon (and as follows, the endangered Southern Resident Orca). This vital food web currently hangs in a precarious balance, and the west side of San Juan Island (and in particular, this location, at the mouth of a productive tideland ecosystem) is no place for shoreline modifications of this magnitude. Furthermore, harbor seals frequent the rocks in this area as haul-out and pupping sites. Increased boat traffic in the area will drive these animals away, constituting harassment, which is a punishable offense.

There is no demonstrated need for this dock whatsoever. This is simply a matter of convenience for the owners who have clearly not shown, based on prior land use actions, any regard for the fragile environment that they are now calling their home.

Given the large environmental cost of this proposed project, simple aesthetics seems to be an afterthought—but as a frequent recreational user of False Bay, and as a resident that has to look at this property every day, a dock of this size would be a serious mar on a once-pristine section of shoreline. The West Side of San Juan is too fragile, and simply too beautiful, to destroy. Please decline this permit.

Sincerely,

Kathleen Foley
426 Mountain Shadows Lane
Friday Harbor, WA 98250
gavia3@gmail.com

September 18, 2017

Re: Permit#PSJ000-17-0003
Application for Joint Use Dock & RO Desal System

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Ms. Thompson,

We are writing to object to the County's decision to issue a mitigated determination of non-significance, (MDNS) for the above referenced permit.

As property owners and part-time residents of San Juan Island on Bailer Hill overlooking False Bay since 1989 we have an abiding passion for the island, its culture and its unique natural environment. We believe island residents value the opportunity to enjoy this environment and thus to act as responsible stewards.

Our concerns/objections:

I. Since purchase of the Mar Vista Resort by the applicants in 2014 the owners have allowed clear cutting of the property in violation of the Shoreline Management Act resulting in a significant fine and a requirement for remediation. My personal observation of the clear-cut on the shoreline by kayak shows minimal compliance; inadequate or negligent stewardship raises serious questions as to commitment to following through on the required MDNS.

II. Current application is deficient in the required surveys.

III. Applicant refers to "community dock" whereas the "community" is the current ownership.

We respectfully request a full EIS be required based on the potential for adverse environmental impact.

The potential for accidental fuel leaks from up to four 18-36 foot motor boats moored between April 1 and November 1 is significant given the powerful winds that occur several times during a summer season and/or improperly tied moorage lines. Witness the absence of existing docks between the moorage at Cape San Juan and Snug Harbor.

The applicant has recourse to safe, fully monitored moorage in Friday Harbor ten minutes by automobile from applicant's property.

Sincerely,

Jim and Camille Uhlir
300 Two Barn Farm Lane
360-378-5689

Julie Thompson

From: Mike Prentiss <mvp@mprentiss.com>
Sent: Monday, September 18, 2017 9:09 AM
To: Julie Thompson
Subject: #PSJ000-17-0003; 4slip dock and RO desalination system

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Ms Thompson:

Once again, I am writing to express our concerns and adamant opposition to the construction of the proposed dock and desalination system being proposed by Orca Dreams LLC. As I said in my letter of May 16, 2014, we are the owners of the property abutting the applicants property. The beach where they propose to place the dock is shared by us, so our use of the beach is directly adversely impacted by what is proposed.

This beach is very pristine and is treasured by all our neighbors. The dock will be detrimental to the esthetics of the area, as it will be seen by all the frequent kayaks and boaters that transit the area. I am perplexed as to why the County would even give any consideration to this application, since the applicant has already demonstrated their lack of concern about the environment, by illegally clear cutting a substantial portion of the cove, for which they were fined by the State.

The proposed dock will infringe upon publicly owned tidelands, that the University of Washington uses for biological research. There is no justification to use public lands for the private benefit of the applicant, particularly because will will definitely be harmful to the surrounding environment.

If this project is allowed to proceed, it will set a terrible precedent that will lead to numerous other attempts to despoil the waterfront for personal gain. The San Juan Islands are a special place that we all should be obligated to make every effort to preserve for future generations. I strongly urge you to reject this application.

Sincerely,

Mike

--

Mike Prentiss
P.O. Box 7046
Dallas,Texas 75209

214-668-1207(cell)

To: Erika Shook, Department of Community Development and Jon Thompson, Planner III
Dock Permit #PSJ000-17-0003
September 17, 2017

DEPARTMENT OF
SEP 18 2017
COMMUNITY DEVELOPMENT

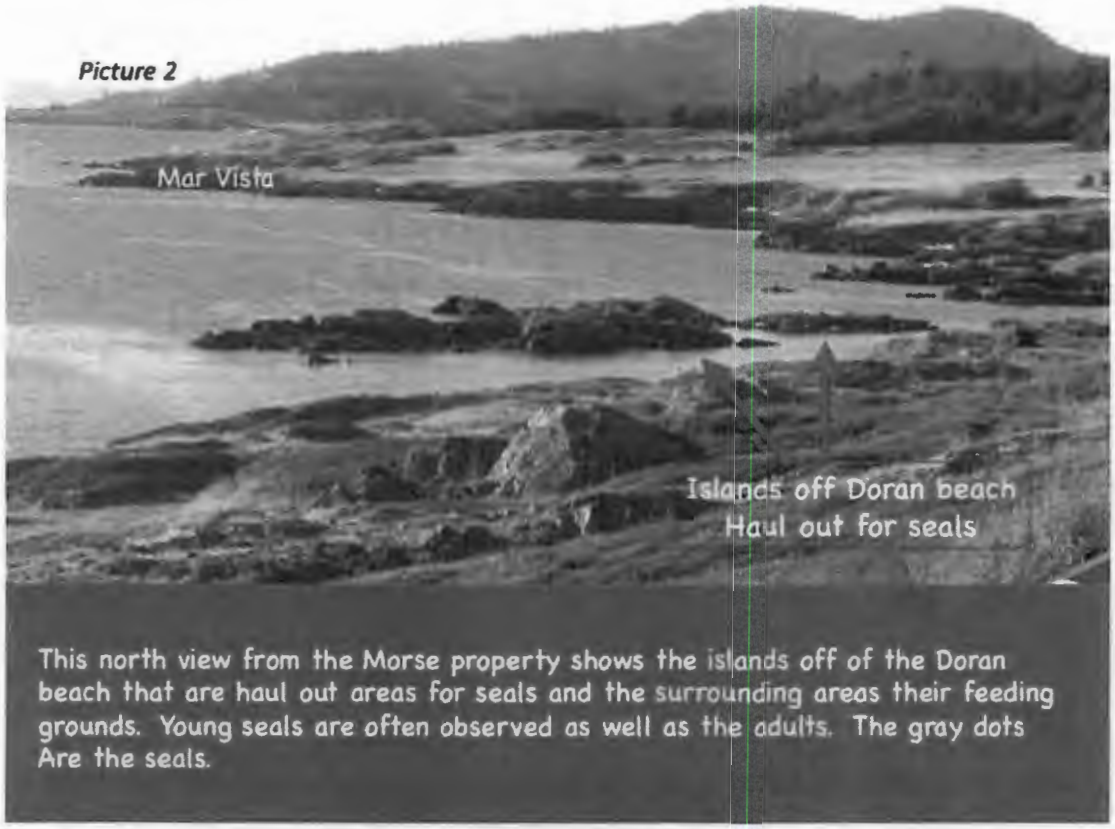
This letter is the third I have submitted relative to this project. I now understand that the proposals include a floating 4 slip dock, and a RO Desalination system. I wish to speak to the impact on the critical habitat of the area surrounding the Honeywell property known to me as Mar Vista.

Picture 1

Proximity of the passage of whales (picture 3) near the "Islands" and the adjacent rocks where seals are seen in picture 2. False Bay is just the other Side of the Honeywell Property known as Mar Vista.

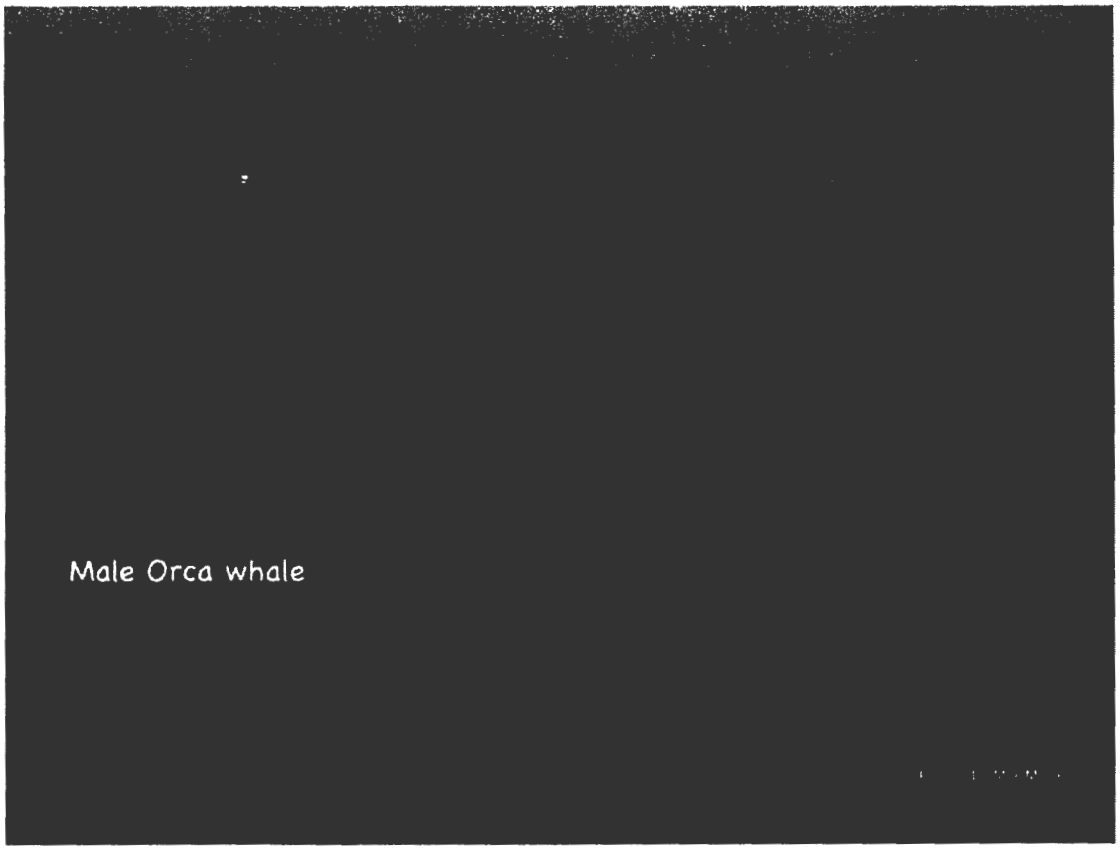
I share the view and have lived on my land since 1985. During the months the whale pods are in residence, they pass by often twice a day, and feed in front of my home. In Picture 1, the "islands" are where Oyster Catchers breed in the summer, an eagle pair land there as thy fish, and the whales often pass close in to these rocks (see Picture 3). The "Rocks" off to the right in Picture 1 are where the seals haul out daily between tidal feeding bouts. They are often seen swimming close into shore, their shiny heads making them very obvious. There are both adult seals and often babies are seen on the rocks. River otters also fish in these waters and haul out on various properties along this shore (including mine). Migrating birds can be very numerous (especially this September 2017), covering the rock islands as well as the rocks in front of my property. These pictures are to provide evidence that in fact the Orcas DO pass by close to the Honeywell Property, and these feeding grounds on up

to Lime Kiln and beyond are inhabited often during their activities feeding mostly on salmon.



This north view from the Morse property shows the islands off of the Doran beach that are haul out areas for seals and the surrounding areas their feeding grounds. Young seals are often observed as well as the adults. The gray dots Are the seals.

The "Islands" in Picture 1 was the sight of a serious accident this summer (2015) in August. Four people aboard a powerboat lost power, were unable to connect to a rescue boat, and the boat crashed into the "Islands." The four occupants were able to scramble on to the rocks and were rescued by a Coast Guard Helicopter. The pieces of the boat are still coming ashore, and have been retrieved from the Doran beach as well as from the rocks on the islands. The winds came quickly and registered on my anemometer at 50 mph. Although these sorts of storms usually come in the late fall, it is NOT unusual to have this happen during the summer. It is lucky that our population up to now can relate that to build a dock on this area of San Juan Island is in fact asking for difficulties and can easily lead to disastrous problems of oil spill impacts, especially with a shallow bay, False Bay, right in the pathway. False Bay and the shoreline in this immediate vicinity is one of the most beautiful and a very unique ecological spots on San Juan Island, is used by our citizens and deserves our protection and stewardship for future generations.



As anyone can tell you who have photographed whales, the one male fin in this picture is only one member of a pod that was passing by the "Islands." It is clear evidence that they DO come close to shore in the immediate area around Mar Vista. I hope these will help the owners of Mar Vista to look toward moorage at the available safe places that are less than seven miles away at the Port of Friday Harbor. It will allow those that end up making Mar Vista their home to enjoy the Whales, seals, migrating birds, eagles and other wonders of nature with their family for years to come. I do hope that building of this dock will not be permitted.

I am not familiar with desalination systems but do understand that the waste water from this system may indeed differ significantly from the usual water that flows into and out of False Bay in a tidal cycle. Anyone who has witnessed this tide change is familiar that this is a very shallow bay, and major changes in the water would undoubtedly have an effect on the organisms that inhabit the mudflat. The ecology of False Bay has been extensively studied by marine scientists, especially, from the U.W. Friday Harbor Laboratories, but I am not aware of evidence of change associated with desalination waste water.

The fragility of the environment of False Bay, the recognition of these problems by folks on the Island who have submitted over 100 letters on past applications for dock structures, and the increases in the severity of storms on this West side of the Island should be revisited as this new application appears.

Sincerely,

M. Patricia Morse

M. Patricia Morse, Ph.D.
Professor Emeritus of Biology
258 Mytilus Lane

Julie Thompson

From: Steve Ulvi <srulvi@gmail.com>
Sent: Sunday, September 17, 2017 7:27 PM
To: Julie Thompson
Subject: Permit # PSJ000-17-0003 Four slip dock and desalination system

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

I do not live on False Bay.

I regularly ride False Bay Road summer and winter for the view of the tidelands and Straight. And yes the pungent salty odor of tidal flats. I fish and boat by the Bay many times a summer and enjoy the undeveloped tidelands, the idea and research function of the Marine Biological Preserve and the absence of docks and tide-line development.

It is patently absurd that land owners could conceive of such a large dock, requiring so many steel pilings and nearly a football field intrusion into the tidelands for recreational use. It will be an eyesore for boaters and kayakers and those residents who live on the north west margins.

There is a good reason that there are no docks on the south end of San Juan Island. And historical events that underline the lack of wisdom in attempting such a structure or mooring larger boats in those waters.

Winter storm waves and high tide flotsam including large logs slam the southwest coast all winter and especially the area of the Bay in consideration. The applicant will not be able to safely use the dock for several months in the winter and storm damage causing summer repairs that will further degrade the natural environment of the site.

But even worse, this is an unwise potential precedent given the location open to the power of the Straight and on it's face degradation of the scientific, recreational and natural values that have been long enjoyed within that quadrant of the Bay.

If a cutting edge desalination plant is necessary for the applicant to properly use their parcel and no significant impacts are possible to the public commons then this is a separate matter for which I have no other comments.

Please deny this revised dock permit application!

Sincerely

Steve Ulvi

136 Baker Vista Trail

San Juan Island

September 17, 2017

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

To: Julie Thompson <JulieT@sanjuanco.com>

From: Richard Strathmann, strath@rockisland.com
PO Box 2263, Friday Harbor, WA 98250

About: proposed dock and desalinization plant; Orca Dreams, LLC.

These comments are on the proposal for a dock for use at Orca Dreams, near False Bay on San Juan Island.

The two pdf documents describing the proposed development were titled SJ000-17-0003_OrcaDreams

The proposed development will have several impacts. Some will be cumulative because the construction of a dock is likely to lead to the construction of other docks along the west side of San Juan Island. Some impacts will be local.

1. Impact on killer whales

The southern resident killer whales are endangered. A number of studies have demonstrated harm to this population of killer whales from decreased food, especially Chinook salmon, increased vessel noise, and pollutants. The proposed development adds to vessel noise by itself and through cumulative effects of similar developments along the west side of San Juan Island that would be encouraged by its precedent. The proposed development, with cumulative effects, may also affect habitat for juvenile salmon and thereby food for the whales.

In 2009, as part of the effort to maintain and restore the southern resident population of killer whales, NOAA proposed a no-go zone for the west side of San Juan Island within 1/2 mile of the shore between Mitchell Bay and Eagle Point. This zone includes habitat that is important for the resident population killer whales. This zone includes the site of the proposed dock. The goal of the proposed no-go zone was to reduce disturbance of the whales by boat traffic. The County Marine Resource Committee responded with a recommendation for limited entry rather than the proposed no-go zone. The Committee report recognized that noise from boat traffic could be a source of disturbance and accepted as fact that the current situation did not adequately protect the whales (http://www.nwstraits.org/uploads/pdf/SAN-2009-0433_NOAAProposedVesselRule_Recommendations_SanJaunCounty.pdf).
The studies of effects of noise from boat traffic, the importance of this coastline of San Juan Island for feeding by the whales, the information in the report by the County MRC, all point to a need to limit rather than increase near shore boat traffic in this area, if this population of killer whales is to be maintained. Toxins and too few fish are also problems for this population, but noise from boats is a problems and one that can be addressed locally, and through its effect on the whales' communication, noise may also interfere with their feeding.

For recent evidence of a shortage of food see
Wasser, S. K., J. I. Lundin1, K. Ayres, E. Seely, D. Giles, K. Balcomb, J. Hempelmann, K. Parsons, R. Booth. 2017. Population growth is limited by nutritional impacts on pregnancy success in endangered Southern Resident killer whales (*Orcinus orca*). PLoS ONE 12(6): e0179824. https://doi.org/10.1371/journal.pone.0179824

Ayres, K. L., R. K. Booth, J. A. Hempelmann, K. L. Koski, C. K. Emmons, et al. 2012. Distinguishing the impacts of inadequate prey and vessel traffic on an endangered killer whale (*Orcinus orca*) population. PLoS ONE 7(6): e36842. doi:10.1371/journal.pone.0036842

Studies on effects of noise on the killer whales of this region include

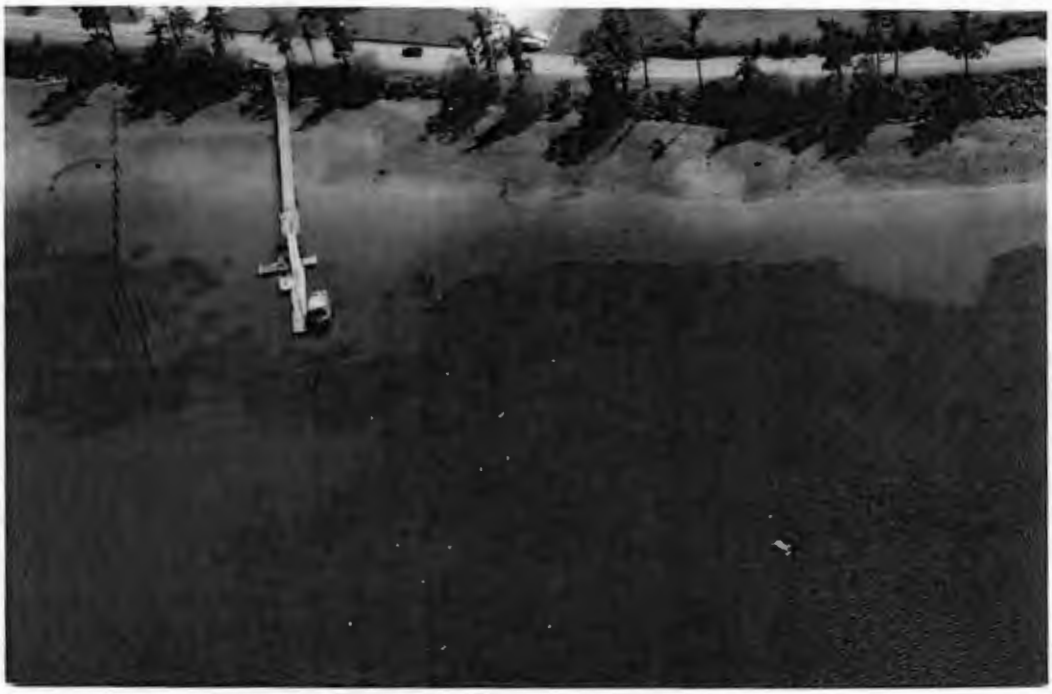
Williams R, Clark CW, Ponirakis D, & Ashe E. 2014. Acoustic quality of critical habitats for three threatened whale populations. Animal Conservation 17: 174–185.

Holt, M. M., D. P. Noren, V. Viers, C.K. Emmons, and S. Viers. 2009. Speaking up: killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. Journal of the Acoustical Society of America 125(1), 12 pages, available at http://scitation.aip.org/content/asa/journal/jasa/125/1/10.1121/1.3040028.

2. Impacts on eelgrass and other organisms

The seafloor in the area of the proposed dock is described as hard bare sand, and eelgrass shoots were observed nearby. The distribution of eelgrass is not fixed. These statements indicate that the area of the proposed dock is suitable habitat for eelgrass and that the dock will decrease habitat for eelgrass. Grating decreases the effect of shading by docks and floats, but does not eliminate effects of docks on eelgrass and other marine life. Also, boats at a dock shade the seafloor.

Aerial photos of docks in areas of eelgrass in Garrison Bay (first photo) and Fisherman Bay (second photo) show bare patches without eelgrass at distances well beyond the area shaded by the dock.



The proposal says that prop wash will be reduced by operating boats at low speeds near the dock, but there is no way to enforce this condition on present or future owners or their guests. A correction of course near a dock can necessitate a sudden change in speed.

Other effects of docks include litter, toxic materials that are associated with use of boats and treated woods, changed deposition of sediments along the shore because floats act as breakwaters, and indirect biological effects, such as increasing shell debris to the sediments below and habitat provided for some crabs and seastars that prey on other organisms in the vicinity, thereby extending the area of disturbance.

The proposed dock increases opportunities for recreational use of larger boats by a few people. By itself and through cumulative effects the proposed dock would impact marine resources used recreationally by many people.

