November 12, 2013

Mr. Tim Sheldan, Deputy Minister
Ministry of Forests, Lands and Natural Resource Operations
PO BOX 9352, STN PROV GOVT
Victoria, BC, V8W 9M1
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Re: Geoduck aquaculture versus herring spawning in Lambert Channel

Dear Mr. Sheldan,

The BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) has received six shellfish aquaculture applications for different locations in Lambert Channel, Baynes Sound, and Comox Harbour. Details of the applications were provided in an advertisement in the newspaper 'Comox Valley Echo'. The advertisement provided websites that showed the details of the individual applications. Each application is about 16 pages and has maps and coordinates describing the locations of the proposed aquaculture developments. *The advertisement also advised that MFLNRO will receive comments on the applications until November 28, 2013.* This letter was prepared in response to that invitation.

The following pages explain that Lambert Channel is the most important herring spawning area in British Columbia. For that reason it would be wise to consider the significance of this area when making decisions about any aquaculture applications. The attached pages provide detail and explanation about the importance of this area for herring, and comment on some of the potential impacts of geoduck aquaculture. The concern is that the proposed aquaculture developments could jeopardize the amount and quality of herring spawning habitat leading to a decline in the herring resource, with unforeseen ecosystem impacts. Such impacts could affect other fauna, especially migratory and resident seabirds, as well as traditional, recreational and commercial fisheries.

The attached comments also explain that in the last 80 years herring have used only about twenty percent of the BC coastline for spawning although most spawning occurs in about ten percent, or less, of the total coastline. This assertion is based on analysis of nearly 80 years of monitoring by DFO and over 30,000 spawning records. The implication is that there are many potential aquaculture locations, in the approximately 80-90 percent of BC coastline that herring do not use for spawning. Aquaculture developments in non-herring-spawning areas would not pose the same risks to herring spawning habitat as the proposed developments in Lambert Channel and adjacent areas.

This letter requests that herring spawning habitat issues be considered in decisions about proposed aquaculture developments. In my view such a request is consistent with established policy of your department. Specifically a bullet in your department's Annual Service Plan report (for 2011/2012), reads as follows: "*Enhance protection, management and stewardship of all natural resources, including ecosystems, water quality and quantity, fish and wildlife habitat, and species at risk*." (See Goal 2: Objective 2.1). The purpose of this letter is to ask you to ensure that your staff adhere to this objective when considering the applications for aquaculture development in Lambert Channel.

The rational use and development of our nearshore coastal marine ecosystem is very important for me, as a scientist and as a resident of BC. Responsible aquaculture development should not occur at the expense or well-being of other resources or valuable parts of our ecosystem. Prior to retirement in 2005 I spent much of my career as a research scientist at the Pacific Biological Station, Nanaimo, addressing issues related to spawning and reproductive biology of herring and other forage fishes. A lot of effort was made, by me and others, to identify important areas for herring and other species. It is troubling to see that shellfish aquaculture applications can be considered without any reference to readily accessible baseline information on coastal habitats. I stress, however, that this letter reflects my views as an individual citizen. I do not speak for the Pacific Biological Station, or Fisheries and Oceans Canada, or any other organization.

Thank you for your attention to this issue. Please feel free to contact me if there are any questions or any matters requiring clarification.

Sincerely

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cc: The Honourable Steve Thomson, MLA, Minister of Forests, Lands, and Natural Resource Operations steve.thomspn.mla@leg.bc.ca

cc: Kathy Evans, BC Crown Lands Operations and Aquaculture Manager kathy.evans@gov.bc.ca

cc: Laura Busheikin, Islands Trust, Denman Island Trustee lbusheikin@islandstrust.bc.ca

cc: David Graham, Islands Trust, Denman Island Trustee dgraham@islandstrust.bc.ca

cc: Bruce Jolliffe, Area "A" Director, Comox Valley Regional District bjolliffe@comoxvalleyrd.ca

cc: March Klaver, Senior Aquaculture Advisor, DFO march.klaver@dfo-mpo.gc.ca

cc: Brenda McCorquodale, Senior Aquaculture Management Coordinator, DFO brenda.mccorquodale@dfo-mpo.gc.ca

cc: Diana Trager, Director, Aquaculture Management Division, DFO Diana.Trager@dfo-mpo.gc.ca

Comments on six applications for shellfish aquaculture in Lambert Channel, Baynes Sound and Comox Harbour: impacts on herring spawning with reference to Land file applications: 1414123-1414128

Objectives and a request

This commentary advises that recent applications for tenure for shellfish aquaculture in Lambert Channel and adjacent areas (Appendix Figure 1) would occur on the most important herring spawning habitat on the British Columbia coast. The proposed developments could have deleterious impacts on spawning herring through the use of 'anti-predator' nets that have been shown to snare herring as 'bycatch'. Other deleterious impacts would occur through the loss of submerged vegetation required for herring spawn. The survival of eggs and herring larvae could be deleteriously impacted through increased sedimentation as a consequence of alteration and disruption of the substrates.

The purpose of this letter is not to take issue with the concept or development of geoduck aquaculture. Instead the intention is to point out that herring need high quality spawning habitat. The maintenance of robust herring populations, as important components of our coastal marine ecosystem, requires the protection of their key spawning habitat, in the same way that salmon spawning habitats are protected. *Protection of vital herring spawning habitat does not imply a cessation to shellfish aquaculture. Less than ten percent of the entire BC coast is classified as important herring spawning area. Shellfish aquaculture could occur on the other 90 percent of the coast without direct impacts on herring.*

The request made in this letter is simple: please ensure that any decisions made about the aquaculture applications for tenure recognize the implications on herring spawning habitat and take full account of the importance of herring in the coastal marine ecosystems. This decision should consider:

(1) The potentially adverse effects of the proposed developments on herring, as spawning adults and on developing eggs and larvae;
(2) The corresponding adverse effects on the ecosystem, including possible trophic impacts on migratory and resident marine seabirds that rely on herring;
(3) The economic importance of herring, both as a contributor to commercial fisheries and as an indispensable linkage in traditional and recreational fisheries for piscivorous salmonids: coho and chinook.

