The Science Case for a Marine Protected Area in Lambert Channel: Conservation Benefits for Pacific Herring

Prepared for:
Conservancy Hornby Island
July, 2020
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Executive Summary

Pacific herring (*Clupea pallasii*) occurring off Canada's Pacific Coast are assessed by Department of Fisheries and Oceans in five Stock Assessment Regions (SARs). Spawning biomass in four of the five Pacific SARs are depleted relative to their historic highs and are close to their limit reference points of 0.3 SB_0(30% of unfished spawning biomass). Those SARs have shown little or no recovery, even after commercial fishing activity ceased. While the Salish Sea/Strait of Georgia component still supports a roe fishery and is considered to be in better condition compared with the other four SARs for Pacific herring, abundance has followed a declining trend since 1995. Conservation groups have expressed concern that the remaining population cannot support current levels of fishing pressure from the spring herring roe fishery conducted by purse seiners and gill-net vessels.

This report also provides details of the location and importance of Pacific herring spawn in the Salish Sea/Strait of Georgia Stock Assessment Region (SAR). Using available Department of Fisheries and Oceans data from 1951 to 2019, it is shown that the spatial extent of spawning has significantly reduced over that period. Early in these data, spawning was broadly documented throughout the eastern Strait of Georgia from the southern tip of Vancouver Island to Quadra Island. In contrast, the distribution of spawning in 2019 was spatially truncated, and occurred from Cape Lazo to off Nanaimo only. The waters around Hornby and Denman Islands are at the centre of the remaining areas of active spawning. These results contrast with the archaeological record which provide persistent evidence of a large number of spawning sites throughout the Salish Sea.

Considering Department of Fisheries and Oceans diver survey information from 1988 to 2019 at the finest level of spatial aggregation available, it is shown that locations around Hornby and Denman Islands include many of the most important spawning areas for herring in the Strait of Georgia SAR. For example, three highly-ranked and well-sampled locations (Collishaw Pt, Komas Bluff and Fillongley Park) contribute a significant fraction (about 21%) of all herring spawning in the Strait of Georgia. The importance of those areas for spawning area seems to be stable from year to year, meaning that an MPA could have lasting importance to the conservation of Pacific herring.

As do all of Canada's marine fish populations, Pacific herring are confronted with a rapidly-changing ocean environment. The Strait of Georgia herring SAR faces increased temperature and acidity, changes in prey fields and competition from other species. The consequences of these changes to the health of the population is unknown. While TAC-based approaches may provide appropriate techniques for managing exploited marine populations in the past, additional management measures (such as a Marine Protected Area) could provide an extra level of insurance for the continuance of the Strait of Georgia Pacific herring SAR against the context of changing ocean conditions.

To provide further background for a possible Marine Protected Area (MPA) intended to protect spawning Pacific herring in the waters around Hornby and Denman Island, this report also contains a literature review on the international and Canadian experience for conservation of marine fish species using MPAs. Among the key points from the literature review, past studies suggest that involving the community, First Nations and the fishing industry early in talks and

planning seems to be critical in having a successful outcome as measured by the establishment of an MPA that both delivers conservation benefits and is also supported broadly by the community.

Background: While there is some uncertainty regarding stock structure of Pacific herring, Canada Department of Fisheries and Oceans provides management advice for five Stock Assessment Regions (SARs) in BC waters. The Salish Sea/Strait of Georgia Stock Assessment Region (referred to as SoG by Fisheries and Oceans Canada, and used here) is considered to the most abundant remaining component of the five Stock Assessment Regions (SARs) for Pacific herring (*Clupea pallasii*) occurring in British Columbia waters. Four of the five Pacific SARs are depleted relative to their historic highs and are close to their limit reference points (LRP) of 0.3 SB_0(30% of unfished spawning biomass). Those SARs have shown little or no recovery, even when commercial fishing activity ceased (Fig. 1). While the SoG component (shown on the top left panel below) still supports a roe fishery and is considered to be in better condition compared with the other four SARs for Pacific herring, abundance has followed a declining trend since 1995. Conservation groups have expressed concern that the remaining population cannot support current levels of fishing pressure from the spring herring roe fishery conducted by purse seiners and gill-net vessels. Hence, they are interested in exploring methods for conserving this critical component of the Salish Sea Ecosystem.

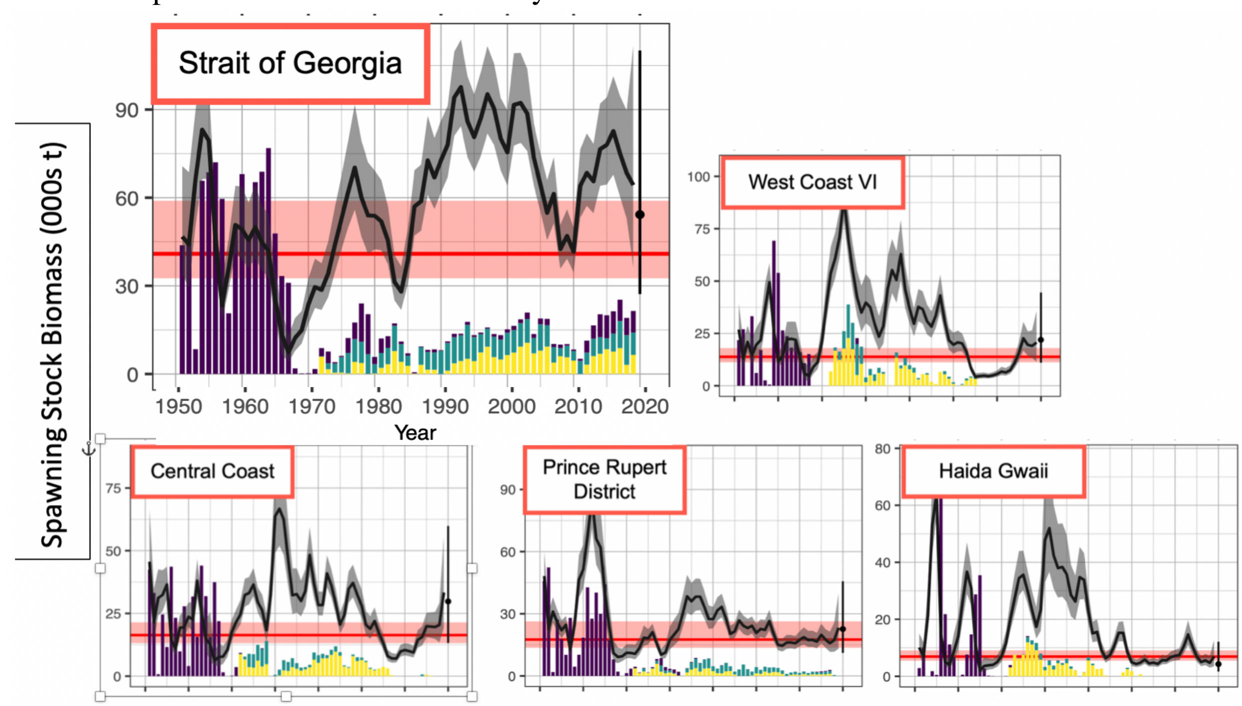


Fig. 1. Estimates of spawning biomass for the five major Stock Assessment Regions for Pacific herring, 1951 to 2019. Circle and vertical line indicate the median and 90% credible interval, respectively, of forecast spawning biomass in 2020 in the absence of fishing. Vertical bars indicate commercial catch, excluding spawn-on-kelp. The red horizontal line indicates the limit reference point for the five SARs. The Strait of Georgia is emphasized. (Extracted from DFO 2020).