Julie Thompson

From: Michelle M. Shober <MMShoberInc@Rockisland.com>
Sent: Sunday, September 17, 2017 2:58 PM
To: Julie Thompson
Cc: Gretchen Allison
Subject: Permit # PSJ000-17-0003 Project description: 4 slip dock and RO desalination system

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Dear Julie Thompson,

I am writing to protect False Bay and protest granting Permit #PSJ000-17-0003, which involves installing a 4 slip dock and RO desalination system on False Bay.

My husband and I have been westside, water-front property owners on San Juan Island since 1988.

When we purchased our land we were told that the law did not allow docks of any kind on the waterfront due to ecological reasons,
not to mention high winds during winter storms that could easily wreck havoc on any dock system on the Sound.
We agreed to this restriction when we bought our land.

Since that time we also became boat owners, and again we respected the restrictions to not install any docking system in front of our property.
Driving to Snug Harbor or Roche Harbor where we housed our boat, was not an inconvenience, just another part of our boating adventure.

I am also an avid kayaker and frequently enjoy the serenity of False Bay. I am devastated to think that the county would allow anyone to destroy
what is an incredible natural resource for the entire population of San Juan County and all of the thousands of tourists and visitors to our beautiful island.

My husband and I knew the law when we purchased our land. Others on the westside also respect the law of the land that the residents established
for the protection of all our natural resources, serenity and beauty. I beseech you to deny Permit #PSJ000-17-0003.

Sincerely,

Michelle Shober

Julie Thompson

From: gretchenducksoup@gmail.com on behalf of Gretchen Allison <gretchen@rockisland.com>
Sent: Sunday, September 17, 2017 1:25 PM
To: Julie Thompson
Subject: Permit # PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

SEPA comment for tax parcel # 353344008, permit # PSJ000-17-0003

My family has lived on False Bay for 34 years and we cherish the landscape and wildlife here. We walk and Kayak regularly in and around the pocket bay where the Honeywell's want to build their dock. This dock would directly impact the access and experience the public now enjoys. I know of no one in this vicinity who is not extremely upset by the prospect of this ill considered development in such a shallow and fragile habitat. It would degrade the landscape for us all and would adversely effect the way we feel about our home and our county.

There are available public docks for boats a short 10 minute drive from the Honeywell's property that they can utilize without undue hardship. A development that is this intrusive is not a reasonable sacrifice for the rest of us to be forced to endure so that one property owner can fulfill their every desire. The costs to the environment and community are too high and the county is not under any obligation to give the go-ahead when so many elements of the project raise serious concerns.

Besides all of the endangered and threatened species that frequent the location not being protected from the intrusion of the construction, boat traffic, potential chemical spills and changes in turbidity,

I am concerned about light pollution resulting from dock lights and the desalinization equipment. Lighting could effect sea life. Because of the previous illegal clear cutting done by the Honeywell's we now have an unobstructed view of their land which is lit up nightly, looking rather like a casino from our property. Dock lights would add significantly to this effect.

I am concerned that there is inadequate information regarding the impacts of 9,000 gallons of hyper-saline waste water entering the bay daily from the proposed water plant. Comparing the water movement within the pocket bay to the mixing flow of water off of Cattle Point needs to be studied and quantified. Their just saying it's OK doesn't make it so.

I believe that requiring a full environmental review is in order, or better yet, the county should JUST SAY NO to the dock.

Thank you,

Gretchen Allison

Julie Thompson

From: James Uhlir <juhlir1@gmail.com>
Sent: Sunday, September 17, 2017 5:07 PM
To: Gretchen Allison
Cc: Julie Thompson
Subject: Re: Permit # PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 20 2017
COMMUNITY DEVELOPMENT

Nice letter, Gretchen!
Jim

Sent from my iPhone

> On Sep 17, 2017, at 1:25 PM, Gretchen Allison <gretchen@rockisland.com> wrote:
>
> SEPA comment for tax parcel # 353344008, permit # PSJ000-17-0003
>
> My family has lived on False Bay for 34 years and we cherish the landscape and wildlife here. We walk and Kayak regularly in and around the pocket bay where the Honeywell's want to build their dock. This dock would directly impact the access and experience the public now enjoys. I know of no one in this vicinity who is not extremely upset by the prospect of this ill considered development in such a shallow and fragile habitat. It would degrade the landscape for us all and would adversely effect the way we feel about our home and our county.
>
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>
> I believe that requiring a full environmental review is in order, or better yet, the county should JUST SAY NO to the dock.
>
> Thank you,
> Gretchen Allison
>
>
>
>

Julie Thompson

From: Mike Lisitza - NOAA Affiliate <mike.lisitza@noaa.gov>
Sent: Thursday, September 14, 2017 11:56 AM
To: Julie Thompson
Cc: Jonathan Molineaux - NOAA Affiliate; Huff, Mary (DNR); Thompson, Doug S (DFW); Houghton, Juliana NWS
Subject: Orca Dreams llc dock and desal

Hi Julie,

NOAA Fisheries has serious concerns regarding this proposal. We are in formal ESA Section 7 consultation with the Army Corps of Engineers for adverse effects of this project to southern resident killer whales (SRKWs). I'm interested in seeing the material you used to support your decision that there would not be a significant impact to SRKWs. The materials on your website only have what the applicant submitted and your decision, but not any other material you may have considered. I also had questions about your SEPA decision process:

1. Did you consider the impacts to SRKWs to be significant without the proposed mitigation measures?

2. Did you consider the indirect impacts of the dock on SRKWs?

3. Did you consider

the likelihood

that approval of

th

is dock

proposal will serve as a precedent for future

docks on the west coast of San Juan Island?

Thanks,

Mike Lisitza
NMFS Contractor
Oregon and Washington Coasts Area Office
Phone: (206) 305-9475

Core office Hours: *Mon-Fri 6am-2pm*

Julie Thompson

To: Mike Lisitza - NOAA Affiliate
Subject: RE: Orca Dreams llc dock and desal

Please see answers below.
Julie

From: Mike Lisitza - NOAA Affiliate [mailto:mike.lisitza@noaa.gov]
Sent: Thursday, September 14, 2017 11:56 AM
To: Julie Thompson <JulieT@sanjuanco.com>
Cc: Jonathan Molineaux - NOAA Affiliate <jonathan.molineaux@noaa.gov>; Huff, Mary (DNR) <Mary.Huff@dnr.wa.gov>; Thompson, Doug S (DFW) <Doug.Thompson@dfw.wa.gov>; Houghton, Juliana NWS <Juliana.Houghton@usace.army.mil>
Subject: Orca Dreams llc dock and desal

Hi Julie,

NOAA Fisheries has serious concerns regarding this proposal. We are in formal ESA Section 7 consultation with the Army Corps of Engineers for adverse effects of this project to southern resident killer whales (SRKWs). I'm interested in seeing the material you used to support your decision that there would not be a significant impact to SRKWs. The materials on your website only have what the applicant submitted and your decision, but not any other material you may have considered. I also had questions about your SEPA decision process:

The materials I used were the materials they submitted.

1. Did you consider the impacts to SRKWs to be significant without the proposed mitigation measures? I did not consider this.

2. Did you consider the indirect impacts of the dock on SRKWs? No.

3. Did you consider

the likelihood

that approval of

th

is dock

proposal will serve as a precedent for future

docks on the west coast of San Juan Island? The MDNS was based on environmental impacts, not precedents.

Thanks,

Mike Lisitza
NMFS Contractor
Oregon and Washington Coasts Area Office
Phone: (206) 305-9475

Core office Hours: Mon-Fri 6am-2pm

Julie Thompson

From: wrmac <wrmac@rockisland.com>
Sent: Thursday, September 14, 2017 8:48 AM
To: Julie Thompson
Subject: Re: Orca Dreams dock and desal application

Comment on Orca Dreams dock and desal application:

I am opposed to this project.

The dock is intended as a moorage for boats. Where will the boats go? Motoring around in False Bay at mid- or high-tide, stirring up the bottom and destroying that fragile ecosystem? Or cruising out into the way of the orcas in an area where there is a concerted effort to establish a safe corridor for the orcas? Although the orcas frequently follow a general route a little way offshore, they also occasionally come in very close to shore. They will not venture close to this development; Orca Dreams will make the orcas stay out "where they belong."

The desalination plant will discharge quantities of brine onto the seafloor, disturbing the animal communities living there. As the tide comes in, a plume of brine will flow into False Bay. Will the starry flounders venture into that plume to reach their feeding ground? How will it affect the mudflat community? As the tide goes out, the plume of brine will flow out into the strait, undoubtedly detectable by marine mammals and fish. How will the orcas and the salmon respond? How will this brine and all the construction and, later, boating activity impact the diminished rockfish population?

There is now a long, beautiful stretch of natural shoreline along the west side of San Juan Island. It is one of the defining characteristics and cherished values of the island. This precedent-setting development is very different from all else along that natural shoreline. If it is permitted, it would be the beginning of the end of that natural, beautiful shoreline and would thus change forever the nature of the island community.

Walter MacGinitie

Julie Thompson

From: Deborah Strasser <strasserseven@hotmail.com>
Sent: Sunday, September 10, 2017 8:18 AM
To: Julie Thompson
Subject: dock at False Bay

S.J.C. DEPARTMENT OF
SEP 13 2017
COMMUNITY DEVELOPMENT

To Whom It May Concern,

I am horrified to hear that the new owners of Marvista (renamed Orca Dreams) feel it is appropriate environmentally and/or aesthetically to build a dock and use motorized boats in False Bay.

I am a 6th generation islander who spent many a summer day coming in with the tide at False Bay as a child and I observed the varied and numerous marine creatures who call that bay their home.

We were always told to leave it as we found it. No crab or flounder or sand dollar came home with us because this special place is a Marine Preserve that is protected for the purpose of study.

Has something changed?

The people requesting the permit for the dock have only been here a handful of years and obviously don't recognize the sanctity of that special bay that has been intentionally protected since the beginning.

Two or three of my college summers were spent at the labs working for Dr Frank Johnson from Princeton and Dr Osomu Shimomura from Woods Hole, MA. The work they did won the Nobel Prize and one of the things Dr Shimomura told me was that a boat propeller turning in the water causes immense damage to the fragile ecosystem, killing plankton and tiny sea creatures. It seems that would be a very good reason to deny the building of this dock.

Please educate yourselves about the potential damage a dock at False Bay could and would cause before allowing this dock to be built.

Respectfully,

Deborah and Robert Strasser

Drew Harvell
Professor
Department of Ecology and Evolutionary Biology

Cornell University
E321 Corson Hall
Ithaca, NY 14853

Telephone: 607 254-4274
Fax: 607 255-8088
E-Mail: cdh5@cornell.edu

Cornell University

S.J.C. DEPARTMENT OF
SEP 13 2017
COMMUNITY DEVELOPMENT

SEPT 7, 2017

Dear San Juan County Planning,

I am writing concerning the Mitigated Determination of Non-significance on the Application for a Shoreline Permit by Orca Dreams LLC for a residential dock for up to 4 boats and a RO desalination plant on tax parcel number 353344008.

I am a marine ecologist specializing in the study of ocean health of essential marine habitats, including seagrass. Additionally, I administer a Research Coordination Network on Ocean Health and Climate Change that involves over 40 scientists and provides scholarships for top PhD students worldwide to participate in a summer course at Friday Harbor Laboratories (FHL), Ecology of Infectious Marine Disease. I and my PhD students are currently working on health studies of the *Zostera marina* (eelgrass) meadows in False Bay as part of a larger assessment of seagrass health and some of the rapidly declining meadows in the San Juan Archipelago.

The intertidal eelgrass meadow in False Bay has declined significantly in area since first described by Ruckeslhaus (1994). In addition to two earlier reports on the health of False Bay and other San Juan Island eelgrass meadows (Groner et al 2014, 2016), we just completed a survey of intertidal and subtidal eelgrass in False Bay in 2016. Please see the attached report on health of False Bay eelgrass and preliminary biotic surveys in the eelgrass beds in the Pocket Bay adjacent to the proposed site of the Orca Dreams dock.

Eelgrass is classified as essential marine habitat because the underwater meadows are important habitat and nursery areas for fish, birds and diverse groups of invertebrates. Additionally, our recent research has shown that eelgrass meadows can filter toxins and coastal pollution (Lamb, Harvell et al., 2017), and other studies show eelgrass meadows contribute to oxygen production and stabilize soft sediment in the nearshore environment. Moreover, on-going research continues to document the vital global function of seagrass species, including eelgrass, as a sink to absorb excess carbon dioxide from the atmosphere.

In addition to the declining intertidal eelgrass meadows we study inside False Bay and adjacent to Kanaka Bay, there are extensive meadows in the University of Washington preserve at the mouth of False Bay and extending up the shoreline to the Pocket Bay,adjacent to where the proposed dock would be built. Our surveys from 2016 show significant levels of disease causing lesions in both intertidal and subtidal eelgrass beds, with lower levels in the more extensive subtidal beds. The percentage of subtidal eelgrass with lesions along our transects in 2016 was highest in the Pocket Bay and lower in our Kanaka Bay site. Additionally, we worked with scientific divers from Friday Harbor Labs to produce a preliminary biotic survey of the eelgrass bed in the Pocket Bay, showing it to be a rich habitat.

The installation of a marina in the Pocket Bay could diminish eelgrass productivity of this bay, but this potential was not addressed in the Biological Assessment, even though it has been one of the main issues raised in the earlier assessment. In particular, several components of the proposed construction could impose stress on the eelgrass that could make it more susceptible to disease. For example, 1) the alteration and reduction of along shore current patterns caused by the extension of an overwater structure from shore, 2) the introduction of hyper-saline water from the RO could favor increased disease if the outflow is anywhere near the eelgrass bed, 3) increased siltation due to construction is a known stressor for eelgrass and 4) the potential spillage of industrial pollutants and gas is known to stress or kill eelgrass.

We have published 2 studies documenting the presence and effect of a disease, termed the "wasting disease", and caused by the protist, *Labyrinthula zosterae*, within eelgrass populations in the San Juan Archipelago (including False Bay) and Northern Puget Sound regions of the Salish Sea (Groner et al., 2014, 2016). Outbreaks of this disease are facilitated by warming temperatures and events that cause more turbid water in small bays where along shore currents are altered.

I file this comment to articulate my concern about the impact of a private marina of the scale proposed on the health of the nearshore environment in the Pocket Bay where the proposed dock would be built. I am concerned about the sustainability of eelgrass meadows within and adjacent to that extremely fragile embayment. While the county proposes 16 mitigating measures, including number 8, "Eelgrass and macroalgae will not be adversely impacted due to any project activities", there is no baseline monitoring in place to inform or enforce compliance.

Sincerely,

Drew Harvell, PhD
Professsor, Cornell University
CDH5@Cornell.edu

Attached: Groner et al. 2014, 2016, False Bay Seagrass Health Report

False Bay Seagrass Research Summer 2016 Report

University of Washington Friday Harbor Laboratories

UNIVERSITY OF WASHINGTON 1861

Table of Contents

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False Bay Seagrass Report—Part I

Plant demographics and environment influence on

seagrass wasting disease in *Zostera marina*

Olivia Graham, Morgan Eisenlord, Drew Harvell

Summer 2016

Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY 14850

Keywords: Eelgrass, *Zostera marina*, seagrass wasting disease, *Labyrinthula zosterae*, marine diseases

Abstract

Eelgrass (*Zostera marina*) is a key marine foundation species that creates essential habitat for economically valuable fish and invertebrates worldwide. *Labyrinthula zosterae*, a marine slime mold and causative agent of seagrass wasting disease, is among the modern threats to eelgrass. To determine how disease patterns vary across environmental gradients, we collected 360 eelgrass blades from three sites in the University of Washington Reserve in False Bay, WA, which have widespread eelgrass beds and disease. We measured characteristic *L. zosterae* lesions on each blade for disease prevalence and severity. We detected significant effects of eelgrass blade length and site on disease prevalence. Across the three sites, subtidal prevalence ranged from approximately 14.4-37.7%, with the highest levels in the Pocket Bay. Seagrass wasting disease has important implications on the sustained health of eelgrass beds. However, the drivers of disease are not fully understood and merit further research. This study highlights the importance of these critical marine habitats, and underscores the need for more marine epidemiological studies to determine which abiotic and biotic factors allow *L. zosterae* to persist in certain environments.

Introduction

Eelgrass (*Zostera marina*) is a marine angiosperm found in temperate coastal waters worldwide.[1] A valuable component of estuarine and marine ecosystems, eelgrass provides many important ecological and economic services, creating safe habitats for fish and invertebrates and serving as a critical food source for waterfowl.[2-5] Furthermore, eelgrass beds assist with sediment stabilization, nutrient filtration, and are key sources of primary production and carbon sequestration.[1]

The marine slime mold *Labyrinthula zosterae* is an opportunistic pathogen that infects eelgrass and is the causative agent of seagrass wasting disease.[6-8] Seagrass wasting disease outbreaks in the 1930s and '40s decimated eelgrass beds worldwide, leading to dramatic shifts in community structures and functions within these habitats.[5-6,8] Seagrass beds along the Atlantic coast of the United States and Europe received the brunt of the epidemic, although documented cases of wasting disease ranged from Nanaimo, British Columbia to San Diego, CA.[2,9-10]

Subsequent smaller epidemics occurred during the 1980s primarily along the Atlantic Coast of the U.S.[7] The eelgrass beds in the San Juan Islands, WA were not immune to wasting disease, and experienced small-scale epidemics, first in the 1980s and later throughout the 1990s and early 2000s.[7,11-12] Recent studies indicate that seagrass wasting disease persists throughout the archipelago,[12-14] although the cause of disease outbreaks remains unclear. Because eelgrass is critical marine habitat, eelgrass research and conservation is a top federal and state priority.[15-16]

While most wasting disease research focuses on monitoring intertidal eelgrass beds—those that are completely exposed at low tide—subtidal eelgrass beds that remain constantly submerged merit further research. Subtidal eelgrass beds are challenging to sample because they require scuba divers or underwater videography for surveys and collections.[17] While these methods can be used to estimate subtidal eelgrass area, to the best of our knowledge, they have not previously been used to examine subtidal wasting disease.

To determine if seagrass wasting disease varied across environmental gradients, we conducted field surveys of intertidal and subtidal eelgrass beds from four sites in the San Juan Islands, WA (Figure 1). We then measured and compared disease prevalence—the proportion of *Z. marina* with lesions—and the severity—the proportion of *Z. marina* covered with necrotic tissue. Because intertidal eelgrass beds are under considerably more environmental stress (eg, large and rapid fluctuations in temperature, desiccation) than subtidal eelgrass populations that are constantly submerged, we predicted that subtidal eelgrass beds would be more resistant to infection and would have lower levels of wasting disease. Furthermore, since warmer temperatures favor the growth of the slime mold *L. zosterae*, we expected eelgrass in warmer, shallower waters to have higher incidences of wasting disease.

Methods and Materials

Eelgrass Field Collections

We collected subtidal eelgrass from Kanaka Bay, Middle False Bay, Pocket Bay (San Juan Island). We conducted paired intertidal and subtidal surveys at Kanaka Bay. We selected these sites from other long term monitoring sites that historically had documented eelgrass beds.[12,18-19] We conducted subtidal surveys from July 26-29, 2016 and intertidal surveys on July 31-August 1, 2016.

We gathered subtidal *Z. marina* blades from evenly-spaced quadrats along submerged transects that ran parallel to shore. At each site, we used one 40-m. transect consisting of three 10 m. sub-transects spaced 5 m apart. We recorded the depth of the transect every 5 m. and averaged them. Within each 10 m. transect, we randomly collected 30 *Z. marina* shoots, taking care to keep the stems and blades intact, and stored them in mesh bags for transport to the laboratory (n=360 subtidal).

To collect intertidal samples, we used three 60 m. transects at approximately -1, -1.5 and -2 ft depths relative to mean low low water (MLLW). Along each transect, we randomly collected 30 *Z. marina* blades (n=180 intertidal blades). Once in lab, we stored the blades in flow-through seawater tables exposed to ambient light. We measured all samples within 5 hours of collection time.

Laboratory Analyses

For disease measurements, we selected the second-oldest blade from each shoot, as is consistent with other studies that measured seagrass wasting disease.[12,19] Because the longest blades are often torn off and younger, smaller blades may not be infected with *L. zosterae*, the second-oldest blades serve as reliable indicators of disease. We identified the second-oldest blade from each shoot by selecting second highest blade from the sheath.

Since we collected entire shoots for subtidal samples, we measured canopy height as the length of the longest shoot from blade tip to the start of the rhizome. We measured canopy height for intertidal blades from ten randomly selected eelgrass shoots every 10 meters and averaged their length. We measured the density of eelgrass blades within a 1 m^2 quadrat every 5 meters for subtidal transects and every 10 m for intertidal transects. For each blade, we measured the length and width of each blade and the length and width of all lesions.

We visually identified *L. zosterae* lesions per established protocol.[12] We only measured spots with clear, dark outlines and lighter interiors, and did not measure lesions near torn or damaged tissue, except those with clear *L. zosterae* borders (Figure 2). Likewise, we did not include sun spots, bleached tissue, or spots less than 1x1 mm in our measurements. From these measurements, we calculated the disease prevalence and severity across all sites. We performed generalized linear mixed effects regressions (GLMER) and linear mixed effects regressions (LMER) in R to determine significant effects and interactions between the different factors (site, tidal regime, depth, average density, blade length, canopy height).

Results

Our data indicated significant statistical differences in disease prevalence between the three subtidal eelgrass beds in False Bay, as indicated by a one-way ANOVA ($F(2, 266)=6.55$,

p=0.00167). Pocket Bay had the highest disease prevalence with 37.7% of subtidal eelgrass infected, followed by Middle and Kanaka Bay with 26.6% and 14.4% prevalence, respectively (Figure 3). When comparing intertidal and subtidal samples from Kanaka Bay and Indian Cove on Shaw Island, there were statistically significant effects of blade length and site on disease prevalence (p=0.000761, $p=8.21*10^{-9}$). There was a slightly significant effect of tidal regime on disease prevalence as well (p=0.0539). Across all subtidal samples at the four sites, there was a statistically significant effect of blade length on disease prevalence ($p=4.115*10^{-5}$, Figure 4). There were no statistically significant effects of factors on disease severity for intertidal and subtidal blades from Kanaka Bay and Indian Cove.