The following pages present some brief analyses and summaries of some pertinent information relevant to these decisions.

Background: proposed aquaculture sites versus herring spawning sites

Lambert Channel refers to the waters between Denman and Hornby Island. Baynes Sound is the area between the west side of Denman and the east side of Vancouver Island. Comox Harbour is the water between the north side of Denman Island and Vancouver Island (Fig. 1). The six applications are mainly in Lambert Channel, Comox Harbour and the shoreline immediately north of Cape Lazo, nearly all of which are very important herring spawning habitats. To date, most aquaculture developments have been confined to Baynes Sound and Comox Harbour with relatively little development in Lambert Channel.

The exact locations of herring spawning habitats are well known and are published in DFO publications and websites. The most important spawning habitats are called 'vital' spawning areas. Nearly all of the locations identified in the six applications occur in habitats that are called 'vital'.

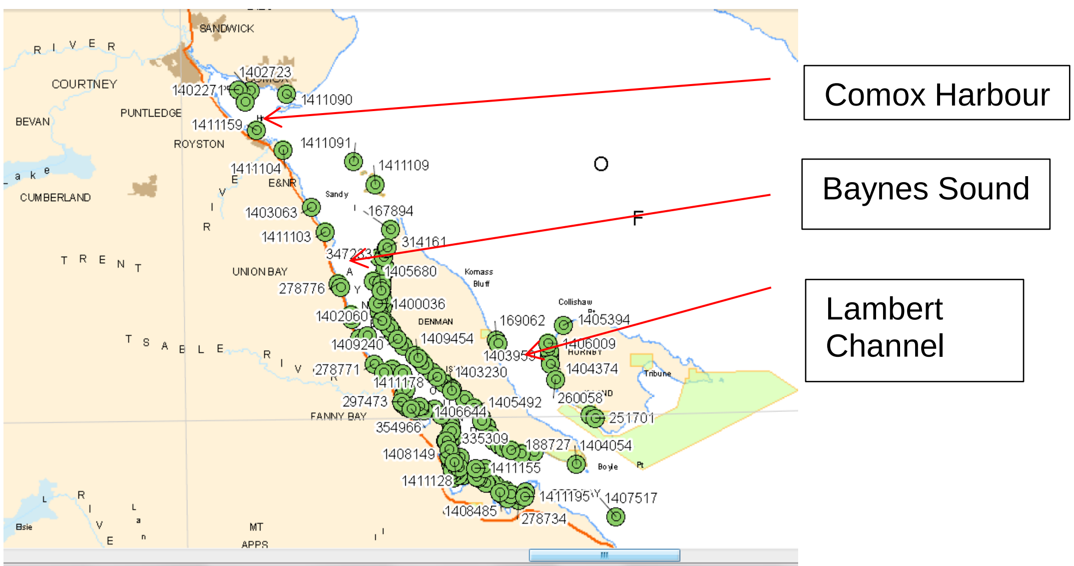


Figure. 1. Lambert Channel, Baynes Sound and Comox Harbour (adapted from a Provincial Government website: **http://www.al.gov.bc.ca/fisheries/**).

Estimation of herring spawning habitat

Herring spawning locations have been documented in most of BC for over 70 years and more than 80 years in the Strait of Georgia where, since 1928, the first detailed spawning records were recorded, showing dates, locations and an estimate of magnitude (total length or egg density). Estimates of spawn abundance are now an integral part of the methodology for annual estimates of herring abundance (e.g. Cleary and Schweigert 2012). Since 1928 herring sites have been documented on a total of 5297 km on the BC coast and 863 km within the Strait of Georgia (defined as the waters between southern Johnstone Strait and the Strait of Juan de Fuca). The total length of the Strait of Georgia coastline is about 3720 km. Therefore, since

1928, herring have spawned one or more times on 22.2 percent of the coastline within the Strait of Georgia but the most important spawning areas occur only on about ten percent of the total coastline.

The amount of spawn per km-segment varies, with some locations having wide, shallow-slope beaches with abundant inter-tidal and submerged vegetation. Such areas often receive substantially more spawn (eggs) than areas with narrow, steep-sloped beaches and limited vegetation. The relative amount of spawn, per km-segment, has been quantified in the form of a 'spawn-habitat-index' (see the following Fisheries and Oceans website for a complete description: *http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/cumulati-eng.html*).

Each km-segment has an associated reference in a statistical database on spawning data within the segment, including an estimate of the cumulative amount of spawn measured since spawn surveys first started. The relative importance of each km-segment can be 'ranked' with the single km-segment with the most spawn having a rank of 1, and the segment with the least spawn having a rank of 5297. It follows that any segment with a rank between 1 and 529 would be among the highest ten percent of the index values – or the top ten percent of the most important spawning areas in BC. The estimates are shown for the entire BC coastline in the following site: *http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/cumulati-eng.html*. ***Eleven of the segments are within the top one percent of all spawn habitat ranks and all but three of the segments have a rank that is among the top ten percent of all BC spawning .*** The spawn data summarized by km-segments in Table 1 correspond, as closely as possible, to the proposed aquaculture locations described in the applications and the numbers on Figure 2. Appendix Table 1 shows all km-segments for all coastal areas in DFO Statistical Area 14 (excluding areas south of Baynes Sound).