The coastal environment around Hornby and Denman Islands is well known as an important location for herring spawning within the SoG component. This annual aggregation of herring underpins abundant and diverse assemblages of marine life including seabirds, shellfish, Pacific salmon and marine mammals (see the Atlas of Marine Life compiled by Conservancy Hornby Island for more details (CHI 2019)). Conservancy Hornby Island has requested a report describing the science basis for a Marine Protected Area in Lambert Channel for Pacific herring in the waters around Hornby Island, given the July 11, 2020 announcement that the Government of Canada continues to work toward its target of protecting 25 per cent of marine and coastal areas by 2025, working toward 30 per cent by 2030. Through the Global Ocean Alliance, Canada joined a growing number of like-minded countries that will advocate internationally for 30 per cent conservation by 2030 around the world.

This report first provides a review of the scientific literature concerning the conservation benefits for marine fishes, especially forage species such as herring. Using Department of Fisheries and Oceans data, the report then provide an analysis of locations in the SoG component that are the most significant for herring spawning, and how that significance varies interannually.

Literature Review:

MPA Lessons from Other Countries

Conservation Benefits

A review of the international literature reveals a situation where the full promise of MPAs for conservation and protection of biodiversity is rarely achieved.

Edgar et al. (2014) completed a comprehensive study of the conservation benefits of 87 MPAs globally. Those workers found that conservation benefits increased exponentially with the accumulation of five key features: no fisheries take, well enforced, long-established (>10 years), large (>100 km^2), and isolated by deep water or sand. Using effective MPAs with four or five key features as an unfished standard, comparisons of underwater survey data from effective MPAs with predictions based on survey data from fished coasts indicate that total fish biomass has declined about two-thirds from historical baselines as a result of fishing. Effective MPAs also had twice as many large (>250 mm total length) fish species per transect, five times more large fish biomass, and fourteen times more shark biomass than fished areas. Edgar et al. (2014) also found that most (59%) of the MPAs studied were ineffective: they had only one or two key features and were not distinguishable from fished sites using the metrics in their study (biomass, fish size composition).

Sumaila et al. (2000) provided a synthesis of the current literature on the potential of marine protected areas (MPAs). Those authors concluded, as did Edgar et al. (2014), that MPAs can be a useful management tool for limiting the ecosystem effects of fishing, including biological and socio-economic aspects. Those authors found evidence through modelling and case studies that the establishment of MPAs, especially for overexploited populations, can mitigate ecosystem effects of fishing.

However, Jameson et al. (2002) argued that the great majority of marine protected areas (MPAs) fail to meet their management objectives. To better address management objectives, those authors recommended two changes, the first related to how they are located and the second related to how they are managed. MPAs are unlikely to be effective if they are located in areas that are subject to numerous, and often uncontrollable, external stressors from atmospheric, terrestrial, and oceanic sources, all of which can degrade the environment and compromise protection. MPA effectiveness is also limited by low institutional and community capacity for management and inappropriate size with respect to ecological needs. A review by Costello (2016) found that while the public perception of Marine Protected Areas was a place where nature is left wild, only a quarter of coastal countries have no-take Marine Reserves. Additionally, Costello asserted that while MPAs have been used to indicate conservation progress, 94% of MPAs allow fishing and thus cannot protect all aspects of biodiversity.

The review of literature conducted here did not identify international studies of MPAs that considered impacts on the forage fish community directly. Fisheries conservation was often given as a goal of MPAs, but rarely speaking to well-defined targets or objectives. Fisheries benefits were often spoken of in terms of the fish community in general (without targeting specific species) and improved (larger) size composition (see Edgar et al. 2014) for examples.

The International Union for the Conservation of Nature has published a useful guidebook for considerations of establishing an MPA, and evaluating its usefulness over time (Parks et al. 2004, available at https://www.iucn.org/content/how-your-mpa-doing-a-guidebook-natural-and-social-indicators-evaluating-marine-protected-areas-management-effectiveness). Following the practical considerations given in the guidebook could help avoid the shortcomings of MPAs identified above. Another recommended resource for optimal MPA design was produced by the Canadian Parks and Wilderness Committee (CPAWS 2019).

Engaging the Fishing Community (International Experience)

Helvey (2004) described the experience of a community group formed to consider establishing marine reserves within the Channel Islands National Marine Sanctuary in southern California. Lessons learned from the project emphasize the need by marine protected area participants to recognize irreconcilable impasses early in the process and to seek solutions to maneuver around them. The importance of keeping the fishing community fully engaged is discussed. Charles and Wilson (2009) also reviewed the history of MPAs globally from a societal perspective. They concluded that planning, implementing, and managing Marine Protected Areas requires that attention be paid not only to the biological and oceanographic issues that influence the performance of the MPA, but equally to the human dimensions: social, economic, and institutional considerations that can dramatically affect the outcome of MPA implementation. Their paper explored ten human dimensions that are basic to the acceptance and ultimate success of MPAs: 0bjectives and attitudes, “entry points” for introducing MPAs, attachment to place, meaningful participation, effective governance, the “people side” of knowledge, the role of rights, concerns about displacement, MPA costs and benefits, and the bigger picture around MPAs.

Unintended Consequences of MPAs (International Experience)

To use a simplistic metaphor, the distribution of fishing pressure could be likened to a balloon. If a balloon is restricted or squeezed in one area, it expands elsewhere. Hilborn et al. (2002) recognized this in the context of fisheries interacting with Marine Protected Areas, and explored the impact of implementing an MPA in a spatially structured model of a single-species fish stock that is regulated by total allowable catch (TAC). Those authors found that when a stock is managed at a maximum sustainable yield, or is overfished, implementation of an MPA will require a reduction in TAC to avoid increased fishing pressure on the stock outside the MPA.

MPA Lessons from Canada

The Canadian and British Columbia Context

In Canada, oceans are divided into three units: Atlantic Ocean, Pacific Ocean and Arctic Ocean (DFO 2009). Ecoregions are classified within each of these units by describing parameters such as bathymetry, hydrography, productivity and trophic linkages. In British Columbia, the first protected area including a marine section was established in 1911. While it is possible for both provincial and federal governments to establish marine protected areas (MPAs), jurisdiction is an important consideration. Jamieson and Levings (2001) provide a useful overview of the statutory powers of the federal and BC governments to create MPAs. Under Federal legislation, the Fisheries Act could be used for fishery closures, but also to protect habitat and prevent pollution. Under the Oceans Act, the mandate is broader, and MPAs may be established to address fishery resources including marine mammals, endangered or threatened species and their habitats, areas of high biodiversity, and areas of interest for scientific research. Other federal agencies that can create marine protected areas include Environment Canada and Climate Change (through the tools of the Canada Wildlife Act, the Migratory Birds Convention Act), and Parks Canada In BC, the Ministry of Environment, Lands and Parks has many legislative tools to establish marine protected areas with different mandates.