Discussion

Of the three eelgrass beds surveyed in False Bay, Pocket Bay had the highest disease prevalence. Further work could explore environmental differences (for example, water temperature, turbidity, salinity) and potential drivers of elevated disease levels. When comparing disease prevalence between sites, there were significant statistical differences between the False Bay sites and Indian Cove. Interestingly, the sites that appear to be most insular and protected — Indian Cove and Pocket Bay—had the highest measured disease prevalence, whereas those that were more exposed to tidal flushing had lower levels of disease prevalence and severity (Figure 1, 3). This suggests that variable geomorphology of the eelgrass beds may create conditions favorable to *L. zosterae*. We found intertidal disease prevalence to be higher than subtidal prevalence at Kanaka Bay. The significant variation in disease prevalence between sites highlights some areas of the San Juan Islands that may need priority in eelgrass conservation.

The results also indicate that blade length influenced subtidal wasting disease prevalence, with longer blades having generally greater disease prevalence than shorter blades (Figure 4). This is consistent with previous research on population demographics of infected *Z. marina* in the San Juan Islands, which found longer blades had higher disease prevalence than shorter blades.[12,19]

There were no statistically significant differences between group means of severity among subtidal, False Bay sites as determined by one-way ANOVA ($(F\ 2, 267) = 2.80$, $p = 0.06$). However, there were higher levels of severity measured in intertidal *Z. marina* compared to subtidal samples, as anticipated (Figure 3). This could be attributed to more favorable conditions for *L. zosterae* in the intertidal or conditions that stress *Z. marina* and make it more susceptible to infection. Further studies examining the environmental conditions and disease prevalence and severity among intertidal and subtidal beds will help determine drivers of eelgrass wasting disease.

Understanding *Z. marina* population declines is important for predicting and mitigating seagrass wasting disease, since disease outbreaks can result in significant shifts in community structure and can significantly alter ecosystem services. Seagrass beds serve as "biological sentinels," and can provide key information about environmental conditions through changes in their abundance and health.[1,3] Continued research will help ascertain which environmental factors influence disease prevalence and severity between intertidal and subtidal *Z. marina*.

This study is an important contribution to seagrass wasting disease research because it serves as a pilot study in quantifying wasting disease prevalence and severity in subtidal eelgrass beds, and because it bridges intertidal and subtidal eelgrass ecology, which typically are examined as separate systems. More broadly, these data can help develop and direct seagrass conservation, restoration, and management efforts within the San Juan Islands, WA.

Supplemental Information

Biodiversity Surveys

Pema Kitaeff, Dive Safety Officer at Friday Harbor Labs, and her University of Washington Scientific Diving Students also performed biodiversity surveys of the False Bay—Pocket Bay subtidal eelgrass beds on August 22, 2016. From identifying and counting the organisms and eelgrass density along eleven 25-m transects, they found an eelgrass bed that supports a diverse marine community with arthropods, mollusks, cnidarians, and echinoderms (n=100, 93, 47, 13). While the eelgrass bed was patchy, the eelgrass density ranged from 0-38 blades/m^2 and averaged 6 blades/m^2. Combined with observations from diving at the other field sites, these surveys indicate that the False Bay eelgrass beds provide important habitat for many marine invertebrates. Please see the Biodiversity Report for further details on these surveys.

Acknowledgements

I would like to thank Dr. Drew Harvell and Morgan Eisenlord their intellectual and field support; Phoebe Dawkins, Miranda Winningham, and Clio Jensen for their field and laboratory assistance; Pema Kitaeff, Colette Feehan, Chris Wells, and the UW Scientific Diving Students for their dive help. I would also like to thank Evan Fiorenza and Erika Mudrak for statistical support and the FHL Adopt-A-Student Fund for financial assistance. Finally, I would like to extend warm thanks to Michael Prentiss and Tom Schultz for allowing access to their private beaches.

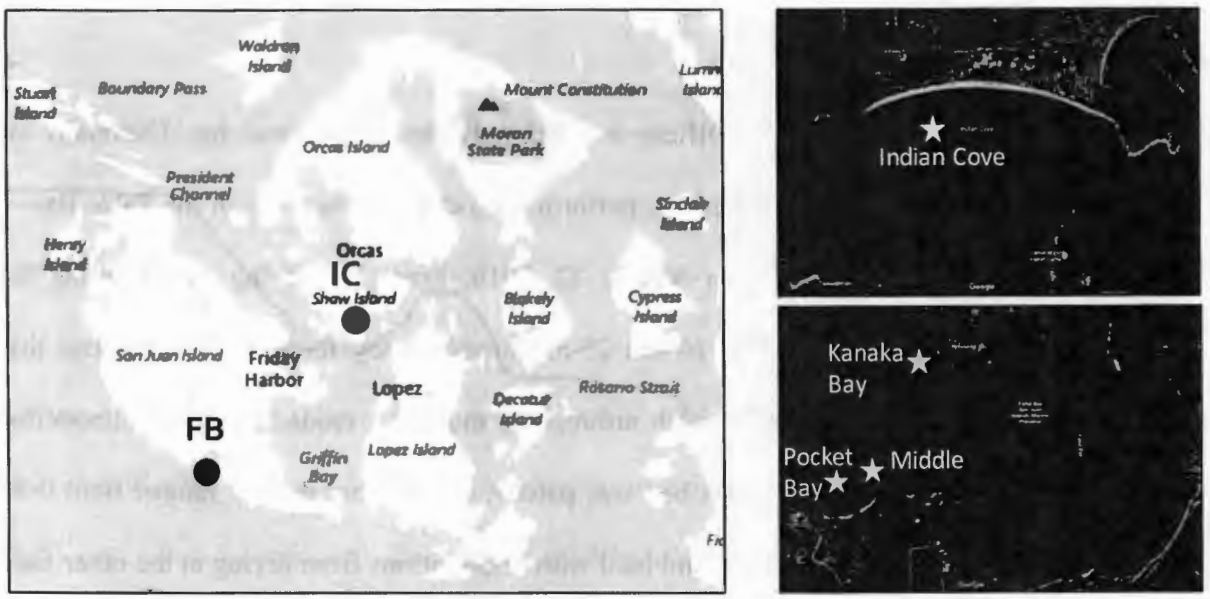

Figure 1. Subtidal and intertidal field sites in the San Juan Islands, WA (Image source: Google maps). Indian Cove and Kanaka Bay (yellow) had paired subtidal and intertidal surveys; all sites had subtidal surveys.

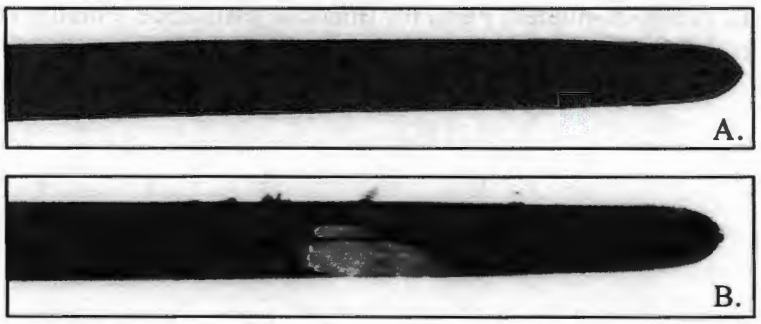

Figure 2. *Zostera marina* blades collected from False Bay and Indian Cove, San Juan Islands, WA in 2016. (A) Healthy and (B) diseases samples with *Labyrinthula zosterae* lesions.

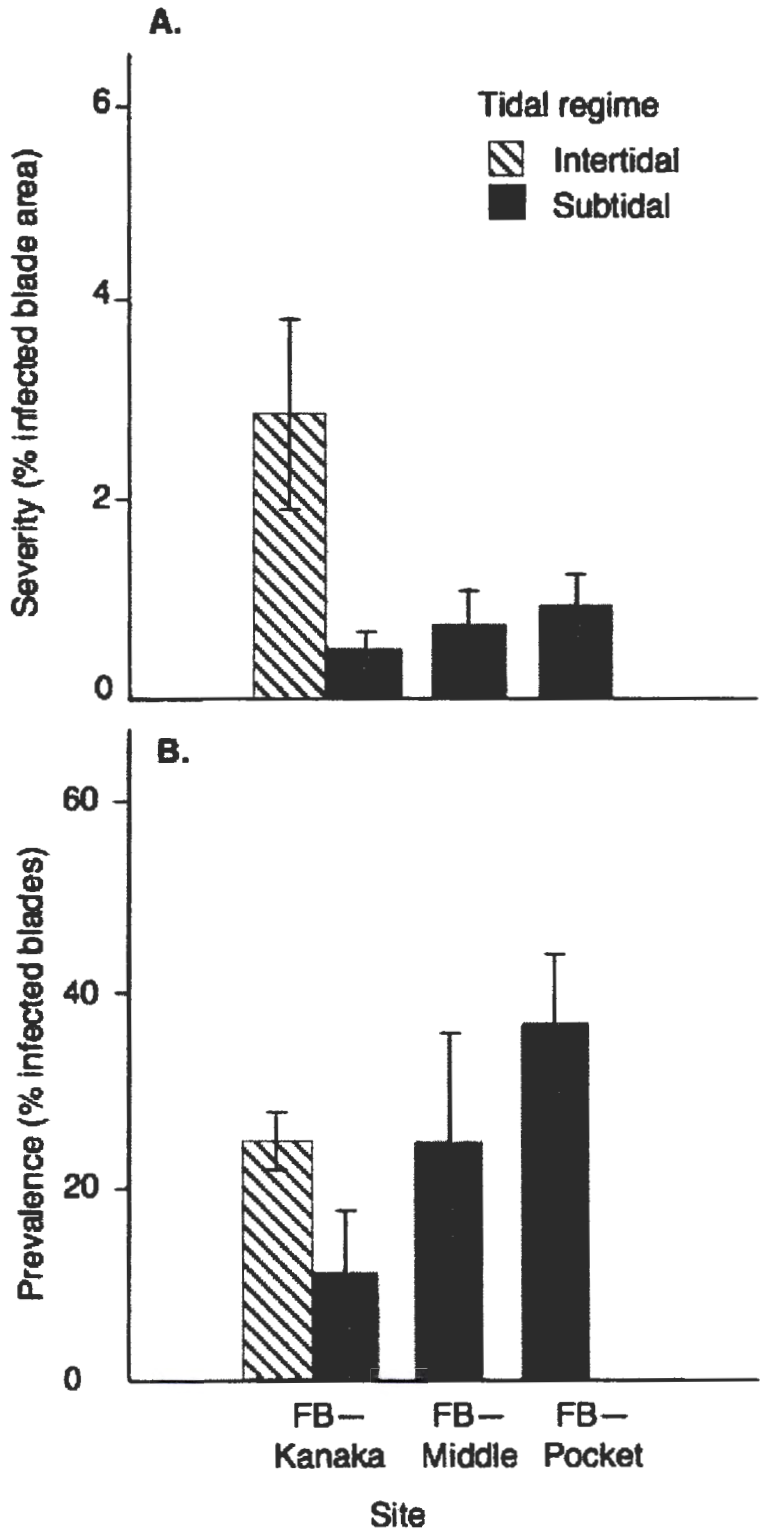

Figure 3. The severity (A) and prevalence (B) of *L. zosterae* in subtidal and intertidal eelgrass from July 2016.

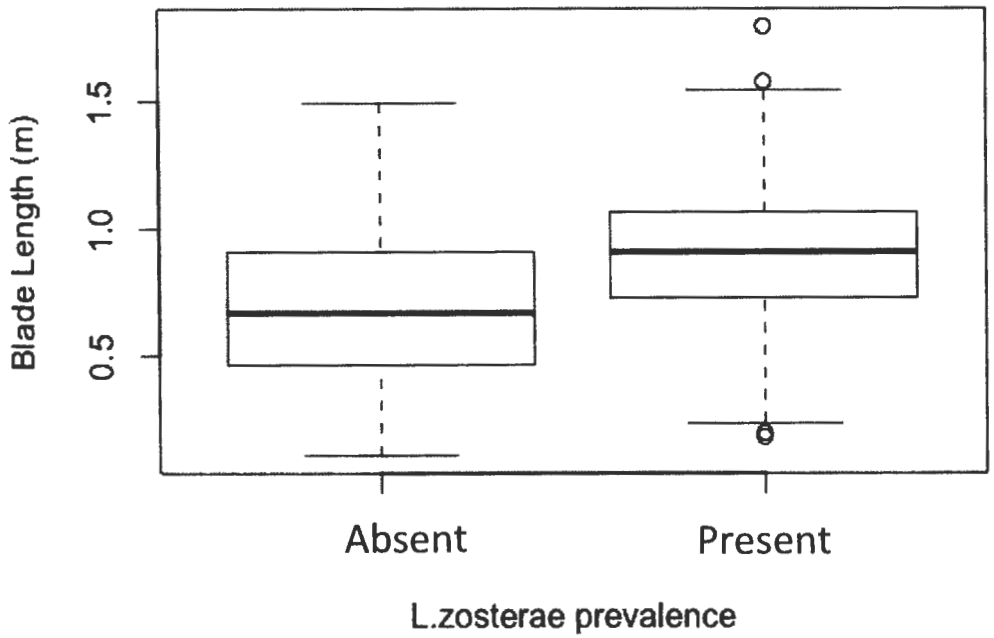

Figure 4. The prevalence of *L. zosterae* by blade length (m) for subtidal eelgrass.

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False Bay Seagrass Report—Part II

Fish diversity and predation within and near *Zostera marina* beds

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Summer 2016

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Keywords: Eelgrass, *Zostera marina*, seagrass wasting disease, *Labyrinthula zosterae*, marine diseases

Introduction

To identify fish communities within and outside of the eelgrass beds, we participated in the Smithsonian Institution's Marine Global Earth Observatory (MarineGEO) BiteMap Project, a collaborative research project involving 25 researchers in 9 countries and 5 continents. For our study site, we focused on the eelgrass bed in the University of Washington Reserve in False Bay, adjacent to Kanaka Bay. Given that eelgrass beds are remarkably productive and serve as key habitat for many species of fish,[1-3] we anticipated that we would find greater number of different fish species (species richness) and in higher numbers (abundance) inside eelgrass beds than outside.

Methods

To determine diversity of fish inside and outside of eelgrass beds, we conducted paired seines in the intertidal eelgrass beds (vegetated) and unvegetated regions of False Bay—Kanaka Bay (Figure 1). We completed a total of six seines (3 unvegetated, 3 vegetated) from July 21-23, 2016. For each, we waded into the water with a 10 m. seine net to a depth of 1 m. at low tide. With the net taught, we pulled the seine net to shore, where we identified (with fish expert Dr. Jeffrey Jensen) and counted all fish; we estimated fish counts greater than 100 and released all fish after each seine. We also measured the length of the first 25 individuals per species in each seine.

Results & Discussion

From these estimates, we found nine different fish species in the eelgrass bed and eight in the unvegetated region without eelgrass (Table 1). Six of these were found in both regions, with

three species found only in the eelgrass and two species found only in the unvegetated area. Fish caught in the eelgrass bed included perch, pipefish, gunnels, and sculpin with several sole and a smelt caught in the nearby sandy region (Figure 2). As predicted, there was remarkably greater fish abundance in the eelgrass (n=2415, 745 total fish respectively).

Differences in fish abundance and richness could be attributed to the fact that eelgrass beds provide robust habitat that is safe and has ample food compared to sparse, sandy regions of the bay nearby. Indeed, the value of eelgrass beds as safe spawning and rearing grounds for juvenile and small fish is widely acknowledged.[2,3] The long blades provide protection and cover for young fish that otherwise be easily predated upon in exposed regions. Furthermore, as critical habitat for many marine invertebrates and algae, eelgrass beds also serve as key feeding grounds for these fish. While English sole were only caught in the unvegetated region, they are commonly found in eelgrass as well. Altogether, these data indicate that False Bay eelgrass beds support a diverse community of fish, many of which are critical forage fish for key marine organisms within the San Juan Islands.

Acknowledgements

I would like to thank Dr. Drew Harvell, Dr. Emmett Duffy, and Ross Whippo for the invitation to participate in this project; Clio and Jeffrey Jensen for assistance with fish identification; Phoebe Dawkins, Miranda Winningham, Drew, Clio, and Jeff for their help with beach seines; and the FHL Adopt-A-Student Fund for financial assistance. Finally, I would like to thank Drew and Dr. Billie Swalla for their valuable feedback on drafts.

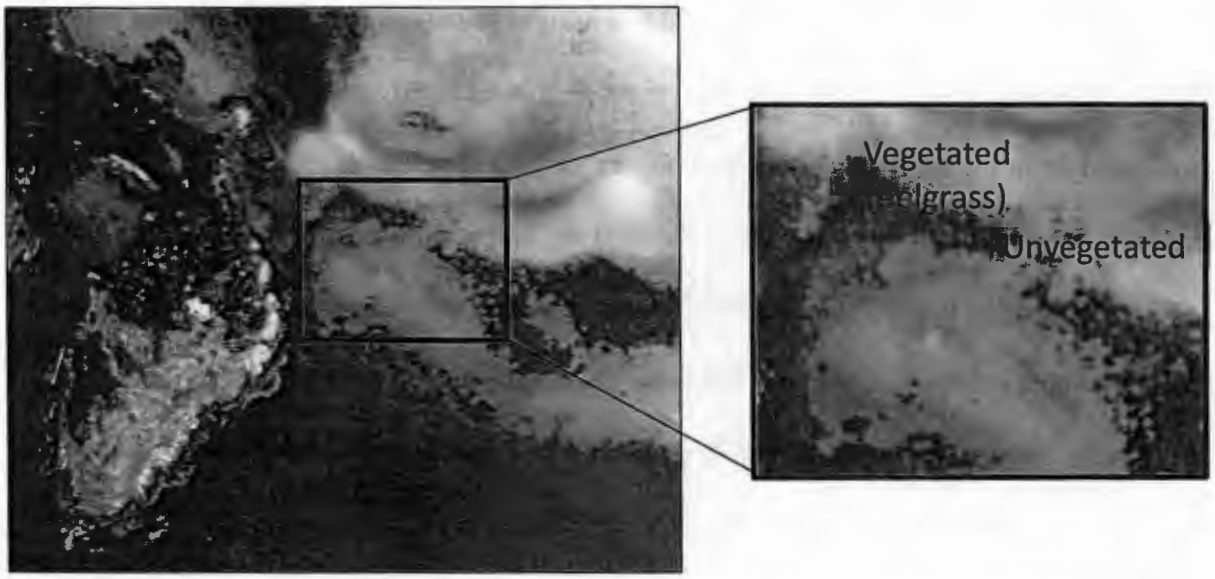

Figure 1. Aerial map of False Bay—Kanaka Bay. Seines were conducted in the vegetated (eelgrass) and unvegetated portions of the bay to survey fish communities. (Image source: Gregg Ridder.)

Table 1. Number of fish collected in unvegetated and vegetated areas of False Bay.

Fish species	Unvegetated	Vegetated
Cymatogaster aggregate (shiner perch)	668	2213
Embiotoca lateralis (striped surfperch)	15	74
Syngnathus griseolineatus (bay pipefish)	2	39
Apodichthys flavidus (penpoint gunnel)	1	20
Pholis ornata (saddleback gunnel)	1	16
Leptocottus armatus (staghorn sculpin)	35	7
Pholis laeta (crescent gunnel)	-	16
Brachyistius frenatus (kelp perch)	-	7
Nautichthys oculofasciatus (sailfin sculpin)	-	1
Parophrys vetulus (English sole)	22	-
Hypomesus pretiosus (surf smelt)	1	-
Total	**745**	**2415**

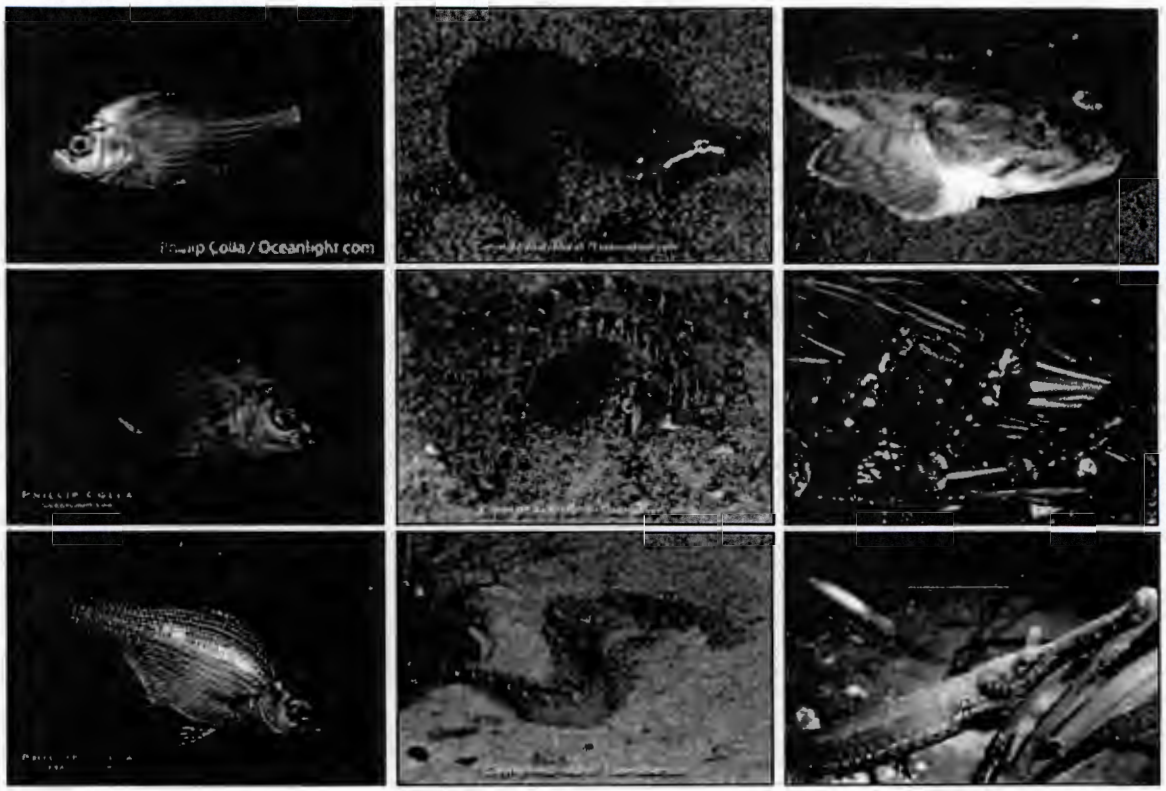

Figure 2. Diverse fish species caught in the False Bay—Kanaka Bay eelgrass bed (top to bottom, left to right): perch, gunnels, sculpin, and pipefish. (Image sources: perch—Phillip Colla; gunnels—Andy Murch; staghorn sculpin—Matt Gieselman; sailfin sculpin—dic.academic.ru; pipefish—John McCall.)