Lambert Channel and the immediately adjacent areas are especially important herring spawning area on the BC coast. About 38 percent of all the herring spawning that has ever occurred (based on >30,000 records) in BC has occurred in the two general areas: 35 percent in the Lambert Channel area and 3 percent in the areas immediately north of Cape Lazo (corresponding to the red circles in Figure 2).

The aquaculture applications would occupy a cumulative shoreline length of 24 km, all of which has been classified as 'vital' or especially important herring spawning habitat (Figure 2). ***How much spawning habitat would be impacted? Approximately 17 percent of all the herring spawn that has ever been recorded in BC since 1928 was deposited within the 24 km that are proposed for aquaculture.*** This estimate is conservative when compared to more recent years – and if estimated since 1980, the proportion deposited within the 24 km application area would increase to 22 percent. In other words, on average, about 22 percent of all of the herring spawning in BC would be impacted.

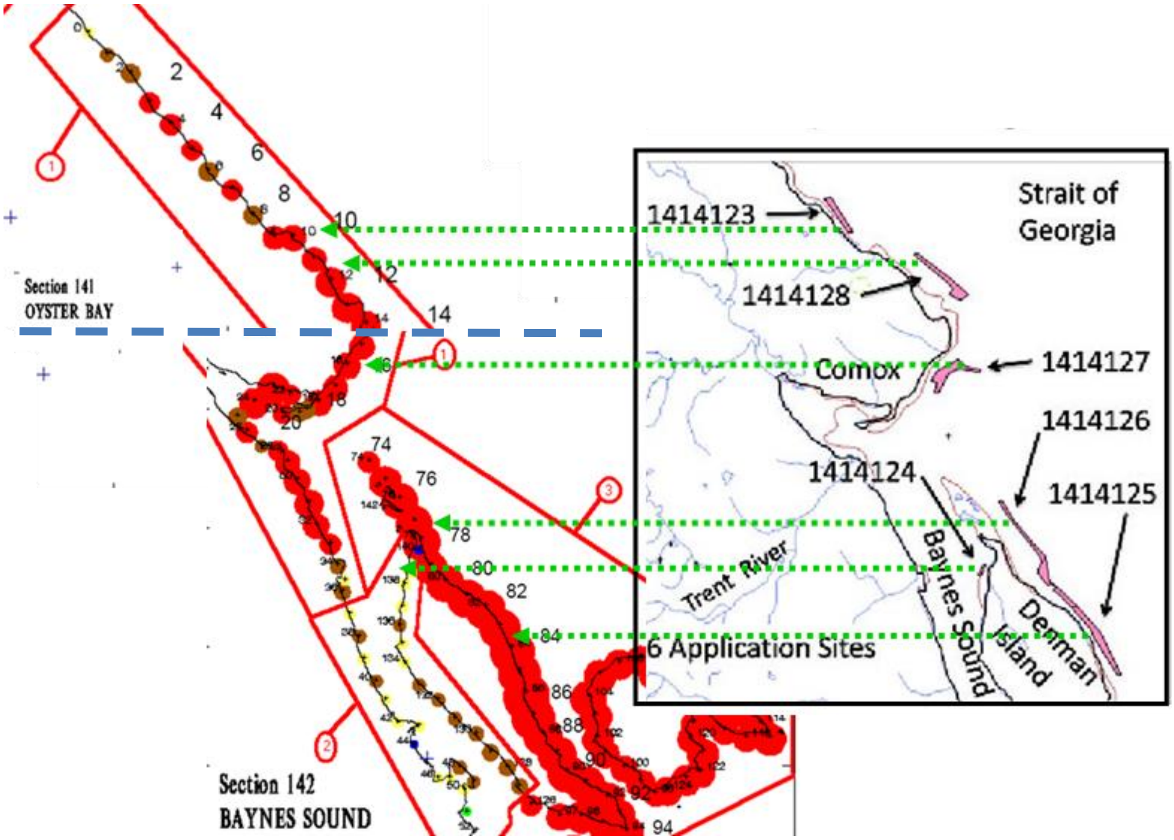


Figure 2. The application sites (numbered within square box) with the positions of herring spawning habitat classified by individual km-segments (red circles) from a DFO website. The dashed blue line separates two different geographical 'Sections': 141 and 142. The dashed green lines indicate the approximate locations of the proposed aquaculture sites relative to herring spawning locations. The exact km-positions are shown by numbers (enlarged and inserted) that correspond to Table 1 and Appendix Table 1. The size and colours of the circles indicate the relative importance of each km-segment circles based on the history of spawning. Large red circles indicate the most important areas as 'vital'. See the following websites for more information: (*http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/141fig-eng.html* *and* *http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/142fig-eng.html*).

Table 1. Details on the herring spawn index by km-segment for proposed shellfish aquaculture sites of six applications (left column) for aquaculture licences in Lambert Channel, Baynes Sound and Comox Harbour (abstracted from Appendix Table 1). The latitude and longitude of each shoreline km (in decimal degrees) is shown for km-segments for each site locations. The herring spawn index is a site-specific estimate of the relative amount of herring spawn since 1928 –presented in units of hectares (ha). See the text for explanations and references. The 'rank' refers to the relative importance of each km-segment according to the spawn deposition that has been assessed for the entire BC coast. *Eleven of the segments are within the top one percent (bold font) of all spawn habitat values and all but three of the segments have a rank that is among the top ten percent of all BC spawning areas (indicated by underlined font).* The 'percent SOG' spawn is an estimate of the total percentage of spawn in the Strait of Georgia (since 1928) deposited on each one-km segment. The cumulative total of this column is the proportion of the total spawn habitat that would be impacted by each of the applications (bold font in blank rows). The final column is the estimated annual value (in thousands of dollars) for each spawn segment (assuming a total annual export value of the fishery of $30 million).