Why are MPAs established?

With a range of different types of legislated MPAs in BC, the management goals of MPAs in BC tend to be general and broad (Jamieson and Levings 2001). Early MPAs were established for aesthetic reasons as well as sanctuaries for migratory birds to protect shorebirds, waterfowl, and seabirds. Presently, reasons for establishing MPAs have grown to include considerations for recreational use, ecosystem protection, cultural importance, natural features, species habitat, research, wildlife, and education (Heck et al., 2012).

Expected outcomes of establishing MPAs include reduced water pollution as well as increased fish resources and marine mammals (Heck and Dearden, 2012).

These somewhat general expected outcomes are consistent with those identified in the review of the international literature earlier.

Conservation Benefits

Robb et al. (2011) reviewed the role of MPAs for fisheries conservation purposes in British Columbia. They found that as of 2008, 161 MPAs had been designated on the Pacific coast of Canada by federal, provincial or municipal authorities. It was found that 160 of the 161 MPAs are open to some commercial harvesting within their boundaries. Those authors concluded that the incongruence between management intent and fisheries permitted suggests a management failure between designation of MPAs and implementation of fisheries management regulations. This conclusion seems consistent with the international literature as well, as Costello (2016) found that the large majority of European MPAs he examined allowed some level of commercial fishery exploitation.

The literature review conducted for this report found few references to conservation of forage fish species. An exception was the 1,000-square-kilometre Banc-des-Américains marine protected area in the Gulf of St. Lawrence that includes the entire submarine bank known as the American Bank, as well as the adjacent plains. The area supports a range of marine habitats and species, including commercially-fished species. There are also many forage species (prey) such as capelin, herring, sand lance and krill. The area also has significant potential as a feeding ground for various species of fish and marine mammals, and could be an important habitat for groundfish populations. It has traditionally been an important fishing area. This MPA example is one of the few in the Canadian context that explicitly targets the protection of forage fish species, within an area that was of considerable interest to other commercial fisheries.

When considering Canadian MPAs, conservation benefits are often difficult to quantify. As noted by Heck et al. 2012, indicators and evaluation of performance are needed to measure conservation benefits. Management goals, conservation values and impacts should be assessed to increase the effectiveness of MPAs (Heck et al. 2012, Heck and Dearden 2012). Heck et al. (2012) suggested that current reactive management approaches toward human impacts on MPAs are the focus rather than active protection of key species (such as forage fish). As such, conservation targets are unclear and lost in the generic nature of outlined management goals.

Unintended consequences of MPAs (Canadian Experience)

Economic outcomes were not identified for provincial MPAs in BC although these benefits are often a divisive factor in communities (Heck et al., 2012). Local attitudes may differ from management views. It seems that the evaluation of MPA effectiveness is limited by the details in management goals. It likely becomes difficult to effectively identify unintended consequences when there is already limited information available for desired MPA outcomes.

Engaging the fishing industry (Canadian Experience)

Charles and Wilson (2009) provide interesting case histories of two early Canadian MPAs, one coastal (Eastport, Newfoundland) and the other offshore (the Gully, Nova Scotia). In the Eastport example, to survive after the groundfish collapse off Newfoundland in the early 1990s, fishers turned to the lobster fishery (*Homarus americanus*), previously only considered a supplemental fishery. The increased effort on lobster stocks led to a decline in catches, which prompted local fishers to establish the Eastport Peninsula Lobster Protection Committee in 1995. In the course of their conservation efforts, the fishers also recruited scientists from Memorial University of Newfoundland, Parks Canada, and DFO, as well as involving a local high school class to assist with collecting and analysing information. This work led to an agreement in 1997 between the Committee and DFO to close fishing areas seen as prime lobster habitats with the aim of building up the lobster stock, with conservation thereby supporting community livelihoods. In 1999, feeling that the closure had been successful and ready for further steps, the Committee requested DFO to consider the closed areas as formal MPAs, to further support ongoing conservation initiatives. The Eastport MPA was officially designated in 2005. This is an excellent example of a community-driven initiative that involved many stakeholders, leading to a successful outcome.

Environmental NGOs' Views on Canadian MPAs

Environmental non-governmental organizations such as the Canadian Parks and Wilderness Society have noted that when it comes to MPAs, Canada is just beginning to catch up to the international community, in its commitment to meet the Convention on Biological Diversity Aichi Target 11 of protecting at least 10% of coastal and marine areas by 2020. According to a 2016 analysis by CPAWS as of December 2017, Canada has protected 7.76% of its marine territory. However, the extent of protection is often weak (echoing the concerns of earlier studies reported here). Less than 0.01% of Canadian waters are fully protected. More recent reports indicate that nearly 14% of Canadian waters have some degree of protection, as of August 2019 (https://www.newswire.ca/news-releases/canada-joins-global-ocean-alliance-advocates-for-protecting-30-per-cent-of-the-world-s-ocean-by-2030-833945175.html.

CPAWS has argued that inconsistency in the implementation of Oceans Act MPAs and Other Effective Conservation Measures (OECMs) results in an approach that seems to favour quantity over quality.

The Suzuki Foundation (2014) produced an "MPA 101", highlighting key design principles that help make MPAs effective. As with other authors, they noted the need for involvement of First Nations and the community in general. However, they added the subject of compensation. The Suzuki Foundation noted that although MPAs have positive economic benefits, some user groups will be affected. They advised including affected parties in the design of the MPA, and noted that sometimes making changes to where MPAs are located can still achieve conservation goals and avoid economic impacts. They further recommend developing a plan to address displacement, including compensation or alternative employment opportunities if necessary.

The Importance of First Nations' Involvement in MPA Planning

The abundance and spatial distribution of archaeological fish bones examined by McKechnie et al. (2014) revealed the widespread importance of herring to indigenous peoples throughout the Salish Sea region, and indicated the abundance of herring in coastal ecosystems over the past several thousand years. Herring were particularly abundant along southwest Vancouver Island and in the Salish Sea. The archaeological record indicates that places with abundant herring were consistently harvested over time, and suggests that the areas where herring massed or spawned were more extensive and less variable in the past than today.

Ocean Watch (2017) highlighted the importance of healthy marine ecosystems for First Nations communities on the B.C. coast. Many hereditary names and crests, origin sites, and spiritual places are associated with marine areas and are critical historical and cultural resources. Coastal First Nations are also closely connected to the surrounding ocean through a variety of traditional marine activities which continue today, including the management, harvesting, preparation, and consumption of seasonal resources. The rich marine environment historically supported large First Nation populations, as evidenced by the many villages, and fishing and hunting camps located throughout the region. Two examples of successfully co-managed marine protected areas in B.C. include the Gwaii Haanas National Marine Conservation Area and Haida Heritage Site, co-managed between the Federal Government and the Haida Nation; and the Hakai

Lúxvbálís Conservancy co-managed between the Heiltsuk Nation and the Province of British Columbia.