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False Bay Seagrass Report—Part III

Invertebrate and algae biodiversity in *Zostera marina* beds

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Keywords: Eelgrass, *Zostera marina*, biodiversity, biodiversity surveys, invertebrates, algae

Abstract

One of the most productive ecosystems in the world, eelgrass (*Zostera marina*) forms dense coastal meadows that serve as valuable habitats for many marine organisms, including arthropods, mollusks, cnidarians, echinoderms, fish, and algae. The San Juan Islands, WA have robust eelgrass beds that are part of federal and state ecological monitoring projects. While False Bay eelgrass is a site for long-term seagrass disease research, little is known about the invertebrate and algae biodiversity within these beds. To establish baseline estimates for invertebrate and algae in the pocket bay of False Bay, University of Washington Scientific Diver students estimated abundance and species richness of invertebrates and algae in the bay. From the 11 transects, divers determined that the eelgrass was spatially patchy and supported abundant arthropods and mollusks, moderate cnidarians, and few echinoderms. Of the kelp and algae identified, green algae were abundant in most quadrats, while brown kelp, other brown algae, and red algae comprised <10% cover in each quadrat. Altogether, these data provide valuable insight into the invertebrate and algae communities in False Bay. In the future, more intensive studies could produce more detailed species list of the biota present.

Introduction

A central theory in ecology is that loss of a few species can impact the functioning of entire ecosystems. Currently, global biodiversity is declining at an unprecedented rate, with extinctions occurring at 100–1000 times historical rates, and future rates predicted to be up to 100 times current rates[1]. It is important to protect species richness, since the number of species is a strong indicator of ecosystem health and confers critical functions: increased productivity, stability in times of disturbance, community structure[2,3], and disease resilience[4].

Eelgrass beds (*Zostera marina*) are diverse, productive ecosystems that are classified as essential marine habitat. The most abundant plant in the northern hemisphere[5], eelgrass forms dense coastal meadows that serve as valuable habitats for many marine organisms, including arthropods, mollusks, cnidarians, echinoderms, fish, and algae. Furthermore, eelgrass is one of the most productive ecosystems worldwide. Compared to corn and sugar cane, eelgrass generates comparable amounts of biomass annually[6]. Combined with its ability to sequester carbon, filter water, and protect coastlines, eelgrass is not only one of the most biologically diverse ecosystems in the world, but also one of the most important[7-9].

Despite its valuable ecosystem services, eelgrass beds worldwide are under threat from anthropogenic and environmental stressors. Nutrient and sediment runoff, habitat destruction, disease, and climate change cause an estimated 110 km^2 annual loss in global eelgrass[10]. Consequently, continued research is needed to identify the most vulnerable eelgrass beds, and inform effective conservation and management strategies in the face of a continually changing planet.

In response, federal and state agencies have made eelgrass monitoring and protection a top priority[11,12]. The Washington Department of Natural Resources (WA-DNR) conducts annual eelgrass monitoring studies to changes in Puget Sound eelgrass populations over time[13]. Likewise, NOAA is working to study the influence of urbanization on eelgrass disease levels[14]. Further north, the San Juan Islands are home to many long-term eelgrass monitoring efforts, focusing on habitat monitoring, eelgrass genetic diversity, and disease dynamics[15-18].

For nearly two decades, certain sites within the San Juan Islands have experienced declining eelgrass density and distribution[13,15,19]. One such well-studied eelgrass bed with a history of decline is in False Bay[15]. While researchers from the University of Washington have studied eelgrass genetic diversity[15,16] and disease in False Bay[17,18], little to no work has been done to examine the invertebrate biodiversity within these eelgrass beds, to the best of my knowledge.

To determine the abundance and species richness of invertebrates and algae, University of Washington Scientific Diver students conducted submerged transects in False Bay (Pocket Bay) in August 2016. This was a pilot study to develop baseline estimates for invertebrate and algae biodiversity.

Methods and Materials

On August 22, 2016, students conducted biodiversity and abundance surveys along eleven 25-m transects at False Bay (Pocket Bay), WA (Figure 1). Transects were oriented perpendicular to shore. Divers estimated eelgrass density and invertebrate species within 1 m^2 quadrats every 5 m along the submerged transects. Invertebrate species were identified by phyla (arthropod, mollusk, cnidarian, echinoderm). For most surveys, epiphytes on eelgrass and substrates within the quadrats were included in estimates. Future, more intensive surveys could enumerate species within these groups. Depth and temperature were recorded using divers' individual dive computers. GPS headings were recorded, when possible, using a Garmin GPS hand-held device. As these surveys were strictly observational surveys, no organisms were collected.

Results

Eelgrass

There was not a clear relationship between mean eelgrass density and depth (Figure 2). However, eelgrass measured at shallower depths usually were more sparse than deeper eelgrass. Eelgrass density ranged from 0-38 blades/m^2 and averaged 7.38 blades/m^2 across the transects (Table 1).

Invertebrates

Arthropods and mollusks were the most abundant invertebrate phyla identified (n=100, 93), including kelp crabs, shrimp, red rock crabs, amphipods, chitons, barnacles, limpets, and snails. Fewer cnidarians were identified (n=47) and included stalk jellyfish and moon jellyfish,

among others. Echinoderms were the least abundant (n=13), and included brittle and other sea stars (Figures 3-6).

Algae

Mean brown kelp cover was 0.48% and ranged from 0-5% across all quadrats. For other brown algae, mean percent cover was 3.89%. Bladed red algae had an 8.30% mean cover, and mean branched red algae cover was 4.76%. Overall mean green algae cover was the highest at 70.13%.

Discussion

Eelgrass density

Across all transects, the eelgrass density was spatially variable around 7.38 blades/m^2, which is comparable to other eelgrass densities measured in False Bay from previous eelgrass fieldwork in July 2016 (Table 1). The mean eelgrass densities by depth (Figure 2) suggest that the eelgrass bed is patchy, with both dense and sparse areas.

Invertebrates

Arthropod abundance was widely variable across the sampled depths. Of the arthropods that were identified, barnacles and crabs were the most dominant, with fewer numbers of shrimp observed. There were usually less than 10 arthropods/m^2, the exceptions being two quadrats at 4 ft that contained 12 hermit crabs and 20 barnacles, respectively (Figure 3).

Mollusks were found from 4-10 ft depths, but were most abundant at 6 ft. Among the mollusks that were identified, snails were easily the most abundant, with only a few clams, chitons and limpets noted. Most counts were less than 10/m^2, although in one instance, there was

an outlier of 31 mollusks/m^2 dominated by snails. This could have resulted if there was a large rock or other hard substrate to which many mollusks could have attached (Figure 4).

Cnidarians were found at all depths except for 12 ft. Abundance appeared to increase with depth. Jellyfish (moon, stalk, unidentified) were the most abundant of the identified cnidarians, followed by several anemones. The number of individuals counted within a single quadrat ranged from 1-6 cnidarians/m^2 (Figure 5), including epiphytes attached to eelgrass.

Echinoderms were the least abundant of all invertebrate phyla identified. The only echinoderms divers encountered were sea stars; no sea urchins or sea cucumbers were observed. While there was not a clear relationship between depth and abundance, the three sea stars counted in a single quadrat were at one of the greatest depths, 10 ft (Figure 6). Overall, divers encountered echinoderms in only seven of the 57 total quadrats. Such low abundance could likely be a remnant of the sea star wasting disease outbreak that decimated over 20 species of echinoderms in 2013-2014 (Eisenlord et al 2016).

Algae

Brown kelp comprised the smallest amount of algae cover in the sampled quadrats. Other brown algae, bladed red algae and mean branched red algae had comparable mean percent cover. Of all the surveyed algae, green algae had the greatest mean percent cover. Because green algae were easily the most dominant, it is possible that environmental conditions in this area are most favorable to green algae growth. Alternatively, the other types of algae could be smaller than green algae and would comprise a smaller percent cover, even if they were abundant.

Conclusion

These biodiversity surveys provide valuable baseline data for invertebrate and algae living in Pocket Bay. Finding these organisms throughout the eelgrass beds across variable

depths highlights the rich marine life within the False Bay eelgrass beds, and underscores the productivity and diversity of this key area. Future more intensive studies could produce more detailed species lists of the biota present. While SCUBA surveys are commonly used to monitor the abundance and richness of tropical marine species, they are not regularly used to survey eelgrass beds in the San Juan Islands, to the best of my knowledge. Therefore, they serve as a useful tool to assess fine-scale biodiversity in False Bay eelgrass beds.

Altogether, the surveys indicate that False Bay eelgrass beds supports many marine invertebrates and algae, which contribute to the productivity and health of this important costal environment. Furthermore, the surveys show that the eelgrass bed is extensive in size with both dense and patchy regions. Repeated surveys could enumerate specific species and indicate changes in the health of the eelgrass beds over time. These findings are important in protecting and sustaining Pocket Bay as a critical marine habitat for local marine species.

Acknowledgements

I would like to give tremendous thanks Pema Kitaeff, the Friday Harbor Labs Dive Safety Officer, for her remarkable organization and execution of the dive surveys. This project would not have been possible without her dedication. I would also like to thank her University of Washington Scientific Diving students and the additional support divers who were the "boots on the ground" collecting data. I would like to thank Mike Prentiss for kindly allowing the divers access to his property to reach the dive site. I would also like to extend warm thanks to Michael Prentiss and Tom Schultz for allowing access to their private beaches. Finally, I would like to thank Dr. Drew Harvell for her continuous intellectual support and inspiration.

Figures and Tables

Figure 1. Approximate locations of biodiversity transects at False Bay (Pocket Bay), San Juan Island, WA. (Image source: Google maps.)

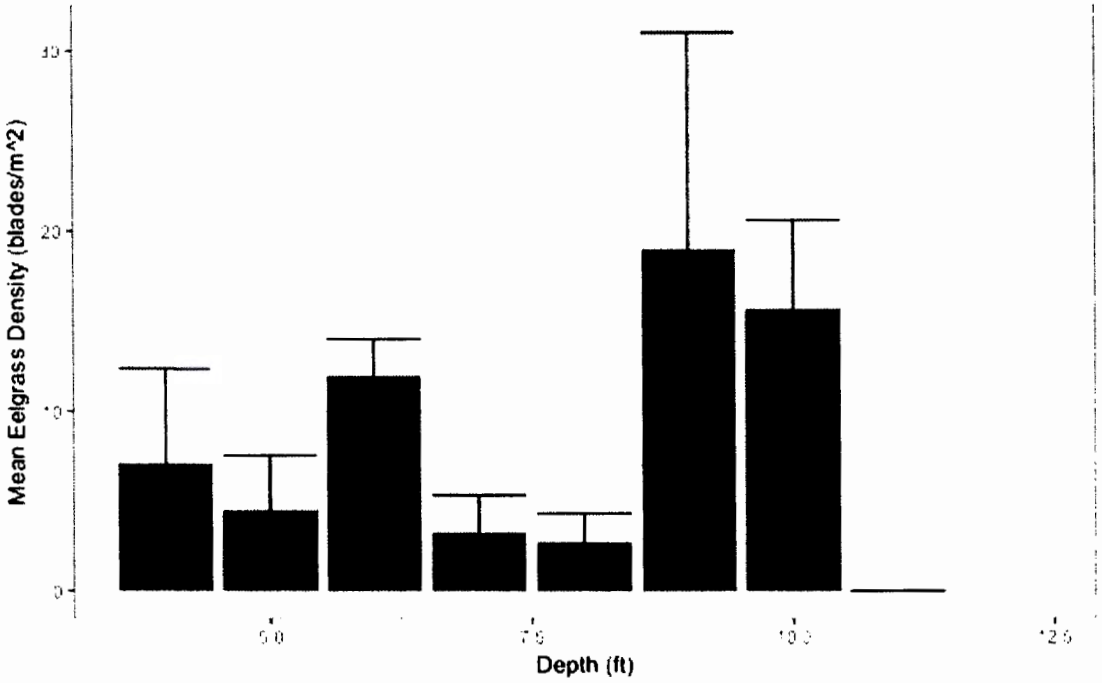

Figure 2. Mean eelgrass density (shoots/$m^{2)}$ (+/- SE) across a depth gradient (ft) in Pocket Bay.

Table 1. Average eelgrass density (blades/m^2) for each subtidal and intertidal site sampled in July and August 2016. *Indicates density measurement is from 8/22 survey. All other densities were measured during July 2016 subtidal and intertidal surveys for annual eelgrass wasting disease surveys.

Site	Tidal Regime	Average eelgrass density (blades/m^2)
FB - Pocket	Subtidal	19
FB - Pocket	Subtidal	7.38*
FB - Middle	Subtidal	10.6
FB - Kanaka	Subtidal	17.3
FB - Kanaka	Intertidal	13.5
Indian Cove	Subtidal	3.2
Indian Cove	Intertidal	16.88

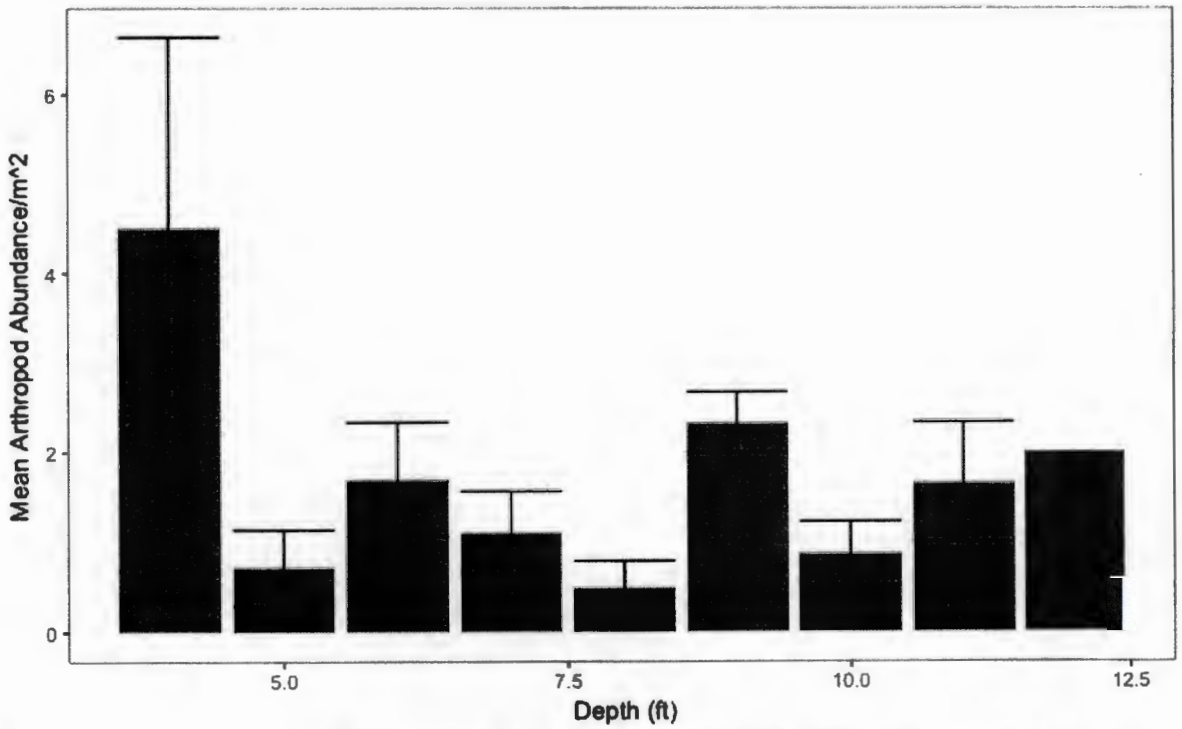

Figure 3. Mean arthropod abundance/m^2 (+/- SE) across a depth gradient (ft) in Pocket Bay.

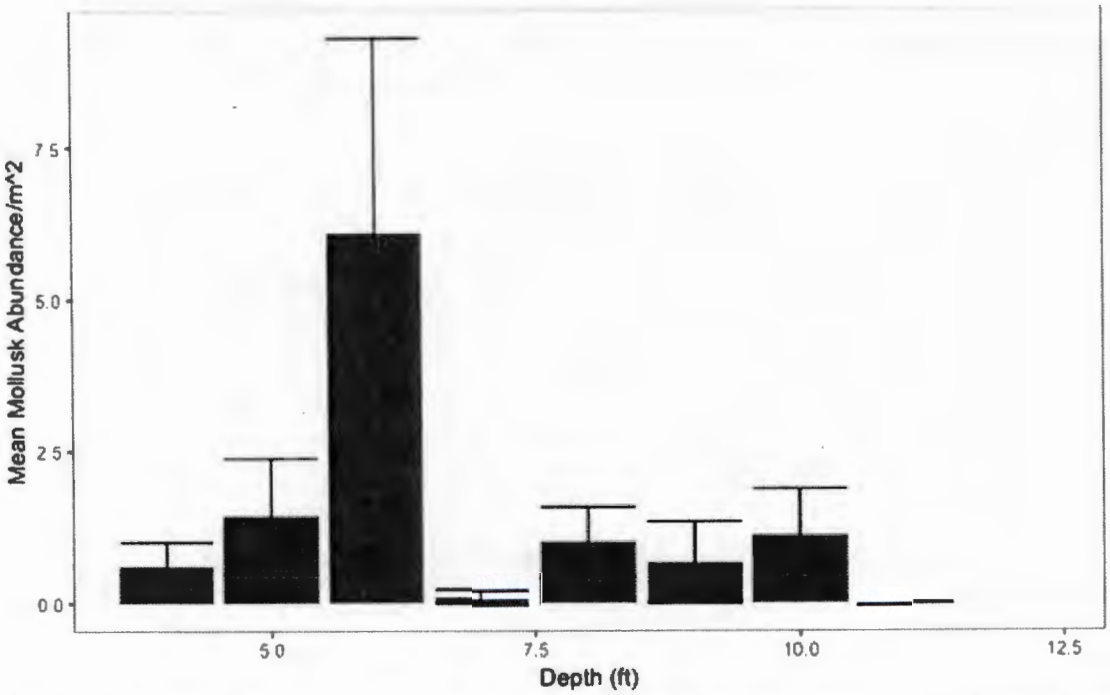

Figure 4. Mean mollusk abundance/m^2 (+/- SE) across a depth gradient (ft) in Pocket Bay.

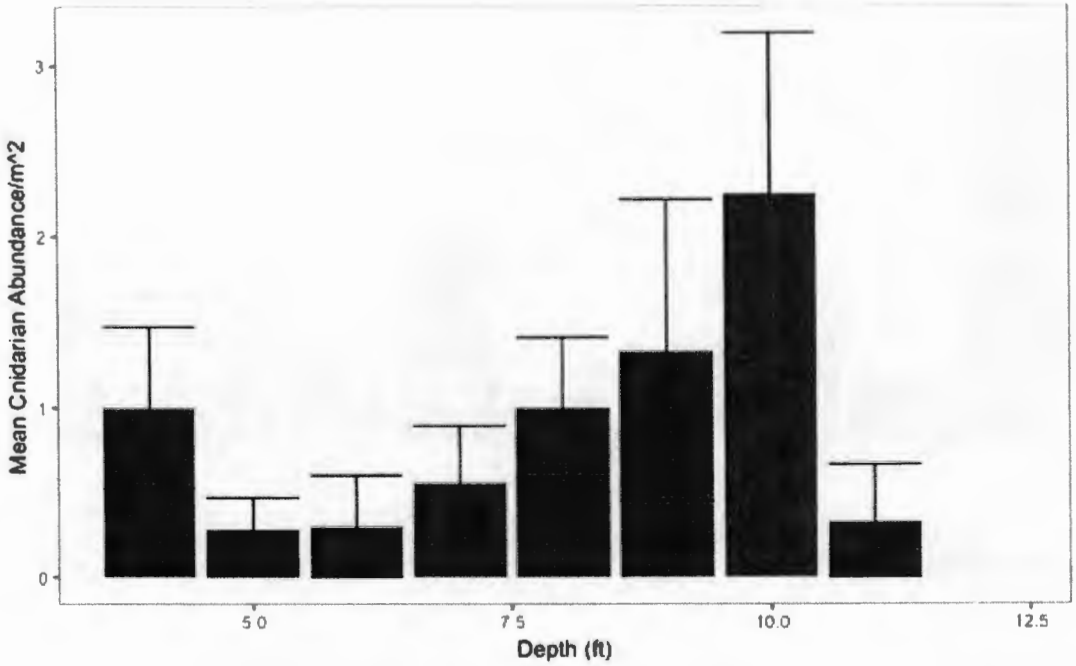

Figure 5. Mean cnidarian abundance/m^2 (+/- SE) across a depth gradient (ft) in Pocket Bay.