Application No. (last three digits)	Latitude	Longitude	Location Name	Frequency	Index (ha)	Index (ha)	Rank	Km-segment	Section	Percent SOG spawn	Value per km per year ($thousands)
127	49.683	-124.878	Willemar Bluff	26	162.1822	0.0162182	90	16	142	0.445	59.1
127	49.673	-124.887	Point Holmes	22	140.1608	0.0140161	117	17	142	0.384	51.0
127	49.667	-124.898	Willemar Bluff	20	137.2893	0.0137289	127	18	142	0.376	50.0
										1.205	$**160.1**
126	49.623	-124.842	Fillongley Park	40	192.8969	0.0192897	**51**	76	142	0.529	70.2
126	49.613	-124.832	Fillongley Park	41	195.0534	0.0195053	**48**	77	142	0.535	71.0
126	49.605	-124.827	Fillongley Park	42	202.9374	0.0202937	**45**	78	142	0.556	73.8
126	49.593	-124.82	Fillongley Park	29	151.4597	0.015146	102	79	142	0.415	55.1
126	49.587	-124.81	Fillongley Park	47	229.9909	0.0229991	**33**	80	142	0.631	83.7
126	49.580	-124.795	Fillongley Park	49	245.1589	0.0245159	**25**	81	142	0.672	89.3
										3.338	$**443.3**
125	49.575	-124.782	Fillongley Park	48	249.5854	0.0249585	**21**	82	142	0.684	90.9
125	49.567	-124.772	Fillongley Park	62	320.5448	0.0320545	**6**	83	142	0.879	116.7
125	49.557	-124.763	Fillongley Park	74	358.5672	0.0358567	**3**	84	142	0.983	130.6
125	49.547	-124.758	Fillongley Park	62	320.0111	0.0320011	**7**	85	142	0.877	116.5
125	49.537	-124.753	Whalebone Pt	76	370.998	0.0370998	**2**	86	142	1.017	135.1
125	49.527	-124.748	Whalebone Pt	66	330.0456	0.0330046	**4**	87	142	0.905	120.2
										5.345	$**710.0**
124	49.590	-124.833	Henry Bay	5	13.2622	0.0013262	1324	139	142	0.036	4.8
124	49.600	-124.828	Henry Bay	2	5.3129	0.0005313	2337	140	142	0.015	1.9
										0.051	**$6.8**
123	49.762	-124.953	Little Rvr	8	35.9842	0.0035984	501	7	141	0.260	13.1
123	49.750	-124.938	Little Rvr	10	24.9175	0.0024918	719	8	141	0.180	9.1
123	49.740	-124.923	Little Rvr	11	42.9452	0.0042945	427	9	141	0.310	15.6
										0.749	$**37.8**
128	49.730	-124.895	Little Rvr	21	72.6015	0.0072602	252	11	141	0.524	26.4
128	49.720	-124.883	Little Rvr	31	172.2568	0.0172257	76	12	141	1.243	62.7
128	49.708	-124.872	Little Rvr	33	188.9875	0.0188988	56	13	141	1.363	68.8
128	49.700	-124.858	Kye Bay	26	171.9943	0.0171994	78	14	141	1.241	62.6
										4.371	**$221.0**
										15.6%	**$1579.0**

Impacts of the proposed aquaculture operations

The applications pertain to culture of geoducks and sea cucumbers. *A priori,* impacts can be evaluated either as an impacts on the physical habitat (mainly the bottom sediments) or biotic habitat (impacts of other species that use the habitat) or socio-economic impact, including the impact on recreational and or commercial fisheries. The locations of the application can be examined relative to (1) the potential shoreline vegetation and (2) the estimated widths of herring spawns as determined by divers during annual herring spawn surveys.

The first impact on the proposed culture sites would be on submerged vegetation. The locations of the proposed aquaculture sites overlap with submerged shoreline vegetation distribution used by herring for spawning (from Haegele and Hamey, 1981). Inter-tidal and submegered vegetation is an essential component of herring spawning habitat. Reduction or destruction of this component of the habitat would have a corresponding impact on the potential for herring spawning.

If the aquaculture applications pertain to sea cucumber culture then there are some other, unresolved issues. Some advocates of sea cumber aquaculture (or 'ranching') advise that they graze only dead detritus, and pose no risk to natural fauna. This is not consistent with the evidence presented by Haegele (1993) that examined consumption of herring eggs by (*Parastichopus californicus*). In tests in laboratory aquaria six of nine *Parastichopus californicus* consumed herring eggs. Haegele (Table 2) estimated the daily ration of these animals to be about 9000 eggs/d. Therefore there is a valid concern about the potential predation by sea cucumber on herring spawning. Clearly, without more definitive examination of this issue, the available evidence indicates that the culture of sea cucumbers could present a risk to herring spawn in the impacted areas.

The most recent review of geoduck aquaculture is a paper by Sauchyn et al.(2013). The main conclusions and advice of the *Sauchyn et al* are copied below (in Italics):

CONCLUSIONS *– extracted from Sauchyn et al.(2013)*

"Larger-scale research is required to examine potential effects due to commercial-scale, more frequent culture/harvest events occurring at various times of the year. Additional work would include a higher-power experimental design to evaluate the potential effects of anti-predator tubes and nets (which provide structure and could lead to changes in abundance and diversity of some organisms) and harvesting. Potential impacts of culture/harvest on local sensitive aquatic vegetation (e.g. eelgrass), water column properties, and larger infaunal organisms should be examined."

Although this conclusion seems to be directed more at vegetation and infaunal animals (creatures that live in the sediments) it applies especially to benthic spawning fishes, such as herring, sand lance, surf smelt and many other species.