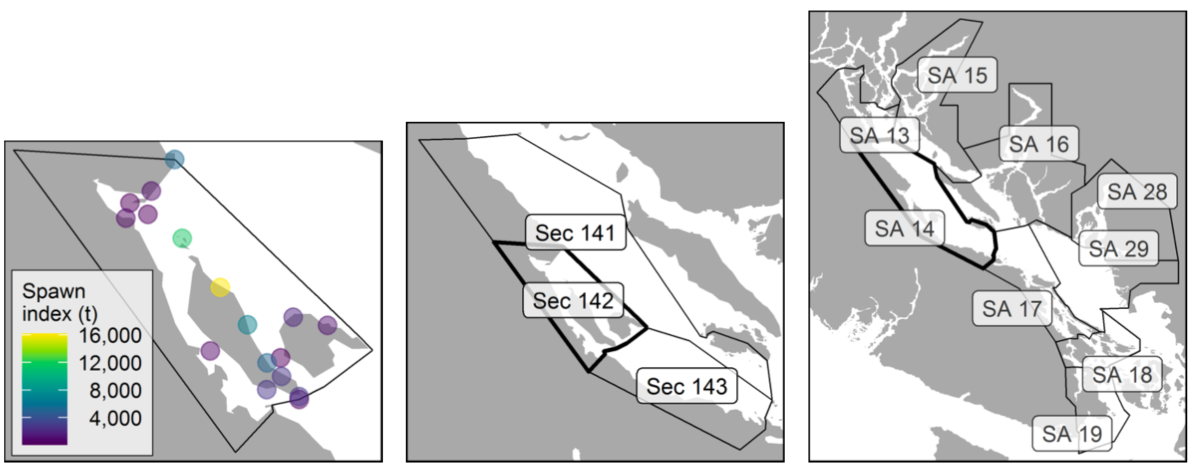
Some General Conclusions from the Literature Review (Canada and International)

The available scientific literature on MPAs is extensive, both nationally and internationally. In spite of the breadth of available information, there are several recurring key points:

- The MPA experience in Canada is in its infancy. For most Canadian MPAs, it is usually too soon to demonstrate conservation benefits. However, without clearly definition of the expected outcomes of MPAs, measuring the effectiveness of MPAs in the future will be difficult.
- MPAs that include fishery "no take" zones are in the minority, both nationally and internationally.
- There are few examples of MPAs that explicitly consider the conservation of forage species, both nationally and internationally.
- The literature suggests that involving the community, First Nations and the fishing industry early in talks and planning seems to be critical in having a successful outcome.

Data Analyses:

The Department of Fisheries Oceans (DFO, Pacific Biological Station, Herring Program) was very helpful in providing available herring spawn information from 1951-2019. These data are aggregated over several spatial scales (Fig. 2), within the Strait of Georgia Stock Assessment Region (SAR). The finest level of spatial aggregation available is the "location" level, and the analyses presented here are provided at that spatial scale.



(a) Spawn index in tonnes (t) by Location in Section 142, SoG SAR.

(b) Sections (Sec) in Statistical Area 14, SoG SAR.

(c) Statistical Areas (SA) in the SoG SAR.

Fig. 2. The three spatial scales for aggregating herring spawn indices in the Pacific herring stock assessment. In increasing scale of aggregations, the data for 2019 are shown for Locations (a), Sections (b) and Statistical Area (c). Figure provided courtesy of the Herring Program, Department of Fisheries and Oceans.

A map showing the most significant place names referred to in this report is shown in Fig. 3 below.

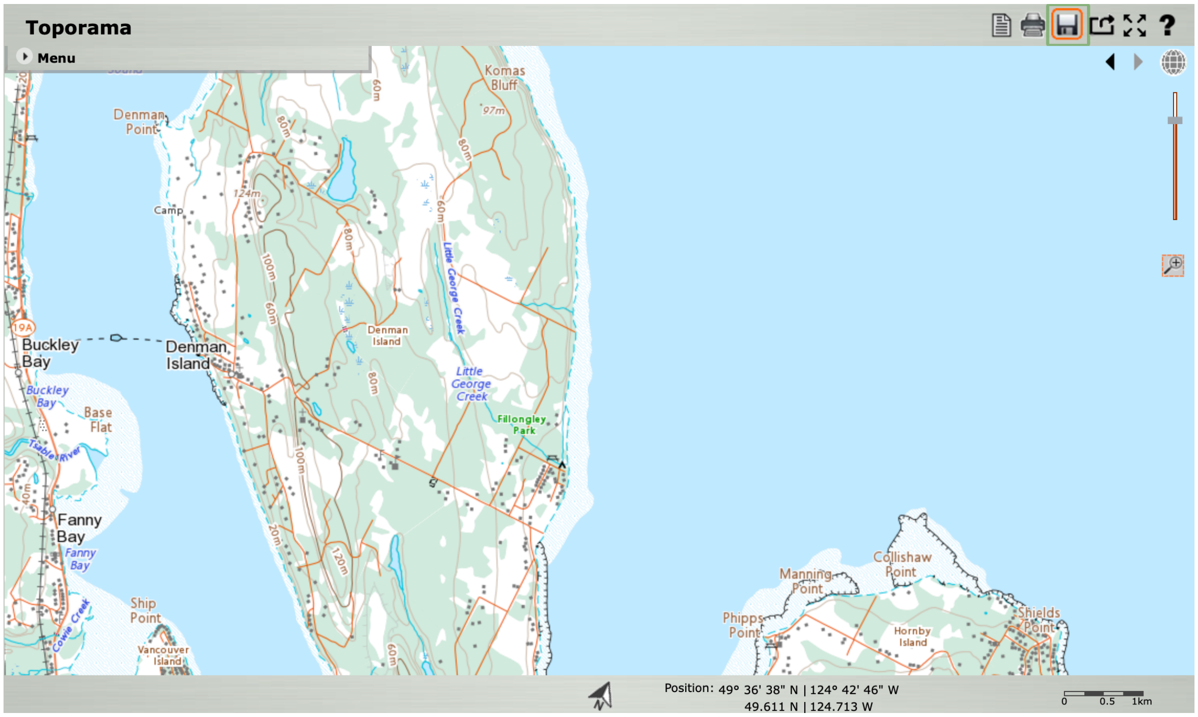


Fig. 3. Denman and Hornby Islands, showing the location of place names in Northern Lambert Channel between Denman and Hornby Islands associated with high levels of herring spawning, as defined later in this report. Map Source: Natural Resources Canada website.

The overall spawning index for a given location can consist of the sum of three different indices (when available) including:

1. Observations of spawn taken from the surface usually at low tide,
2. Underwater observations of spawn on giant kelp, *Macrocystis* (*Macrocystis* spp.), and
3. Underwater observations of spawn on other types of algae and the substrate, referred to as ‘understory.’

The three indices summed by SAR and year comprise a relative annual abundance index of combined sex spawning biomass. This is the index of stock abundance used in the current stock assessment.

These data have evolved over the long time series of herring spawn surveys, as have the relative weight given to the three index components. As with any fisheries data, there are a number of *caveats* associated with the indices that users need to be mindful of. The most important of these are:

1. The spawn index is a relative index of spawning biomass,

2. The spawn survey is a presence only survey; thus the spawn index is a minimum spawning biomass (in other words, in any year, there could be spawning elsewhere which went unrecorded),

3. The spawn index is derived from surface and dive observations of egg deposition, and includes uncertainty and assumptions.