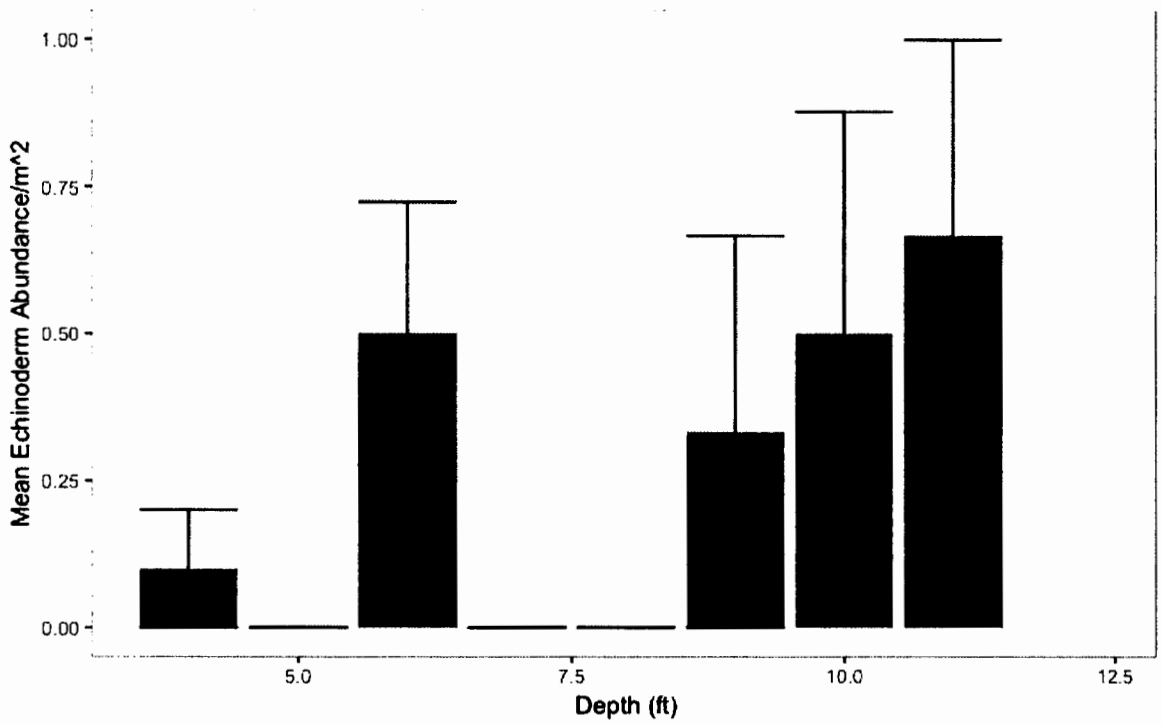

Figure 6. Mean echinoderm abundance/m^2 (+/- SE) across a depth gradient (ft) in Pocket Bay.

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Plant characteristics associated with widespread variation in eelgrass wasting disease

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ABSTRACT: Seagrasses are ecosystem engineers of essential marine habitat. Their populations are rapidly declining worldwide. One potential cause of seagrass population declines is wasting disease, which is caused by opportunistic pathogens in the genus *Labyrinthula*. While infection with these pathogens is common in seagrasses, theory suggests that disease only occurs when environmental stressors cause immunosuppression of the host. Recent evidence suggests that host factors may also contribute to disease caused by opportunistic pathogens. In order to quantify patterns of disease, identify risk factors, and investigate responses to infection, we surveyed shoot density, shoot length, epiphyte load, production of plant defenses (phenols), and wasting disease prevalence in eelgrass *Zostera marina* across 11 sites in the central Salish Sea (Washington state, USA), a region where both wasting disease and eelgrass declines have been documented. Wasting disease was diagnosed by the presence of necrotic lesions, and *Labyrinthula* cells were identified with histology. Disease prevalence among sites varied from 6 to 79%. The probability of a shoot being diseased was higher in longer shoots, in patches of higher shoot density, and in shoots with higher levels of biofouling from epiphytes. Phenolic concentration was higher in diseased leaves. We hypothesize that this results from the induction of phenols during infection. Additional research is needed to evaluate whether phenols are an adaptive defense against *Labyrinthula* infection. The high site-level variation in disease prevalence emphasizes the potential for wasting disease to be causing some of the observed decline in eelgrass beds.

KEY WORDS: Opportunistic pathogens · Seagrass declines · Phenols · Plant defenses · *Labyrinthula* · Coastal ecosystems · Restoration · *Zostera marina*

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INTRODUCTION

Recent data suggest that infectious diseases are increasing in both incidence and severity in the ocean (Harvell et al. 2004, Ward & Lafferty 2004). The effects of marine diseases can be especially pronounced when these diseases negatively impact ecosystem engineers such as reef-building corals (Aronson & Precht 2001), sea urchins (Feehan & Scheibling 2014), oysters (Mann et al. 2009), abalone (reviewed by Burge et al. 2014), and seagrasses (Cottam 1933, Short et al. 1987). Ecosystem engineers provide habi-

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tat and ecosystem services, and understanding the factors that lead to increased prevalence and severity of disease in these species is critical for conservation of marine biodiversity and ecosystem function in the face of our changing oceans.

Wasting disease is one of many causes of global seagrass declines and threatens the numerous ecosystem functions provided by seagrass (Orth et al. 2006, Sullivan et al. 2013). Caused by intracellular infection of the host mesophyll by opportunistic protists of the genus *Labyrinthula*, wasting disease affects several species of seagrass (Muehlstein et al. 1988, 1991, Sullivan et al. 2013). Disease outbreaks have the potential to cause rapid, dramatic population declines, which can compromise the ecosystem services provided by these plants. In the early 1930s, an outbreak along the Atlantic coasts of North America and Europe resulted in up to 90% mortality of eelgrass *Zostera marina* populations (Cottam 1933, Short et al. 1987). Smaller, more isolated epidemics have been documented in *Z. marina* populations along the Atlantic and Pacific coasts of North America since the 1980s (Short et al. 1987, Groner et al. 2014). However, aside from extreme outbreaks, the impact of chronic infections on seagrass declines is relatively unknown. Loss of seagrass habitats compromises habitat for economically valuable invertebrates, fish, and birds, and affects the ecosystem services provided by these systems, including the stabilization of of coastal sediments, biological filtration of terrestrial-derived nutrients, carbon sequestration, and local buffering of ocean pH (Barbier et al. 2011, Fourqurean et al. 2012, Plummer et al. 2013).

Targeted monitoring of diseases and their associated risk factors is critical for early detection and mitigation of marine diseases (e.g. Groner et al. 2015). For many opportunistic pathogens, environmental risk factors cause disease by compromising physiological host defenses (Burge et al. 2013). Recent studies have identified salinity, temperature, and turbidity as factors contributing to wasting disease (McKone & Tanner 2009, Bull et al. 2012, Groner et al. 2014). A potentially overlooked facilitator of disease from opportunistic pathogens is host population structure. Defenses against pathogens often change during development and may be compromised by stressors such as density, reduced light penetration, for example as caused by growth of epiphytes on leaves, or an individual's microbial community (Kazan & Manners 2009). Indeed, recent studies have shown that leaf age and plant size are important determinants of disease in eelgrass (Groner et al. 2014).

Defenses of eelgrass against *Labyrinthula* are not well understood; however, phenolic compounds may play a role (Buchsbaum et al. 1990, Vergeer et al. 1995, Vergeer & Develi 1997, Sneed 2005, Trevathan-Tackett et al. 2015). Phenolic compounds produced by *Z. marina* have been correlated with resistance to wasting disease (Buchsbaum et al. 1990) and are capable of inhibiting growth of *Labyrinthula in vitro* (Vergeer et al. 1995). However, it is not known whether phenols produced *in vivo* are capable of inhibiting infections.

Since the early 1990s, a number of eelgrass beds in the Salish Sea, located in the northeast Pacific Ocean, have experienced periodic mortalities and are declining from unknown causes (Wyllie-Echeverria et al. 2003, 2010, Dowty et al. 2010, Washington State Department of Natural Resources 2015). Hypothesized causes for these declines include wasting disease and sulfide toxicity (Dooley et al. 2013, Groner et al. 2014). Wasting disease has long been observed in this system (Muehlstein et al. 1991, Muehlstein 1992), and pathogenic strains of *L. zosterae* have been isolated from diseased leaves (Groner et al. 2014).

In this study, our primary objectives were to identify eelgrass beds with high disease prevalence and to quantify risk factors for disease that could occur at the host level. We surveyed 11 sites throughout the San Juan Archipelago and Puget Sound (i.e. the central Salish Sea). We focused on the role of 3 factors in altering disease prevalence: shoot length, shoot density, and biofouling of leaves by epiphytes. We hypothesized that increases in each of these factors would lead to increased disease prevalence. A second objective of our study was to quantify the relationship between phenolic compounds and disease. We hypothesized that, across sites, diseased leaves would have greater phenolic concentration than healthy leaves.

MATERIALS AND METHODS

Field survey

We sampled 11 sites in the San Juan Archipelago and Northern Puget Sound regions of the Salish Sea in Washington state, USA, between 19 and 24 July 2013 (Fig. 1). We focused on this region because declines in the distribution and density of *Zostera marina* were documented at several sites in the early 2000s (Wyllie-Echeverria et al. 2003, 2010, Ferrier & Berry 2010). Some of these sites show evidence of population decline, while others have remained stable (Fig. 1, Table 1).

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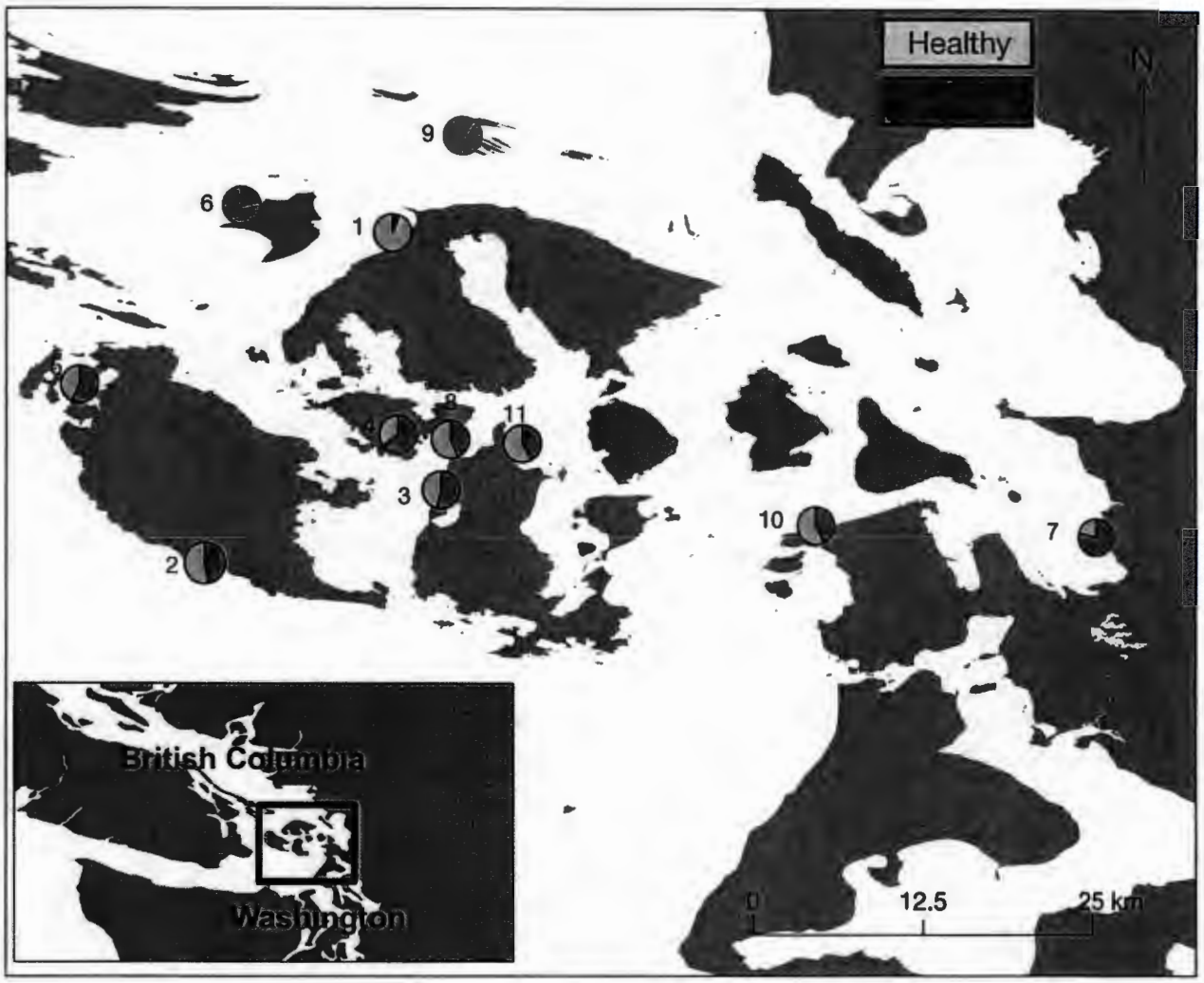

Fig. 1. Prevalence of eelgrass wasting disease (as analyzed on the second longest leaf in surveyed shoots of *Zostera marina*) among study sites: (1) Beach Haven, (2) False Bay, (3) Fisherman Bay, (4) Indian Cove, (5) Mosquito Bay, (6) North Cove, (7) Padilla Bay, (8) Picnic Cove, (9) Shallow Bay, (10) Ship Harbor, (11) Shoal Bay

At each site, data were collected along 3 transects (each 50 m long) laid 2 m apart and parallel to the shore in the intertidal region, with the middle transect at approximately −1 m Mean Lower Low Water. Each 50 m transect was divided into 10 m sections (n = 5), and in each section, the second oldest leaf was collected from 10 randomly selected shoots. We surveyed the second oldest intact leaf in a shoot to standardize our measurements. We picked this leaf to be conservative, since the older leaves were slightly senescent and much more likely to have lesions, while the youngest leaves may not have been present long enough to present lesions even if the shoot was diseased. In order to determine site-level differences in population density, we also counted the number of shoots in 3 quadrats (0.12 m^2 each) per transect (at 0, 25, and 50 m). The mean density for each transect was used in the analyses.

Collected leaves were placed in coolers and taken to the Seagrass Lab, Friday Harbor Laboratories, WA, USA, for further measurement. For each leaf, we measured length and width, and described disease status (healthy or diseased) based on visual characteristics. Leaves were diagnosed with wasting disease if they had lesions with irregular, dark, necrotic centers surrounded by a black border (e.g. Burdick et al. 1993, Groner et al. 2014). For 2 of the leaves collected in each 10 m section, we measured the dry weight of all attached epiphytes. We scraped off all epiphytes from both sides of the leaves onto weigh paper and dried these samples in a drying oven until the mass remained constant (minimum of 24 h). We

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Table 1. Survey site locations and known information on population trends and summaries (means ± SD) of eelgrass *Zostera marina* shoot density and length, epiphyte biomass, and wasting disease prevalence at each site. ID numbers as in Fig. 1; (–) sites where population status has not been assessed

ID	Site	Latitude (°N)	Longitude (°W)	Population trend(s)	Shoot density (m^{-2})	Shoot length (cm)	Epiphytes (mg cm^{-2} of shoot)	Prevalence (%)
1	Beach Haven	48° 41.460′	122° 57.120′	Stable[a]	297 ± 129	84.6 ± 22.9	1.17 ± 1.12	6 ± 4
2	False Bay	48° 28.975′	123° 04.451′	Declining[a,b]	136 ± 42	57.4 ± 15.0	3.37 ± 1.85	47 ± 17
3	Fisherman Bay	48° 31.572′	122° 55.088′	Stable[a]	213 ± 29	59.6 ± 15.8	0.39 ± 0.46	54 ± 4
4	Indian Cove	48° 33.773′	122° 56.078′	Stable[a]	336 ± 106	81.0 ± 17.8	0.52 ± 0.28	65 ± 12
5	Mosquito Pass	48° 35.346′	123° 10.208′	Declining[a]	214 ± 4	84.9 ± 19.3	3.70 ± 2.19	57 ± 2
6	North Cove	48° 42.287′	123° 03.221′	Declining[b]	542 ± 31	63.8 ± 12.0	0.70 ± 0.49	22 ± 8
7	Padilla Bay	48° 29.690′	122° 29.244′	–	358 ± 13	58.7 ± 10.7	1.10 ± 1.49	79 ± 13
8	Picnic Cove	48° 33.942′	122° 55.448′	Declining[a], Stable[b]	75 ± 43	66.9 ± 13.7	0.61 ± 0.72	44 ± 2
9	Shallow Bay	48° 45.613′	122° 54.892′	Declining[a]	19 ± 19	75.4 ± 17.1	1.46 ± 1.16	9 ± 15
10	Ship Harbor	48° 30.307′	122° 40.202′	–	158 ± 102	73.4 ± 16.1	4.91 ± 2.64	43 ± 2
11	Shoal Bay	48° 33.215′	122° 52.499′	–	164 ± 4	70.3 ± 11.9	1.49 ± 3.38	42 ± 23

[a]Population status estimated from shoot density data collected by Wyllie-Echeverria et al. (2010, or unpubl.)
[b]Population status estimated from data collected by Washington State Department of Natural Resources (2015)

then divided the dry weight of the epiphytes by the surface area of the leaf they were collected from to calculate the surface area-standardized epiphyte load. In order to understand the relationship between disease and phenolic content in these populations, we quantified phenolic concentration in 3 visually healthy and 3 visually diseased leaves that were collected along each transect. The processing of leaves described above typically occurred within 12 h of collection. Plants were kept in bags on ice to prevent further development of disease between collection and processing.

Phenolic measurements

Eelgrass samples frozen at –80°C were transported to the Shannon Point Marine Center in Anacortes, WA, where they were lyophilized and ground to a fine powder with a SPEX mixer/mill. Samples of approximately 10 mg were weighed and extracted in 80% methanol overnight in darkness at –80°C. The extracts were spun down with a centrifuge, and a 50 µl aliquot of each extract was diluted with 950 µl of ANSI Type I water. Three replicate 100 µl aliquots of each diluted sample were dispensed into the cells of a 96-well microplate. Forty µl of 40% Folin & Ciocalteu's phenol reagent (Sigma F9252) were then dispensed into each cell of the microplate. The plates were incubated at 50°C with shaking for 5 min, then 100 µl of 2 N sodium carbonate were added to each well. The absorbance at 765 nm was read after 30 min of incubation. Caffeic acid was initially used as a standard for these assays to generate phenolic measurements that were caffeic acid equivalents, because a native standard was not available at the time the analyses were run. A native standard was produced at a later time and was standardized to caffeic acid (see Fig. S1 in Supplement 1, available at www.int-res.com/articles/suppl/d118p159_supp/). Because of the strong linear relationship ($R^2 = 0.994$, $p < 0.001$) between absorbances obtained with the native standard and absorbances obtained with caffeic acid, we then used this regression to convert the concentrations of phenolic compounds obtained using caffeic acid to concentrations of phenolic compounds based on the native standard. Although the native standard was likely to contain some non-phenolic metabolites, it was more representative of the phenolic compounds in *Z. marina* than the caffeic acid standard.

To obtain the native standard, 10 g of lyophilized, ground *Z. marina* collected from Ship Harbor in July 2014 were extracted once in 1 l of 70% acetone containing 5.5 mM ascorbic acid, and twice in 1 l of 80% methanol containing 5.5 mM ascorbic acid. The extracts were combined and the solvents were evaporated under vacuum with a rotary evaporator until only 200 ml of aqueous extract remained. The extract was partitioned 3 times with hexanes to remove nonpolar metabolites. The remaining aqueous extract was mixed with 50 ml of Sephadex LH-20 (Sigma GE17-0090) and placed into a Kontes 4.8 cm diameter chromatography column. Non-phenolic metabolites were removed by washing with 3 column vol-

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umes of water. The phenolic compounds were then eluted with 3 column volumes of methanol. Water (100 ml) was added to the methanol fraction, and the methanol was evaporated under vacuum. The remaining aqueous extract was partitioned with 1:1 ethyl acetate:hexanes to remove any remaining nonpolar metabolites. Any remaining solvents in the aqueous fraction were then evaporated under vacuum. The fraction was frozen to −80°C and lyophilized to produce brownish-yellow colored flakes.

Histology

We subsampled leaves collected in Indian Cove and False Bay (Fig. 1) to qualitatively confirm visual disease diagnostics with histological analysis. Six healthy and 12 diseased leaves from Indian Cove and 10 healthy and 10 diseased leaves from False Bay were used for this analysis. Assessments of 'healthy' or 'diseased' were based on visual characteristics as described above. For each diseased leaf, we sampled an area including the leading edge of the lesion and adjacent, visually healthy, tissue. Samples were fixed for 24 h in 4% seawater-buffered formalin, and then stored in 70% ethanol. At Cornell University's Diagnostic Laboratory, leaves were embedded in paraffin, sectioned (5 µm), and stained with hematoxylin and eosin (e.g. Groner et al. 2014). Stained sections were randomized and viewed under a bright field Olympus BH-2 microscope with the Olympus DP-20 camera system. Sections were examined blindly (without demarcation of site or disease status) by a single viewer for the presence/absence of *Labyrinthula* spp. cells or other parasites within the tissues. The number of *Labyrinthula* spp. cells was counted at 40× magnification for three 0.5 mm fields of view on each slide. *Labyrinthula* spp. cells stained purple in contrast to pink plant tissue and were located intracellularly within the mesophyll (e.g. Renn 1936, Porter 1972, Groner et al. 2014). Active *Labyrinthula* spp. cells could be identified by their spindle shape (~15 µm length), and resting *Labyrinthula* spp. cells could be identified by their slightly smaller round shape. In some cases, extracellular mucus was also observed.

Statistical analyses

We used mixed effects logistic regression to understand the additive effects of shoot density, shoot-standardized epiphyte biomass, and shoot length on the disease status of each individual. We ran all possible additive combinations of these predictors in separate models and evaluated their fit using Akaike's information criterion (AIC). We included site as a random intercept in all models.

We used a linear mixed effect model to quantify the effects of shoot length and disease status (e.g. diseased or healthy) on the phenolic concentration (% of dry biomass) of leaves. We ran models with each of these predictor variables separately, both together additively, and both together with an interaction. We then used model selection, minimizing AIC values, to select the best fit model. We included site as a random intercept in all models. The model met the assumptions of normality and homoscedasticity.

All analyses were run in R (R Core Team 2014, v. 3.1.2) using the 'lme4' package (Bates et al. 2014). R-scripts and datasets for these analyses are available in Supplements 2 and 3 at www.int-res.com/articles/suppl/d118p159_supp/, respectively.

RESULTS

Field data

In total, 1645 samples were collected from the 11 sites. All sites were diseased; prevalence among sites varied from 6% at Beach Haven to 79% at Padilla Bay (Fig. 1). The geometric mean of disease prevalence across sites was 34%.

The best fitting model included shoot length, shoot density, and epiphyte biomass. The next best fitting model included only shoot length and epiphyte biomass (ΔAIC from best model = 1.3). No other models were strong candidates (ΔAIC from next best model = 6.4). Longer shoots, high shoot density, and high epiphyte biomass on shoots increased the probability of disease (Fig. 2, Table 1). For every 1 cm of shoot length, the odds of being diseased increased by 1.8% ($z = -4.61$, $p < 0.00001$). For every additional shoot in a 100 cm^2 area, the odds of being diseased increased by 19.9% ($z = 1.84$, $p = 0.067$). For every additional 1 mg of epiphytes per cm^2 of shoot, odds of disease increased by 21.9% ($z = 2.88$, $p = 0.003$).