ADVICE *from Sauchyn et al.(2013).*

"The following question was posed by Fishery and Aquaculture Management in the official Request for Science Information and/or Advice: "Does harvesting geoduck in the intertidal or subtidal marine environment have a significant environmental impact?" The current small-scale (3 x 20 m) and short-term (1-year) intertidal study revealed few ecologically-significant

effects of intertidal geoduck culture/harvest. There were two notable exceptions. The silt and clay fraction of the sediment increased significantly immediately after (1 day) harvesting, but only within the culture plot (0 m) and the impact was short-lived, sediment structure returning to baseline values within 123 days after harvesting. There was also a lack of seasonal increase in infaunal abundance and richness after harvesting in the harvest zone (0 m), an increase evident at 10 m outside the disturbed plot. The study, unfortunately, cannot assess the rate of recovery of the infaunal community after harvesting due to the subsequent seasonal decline in abundance and richness and lack of long-term sampling. These two impacts were restricted to the area of harvest and the change in sediment composition was relatively short-lived (123 days). It must be noted, however, that changes in habitat, size of the culture/harvest plot, frequency of culture, and seasonal timing of out-planting and harvest may alter the degree of impact on, and rate of recovery of, the marine environment. Further research is required to examine potential culture/harvest effects due to commercial-scale, more frequent culture/harvest events occurring at various times of the year in varying environments."

These conclusions also are summarized in a 2012 DFO 'Science Advisory Report' based on the same study. Both reports emphasize that the comments were limited to 'short-term' impacts. Neither report considered the impacts on inter-tidal and shallow sub-tidal spawning habitats on fish species such as herring, sand lance or surf smelt.

Therefore in addition to the conclusions from Sauchyn et al.(2013) this document points out that the proposed aquaculture could lead to (i) a loss or disruption of macrophytes used as spawning substrates; and (ii) potential deleterious impacts of sediments on developing fish eggs. The loss of spawning substrate has an obvious impact. The additional impacts of increased sedimentation are a particular concern for herring embryos and larvae as described in recent work (Griffin et al. 2009, 2013).

A further important point about severe alteration of shoreline vegetation and substrates is that the impacts could well extend beyond the exact boundaries of the application sites. An industrial project within part of a major herring spawning region, such as Lambert Channel may impact much more than the specific sites and extend beyond the culture sites to adjacent locations.

Ecosystem and socio-economic impacts

There is a risk that any major disruption to herring spawning could lead to either a change of herring spawning areas or a decline in overall abundance of herring in the Strait of Georgia. In both cases there could be cascading and increasing adverse impacts on other valued ecosystem components, such as marine birds and salmon.

Spawning habitat is essential to produce commercially valuable herring. It follows that spawning habitat then has economic 'worth' that can be evaluated by pro-rating that value of the fishery (as landed value, or as a contribution to the GDP) according to the amount of spawn habitat that is required to sustain it (Hay, 1991). This value was estimated in Table 1 (last column) which shows the estimated annual return, in dollars, of each km of herring spawn in herring Sections 142 and 141. The estimated annual worth of the 24 km of impacted coastline, as herring spawning habitat, is estimated at about $1.58 million dollars per year. This estimate is based on an estimated worth of the commercial fishery in BC at about $30 million per year, which is the value of the herring as a Canadian export product to Japan (Japanese Customs data). This estimate is actually very conservative because the economic value of each km was pro-rated according to the total catch and contribution of spawning areas *throughout all of BC*. If the estimation were confined to the spawning and value of herring landed from within the Strait of Georgia, then the estimated economic worth of each km-segment of herring spawning habitat, within the Strait, would increase substantially, by a factor of two or more.

The point of the preceding calculations is to illustrate that undisturbed herring spawning habitat in Lambert Channel, Baynes Sound and Comox Harbour has ***significant intrinsic economic value*** – that sometimes can be estimated in terms of monetary value. However, the contribution to the commercial industry is just one form or estimate of such value - and there are others – that also might be weighed in terms of its extraordinary contribution to this ecosystem (as a trophic base for salmon and seabirds). **It would be counter-productive to destroy the habitat for one species, especially one as important as herring, in a quest to culture another.** It is unnecessary to degrade or destroy the most important herring spawning habitat on the BC coast – especially when there are areas of the coastline that could be considered and that do not pose the same risks.

There also would be impacts on commercial fisheries. Of course, one is a possible decline in herring spawning biomass in the Strait of Georgia. Another impact of concern is the presence of submerged infra-structure (tubing or anti-predator nets) that could adversely affect both commercial and recreational fishing gear, leading to declines in catches.

Recommendations

This document echoes the main points of the CSAS report by Sauchyn et al (2013) about impacts of geoduck culture: that there is insufficient information to evaluate the long-term ecological impacts and more investigation is required. This applies especially to proposed aquaculture developments in Lambert Channel that has the most important spawning areas on the BC coast. Therefore there is ample reason for concern that there could be severe negative impacts on herring spawning areas. Such impacts may also affect other species, such as sand lance and surf smelt that also spawn in inter-tidal and shallow sub-tidal habitats. This also warrants investigation. The most important recommendation, however, is that intense aquaculture development should not proceed in the vital herring spawning areas of Lambert Channel.

References

Cleary, J.S. and J.F. Schweigert. 2012. Stock Assessment and Management Advice for the British Columbia Herring Stocks: 2010 Assessment and 2011 Forecasts. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/115. viii + 90 p.

DFO. 2012. Assessing potential benthic habitat impacts of small-scale, intertidal aquaculture of the geoduck clam (*Panopea generosa*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep.2011/083.

Griffin, F.J., E.H. Smith, C.A. Vines, and G.N. Cherr. 2009. Impacts of suspended sediments on fertilization, embryonic development, and early larval life stages of the Pacific Herring, *Clupea pallasi*. *Biological Bulletin*, 216:175-187.