4. There are two different spawn survey periods with substantial differences in survey effort and method:
   a. Surface period from 1951 to 1987, and
   b. Dive period from 1988 to present,

5. Surface spawn surveys use two different methods to estimate the number of egg layers:
   a. Spawn intensity categories:
      i. Five categories from 1951 to 1968, and
      ii. Nine categories from 1969 to 1978, and
   b. Direct estimates from 1979 to present.

Surface spawn surveys are believed to be the least accurate of the three survey types, but they have the greatest temporal and spatial extent (Schweigert 1993). Surface spawn surveys were the only survey type prior to 1988. *Macrocystis* and understory spawn surveys are conducted under water using SCUBA gear, and have been used for all major spawns since 1988. Thus, we describe the spawn index as having two periods based on the predominant survey type: the surface survey period from 1951 to 1987, and the dive survey period from 1988 to present. The differences in sampling methodologies between the two periods makes direct comparison between problematic for some types of analyses. Thus, for most of the analyses presented in this report (an exception being Appendix One which contains all years), the data used are the understory data only starting in 1988.

The locations of permanent transects that guide the divers' annual surveys are shown in Figure 4. Due to variations in spawn deposit patterns each year and other factors, the precise locations that are covered from year to year vary. Extensive details on the dive protocols that are followed may be found in Fort et al. (2013). The expected maximum depth of spawning in the Denman/Hornby Islands is 12.8 m (42'). Diver survey information is integrated with other data such as aerial overflights to determine length of spawn and egg counts to obtain an overall index.

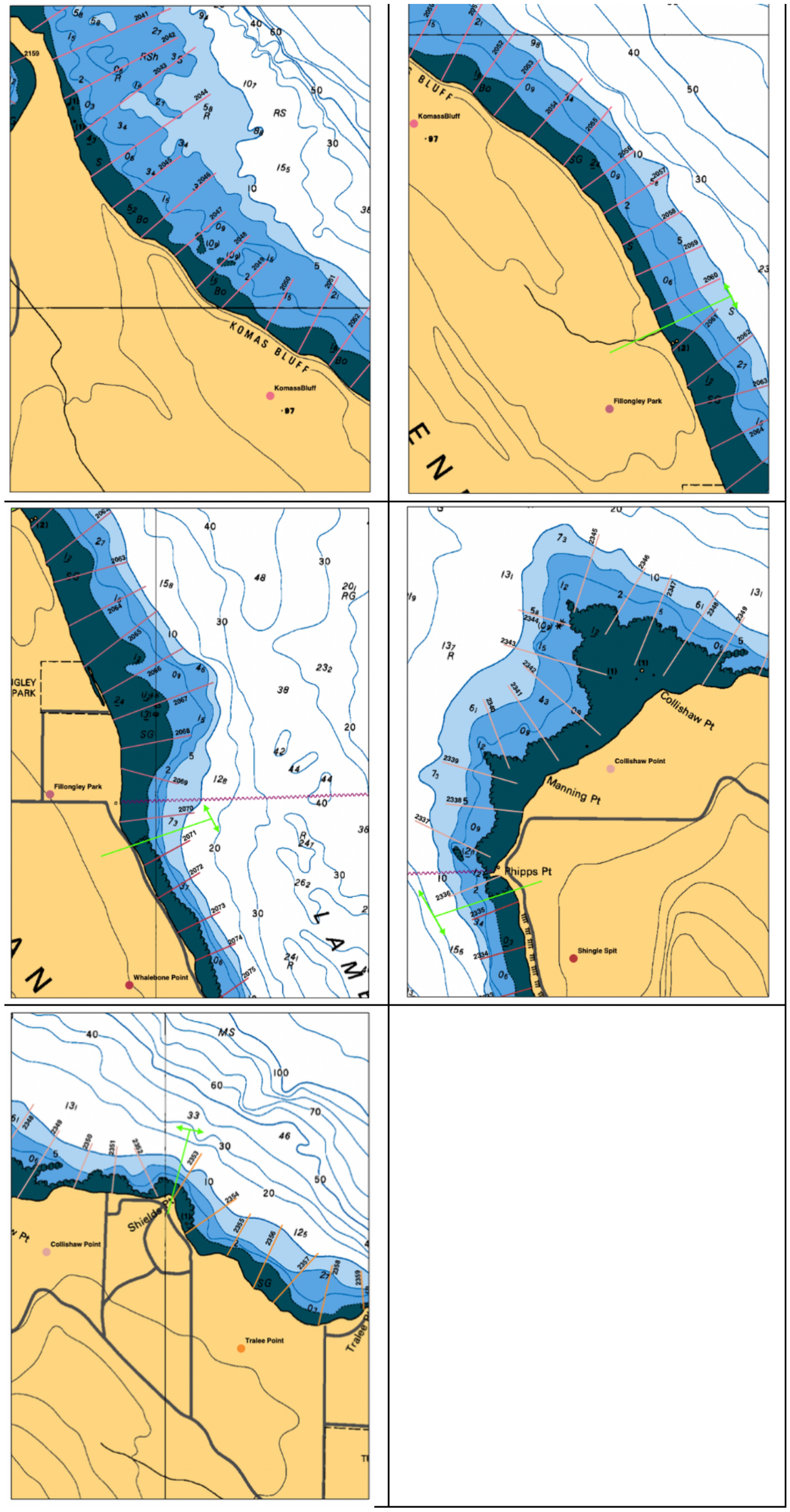


Fig. 4. The permanent dive transects established by DFO at significant Locations for spawning, as defined in this report. The green line represents the boundary between adjacent Locations. The top left panel represents the Komass Bluff location, the top right is the Komass to Fillongley Park Locations, and the middle left is Fillongley Park. The middle right is Collishaw Point, and the bottom left is Collishaw Point to Tralee Point. Data provided courtesy of the Herring Program, DFO.

Results

Spatial Distribution Throughout the SAR

Appendix One shows the spatial extent of the distribution of spawning in the Strait of Georgia SAR as shown from the total relative index described above. Note that the .pdf document can be viewed page by page for each year, or as an animated series ("slide show"). Viewing the time series as an animation illustrates that the geographic extent of spawning has been reduced over time. For example, there was spawning broadly documented throughout the eastern Strait of Georgia in 1951 from the southern tip of Vancouver Island to Quadra Island. In 1951, there were major spawning activity in five areas on the BC coast, which in 2019 have been reduced to the Salish Sea area only, with one main area left between Comox and Parksville concentrating around Hornby and Denman Islands. The most recent stock assessment (DFO 2020) also reports that the proportion of the overall Strait of Georgia SAR annual spawning index in Statistical Areas 14 and 17 comprised 98.4 and 98.5% in 2018 and 2019 respectively. This indicates a recent reduction of the spatial extent of spawning activity in the Strait of Georgia, and the waters around Hornby and Denman Islands are at the centre of the remaining areas of active spawning.