Phenolics

We processed 175 samples for phenolic concentrations. The best model included disease status (healthy or diseased) as a fixed effect and site as a random intercept (ΔAIC from next best model = 7.5). When diseased and healthy shoots were combined,

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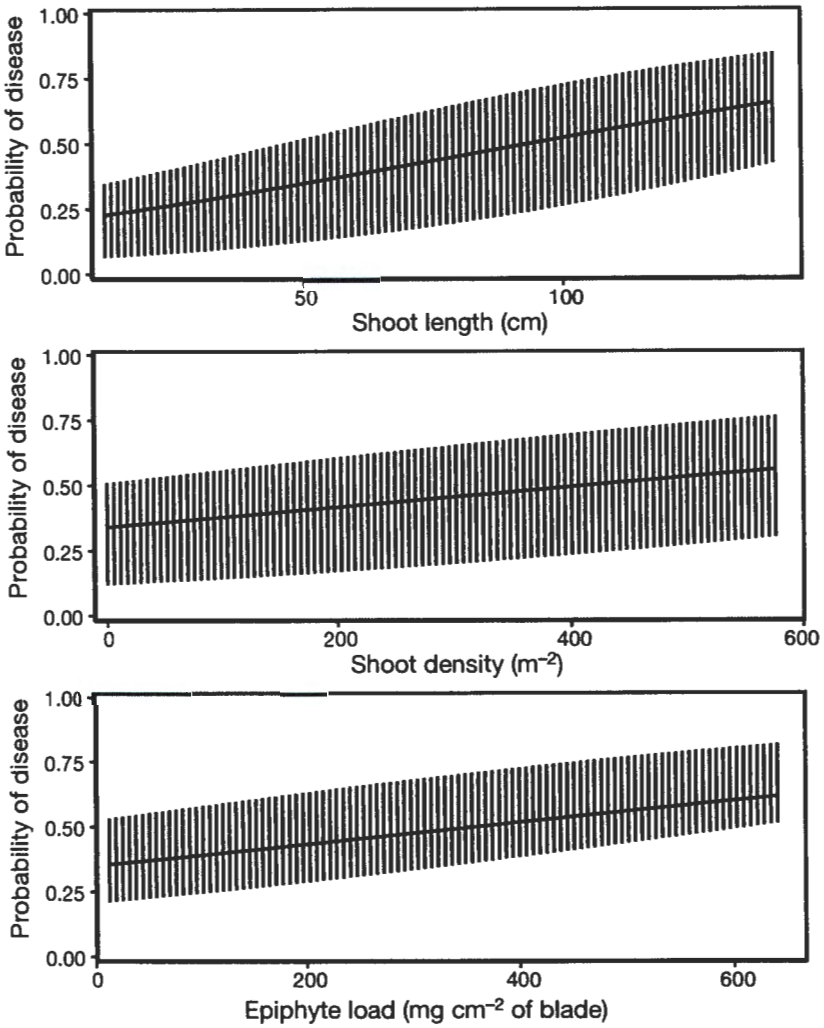

Fig. 2. Effects of eelgrass *Zostera marina* shoot length, shoot density, and biofouling by epiphytes on the predicted probability that a leaf will have wasting disease. Predicted probabilities were calculated using a logistic regression of shoot length, shoot density, and biofouling by epiphytes on the disease status of a shoot. Vertical lines indicate 25 and 75% quantiles. For each simulation, 2 variables were held constant, while the variable of interest was allowed to vary. Constants were: shoot length = 70 mm, shoot density = 200 shoots m^{-2}, epiphyte biomass = 120 mg epiphytes per 1 mm shoot

the phenolic concentration (mean ± SD) varied across sites from 4.9 ± 0.5% of biomass in False Bay to 14.7 ± 0.9% of biomass in Padilla Bay. Across sites, the mean phenolic concentration was 7.5 ± 0.6% of biomass in healthy leaves and 8.5 ± 0.8% of biomass in diseased leaves. After accounting for random site effects, diseased leaves had an increase in phenolic concentration of 0.76 (in units of % of biomass, t = 2.33, p = 0.021; Fig. 3). This corresponds to a 10% increase in phenolic concentration in diseased plants relative to plants with no lesions. Shoot length did not improve the model fit and was excluded from the final model.

Histology

Labyrinthula sp. was observed in samples of both healthy and diseased tissue at all sites sampled. Cell counts per field of view were (mean ± SD): healthy: 7.83 ± 2.16 (Indian Cove) and 5.1 ± 2.8 (False Bay); and diseased: 4.54 ± 2.30 (Indian Cove) and 14.7 ± 3.29 (False Bay). Due to the qualitative nature of histological observations, these data were not analyzed statistically. No other potential infectious agents were noted.

DISCUSSION

Globally, seagrasses are declining at a rate of 7% yr^{-1}, and identification of factors contributing to these declines is critical for conservation of seagrasses, the habitats that they create, and the ecosystems services that they provide (Waycott et al. 2009). While in a few instances, recent seagrass declines have been associated with disease (Short & Wyllie-Echeverria 1996), the relation between population decline and disease is more frequently unknown. The prevalence of eelgrass wasting disease varied widely across our study region, from 6 to 79%. This result is similar to findings in the Wadden Sea, where disease prevalence varied from 11 to 80%, (Bockelmann et al. 2013). Our study indicates that eelgrass population structure (i.e. shoot length and density) and fouling are correlated with wasting disease in the Salish Sea. This emphasizes the potential for wasting disease to be contributing to observed population declines. Consistent with previous studies (Buchsbaum et al. 1990, Vergeer et al. 1995, Vergeer & Develi 1997), we show a potential role for phenols as a defense against disease.

Shoot density and shoot length were positive predictors of disease. Correlations between wasting disease and both shoot density and shoot length have been found in previous field studies. For example, disease was positively correlated with density in European populations of eelgrass (Bull et al. 2012),

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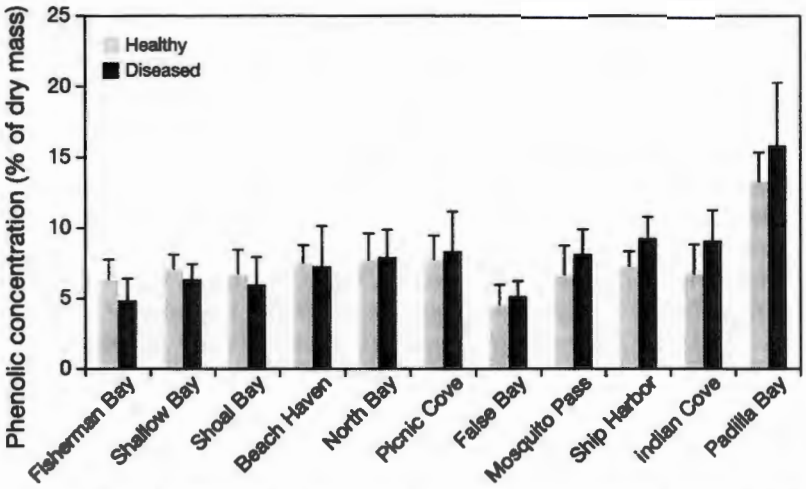

Fig. 3. Phenolic contents (as percent of dry mass equivalents) of healthy (light bars) and diseased (dark bars) eelgrass *Zostera marina* leaves from 11 sites. The data are means ± 1 SD. The standard curves used to calibrate the analyses were derived from absorbances obtained from Folin-Ciocalteu analyses using known amounts of extracted phenolic compounds from *Z. marina* collected from Ship Harbor (see Fig. S1 in Supplement 1 at www.int-res.com/articles/suppl/d118p159_supp/)

and a field survey of 3 sites in the San Juan Archipelago found that longer shoots had higher levels of infection (Groner et al. 2014). Experimental infections also were more successful on older shoots compared to younger shoots on a single ramet (Groner et al. 2014). While trade-offs between shoot length and shoot density are common (Olesen & Sand-Jensen 1994a, Yang et al. 2013), our model suggests that disease risk may be higher in areas with increased biomass (e.g. beds with short shoots or low density sites with long shoots). It is possible that such populations are at or near their carrying capacity and are experiencing negative density-dependent growth rates as a result of competition or have attained high enough biomass to allow for spread of disease.

The contribution of epiphytes to wasting disease has not been observed previously. One hypothesis for this effect is that the epiphytes cause a reduction in immune defenses by blocking carbon uptake and light, thereby reducing photosynthesis and allocation of resources towards immune defenses (Sand-Jensen 1977). Another hypothesis is that increased nutrients drive the changes in epiphytes, wasting disease, and phenolics. Increased biofouling by epiphytes is frequently indicative of increased nutrient loading (Borum 1985, Williams & Ruckelshaus 1993), and higher nitrogen levels have been associated with reduced production of phenols and increased wasting disease in experimental treatments (Buchsbaum et al. 1990). Further research is needed to investigate the mechanism behind this relationship.

While disease prevalence was high at several sites, it is unclear what role this may play at the population level. We hypothesize that wasting disease has 2 important effects on eelgrass beds: (1) to lower overall plant fitness, potentially contributing to population declines; and (2) to increase the decay rate of senescing leaves, remineralizing nutrients for availability in the food web (Raghukumar 2002, Raghukumar & Damare 2011). During warm seasons, leaves are turned over rapidly in eelgrass shoots, and it is likely that the sampled leaves were weeks away from senescing (Olesen & Sand-Jensen 1994b). Nonetheless, fitness costs may be incurred from wasting disease at high-prevalence sites in the Salish Sea. While wasting disease has previously caused rapid population declines (Atlantic coastlines in the 1930s), more work will be needed to pinpoint how much wasting is contributing to the current population declines in the Salish Sea. The high prevalence of wasting disease and extent of recent eelgrass population declines warrants further investigation into these topics.

Our study supports previous field observations of increased phenolic content in diseased seagrasses (Vergeer & Develi 1997). This positive association is consistent with some previous laboratory and mesocosm studies (e.g. Buchsbaum et al. 1990, Vergeer et al. 1995, Steele et al. 2005), but not others (McKone & Tanner 2009). Indeed, the wide variation in the association of disease status on phenolic content found across the 11 sites suggests that, in addition to disease, other factors such as nutrient availability, herbivory, and genetics may be influencing the production of phenols.

Phenolic compounds in seagrasses, including *Zostera marina*, are a complex mixture of metabolites that include condensed tannins (proanthocyanidin polymers), phenolic acids, flavonoids, and lignins (Van Alstyne & Padilla in press). In the Salish Sea, the phenolic acids produced by *Z. marina* include ferulic (4-hydroxy-3-methoxycinnamic), vanillic (4-hydroxy-3-methoxybenzoic), p-hydroxybenzoic (4-hydroxybenzoic), caffeic (3,4-dihydroxycinnamic), gallic (3,4,5-trihydroxybenzoic), protocatechuic (3,4-dihydroxybenzoic), and gentisic (2,5-dihydroxybenzoic) acid (Quackenbush et al. 1986, Ferrat et al. 2012). No single assay can measure the concentra-

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tions of these structurally diverse compounds. Folin assays, such as the Folin-Ciocalteu assay that was used in this study, provide a measurement of the reducing activity of extracts containing phenolic compounds. This can be used as a proxy for the concentration of the compounds in the plants. The assay measures the ability of hydroxylated aromatic compounds in the extracts to reduce phosphomolybdic and phosphotungstic acid reagents, and reducing ability is thought to be correlated with the biological activity of the compounds (Appel et al. 2001). Because the ability of phenolic compounds to reduce these reagents is dependent on the compounds' structures, changes in 'phenolic contents' of plants, as measured with Folin assays, could result from changes in the amounts of compounds present in the extracts or in their structural types. These assays provide a relatively rapid and inexpensive 'first look' at changes in plant biochemistry that correlate with differences in the plants' environment and disease state, but to understand the specific mechanisms by which plants are responding to pathogens and environmental factors, more detailed analyses of specific compounds (e.g. phenolic acids) or more closely related groups of compounds (e.g. condensed tannins) are needed.

Phenols are associated with disease resistance in many plants (Nicholson & Hammerschmidt 1992); however, it is unclear whether the association found here is indicative of an adaptive response to infection. Increased production of caffeic acid in response to *Labyrinthula* spp. infection has been found in *Z. marina*, and caffeic acid can inhibit growth of *Labyrinthula* spp. *in vitro* (Buchsbaum et al. 1990, Vergeer et al. 1995, Vergeer & Develi 1997). In contrast, a potentially non-adaptive pseudo-induction of phenolics in another seagrass species, turtlegrass *Thalassia testudinum*, is hypothesized to occur when shoots cannot move photosynthates down the leaf past the site of infection (Steele & Valentine 2012, Trevathan-Tackett et al. 2015). This causes carbohydrates to accumulate above the sites of the *Labyrinthula* spp. infections, where they are then used to synthesize phenolic compounds (Steele et al. 2005). Finally, *Labyrinthula* may inhibit production of phenols that are capable of inhibiting growth of *in vitro* strains (e.g. Sneed 2005). Numerous other factors influence phenolic concentrations in plants. Phenol concentration decreases with blade age (Ravn et al. 1994) and is negatively correlated with environmental factors, including turbidity (Sneed 2005), temperature (Vergeer et al. 1995), ocean acidification (Arnold et al. 2012), low salinity (Sneed 2005) and heavy metal contamination (Ferrat et al. 2012). Mechanistic studies that quantify the locations and types of phenols produced over the course of an infection, and how those phenols affect the growth of *Labyrinthula* under various environmental conditions, are necessary to characterize the roles of these compounds.

The presence of *Labyrinthula* spp. cells in both diseased and healthy tissue is consistent with opportunistic pathogens, whereby the presence of pathogens is not necessarily indicative of disease (reviewed by Burge et al. 2013). The wide range of cell densities in the histology samples could reflect a heterogeneous distribution of *Labyrinthula* spp. in the hosts. Indeed, this is the case with sea fan corals infected with the labyrinthulomycete *Aplanochytrium* (Burge et al. 2012), and indicates that while histology can be an effective qualitative indicator of pathogen presence and infection of host tissues, it is not an accurate method to measure pathogen load, disease state, or strain. This highlights the importance of quantitative PCR methods for quantifying pathogen load in *L. zosterae* infections. Paired measurements of pathogen load and wasting disease status are necessary to understand whether a specific pathogen load and/or strain is associated with disease status.

We have highlighted the influence of host factors on eelgrass wasting disease prevalence across sites in the central region of the Salish Sea. Many questions remain about what other biotic or abiotic factors contribute to or are necessary for disease expression in Pacific Northwest eelgrass meadows. Other potential risk factors have not been fully evaluated in Pacific eelgrass meadows, including temperature, light, salinity, nutrients, and hydrogen sulfide toxicity (Holmer & Bondgaard 2001, Dooley et al. 2013, Yang et al. 2013, Kaldy 2014). Moreover, while our survey provides data on wasting disease prevalence across 11 sites, it is a single snapshot in time. Longitudinal studies to track disease progression and eelgrass population status over seasonal and multi-year fluctuations are critical for clarifying the relationship between disease and declining eelgrass meadows. Finally, the role of strain variation in the incidence and severity of wasting disease is not well understood, although preliminary evidence suggests that this variation may be substantial (Groner et al. 2014). Nonetheless, our study highlights the potential for wasting disease to cause eelgrass population declines in the Salish Sea and provides impetus and direction for further research. More broadly, the important role of host demography in the epidemiology of eelgrass wasting disease suggests that demo-

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graphy may be an important area for research in other marine or terrestrial organisms that are infected with pathogenic labyrinthulomycetes.

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Host demography influences the prevalence and severity of eelgrass wasting disease

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ABSTRACT: Many marine pathogens are opportunists, present in the environment, but causing disease only under certain conditions such as immunosuppression due to environmental stress or host factors such as age. In the temperate eelgrass *Zostera marina*, the opportunistic labyrinthulomycete pathogen *Labyrinthula zosterae* is present in many populations and occasionally causes severe epidemics of wasting disease; however, risk factors associated with these epidemics are unknown. We conducted both field surveys and experimental manipulations to examine the effect of leaf age (inferred from leaf size) on wasting disease prevalence and severity in *Z. marina* across sites in the San Juan Archipelago, Washington, USA. We confirmed that lesions observed in the field were caused by active *Labyrinthula* infections both by identifying the etiologic agent through histology and by performing inoculations with cultures of *Labyrinthula* spp. isolated from observed lesions. We found that disease prevalence increased at shallower depths and with greater leaf size at all sites, and this effect was more pronounced at declining sites. Experimental inoculations with 2 strains of *L. zosterae* confirmed an increased susceptibility of older leaves to infection. Overall, this pattern suggests that mature beds and shallow beds of eelgrass may be especially susceptible to outbreaks of wasting disease. The study highlights the importance of considering host and environmental factors when evaluating risk of disease from opportunistic pathogens.

KEY WORDS: Labyrinthulomycetes · Opportunistic pathogens · Seagrass declines · *Zostera marina* · Seagrass · Marine diseases · *Labyrinthula zosterae*

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INTRODUCTION

While disease is a natural component of all ecosystems, increases in global emerging diseases present a serious risk to multiple species and ecosystems (Jones et al. 2008). In the oceans, increases in the prevalence and severity of infectious diseases have been associated with changes to trophic interactions, biotic structure, age distributions, and hydrodynamics (reviewed by Burge et al. 2014). Marine diseases that affect ecosystem engineers such as corals, oysters, and seagrasses may be of particular concern, because population declines in these organisms can result in dramatic shifts in community structure

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(Harvell et al. 2004, Ward & Lafferty 2004, Burge et al. 2014). Accumulating evidence suggests that many of these diseases are caused by opportunistic pathogens, which are omnipresent in the environment but have increased in pathogenicity as a result of environmental changes that reduce host defenses against infection (reviewed by Burge et al. 2013). Understanding what can cause this increase in an opportunist's pathogenicity is important for predicting and mitigating disease.

Identification of environmental factors that can cause opportunists to switch from a commensal to a pathogenic state has recently become a research priority (Burge et al. 2013); however, population demographics of the host may also be important in determining the prevalence and severity of disease. In particular, the density, age-, and size-structure of a population may influence the severity, extent, and timing of disease as a result of changes to density-dependent transmission (e.g. Anderson & May 1979, Arneberg et al. 1998), and age- and size-dependent susceptibility to infection (e.g. Raffel et al. 2011). While these ideas have been explored in primary pathogens (i.e. pathogens that are not opportunists), less is known about the role that demography may play in epidemics of opportunistic pathogens.

Wasting disease in the temperate seagrass *Zostera marina* is a tractable system for investigating the role of demographic factors in driving patterns of opportunistic diseases. *Z. marina* inhabits coastal marine and estuarine ecosystems across the northern hemisphere and forms highly productive ecosystems that provide a variety of services, such as habitat for economically valuable invertebrates, fish, and marine birds, stabilization of coastal sediments, and biological filtration of terrestrial-derived nutrients (Wilson & Atkinson 1995, Moore & Short 2006, Orth et al. 2006, Fourqurean et al. 2012, Plummer et al. 2012). These marine angiosperms are highly susceptible to natural and human-caused environmental stress and disease (Short & Wyllie-Echeverria 1996, Orth et al. 2006). Eelgrass wasting disease in particular has caused dramatic, rapid population declines. In the early 1930s, an outbreak along the Atlantic coasts of North America and Europe resulted in up to 90% mortality of *Z. marina* populations (reviewed by Muehlstein et al. 1991). Less severe epidemics have been documented along the Atlantic coasts since the 1980s (Short et al. 1987). Since the early 1990s, a number of *Z. marina* beds across the Salish Sea in the Pacific Northwest of North America have experienced periodic mortalities from unknown causes (Berry et al. 2003, Wyllie-Echeverria et al. 2003, Dowty et al. 2010). It has been hypothesized that these mortality events may be partially due to wasting disease, which has been observed in the Salish Sea during the past few decades (Muehlstein et al. 1988, Muehlstein 1992).

The causative agent of wasting disease in *Zostera marina* is *Labyrinthula zosterae*, a marine protist (Muehlstein et al. 1988, 1991). Like many Labyrinthulomycetes, *L. zosterae* is an opportunistic pathogen that is ubiquitous in the marine environment. It is characterized by spindle-shaped or fusiform zoospores that secrete a mucus network, which it uses for cell adhesion and signaling, transport of nutrients, and motility (Porter 1972, Muehlstein et al. 1991). Analyses of *L. zosterae* in the San Juan Archipelago show a widespread population with little genetic variation, although strains vary considerably in virulence (Muehlstein et al. 1991).

Factors that contribute to an increased prevalence of eelgrass wasting disease, as well as the role of wasting disease in declines of *Zostera marina*, are poorly understood (Muehlstein et al. 1988). At a population level, *Z. marina* beds show within- and among-population variation in density and age structure (Bull et al. 2012), but the link between eelgrass age structure and risk of disease has not been addressed. The morphology of *Z. marina* makes it ideal for testing the effect of host age in opportunistic infections. In a typical plant, several leaves extend from a meristem along a single rhizome (Short & Duarte 2003), and shoots toward the distal end of the rhizome are progressively younger. Leaves within the same shoot differ in age, such that smaller leaves are younger (Tomlinson 1974). Therefore, the effect of age and size on disease can be examined both within and among shoots in a single ramet.

We used a field study and inoculation trials to (1) identify and quantify signs of wasting disease on *Zostera marina* at selected sites in the San Juan Archipelago; (2) confirm the etiologic agent of these signs to be *Labryinthula* spp.; and (3) examine the relationship between shoot size (a proxy for age structure) and susceptibility to wasting disease.