Griffin, F.J., T. DiMarco, K.L. Menard, J.A. Newman, E.H. Smith, C.A. Vines, and G.N. Cherr**.** 2012. Impacts of suspended sediments on Pacific herring (*Clupea pallasi*) larval survival and condition. *Estuaries and Coasts*, DOI 10.1007/s12237-012-9518-7.

Haegele, C. W., and M. J. Hamey. 1981. Shoreline vegetation on herring spawning grounds for Comox, Denman Island and Hornby Island. Can. MS Rep. Fish. Aquat. Sci. 1617: 41 p.

Haegele, C. W. 1993. Epibenthic invertebrate predation of Pacific herring, *Clupea pallasi*, spawn in British Columbia. Can Field-Nat 107(1): 83-91.

Hay, D.E. 1991. How much is herring worth? Potential economic and ecological consequences of impacts on herring spawning areas, p. 583-591. *In* Proceedings of the International Herring Symposium, October 23-25, 1990. Anchorage, Alaska. Alaska Sea Grant Program Report No.9101.

Hay, D.E., C. Fort, J. F. Schweigert, L. Hamer and P.B. McCarter. 2011. Investigating changes in Pacific herring spawn intensity (layers). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/064. vi + 89 p.

Sauchyn, L., Pearce, C.M., Blackburn, J., Keddy, L., and Williams, S. 2013. Assessing potential benthic habitat impacts of small-scale, intertidal aquaculture of the geoduck clam (*Panopea generosa*). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/001. vi + 34 p.

Appendix Figure 1. Advertisement from the Comox Valley Echo.

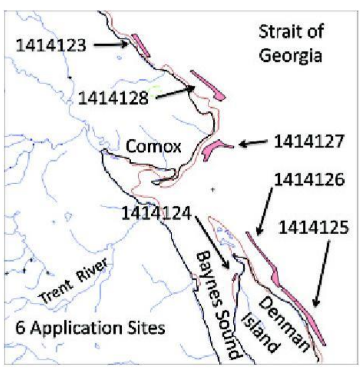
Land Act: Notice of Intention to Apply for a Disposition of Crown Land

Take notice that **Salish Sea Farms LP of Comox, BC,** intends to make six applications to Ministry of Natural Resource Operations (MFLNRO), West Coast Service Centre, for a **Licence of Occupation – Shellfish** (Geoduck on bottom) situated on Provincial Crown lands located within the core territory of the K'omoks First Nation.

The following Land File Numbers have been established for the applications; **1414123, 1414124, 1414125, 1414126, 1414127, 1414128**. Written comments concerning these applications should be directed to the Manager, Aquaculture, Ministry of Forests, Lands and Natural Resource Operations 2500 Cliffe Avenue, Courtenay, BC, V9N 5M6, or emailed to: **AuthorizingAgency.Nanaimo@gov.bc.ca**. Comments will be received by MFLNRO until November 28, 2013. MFLNRO may not be able to consider comments received after this date. Please visit our website:

http://arfd.gov.bc.ca/ApplicationPosting/index.jsp
for more information.

Be advised that any response to this advertisement will be considered part of the public record. For information, contact the FOI Advisor at the Ministry of Forests, Lands and Natural Resource Operations regional office.



Appendix Table 1. Details on the herring spawn index by km-segment for herring sections 142 and 143, with reference to the positions of six applications (shaded boxes) for aquaculture applications in Lambert Channel, Baynes Sound and Comox Harbour. All data on herring spawning were taken from DFO websites indicated in the text. Each km-segment corresponds to the numbers shown in Figure 1. The latitude and longitude of each shoreline km (in decimal degrees) is shown for km-segments in different locations. The herring spawn index is a site-specific estimate of the relative amount of herring spawn since 1928 –presented in units of hectares (ha). See the text for explanations and references. The 'rank' is the rank among the more than 5000 km included in the estimation of the herring spawn index. The 'percent SOG' spawn is an estimate of the total percentage of spawn in the Strait of Georgia (since 1928) deposited on the one km-segment. The final column is the estimated monetary value (dollars/km/year) of the herring spawn as a support to the annual herring fishery (see text for explanation). The yellow highlighted rows refer, approximately, to the km segments related to each of six different applications.

Km-segment	Application (last 3 digits)	Latitude	Longitude	Location Name	Freq-uency	Index (ha)	Rank	Section	Percent SOG spawn	Value (Dollars/km/y)
15		49.692	-124.868	Willemar Bluff	19	139.9	120	142	0.384	50945
16	127	49.683	-124.878	Willemar Bluff	26	162.2	90	142	0.445	59057
17	127	49.673	-124.887	Point Holmes	22	140.2	117	142	0.384	51038
18	127	49.667	-124.898	Willemar Bluff	20	137.3	127	142	0.376	49993
19		49.662	-124.912	Willemar Bluff	9	64.1	300	142	0.176	23344
20		49.662	-124.923	Union Bay	11	58.0	327	142	0.159	21131
21		49.663	-124.907	Union Bay	5	23.8	755	142	0.065	8660
22		49.670	-124.918	Comox Hrbr	10	45.6	397	142	0.125	16612
23		49.673	-124.93	Comox Bar	51	206.6	43	142	0.566	75228
24		49.667	-124.943	Comox Bar	28	168.4	84	142	0.462	61315
25		49.660	-124.955	Comox Hrbr	9	49.3	380	142	0.135	17948
26		49.653	-124.948	Gartley Pt	12	72.8	249	142	0.200	26515
27		49.647	-124.938	Gartley Pt	3	17.0	1056	142	0.047	6204
28		49.645	-124.927	Gartley Pt	9	51.3	364	142	0.141	18671
29		49.640	-124.92	Gartley Pt	20	120.7	151	142	0.331	43957
30		49.632	-124.913	Union Bay	21	125.9	141	142	0.345	45856
31		49.622	-124.905	Hart Cr	34	176.4	71	142	0.483	64218
32		49.612	-124.9	Hart Cr	28	137.8	126	142	0.378	50162
33		49.603	-124.89	Hart Cr	21	92.4	194	142	0.253	33655
34		49.593	-124.885	Hart Cr	12	53.6	350	142	0.147	19527
35		49.587	-124.88	Hart Cr	6	14.4	1234	142	0.039	5239
36		49.582	-124.882	Union Bay	21	35.2	509	142	0.097	12826
37		49.572	-124.877	Union Bay	5	12.0	1435	142	0.033	4387
38		49.562	-124.87	Union Bay	8	20.8	870	142	0.057	7576
39		49.552	-124.867	Hind. Cr	5	15.7	1150	142	0.043	5708