Relative Importance of Spawning Around Hornby and Denman Islands

To address the question of the most important spawning locations within the Strait of Georgia SAR, the understory dive data were examined. The understory dive data are considered to be the most complete and reliable data for the SAR, and were available from 1988 to 2019. The average dive indices were calculated by Location through those years, and the locations ranked among the 147 unique Locations within the Strait of Georgia SAR, with the highest index given the rank of 1. Referring to the text table below, those locations that are in the waters around Hornby and Denman Islands are highlighted.

Location Name	Average Dive index	Rank	Number of Years Surveyed
Cape Lazo	8755.64	1	23
Sandy Is	8007.53	2	5
Dunlop Pt	7589.17	3	1
Newcastle Is E	7210.30	4	1
Kitty Coleman Beach	5703.97	5	11
Collishaw Pt	5178.35	6	28
Komas Bluff	5140.46	7	32
Marina Is	4650.49	8	1
Fillongley Park	4631.60	9	30
Kye Bay	3965.45	10	17
Flat Top Is	3563.16	11	1
Oyster Bay	3415.26	12	1
French Cr	3285.48	13	27
Phipps Pt	3259.89	14	2

Big Qualicum Rvr	3256.99	15	26
Seal Islets	3095.18	16	20
Whalebone Pt	2998.08	17	26
Downes Pt	2884.41	18	17
Qualicum Rvr	2659.54	19	2
Columbia Beach	2510.80	20	22

Table 1. The top 20 Locations within the Strait of Georgia herring SAR, ranked on average annual spawning indices, calculated from 1988 to 2019. Those locations that are in waters around Denman and Hornby Islands are highlighted. For a complete list of the ranks of all Strait of Georgia Locations, refer to Appendix 2.

Of the 20 Locations shown in Table 1, nine are in waters around Hornby and Denman Islands, further illustrating the importance of that area for spawning herring.

As an example of the potential impact of an MPA around Hornby and Denman Islands, three highly-ranked and well-sampled Locations from waters around Hornby and Denman Islands were selected from Table 1 (Collishaw Pt, Komas Bluff and Fillongley Park. Also note that while there were higher herring spawn indices observed at Sandy Island and Dunlop Point, only five and one year respectively of surveys were available). Their relative contribution to the total Strait of Georgia SAR is summarized in the Table 2 below:

	Collishaw %	**Fillongley %**	**Komas %**	**Sum of Three Locations**
1988	6.6	6.5	1.7	14.8
1989	16.6	7.2	13.7	37.5
1990	10.3	10.3	11.2	31.8
1991	0.0	8.0	11.5	19.5
1992	6.6	5.6	7.2	19.4
1993	7.0	3.9	6.1	17.0
1994	6.3	7.6	14.9	28.8
1995	13.5	8.5	8.3	30.4
1996	12.8	5.8	10.1	28.8
1997	2.0	12.8	14.5	29.2
1998	11.2	8.8	5.9	25.9
1999	6.5	11.7	1.8	19.9
2000		6.0	7.6	13.6
2001	4.0	2.1	5.4	11.6
2002			2.1	2.1
2003	3.7	6.2	6.2	16.1
2004	6.5	3.5	1.8	11.8
2005	7.7	7.1	13.7	28.5
2006	9.3	7.1	10.0	26.4
2007	22.4	3.2	4.9	30.5
2008	2.7	13.7	7.7	24.0
2009	4.5	0.1	0.8	5.4
2010	8.1	1.5	0.1	9.7
2011	13.1	1.2	0.0	14.3
2012	0.2	10.6	14.8	25.7
2013	5.4	6.8	10.9	23.2
2014	5.1	6.1	8.5	19.6

2015			0.3	0.3
2016	13.3	11.6	15.1	40.0
2017	3.7	3.3	6.6	13.6
2018	0.0	0.0	0.2	0.3
2019	2.9	11.1	25.7	39.7

Table 2. Percentage of the contribution to the total Strait of Georgia SAR spawning index by year, for three significant Locations around Hornby and Denman Islands.

Referring to the above table, the three significant Locations contributed an average of 20.6% to the overall Strait of Georgia SAR spawn index. In recent years (2016 and 2019), the contribution was as high as 40%.

Temporal Persistence of Important Spawning Areas

To assess how persistent the top-ranked Locations were over time, the annual rankings of those three locations (Collishaw Pt, Komas Bluff and Fillongley Park) described in the previous section was calculated, and those rankings are shown from 1988 to 2019 (Fig. 5).

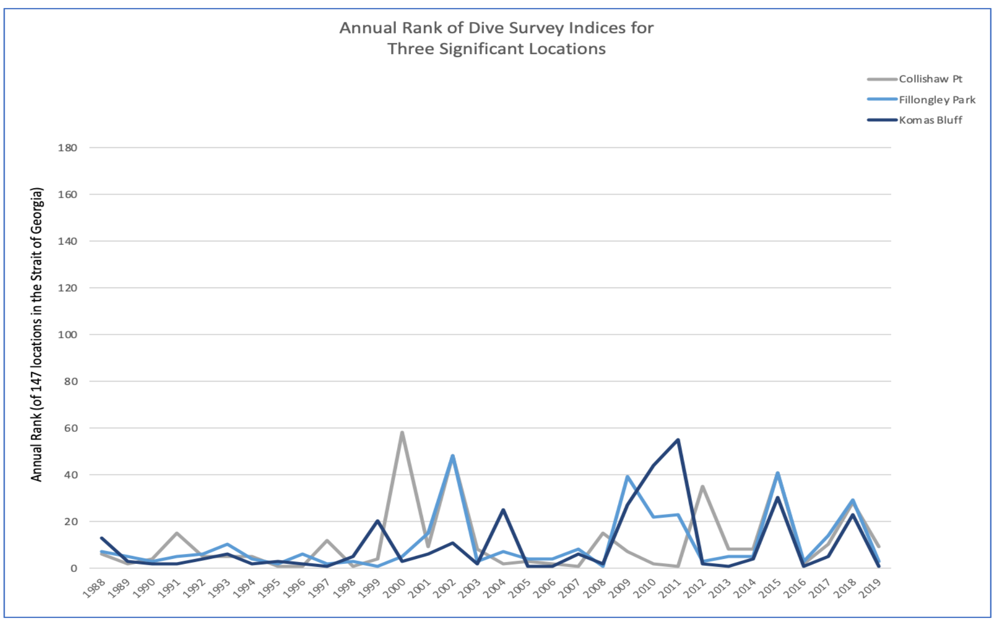


Figure 5. Trends in ranks of three significant and well-sampled Locations around Denman and Hornby Islands, 1988-2019.

Those three Locations tended to be consistently highly ranked, particularly from 1988 to 1999. While there was somewhat more interannual variability in annual rankings in the latter half of the time series, those Locations were generally associated with higher ranks throughout the entire period.

Discussion and Conclusions:

DFO has established a biogeographic classification of Canada's marine waters (Fig. 6, taken from DFO 2009). An MPA established in waters around Hornby and Denman Islands would lie within the Strait of Georgia biogeographic region, and protect an important example of that region.