MATERIALS AND METHODS

Field study

Field sampling was in the San Juan Archipelago region of the Salish Sea in Washington, USA (Fig. 1). We chose this region due to ongoing declines in the distribution and density of *Zostera marina* since the early 2000s (Wyllie-Echeverria et al. 2003, 2010, Fer-

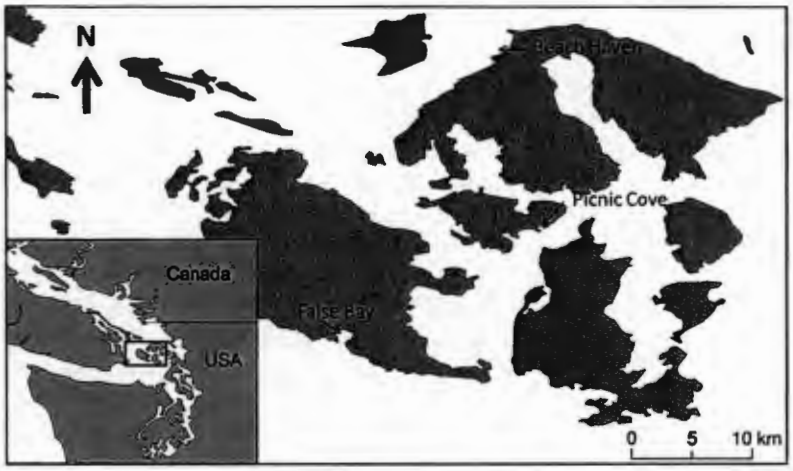

Fig. 1. Study sites in the San Juan Islands, Washington, USA

rier & Berry 2010). We chose 2 sites, Picnic Cove (48.566° N, 122.924° W) and False Bay (48.483° N, 123.074° W), with a history of decline, and 1 site (Beach Haven, 48.691° N, 122.952° W) with a relatively stable population (Wyllie-Echeverria et al. 2010). Picnic Cove is an embayment on the southern coast of Shaw Island. Beach Haven is on the northern coast of Orcas Island and represents a fringing coastline; it was also chosen for its exposure to oceanic currents and its proximity to the Fraser River effluent. False Bay is an embayment on the southwestern coast of San Juan Island and has experienced highly variable shoot densities since 2005 (S. Wyllie-Echeverria et al. unpubl. data). All surveys were conducted between 30 July and 3 August 2012.

Data were collected along 2 (Picnic Cove) or 3 (False Bay and Beach Haven) 10 m transects laid 1 m apart in both shallow and deep sites of the intertidal region. Transects were laid out parallel to the shore, with a distance of 6 m between shallow and deep sites and the midpoint between shallow and deep transects at −1 m Mean Lower Low Water (MLLW). All adult non-flowering shoots within 15 cm of each transect were counted, and the lengths of the longest leaf on each shoot and of all visible lesions due to wasting disease were measured. At Beach Haven, due to the rising tide and the high density of shoots, leaf and lesion measurements were only made directly under the transect tape. Lesions associated with wasting disease were identified by an irregular dark necrotic center surrounded by a black border (e.g. Burdick et al. 1993; Fig. 2). While other lesions on these leaves might have also been caused by *Labyrinthula zosterae*, we conservatively limited our identification to lesions with a black border.

Using these data, we generated measurements of disease prevalence (number of diseased leaves / total number of leaves × 100) and severity (total lesion length / leaf). We also counted the number of shoots in 3 quadrats (0.25 m^2 each) placed at 0, 5, and 10 m in each transect in order to determine site-level differences in population density.

Histology

From select transects, we sampled leaves for histological analysis to confirm our field diagnosis. At Picnic Cove, we sampled eelgrass along 2 transects: 14 healthy leaves (no visible lesions) and 13 diseased leaves (visible lesions) from transect 1, and 15 diseased leaves from transect 2. At Beach Haven and False Bay, we sampled 3 to 4 diseased leaves from each site. Leaves were fixed for 24 h in 4 % seawater-buffered formalin, followed by storage in 70 % ethanol. For the diseased leaves, areas including the leading edge of the lesion and adjacent healthy tissue were sampled. At Cornell University's Diagnostic Laboratory, leaves were embedded in paraffin, sectioned (5 µm), and stained with hematoxylin and eosin. Stained sections were randomized and viewed

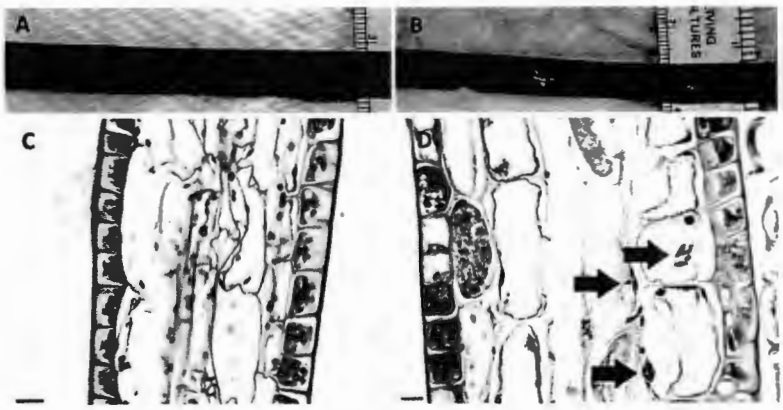

Fig. 2. *Zostera marina*. Samples collected from Picnic Cove, San Juan Islands, Washington, USA, in 2012: (A) outwardly healthy, (B) outwardly diseased, (C) histological section of (A), and (D) histological section of (B) showing *Labyrinthula* cells (arrows). Scale bar in (C,D) = 10 µm

under a bright-field Olympus BH-2 microscope with the Olympus DP-20 camera system. Sections were examined blindly (without demarcation of site or disease status) by a single viewer for the presence/absence of *Labyrinthula* spp. cells or other parasites within the tissues. The number of *Labyrinthula* spp. cells was counted in 3 fields of view for each slide.

Culturing and identification of etiologic agents in field studies

Leaves of *Zostera marina* with distinctive lesions were collected and brought back to the lab to culture *Labyrinthula* spp. Leaf sections with identified lesions were cut into pieces of ~0.5 cm, surface-rinsed with 70% ethanol, and then allowed to dry. These leaf sections were then put onto serum seawater agar (SSA) plates, wrapped in parafilm, and allowed to grow at room temperature. Samples were re-plated as the *Labyrinthula* grew or if fungal contamination became apparent on the plate. We made liquid cultures by inoculating serum seawater (SS) broth with a streak from the desired plate culture. Liquid cultures grew at room temperature for at least 7 d. In total, 4 isolates were cultured: 3 from False Bay and 1 from Beach Haven. The isolate with the fastest growth, FBSH1TD, which originated from False Bay, was verified as *Labyrinthula* spp. under the microscope and used for inoculation experiments (described below).

SSA was modified from Porter (1990): to 1 l of filter-sterilized seawater (salinity = 25 ppt) we added 12 g of USB Noble Agar, 1.5 mg of germanium dioxide, 0.1 g of yeast extract, 0.1 g of peptone, and 1.0 g of glucose. The mixture was autoclaved and tempered to 50 to 55°C before adding 10 ml of horse serum and 25 ml of 100× penicillin/streptomycin. SS broth followed the same recipe, but did not contain agar.

Inoculation trial

To determine the effect of leaf age on susceptibility to disease, we conducted a full-factorial experiment, consisting of 2 age treatments (younger and older leaves from a single shoot) and 3 infection treatments (2 *Labyrinthula* spp. strains and a sham inoculate). Each treatment was replicated on 10 unique ramets for a total of 60 experimental units.

On 22 October 2012, 10 healthy plants (free of lesions on visual inspection) with intact older (terminal) and younger (daughter) shoots on the same rhizome were collected at False Bay. The collected shoots were placed in a sea table at the Friday Harbor Laboratories (FHL), Washington, USA. In order to expose individuals from each shoot to all treatments, the second leaf of each terminal and daughter shoot was divided into 3 segments (5 cm each). Both the second and third leaves from the same shoot were used when a leaf was not long enough to obtain all individual segments. Segments were placed in individual sterile petri dishes with 25 ml of filtered seawater (FSW) and allowed to acclimate overnight in a light- and temperature-controlled incubator (12 h light: 12 h dark, 20°C). Leaf segments remained in the incubator for the entirety of the experiment except during inoculation and photo-documentation.

The experiment began on 23 October 2012. Two strains of *Labyrinthula* spp. were used in the inoculations: 8.16.D and FBSH1TD. FBSH1TD was isolated from False Bay (described above), and 8.16.D was isolated in 2011 from non-flowering adult *Zostera marina* shoots that were collected at Picnic Cove in 2006 and subsequently grown in a continuous flow mesocosm at FHL. Both strains were cultured in SS broth in 15 ml centrifuge tubes after initial isolation onto SSA. Immediately prior to inoculation, the liquid cultures were homogenized with a vortex, centrifuged, and resuspended in FSW. Resuspended samples were vortexed again and quantified using a hemocytometer. Approximately 1.37×10^4 cells were used in each inoculation. The inoculation method was modified from Muehlstein et al. (1988): 70 µl of inoculum (experimental treatments) or sterile seawater (negative controls) were pipetted onto autoclaved leaf segments of 2 to 3 cm and allowed to sit for 1 h. The inoculated autoclaved segments were then attached to the field-collected eelgrass leaves, with the inoculated side of the autoclaved segment in contact with the prepared leaf (Muehlstein et al. 1988). Thin plastic tubing cut into 1 cm sections and slit through on one side was used to 'clip' the autoclaved, infected piece to the uninfected leaf segment. The clipped leaves were placed in sterile petri dishes with 25 ml FSW and returned to the incubator. After 12 h, the plastic clips and autoclaved leaves were removed.

The experiment was terminated after 2.5 d, and all leaves were photographed. Lesions in the photographed leaf segments were scored blindly by 4 independent scorers. Scores were based on the percentage (to the nearest 10%) of tissue that had not deteriorated (i.e. a score of 0.1 corresponded to 10% health, a score of 0.2 corresponded to 20% health).

Statistical analyses

Field data

We used a multivariable 2-part random effects model to determine the effect of site, depth, and shoot length on the presence and severity of wasting disease (e.g. Kristoffersen et al. 2013). The first part of the model analyzed the odds that a shoot was infected using logistic regression and a binary error term:

$$\begin{aligned}\text{logit}(P_{(\text{infected})}) = {} & A_0 + A_1 \times \text{site1} + A_2 \times \text{site2} + \\ & A_3 \times \text{depth} + A_4 \times (\text{shoot length}) + \\ & A_5 \times (\text{shoot length}) \times \text{site1} + \\ & A_6 \times (\text{shoot length}) \times \text{site2} + u_1 \qquad (1)\end{aligned}$$

where site 1 is False Bay, site 2 is Picnic Cove, and the reference site is Beach Haven (the healthiest of the 3 sites). A_0 is the model intercept, and u_1 is the error term.

The second part of the model used regression with a log-normal distribution to model the lesion length (cm):

$$\begin{aligned}\text{Lesion length} = {} & B_0 + B_1 \times \text{site1} + B_2 \times \text{site2} + \\ & B_3 \times \text{depth} + B_4 \times (\text{shoot length}) + \\ & B_5 \times (\text{shoot length}) \times \text{site1} + \\ & B_6 \times (\text{shoot length}) \times \text{site2} + u_2 \qquad (2)\end{aligned}$$

where B_0 is the model intercept, and u_2 is an error term. For both parts of the model, we included a random effect of the transect location and the fixed effects of site, depth, and shoot length.

As a diagnostic tool, we compared the observed number of shoots with no lesions to the expected number of disease-free shoots as predicted by part 1 of the model. High agreement between these values (757.98 predicted disease free to 758 measured disease free) indicated a good model fit. For part 2 of the model, we evaluated the fit of the model by plotting the Anscombe residuals against the fitted values.

The model was implemented in SAS PROC NLMIXED (SAS® 9.1.3 for Windows, SAS Institute) and estimated by adaptive Gaussian quadrature using 12 quadrature points (Kristoffersen et al. 2013). The data were left-skewed, and a 0.2 power transformation was required to meet the assumption of normality for the second part of the model; however, the results for the 0.2 power transformed data and the log-normal data were similar. Therefore, we present the latter for part 2 of the model as the interpretation is more straightforward. The data met the assumption of homoscedasticity.

Histology

We used a generalized linear mixed model with a Poisson distribution to compare counts of *Labyrinthula* spp. cells in healthy leaves with healthy and diseased sections of diseased leaves collected on transect 1 at Picnic Cove. Since cells were counted in 3 spots for each histological sample, these 3 counts were nested as a random effect within each sample. These data were analyzed using the 'glmer' function in the 'lme4' package in R (v.2.15.2; R Development Core Team 2012).

Inoculation trial

Data on inoculation trials were analyzed using a linear mixed effects model (package 'lme4') in R (v.2.15.2). We included genotype as a random effect and evaluated the fixed effects of strain (control, 8.16.D or FBSH1TD), shoot (terminal or daughter), and the strain×shoot interaction. Post hoc analyses were conducted on Bonferroni-corrected p-values that were calculated using Markov chain Monte Carlo estimation with the 'mcposthoc.fnc' function in the 'lme4' package. In order to meet the assumption of normality, we analyzed the arcsine square-root transformations of the average rankings of health. The data were homoscedastic.

RESULTS

Field study

In total, 1542 shoots of *Zostera marina* were examined at 3 field sites in the San Juan Islands, of which 784 showed visual evidence of wasting disease. Disease prevalence was 63% at Picnic Cove, 53% at Beach Haven, and 33% at False Bay. The shoot lengths varied between 3 and 234 cm, and the size structure of shoots varied by site (Fig. 3). At all sites, less than 5% of the shoots surveyed were under 10 cm in length. Representation of size classes varied across sites for shoots greater than 40 cm: over 75% of shoots surveyed at Beach Haven and Picnic Cove, but only 50% of the shoots at False Bay, were over 40 cm in length. Beach Haven had the greatest mean (±SE) density of shoots, at 182 ± 20 shoots m^{-2}, while False Bay and Picnic Cove had 61 ± 16 and 55 ± 13 shoots m^{-2}, respectively.

Disease prevalence varied significantly as a function of depth, shoot length, and the interaction of site

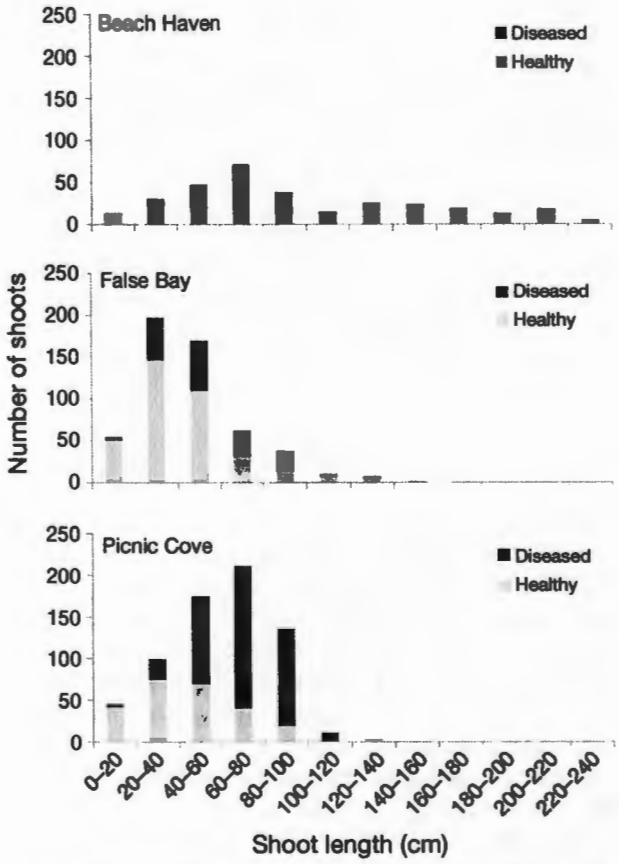

Fig. 3. *Zostera marina*. Counts of diseased and healthy leaves by size class for each site

and shoot length (Fig. 3, Table 1). Across all sites, controlling for shoot size, transects that were taken above −1 m MLLW had 73% greater disease prevalence than transects that were deeper than −1 m MLLW (t_{14} = 2.4, p = 0.031). Shoot length explained the most variation in disease prevalence (t_{14} = 14.45, p < 0.0001). At False Bay, the odds of having wasting disease increased by 58% for every 10 cm increase in shoot length (t_{14} = 1.97, p = 0.068), while at Picnic Cove the odds of having wasting disease increased by 84% for every 10 cm increase in shoot length (t_{14} = 5.21, p = 0.0001). In contrast, at the least impacted site, Beach Haven, the odds of having wasting disease only increased by 26% for every 10 cm increase in shoot length (t_{14} = −3.3, p = 0.005)

Disease severity (the total lesion length / leaf) was influenced by site, shoot length, and the interaction of these terms (Table 1). At False Bay and Picnic Cove, the total lesion length increased by 0.16 and 0.29 cm for every 10 cm increase in shoot length (t_{14} = −3.3, p = 0.069; and t_{14} = 5.21, p < 0.0001, respectively), while at the reference site, Beach Haven, the total lesion length increased by only 0.08 cm for every 10 cm increase in shoot length (Fig. 4). After controlling for shoot length, disease severity was lower at Picnic Cove than Beach Haven (t_{14} = −3.23, p = 0.006), and there was no difference in disease severity between False Bay and Beach Haven (t_{14} = −0.33, p = 0.75).

Table 1. *Zostera marina*. Coefficient estimates (see Eqs. 1 & 2), standard errors, *t*- and p-values, and odds ratios from a 2-part model. The model evaluates the influence of site, depth, shoot length, and the interaction of shoot length and site on the probability of being diseased (part 1) and the severity of disease (defined as the lesion length) for diseased plants (part 2). In both parts of the model, the reference site is Beach Haven, the reference depth is shallow, and the estimates for shoot length are based on 1 m intervals

Term	Coefficient estimate	SE	*t* (df = 14)	p	Odds ratio (95% CI)
Part 1 Logit model					
Intercept	−1.68	0.70	−2.4	0.031	
False Bay	−0.87	0.85	−1.03	0.32	0.417 (0.068, 2.58)
Picnic Cove	−0.69	0.86	−0.81	0.43	0.499 (0.08, 3.14)
Depth	−1.30	0.54	−2.4	0.031	0.272 (0.085, 0.87)
Shoot Length (m)	2.34	0.42	5.58	<0.0001	10.33 (4.21, 25.3)
False Bay × Shoot Length	2.27	0.68	3.32	0.005	9.67 (2.23, 41.9)
Picnic Cove × Shoot Length	3.78	0.66	5.73	<0.0001	43.7 (10.63, 179.8)
Part 2 Continuous model					
Intercept	0.90	0.27	3.35	<0.005	
False Bay	−0.11	0.34	−0.33	0.75	0.90 (0.44, 1.84)
Picnic Cove	−1.15	0.35	−3.23	0.006	0.32 (0.32, 0.15)
Depth	−0.28	0.17	−1.69	0.11	0.75 (0.53, 1.08)
Shoot Length (m)	0.80	0.21	3.8	0.002	2.23 (1.42, 3.51)
False Bay × Shoot Length	0.73	0.37	1.97	0.069	2.07 (0.94, 4.58)
Picnic Cove × Shoot Length	1.76	0.34	5.21	0.0001	5.81 (2.82, 11.98)

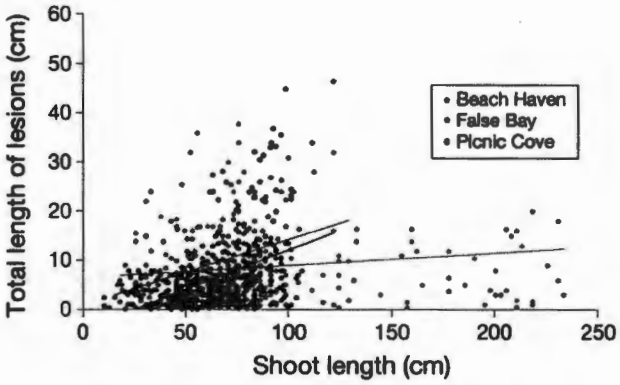

Fig. 4. *Zostera marina*. Linear regression of the relationship between shoot length and total lesion length at each site

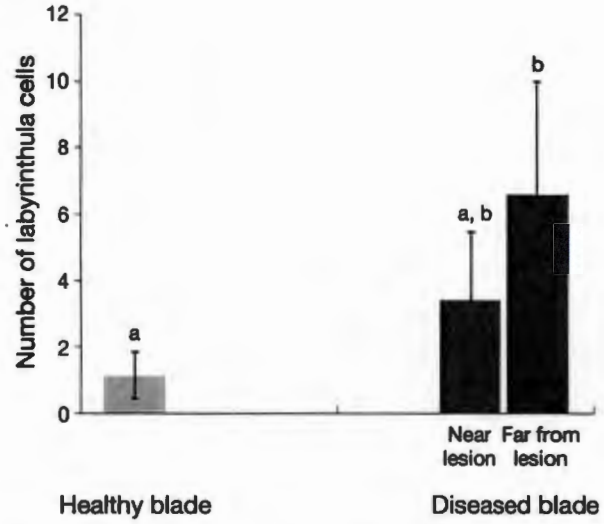

Fig. 5. *Labyrinthula* spp. Mean ± SE cell abundance using histology within healthy and diseased *Zostera marina* leaves. Letters indicate significant differences ($p < 0.05$)

Histology

We used histology of field samples to verify that observed lesions were caused by *Labyrinthula* pathogens. Because *Labyrinthula* spp. are ubiquitous and cells can appear in healthy tissue, we quantified the number of *Labyrinthula* spp. cells in healthy leaves, lesions, and healthy portions of diseased leaves.

Histological examination confirmed *Labyrinthula* spp. infection in all selected diseased leaves from all sites. The mean (±SE) numbers of cells per leaf varied among sites: Picnic Cove (transect 1: 3.45 ± 2.02 *Labyrinthula* spp. cells outside lesion, 6.64 ± 3.38 cells inside lesion area; transect 2: 2.50 ± 0.95 and 3.05 ± 0.88, respectively), Beach Haven (9.33 ± 5.86; 0.33 ± 0.33), and False Bay (4.67 ± 3.83; 6.3 ± 4.21).

At transect 1 at Picnic Cove, *Labyrinthula* spp. cell abundance in diseased lesions (6.64 ± 3.38) was significantly higher than in healthy leaves (1.15 ± 0.72; $z = -2.943$, $p = 0.0091$; Fig. 5). Cell abundance did not differ significantly between healthy leaves and healthy sections of diseased leaves (3.45 ± 2.02, $z = 1.131$, $p = 0.495$), nor between the inner and leading-edge portions of lesions on diseased leaves ($z = -1.812$, $p = 0.165$).

Inoculation trials

To determine how age structure might influence a population's susceptibility to wasting disease, we inoculated old and young leaves from the same plant with 1 of 2 different *Labyrinthula* spp. strains. Photographs of inoculated leaves were then scored according to the amount of degradation due to wasting disease (see 'Materials and methods' for details).