40		49.542	-124.858	Hind. Cr	8	19.0	940	142	0.052	6912
41		49.533	-124.852	Hind. Cr	3	10.3	1569	142	0.028	3765
42		49.523	-124.843	Buckley Bay	5	12.9	1363	142	0.035	4713
43		49.522	-124.828	Buckley Bay	2	3.9	2714	142	0.011	1427
45		49.505	-124.823	Fanny Bay	6	9.6	1673	142	0.026	3482
46		49.498	-124.815	Shingle Spit	2	6.6	2071	142	0.018	2418
47		49.498	-124.807	Shingle Spit	2	5.3	2340	142	0.015	1929
48		49.503	-124.8	Ship Pt	10	29.2	618	142	0.080	10642
49		49.497	-124.79	Ship Pt	6	19.2	925	142	0.053	7007
50		49.493	-124.797	Ship Pt	10	19.2	928	142	0.053	6992
51		49.483	-124.795	Mud Bay (Baynes)	3	5.4	2309	142	0.015	1982
52		49.475	-124.788	Mud Bay (Baynes)	1	2.1	3531	142	0.006	768
55		49.467	-124.767	Deep Bay	1	4.5	2545	142	0.012	1645
56		49.460	-124.755	Deep Bay	2	9.3	1707	142	0.026	3387
58		49.453	-124.747	Deep Bay	1	4.8	2480	142	0.013	1742
59		49.457	-124.738	Deep Bay	4	9.3	1708	142	0.026	3387
60		49.462	-124.727	Collishaw Pt	4	19.2	931	142	0.053	6983
61		49.465	-124.73	Collishaw Pt	35	127.5	140	142	0.349	46410
62		49.467	-124.72	Collishaw Pt	27	116.3	158	142	0.319	42356
74		49.640	-124.863	Sandy Is	8	40.6	448	142	0.111	14789
75		49.632	-124.852	Fillongley Park	34	156.1	99	142	0.428	56831
76	*126*	*49.623*	*-124.842*	*Fillongley Park*	*40*	*192.9*	*51*	*142*	*0.529*	*70242*
77	*126*	*49.613*	*-124.832*	*Fillongley Park*	*41*	*195.1*	*48*	*142*	*0.535*	*71027*
78	*126*	*49.605*	*-124.827*	*Fillongley Park*	*42*	*202.9*	*45*	*142*	*0.556*	*73898*
79	*126*	*49.593*	*-124.82*	*Fillongley Park*	*29*	*151.5*	*102*	*142*	*0.415*	*55153*
80	*126*	*49.587*	*-124.81*	*Fillongley Park*	*47*	*230.0*	*33*	*142*	*0.631*	*83749*
81	*126*	*49.580*	*-124.795*	*Fillongley Park*	*49*	*245.2*	*25*	*142*	*0.672*	***89273***
82	125	49.575	-124.782	Fillongley Park	48	249.6	21	142	0.684	**90885**
83	125	49.567	-124.772	Fillongley Park	62	320.5	6	142	0.879	**116724**
84	125	49.557	-124.763	Fillongley Park	74	358.6	3	142	0.983	**130569**
85	125	49.547	-124.758	Fillongley Park	62	320.0	7	142	0.877	**116529**
86	125	49.537	-124.753	Whalebone Pt	76	371.0	2	142	1.017	135096
87	125	49.527	-124.748	Whalebone Pt	66	330.0	4	142	0.905	120183
88		49.518	-124.742	Whalebone Pt	45	228.5	35	142	0.626	83207
89		49.510	-124.732	Gravelly Bay	44	229.0	34	142	0.628	83391
90		49.502	-124.725	Gravelly Bay	58	288.7	10	142	0.792	105141
91		49.497	-124.712	Gravelly Bay	53	268.7	15	142	0.737	97854
92		49.490	-124.697	Gravelly Bay	47	226.5	37	142	0.621	82470
93		49.483	-124.688	Gravelly Bay	27	137.8	125	142	0.378	50176
94		49.475	-124.683	Whalebone Pt	37	179.4	65	142	0.492	65322
95		49.478	-124.7	Whalebone Pt	28	149.2	106	142	0.409	54347
96		49.482	-124.715	Whalebone Pt	36	185.7	57	142	0.509	67612
97		49.482	-124.73	Metcalf Bay	22	111.0	166	142	0.304	40421
98		49.492	-124.663	Metcalf Bay	18	87.3	208	142	0.239	31794
99		49.497	-124.673	Ford Cv	31	161.0	91	142	0.441	58612
100		49.503	-124.685	Ford Cv	25	121.8	150	142	0.334	44369
101		49.510	-124.698	Ford Cv	42	189.7	55	142	0.520	69077
102		49.517	-124.703	Ford Cv	38	170.5	81	142	0.467	62082
103		49.527	-124.705	Ford Cv	38	182.2	63	142	0.500	66353
104		49.535	-124.71	Collishaw Pt	48	251.9	19	142	0.691	91740