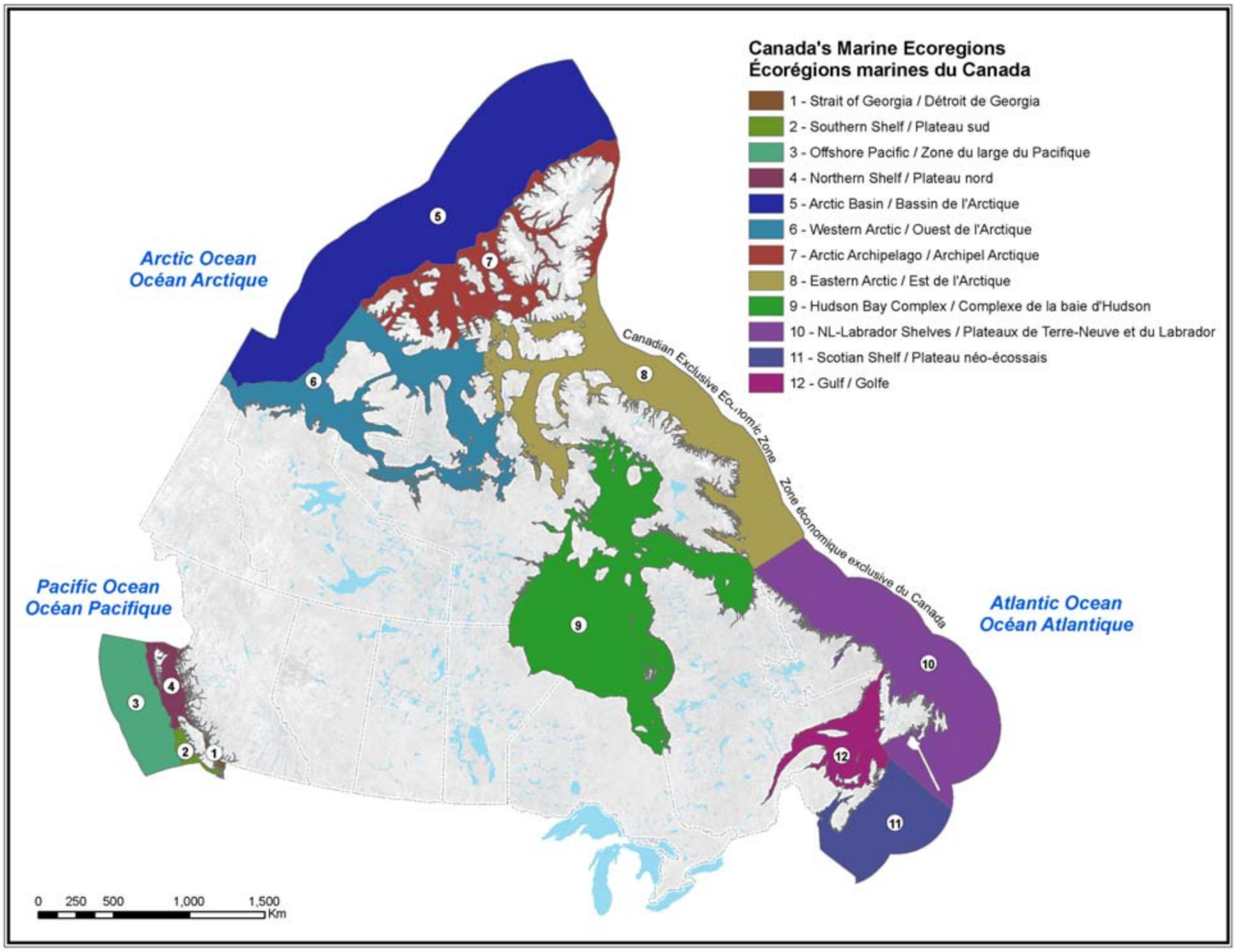


Fig. 6. Biogeographical zones in Canadian waters, as proposed in DFO (2009).

Locations around Hornby and Denman Islands represent many of the most important spawning areas for herring in the Strait of Georgia biogeographical zone. This is probably the most important conclusion of this report. Continuing with the example of the three highly-ranked and well-sampled Locations from waters around Hornby and Denman Islands (Collishaw Pt, Komas Bluff and Fillongley Park), an MPA that protected spawners from fishing mortality could protect a significant fraction of the overall spawning with the Strait of Georgia SAR. The importance of those areas for spawning area seems to be stable from year to year, meaning that an MPA could have lasting importance to the conservation of Pacific herring. An MPA with no-take provisions for the herring fishery located in the northern entrance to Lambert Channel (separating Denman and Hornby Islands, Fig. 3) could protect those three significant spawning areas.

As do all of Canada's marine fish populations, Pacific herring are confronted with a rapidly-changing ocean environment. In particular, the Strait of Georgia herring SAR faces increased temperature and acidity, changes in prey fields and competition from other species, according to the Intergovernmental Panel on Climate Change (Hoegh-Guldberg 2014). The consequences of these changes to the health of the population is unknown. While TAC-based approaches may have provided appropriate techniques for managing exploited marine populations in the past, additional management measures (such as a Marine Protected Area) could provide an extra level of insurance for the continuance of SAR against the context of changing ocean conditions. Even before the risks of climate change were fully understood, earlier papers have concluded that marine reserves containing areas closed to exploitation provide an additional management tool that could help control fishing mortality and thus hedge against the risk of fisheries collapse (Bohnsack 1996; Guenette et al., 1998; Sumaila, 1998).

Some Possible Next Steps:

1. First Nations partnerships are a necessary part of any plan for an MPA. There are models in BC identified here for the collaboration between First Nations and other user groups that have been effective.

2. Returning to the "balloon" concept for the re-distribution of fishing effort following the establishment of an MPA that dictates a reduction in TAC to avoid increased fishing pressure on the stock outside the MPA, further investigation of the distribution of pre-spawning herring would be important to ensure that expected conservation benefits of an MPA actually materialize. The availability of data to examine the question is presently unknown, but having information on the location of the fishing fleet in relation to their fishing success (possibly through VMS data) just prior to spawning would be informative. Having the expert opinions of fishing masters willing to work on the MPA plan would be another approach.

3. The observation by the Suzuki Foundation that fair compensation should be provided for displaced fishing activity is important. By recognizing that, and involving the fishing industry early in the process, the chances of successful planning and implementation increase.

4. Just north of Hornby and Denman Islands, there are plans underway for an ambitious network of Marine Protected Areas. The initiative is led by a tripartite partnership between Canada, BC, and 17 First Nations. The network design is still in development and a Network Action Plan has yet to be drafted. Material related to the initiative can be found here: http://mpanetwork.ca/bcnorthernshelf/. Linkage to that MPA network, either formally or informally, could offer benefits and opportunities.