The health score of leaf sections in the inoculation trials was influenced by strain ($F_{2,45} = 9.022$, $p = 0.0005$) and the interaction of strain and shoot age ($F_{2,45} = 5.64$, $p = 0.006$; Fig. 6). Compared to FSW control inoculates, the health score of leaf sections was 8% lower for sections exposed to *Labyrinthula* spp. strain 8.16.D and 3% lower for sections exposed to *Labyrinthula* spp. strain FBSH1TD ($t_{45} = -4.21$, $p < 0.0001$; and $t_{45} = -2.55$, $p = 0.0142$, respectively). Older shoots had lower health scores than younger shoots; however, the difference depended on the strain to which they were exposed. Older shoots exposed to strain 8.16.D had a 10% lower health score than younger shoots ($t_{45} = 3.34$, $p < 0.002$), and older shoots exposed to strain FBSH1TD had a 2%

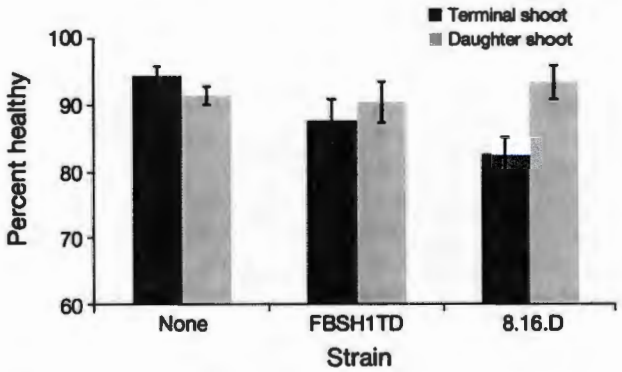

Fig. 6. *Labyrinthula zosterae*. Effect of *Zostera marina* shoot age and strain of *L. zosterae* on health. Mean % healthy shoots ± SE across *Z. marina* genets with older terminal shoots and younger daughter shoots (n = 10 genets)

lower health score, although the latter trend was not significant ($t_{45} = 1.40$, $p = 0.17$). There was no effect of age on the health score in the control treatment. By itself, age was not a significant predictor of shoot health ($t_{45} = -1.25$, $p = 0.2$).

DISCUSSION

Identification of factors that increase host susceptibility to opportunistic pathogens is crucial for understanding patterns of disease in infected populations. Previous studies of opportunistic pathogens show that environmental factors such as rising temperatures may correlate with disease outbreaks by increasing host susceptibility (reviewed by Burge et al. 2013). Here, we present evidence that population age and size structure also influence the prevalence and severity of a disease caused by an opportunistic pathogen. The field prevalence of wasting disease in *Zostera marina* is greater on larger, older leaves, and experimental exposure to *Labyrinthula zosterae* demonstrates increased susceptibility of older shoots to eelgrass wasting disease. While other environmental and genetic factors most likely contribute to patterns of disease in declining populations of this marine plant, the results of our study allow for the identification of susceptible populations based on measurable demographic properties.

Several isolates of *Labyrinthula* spp. (with differences in host specificity) and at least 2 species of *Phytophthora*, viz. *P. gemini* and *P. inundata*, can infect *Zostera marina* (Garcias-Bonet et al. 2011, Man in 't Veld et al. 2011). Proper identification of pathogens and verification of the etiologic agents of disease has been a challenge for *Z. marina*. Lesions similar to those caused by wasting disease can result from other stressors, including desiccation (Boese et al. 2003), invertebrate grazing (Hily et al. 2004, Boese et al. 2008), and mechanical damage (Boese et al. 2008). Moreover, because opportunistic pathogens are ubiquitous in many seagrass populations and do not always cause disease (Burge et al. 2013), identification by molecular or microbiological methods alone will not confirm an association with disease (e.g. Bockelmann et al. 2012, 2013). Indeed, in a subset of samples, histology indicated that *Labyrinthula* spp. cells are found in healthy *Z. marina* shoots as well as diseased ones, although the number of cells was consistently higher in tissue with lesions than in healthy tissue. We used both histology and isolation and re-infection with local strains to confirm that the lesions we identified were associated with a *Labyrinthula* pathogen. We recommend this paired approach for confident verification of both disease and the etiologic agent. Future work developing a qPCR diagnostic for Pacific strains of *L. zosterae* and immunohistochemistry for identifying cryptic *L. zosterae* cells would greatly enhance diagnostic capabilities.

The effect of shoot length on disease prevalence depended upon site such that a positive correlation was most apparent at the 2 disturbed sites, False Bay and Picnic Cove. The density of shoots was nearly 4 times greater at Beach Haven, suggesting that density-dependent transmission is not driving infection prevalence. In addition, both of the disturbed sites had smaller shoots than Beach Haven. This may be because larger shoots had decayed as a result of disease or simply because environmental conditions caused a different phenotypic expression of shoots (see Backman 1991). While Beach Haven experiences high wave action, has a steep slope, and faces to the north, Picnic Cove and False Bay are in south-facing shallow embayments and are characterized by warm water during low tides (S. Wyllie-Echeverria et al. unpubl. data). Collectively, these factors may contribute to increased disease after controlling for the effect of shoot size. Warmer temperatures promote *in vitro* growth of *Labyrinthula zosterae* (S. Wyllie-Echeverria et al. unpubl. data) and may be a source of stress to *Zostera marina* shoots growing in this region (e.g. Vergeer et al. 1995). At Picnic Cove in particular, *Z. marina* beds have been in decline since 2000 (Ferrier & Berry 2010, Wyllie-Echeverria et al. 2010). The site has fewer herbivores and higher densities of diatomaceous epiphytes in comparison to our other study sites (S. Wyllie-Echeverria pers. obs.), as well as high levels of hydrogen sulfide, which is toxic to adult plants and seedlings at high concentrations (Krause-Jensen et al. 2011, Dooley et al. 2013). Further work investigating how these ecological factors influence disease susceptibility may help to explain declines at Picnic Cove.

Across all sites, disease severity and prevalence increased with leaf length. An increase in disease prevalence with size or age is a common pattern, for example in invertebrates such as corals (Dube et al. 2002) and terrestrial plants such as the Port Orford cedar *Chamaecyparis lawsoniana* (Kauffman & Jules 2006). Several mechanisms may explain this pattern. Larger individuals have longer cumulative exposure times and greater surface area available for infection (e.g. *Daphnia* in Hall et al. 2007). In addition, exposure to stressors over time may decrease plant allocation to defenses, allowing infected plants to become

diseased (Zangerl & Bazzaz 1992). Larger plants may also experience more mechanical stress and herbivory, damaging leaf tissue and creating more infection opportunities for the pathogen (reviewed by Lafferty & Harvell 2014). An association between wasting disease lesions and *Zostera marina* leaf age has previously been noted (Burdick et al. 1993); however, those authors assumed that it was due to increased contact with infected plants and the trend was not statistically tested. Interestingly, the highest abundance of *Labyrinthula zosterae* cells using qPCR has been noted in the third longest leaf (Bockelmann et al. 2013). The histological results of our and other studies show that the highest densities of *L. zosterae* can be found at the leading edge of the lesion, or before darkening has occurred (Muehlstein 1992). Thus the most diseased leaf as assessed by the presence of lesions may not be the site of the greatest infection.

Our experimental inoculations suggest that the higher levels of disease in older shoots may be caused by an increase in susceptibility. Increased resistance with age and size has been observed in many plant species due to a change in nutrient status and activation of defense pathways as a result of development (reviewed by Develey-Rivière & Galiana 2007). On the other hand, decreased resistance has also been observed with age due to increased allocation of defenses to young tissue (Dube et al. 2002) and a trade-off between growth and defense (Bazzaz et al. 1987, Fine et al. 2006). In *Zostera marina*, experimental evidence suggests that phenols, particularly caffeic acid, may be associated with resistance to *Labyrinthula zosterae* (e.g. Buchsbaum et al. 1990, Vergeer et al. 1995, Vergeer & Develi 1997). Total phenol concentrations are generally decreased in older leaves (Ravn et al. 1994). More research is needed to understand the role of phenols in resistance to wasting disease; however, if phenols are an important mechanism for resistance, it would be consistent with our results. Other mechanisms not tested in this study, such as increased contact with diseased shoots or mechanical damage, may also contribute to increased disease in older shoots.

CONCLUSION

This study is the first demographic assessment of wasting disease in an area of recent seagrass declines. Our finding of nearly 50% prevalence across all sites suggests that the role of wasting disease as a factor in seagrass population decline warrants further investigation. Moreover, patterns of infection from both the field and laboratory inoculation trials suggest that older *Zostera marina* leaves at shallower depths may be more vulnerable to wasting disease. While demographic factors are well studied in primary (non-opportunistic) pathogens, they are often overlooked in opportunistic pathogens. The class Labyrinthulomycetes includes a variety of opportunistic pathogens associated with recent disease outbreaks, such as those infecting gorgonian corals (Burge et al. 2012) and hard clams (Ragan et al. 2000). The association between demography and disease, such as we found here, allows for identification of eelgrass populations that are at higher risk of disease based on demographic measurements. More broadly, these results highlight host population demographics as an important research area in the understanding of the epidemiology of these and other opportunistic pathogens.

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Editorial responsibility: Rebecca Gast, Woods Hole, Massachusetts, USA

Submitted: October 1, 2013; Accepted: December 12, 2013
Proofs received from author(s): February 13, 2014

Julie Thompson

From: Chris Morgan <chrismorgan54@hotmail.com>
Sent: Wednesday, September 6, 2017 2:22 PM
To: Nancy Morgan
Cc: Julie Thompson; Meg Harris; Gretchen Allison; Peter Morgan; Michael Morgan
Subject: Re: Permit# PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 11 2017
COMMUNITY DEVELOPMENT

Dear Ms. Thompson,

I wish to reiterate all of Nancy's points below and also to add a couple of new ones. There is not a single dock on the west side of SJI that has been able to withstand the winter weather that is encountered in the straits every winter. One can look to the north of False Bay to the next cove which has signs of a former dock. There are still at least 10 pilings in the water - but no dock! Winds of over 100 mph have been recorded in the vicinity of where the dock is being proposed. The protected cove of False Bay would be damaged by the flotsam and jetsam that will result from any dock that is installed when ultimately it will be destroyed by Mother Nature who regularly destroys such foolish acts of folly.

Even were a dock to be constructed that could withstand such relentless forces of nature, we as residents who enjoy the pristine beauty of False Bay's protected environment, don't want to see a dock or the increased on-water activity that would result from the use of such a dock.

As Nancy noted, there are adequate dock facilities in numerous other locations on San Juan Island. The Honeywells would be wise to pursue those instead of irreparably damaging the very fragile environment of False Bay which really belongs to all citizens.

Chris Morgan
287 Mountain Shadows Lane
Friday Harbor, WA 98250

On 5 Sep 2017, at 12:16 PM, Nancy Morgan <nancy.m.morgan@hotmail.com> wrote:

Subject: 4 Slip Dock and RO desalination system

Dear Ms. Thompson,

I am writing (AGAIN!) to express my urgent request that you and the county **do not authorize** a 4 slip dock in the cove at the mouth of False Bay!

I love our island for many reasons. I appreciate that most residents recognize this unique treasure we call home and share in a profound respect, in particular, for our marine environment.

I love boating too! But my boat would be kept in a marina or an area where it is not impacting the marine wild life as it would be if such a permit went through at the cover area of False Bay. I find it unfathomable that we are still fighting and paying lawyers to defend the environment here which has been shown time and time again

it's importance to marine biologists, to the valued wildlife, and for the public's enjoyment through kayaking and nature watching.

In allowing the construction and ongoing use of the 260' dock to False Bay poses a direct threat to the biological preserve. There undoubtedly will be harmful effects to marine wild life. Potential fuel or chemical spills, changes to the water dynamics and siltation of the bottom under and around the dock are just some obvious worries.

False Bay is an important area where the University of Washington does its studies on endangered species as they frequent this location. Further, the mouth of the bay is a prime feeding habitat for the Southern resident orca. The environmental risks are just too high to allow a dock anywhere near this area.

The property owners have not demonstrated they share in caring for the environment as their neighbors do. A past clear cutting done purely for their own building purposes caused a large portion of the bank of land to erosion which they were fined. Further, contrary to the owners assertion that the dock will be hidden from view. It will not. It will hugely affect those people living on the north side of False Bay.

Commercial docks are nearby and really is the answer. They can have as many boats as they want and need.

Desalination technology can kill marine life! The dangerous solution of sodium and industrials endangers fish and other sea life. Ocean water desalination harms marine ecosystems promotes unsound coastal zone management, wastes energy and impacts human health. The cons far outweigh its potential benefits.

Respectfully,
Nancy Morgan
False Bay resident

Julie Thompson

From: Nancy Morgan <nancy.m.morgan@hotmail.com>
Sent: Tuesday, September 5, 2017 12:17 PM
To: Julie Thompson
Cc: Chris Morgan; Meg Harris; Gretchen Allison; Peter Morgan; Michael Morgan
Subject: Permit# PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 06 2017
COMMUNITY DEVELOPMENT

Subject: 4 Slip Dock and RO desalination system

Dear Ms. Thompson,

I am writing (AGAIN!) to express my urgent request that you and the county **do not authorize** a 4 slip dock in the cove at the mouth of False Bay!

I love our island for many reasons. I appreciate that most residents recognize this unique treasure we call home and share in a profound respect, in particular, for our marine environment.

I love boating too! But my boat would be kept in a marina or an area where it is not impacting the marine wild life as it would be if such a permit went through at the cover area of False Bay. I find it unfathomable that we are still fighting and paying lawyers to defend the environment here which has been shown time and time again it's importance to marine biologists, to the valued wildlife, and for the public's enjoyment through kayaking and nature watching.

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Respectfully,
Nancy Morgan
False Bay resident

Julie Thompson

From: Mary Karen Ryan <mkcalryan@gmail.com>
Sent: Monday, September 4, 2017 12:21 PM
To: Julie Thompson
Subject: Permit# PSJ000-17-003

S.J.C. DEPARTMENT OF
SEP 05 2017
COMMUNITY DEVELOPMENT

Hello

I am writing to comment on an application which is before you for a 260 foot "community" dock at the mouth of False Bay. Although I would not have a view of this from my house at all, I am truly concerned about how this work might affect the health of that area. I know that it has been shown that many organisms thrive there - organisms which affect the the diet and health of whales and salmon. It seems to me that both the Orca and salmon are facing enough environmental challenges as is without adding further threats to their survival.

Please thoughtfully consider these issues when evaluating the need for this project. I encourage you to reject this application.

Thank you.

Mary Karen Ryan

Julie Thompson

From: steve porten <steviep43@hotmail.com>
Sent: Sunday, September 3, 2017 4:15 PM
To: Julie Thompson; steve porten
Subject: permit # PSJ000-17-0003

S.J.C. DEPARTMENT OF
SEP 05 2017
COMMUNITY DEVELOPMENT

In re a four boat dock (extremely long one, at that!) and a desalination plant.

Please add my name (a long term resident of this island and a property owner) to others that may want this permit quashed--rejected--turned down.

Its too big---they have have other options to berth their boats---it will be an eye sore for those of us that walk the area, and may ill affect the study area for the 'labs', who have a preserve close at hand--- it will affect the ecology---its horrible precedent for other similarly situated parcels with big money behind them----
its unknown how the desalination plant will affect the ecology of a very shallow basin

please reject the permit!

sincerely, steve porten

Cornell University
Earth and Atmospheric Sciences
Ocean Resources and Ecosystems Program
4120 Snee Hall
Ithaca, NY 14853-2701

Julie Thompson, Planner III
San Juan County Community Development & Planning
PO Box 947
Friday Harbor, WA 98250

August 30, 2017

Dear Ms. Thompson:

I am writing to comment on the determination of non-significance (DNS) for the four-slip dock and RO desalination system project (PSJ000-17-0003) submitted on behalf of Orca Dreams LLC. To provide some background information on myself, I have been a property owner on San Juan Island for 32 years and moved into my house on False Bay eight years ago. I am the Director of the Ocean Resources & Ecosystems Program at Cornell University and teach summer and spring courses for Cornell and the University of Washington (UW) at the UW's Friday Harbor Laboratories. I received my PhD in Oceanography at the UW in 1985 and have been visiting False Bay for 39 years. I am an internationally recognized expert on marine bioacoustics, and I conduct research and teaching in Conservation Oceanography, with a special focus on protected species. I will therefore confine my comments to these areas of my professional expertise in oceanography.

Construction of the dock will involve drilling and/or driving the pier pilings into place. This activity will result in significant underwater noise adjacent to a critical foraging area for endangered Southern Resident orca pods J, K, and L during the proposed dock's construction. However, the real Achilles heel of this project is the applicant's failure to consider the ongoing effects of underwater noise on the endangered Southern Resident orca population. These Resident orcas are known to react to underwater noise, including boat engines and traffic by altering their normal behavior, and in some cases, by ceasing feeding and abandoning the foraging area. The effects of such underwater boat noise was cited by NOAA as the primary justification for proposing a 0.5-mile "no-go zone" along the west coast of San Juan Island several years ago. Since the proposed dock is sited adjacent to a critical orca foraging area, the applicant should seek a determination on whether their activities will be in compliance with the Endangered Species Act and Marine Mammal Protection Act. Drs. Lynne Barre and Brad Hanson, at NOAA's Northwest Fisheries Science Center in Seattle, would be appropriate officials to contact for further information about these compliance issues. Since federal laws override the authority of any county or state approvals, and since failure to comply with them is a federal offense, the applicant should take these concerns very seriously.

In addition to the Southern Resident orca pods, other threatened and endangered species likely to occur on or near the project site include: canary rockfish, chinook salmon, chum salmon, cutthroat trout, marbled murrelet, steelhead trout, and Steller sea lion. Species or candidate species of concern occurring on or near the project site include: bald eagle, black rockfish, china rockfish, common murre, copper rockfish, golden eagle, Pacific harbor porpoise, Pacific herring, peregrine falcon, pinto abalone, quillback rockfish, tiger rockfish, western grebe, widow rockfish, and sunflower seastar. The biodiversity of this area is one of the reasons why False Bay was set aside to be managed by the UW as a biological preserve. The UW biological preserve extends into the cove where the proposed dock would be located, and significant development on the edge of the preserve is inconsistent with the conservation goals of the University and state of Washington.

The proposed dock will strongly impact the near-shore habitat, especially the eel grass beds and rocky outcrops used by local wildlife immediately adjacent to the proposed dock. Eel grass beds are recognized as essential marine habitat by the state of Washington, and these particular beds are already under significant stress due to disease. At a time when eel grass beds in the UW's False Bay biological preserve are diminishing in areal extent due to disease, it is unwise to intensify the stresses on these particular beds by increasing sedimentation and shading associated with the dock's construction. With regard to the rock outcropping near the proposed dock, it is used consistently for hauling out by harbor seals, and for roosting and feeding by shorebirds, including black oystercatcher, black turnstone, and blue heron. As mentioned previously, this habitat is adjacent to a critical foraging area for orca pods J, K, and L. Potential disruptions of prey behavior imposed by the dock could impact orca foraging success.

The proposed location of the dock is one of the most exposed sites on San Juan Island. Winds frequently exceed 50 knots, and, with exposure to the full fetch of the Strait of Juan de Fuca and Haro Strait, large waves commonly impact this shoreline during the winter months of November through March. Although less common, summer and autumn storms of comparable intensity can strike rapidly and be similarly destructive. For the proposed dock, it is not a matter whether it will be destroyed or severely damaged by a storm; rather, it is a question of when it will happen. My primary concern about storm-related destruction or damage of the dock is the associated risk of a significant fuel spill. Should such a spill occur at the wrong time in the tidal cycle, it could potentially damage large portions of the False Bay biological preserve for many years or even decades. This is not a risk that the biological preserve nor the applicant's neighbors should be forced to endure.

Thank you for taking my comments into consideration. I do hope that the

applicant will finally begin to understand the many risks associated with the proposed dock.

Sincerely,

Charles H. Greene

Julie Thompson

From: Fritzen, Bob (ECY) <BFRI461@ECY.WA.GOV>
Sent: Tuesday, May 30, 2017 3:45 PM
To: Padgett, Rebekah (ECY); Yunge, Chad (ECY); Julie Thompson
Subject: RE: [Non-DoD Source] Orca Dreams Dock - NWS-2014-476

I've mentioned this before, and it may not make a difference in deciding the permit, but the bottom contour map is misleading. The profile on page 4 shows it just getting deeper and deeper where the rock outcrops are. The contour lines end at -4 under the ramp, but I don't see anything under the float.

-----Original Message-----
From: Padgett, Rebekah (ECY)
Sent: Friday, May 26, 2017 1:55 PM
To: Fritzen, Bob (ECY) <BFRI461@ECY.WA.GOV>
Subject: FW: [Non-DoD Source] Orca Dreams Dock - NWS-2014-476

fyi

-----Original Message-----
From: Houghton, Juliana CIV USARMY CENWS (US) [mailto:Juliana.Houghton@usace.army.mil]
Sent: Thursday, May 18, 2017 6:38 AM
To: Mike Lisitza - NOAA Affiliate <mike.lisitza@noaa.gov>; Padgett, Rebekah (ECY) <RPAD461@ECY.WA.GOV>
Subject: FW: [Non-DoD Source] Orca Dreams Dock - NWS-2014-476

FYI - revised drawings for Orca Dreams, NWS-2014-476.

Thanks,

Juliana

-----Original Message-----
From: Francine Shaw [mailto:fshaw@rockisland.com]
Sent: Wednesday, May 17, 2017 2:54 PM
To: 'Dale Youngkin - NOAA Federal' <dale.youngkin@noaa.gov>; Houghton, Juliana CIV USARMY CENWS (US) <Juliana.Houghton@usace.army.mil>; 'Thompson, Doug S (DFW)' <Doug.Thompson@dfw.wa.gov>
Subject: [Non-DoD Source] Orca Dreams Dock - NWS-2014-476

Hi All:

Attached is the current set of permit drawings for the Orca Dreams dock. The change is the lot configuration of the property the dock will serve.

Francine Shaw, Land Use Planner
Law Offices of Stephanie Johnson O'Day
P.O. Box 2112
Friday Harbor, WA 98250
Phone: (360) 378-6278