105		49.545	-124.702	Collishaw Pt	35	183.0	60	142	0.502	66645
106		49.550	-124.688	Collishaw Pt	28	150.9	103	142	0.414	54952
107		49.552	-124.673	Tralee Pt	27	145.9	111	142	0.400	53131
108		49.547	-124.662	Tralee Pt	51	271.1	14	142	0.743	98705
109		49.542	-124.648	Tralee Pt	44	239.5	29	142	0.657	87224
110		49.538	-124.637	Tralee Pt	42	226.2	38	142	0.620	82365
111		49.537	-124.622	Tralee Pt	50	247.6	23	142	0.679	90174
112		49.530	-124.61	Tralee Pt	27	134.3	129	142	0.368	48893
113		49.528	-124.602	Tralee Pt	27	134.7	128	142	0.369	49050
114		49.523	-124.59	Whaling Station Bay	19	100.9	178	142	0.277	36729
115		49.517	-124.583	Flora Islet	30	149.6	105	142	0.410	54471
116		49.517	-124.6	Whaling Station Bay	22	115.0	160	142	0.315	41889
117		49.520	-124.615	Whaling Station Bay	22	114.9	161	142	0.315	41836
118		49.527	-124.627	Whaling Station Bay	25	122.0	149	142	0.335	44436
119		49.523	-124.637	Tribune Bay	23	111.5	165	142	0.306	40587
120		49.517	-124.638	Downes Pt	29	147.7	109	142	0.405	53787
121		49.510	-124.63	Dunlop Pt	38	191.2	52	142	0.524	69631
122		49.502	-124.632	Dunlop Pt	33	167.0	87	142	0.458	60805
123		49.498	-124.642	Dunlop Pt	34	173.3	73	142	0.475	63092
124		49.493	-124.655	Dunlop Pt	31	159.2	92	142	0.437	57981
126		49.487	-124.75	Metcalf Bay	17	60.2	317	142	0.165	21910
127		49.495	-124.758	Metcalf Bay	14	38.6	468	142	0.106	14066
128		49.503	-124.767	Metcalf Bay	16	43.7	418	142	0.120	15931
129		49.510	-124.778	Metcalf Bay	22	56.7	334	142	0.156	20658
130		49.518	-124.788	Metcalf Bay	15	39.5	463	142	0.108	14366
131		49.525	-124.803	Metcalf Bay	12	32.7	560	142	0.090	11896
132		49.533	-124.815	Metcalf Bay	10	26.6	677	142	0.073	9702
133		49.540	-124.828	Metcalf Bay	9	24.6	732	142	0.067	8949
134		49.550	-124.838	Metcalf Bay	7	19.2	932	142	0.053	6980
135		49.558	-124.84	Henry Bay	7	19.1	937	142	0.052	6958
136		49.567	-124.842	Henry Bay	12	29.9	609	142	0.082	10884
137		49.575	-124.84	Henry Bay	9	21.7	834	142	0.059	7897
138		49.585	-124.838	Henry Bay	8	20.1	893	142	0.055	7332
139	124	49.590	-124.833	Henry Bay	5	13.3	1324	142	0.036	4829
140	124	49.600	-124.828	Henry Bay	2	5.3	2337	142	0.015	1935
141		49.608	-124.843	Henry Bay	1	2.6	3290	142	0.007	930
142		49.618	-124.853	Henry Bay	1	2.6	3291	142	0.007	930
0		49.833	-125.055	Cape Lazo	1	8.3	1837	141	0.002	3015
1		49.823	-125.042	Cape Lazo	1	8.3	1838	141	0.002	3015
2		49.815	-125.025	Kitty Coleman Beach	9	35.2	510	141	0.009	12826
3		49.802	-125.012	Kitty Coleman Beach	10	36.1	497	141	0.009	13128
4		49.792	-124.997	Kitty Coleman Beach	9	40.9	445	141	0.011	14877
5		49.780	-124.982	Little Rvr	8	35.1	515	141	0.009	12781
6		49.770	-124.97	Little Rvr	7	28.7	631	141	0.008	10443
7	*123*	*49.762*	*-124.953*	*Little Rvr*	*8*	36.0	*501*	*141*	0.009	*13103*
8	*123*	*49.750*	*-124.938*	*Little Rvr*	*10*	24.9	*719*	*141*	0.007	*9074*
9	*123*	*49.740*	*-124.923*	*Little Rvr*	*11*	42.9	*427*	*141*	0.011	*15638*
10		49.740	-124.91	Little Rvr	26	75.5	237	141	0.020	27482
11	128	49.730	-124.895	Little Rvr	21	72.6	252	141	0.019	26437
12	128	49.720	-124.883	Little Rvr	31	172.3	76	141	0.045	62726

13	128	49.708	-124.872	Little Rvr	33	189.0	56	141	0.050	68818
14	128	49.700	-124.858	Kye Bay	26	172.0	78	141	0.045	62630
23		49.898	-125.155	Oyster Bay	2	2.8	3132	141	0.001	1033
24		49.898	-125.147	Oyster Bay	1	2.0	3568	141	0.001	742
25		49.893	-125.13	Oyster Bay	1	2.0	3569	141	0.001	742
26		49.888	-125.12	Oyster Bay	6	10.4	1560	141	0.003	3793
27		49.878	-125.113	Oyster Bay	5	10.0	1608	141	0.003	3641
28		49.868	-125.113	Oyster Bay	3	6.3	2124	141	0.002	2306
						13861.1			35.494	