5. One possible avenue to explore is attempting to quantify the potential economic benefits of ecotourism associated with a strong herring base. Establishing an MPA could help protect and develop economic benefits (ecotourism, recreational fishery, increased demand for overnight accommodation, boat rentals, etc) by ensuring the continuance of abundant spawning around Hornby and Denman Islands, thereby providing the basis for the seasonal attraction of significant aggregations of marine life as described in the CHI Marine Conservation Atlas

6. The legislative basis for MPAs is evolving within Canada, and it will be important to develop linkages with knowledgeable governmental officials. For example, (K. Leslie,

Regional Manager, Marine Spatial Planning, North Coast Fisheries and Oceans Canada, pers. Comm.) has noted that when considering the development of an MPA, there are new authorities under the new Fisheries Act for Biodiversity Protection which could be explored, and policy direction is being developed about use of Fisheries Act closures for marine refuges, consistent with international direction.

Acknowledgements: Dr. Jaclyn Cleary and herring program staff (Department of Fisheries and Oceans Canada) provided the data used here, and addressed numerous questions with promptness and professionalism. Mr. Mark Kelly, Hornby Island, helped considerably with the literature review component of this report.

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Appendix One – The Spatial Distribution of Herring Spawning (1951-2019).

(Please refer to attached PDF. It is suggested to view the PDF as a slide show to visualize the changes in the distribution of spawners)

Appendix Two – Ranking of Herring Spawning Abundance Indices by Location and Year. Strait of Georgia Stock Assessment Region (1988-2019)

Location Name	Average SS index	Ranked	# of Survey Years
Cape Lazo	8755.64	1	23
Sandy Is	8007.53	2	5
Dunlop Pt	7589.17	3	1
Newcastle Is E	7210.30	4	1
Kitty Coleman Beach	5703.97	5	11
Collishaw Pt	5178.35	6	28
Komas Bluff	5140.46	7	32
Marina Is	4650.49	8	1
Fillongley Park	4631.60	9	30
Kye Bay	3965.45	10	17
Flat Top Is	3563.16	11	1
Oyster Bay	3415.26	12	1
French Cr	3285.48	13	27
Phipps Pt	3259.89	14	2
Big Qualicum Rvr	3256.99	15	26
Seal Islets	3095.18	16	20
Whalebone Pt	2998.08	17	26
Downes Pt	2884.41	18	17
Qualicum Rvr	2659.54	19	2
Columbia Beach	2510.80	20	22
Francisco Pt	2424.38	21	1
Norman Pt	2411.71	22	18
Bowser	2260.39	23	26
Qualicum Beach	2101.39	24	26
Repulse Pt	1885.06	25	23
Mapleguard Pt	1879.27	26	23
Tralee Pt	1863.77	27	29
Whaling Station Bay	1843.75	28	29
Oyster Rvr	1824.67	29	2
Horswell Bluff	1819.29	30	11
Wallis Pt	1750.55	31	4
Englishman Rvr	1743.63	32	25
Lock Bay	1647.67	33	3
Willow Pt	1570.99	34	1
Icarus Pt	1567.13	35	19
Sunrise Beach +	1539.54	36	18
Whaletown Bay	1483.22	37	1
Parksville Bay	1479.80	38	25
Bargain Bay	1433.96	39	1
Seal Bay+	1356.23	40	2
Valdes Is	1327.05	41	3
Baynes Snd	1263.28	42	6
Comox Bar	1258.39	43	7
Boyle Pt	1241.61	44	27
Little Rvr	1202.36	45	13
Tribune Bay	1199.08	46	23
Ruxton Is	1193.33	47	2
Gartley Pt	1181.11	48	6
Degnen Bay	1176.09	49	3

Madrona Pt	1124.38	50	15
Henry Bay	1113.25	51	10
Nuttal Bay	1097.68	52	7
Taylor Bay	1087.04	53	3
Grief Pt	1083.43	54	2
Shingle Spit	1036.95	55	23
Breakwater Is	1028.61	56	4
Blunden Pt	1028.54	57	12
Gravelly Bay	1017.22	58	23
Southey Is	992.18	59	3
Willemar Bluff	915.76	60	17
De Courcy Is	911.66	61	13
Ship Pen	892.38	62	8
Nankivell Pt	875.68	63	5
Boat Cv	862.78	64	2
Yellow Pt	825.49	65	11
Cedar Ramp +	817.52	66	10
Coffin Pt (Is)	815.21	67	15
Blackberry Pt	789.55	68	3
Ford Cv	746.92	69	18
Metcalf Bay	741.20	70	15
Ranch Pt	732.87	71	5
Mud Bay (Baynes)	714.42	72	6
Quarry Bay	713.30	73	1
Protection Is E	713.08	74	8
Valdes Is East	711.97	75	1
Patricia Bay	706.16	76	4
Qualicum Bay	695.89	77	24
Kulleet Bay	664.84	78	14
Brentwood Bay	635.62	79	2
McKay Pt	634.53	80	9
Gabriola Is S	632.51	81	7
Northwest Bay	631.87	82	11
Mudge Is	630.18	83	18
Maude Is	618.69	84	1
Schooner Cv	607.38	85	5
Deadman Is	594.07	86	1
Yellow Pt N	570.21	87	9
Neck Pt	566.92	88	15
Nares Pt	552.73	89	12
Vesuvius	550.80	90	1
Pylades Chnl	543.70	91	2
Westview	499.79	92	1
Denman Is W	492.51	93	12
Gillies Bay	490.32	94	1
Rathtrevor Beach	474.48	95	20
Boat Hrbr	456.56	96	7
Cottam Pt	446.51	97	9
False Nrws	436.17	98	5
Sear Is	434.54	99	1
Lantzville	432.10	100	13
Nanoose Bay Hd	417.55	101	6
Boulder Pt	416.41	102	1
Lagoon Hd	401.51	103	11

Round Is	384.40	104	8
Flewett Pt	377.81	105	5
Little Qualicum Rvr	362.99	106	23
Nanoose Bay	349.38	107	6
Flora Islet	332.54	108	9
Hammond Bay	318.77	109	12
Coles Bay	300.96	110	3
Evening Cv	275.44	111	5
Hospital Pt (Chemainus)	265.42	112	1
Unknown Sec 173	229.76	113	1
Jack Pt	228.58	114	3
Link Is	208.04	115	9
Dorcas Pt	202.85	116	5
Booth Bay	199.61	117	1
Deep Cv	186.10	118	4
Thormanby Is	184.66	119	1
Harwood Is	176.61	120	1
Harmac	169.33	121	2
Goose Spit	166.23	122	9
Lang Bay	156.77	123	1
Dodd Nrws S	154.12	124	12
Ganges Hrbr	153.77	125	4
Hudson Is	152.78	126	1
Departure Bay	149.21	127	9
Francis Pt	137.47	128	1
Entrance Is	136.14	129	1
Chrome Is	94.87	130	9
Descanso Bay	93.11	131	2
Chain Is	85.01	132	1
Walker Hook	82.34	133	1
Fanny Bay	62.48	134	1
Rebecca Spit	57.57	135	1
Nanaimo	40.31	136	1
Parksville	39.86	137	2
Bath Is	39.27	138	1
Welbury Bay	37.82	139	2
Maxwell Pt	34.68	140	1
Dodd Nrws N	33.87	141	1
Myrtle Pt (Cr, Rks)	30.60	142	1
Pylades Is	27.55	143	2
Gibsons Landing	26.31	144	2
Moses Pt	22.20	145	1
Ruth Is	13.03	146	1
Newcastle Chnl	6.05	147	2