Kitasoo/Xai'xais Management Plan for Pacific Herring

Herring eggs cover the intertidal zone while a bald eagle consumes an adult herring, Kitasu Bay (photo: Markus Thompson)

January, 2018

Kitasoo/Xai'xais Management Plan for Pacific Herring

Table of Contents

Page

Kitasoo/Xai'xais Management Plan for Pacific Herring

Introduction

This document presents a management plan for Pacific herring in the Territory of the Kitasoo/Xai'xais Nation, where our people have lived for thousands of years. The plan models respect and reciprocity, two of our legal principles.

Our authority to develop and implement the plan stems from our inherent indigenous rights and responsibilities, and our constitutionally protected aboriginal rights and title under section 35(1) of the Canadian Constitution, to use, manage, take care of and rely upon the resources of our Territory. Our peoples have traditionally used, occupied and exercised jurisdiction over our Territory for thousands of years. We remain occupants and stewards of our unceded Territory with legal rights and responsibilities to past, present and future generations and all living things.

To remain here as the Kitasoo and Xai'xais people we need to care for, manage and enhance the resources and our culture in order to protect our heritage. We depend on the health of our ecosystems to survive and flourish. This plan explains how we intend to manage and protect Pacific Herring in our Territory so that we may fulfill the obligations bestowed upon us by our ancestors to manage our marine resources based on our traditional laws, knowledge and values[1].

Pacific herring are integral to our culture and well-being. They play a pivotal role in the ecology of our Territory and throughout most coastal areas of the North Pacific Ocean, where dense spawning aggregations have, predictably for millennia, formed in late winter and early spring, often at the same bays and inlets, year after year. These spawning events create a pulse of food for our people and myriad other predators, including whales and wolves, which rely on spawning herring for an end-of-winter energy boost.

Archaeological evidence corroborates the importance of Pacific herring in our culture and economy; throughout coastal British Columbia and adjacent areas, the species has been a primary food of indigenous people for over ten thousand years[2]. Herring also sustain us indirectly; they are prey to other species in our traditional diet, such as salmon, rockfish, halibut and lingcod. Beyond providing physical sustenance, herring are inherent to our cultural identity; they play critical roles in the stories and spirituality of our people[1].

Two major and interacting forces—industrial fisheries and climate change—threaten the future of Pacific herring and the cultural and ecological interactions that they sustain[3,4]. While climate change is beyond the scope of what we can tackle on our own, what we can do is apply our knowledge and indigenous laws to create a better way of understanding and managing fisheries, thereby preserving our Territory as habitat for Pacific Herring, increasing the resilience of Pacific herring to climate change and other stressors, and ensuring that the people and ecosystems fed by this species remain vital.

Our management plan is a living document, one we will evolve and update as new information, observations and scientific data become available. It stems from the need for us to proactively manage our resources, thereby departing from a prior history of reacting to external management policies that failed to consider our knowledge and perspective. While science and traditional knowledge inform this plan, our indigenous laws and guidance from hereditary chiefs are also foundational to the plan.

Respect is a core principle of our indigenous laws[1]. This principle reoccurs throughout our oral history. All living things have the right to be respected in all forms, including physically and verbally. Respect extends to the people, as well as the plants and animals of the ocean and land. Animals and plants are always respected—regardless of whether they are being harvested—or they can easily be taken away. Wrongful actions have natural and spiritual consequences. For example, in the story Gunarhnesemgyet seal hunters are out in their canoe when the steersman notices a seal in the mouth of a sea anemone. He urges the hunters to take the seal, but they respond with taunts and scorns, scoffing that they can hunt their own seals without assistance from a lowly sea anemone. Because of disrespect to the anemone, the group becomes stranded and everyone but the steersman dies. Another story recounts a group of young boys on their canoe hooking sea cucumbers for amusement. One of the boys tells the others to stop, but they do not. Similar to the group of seal hunters, the boys are caught in a freak storm and capsize; only one boy survives so that others may learn from his testimony. These and other stories from our oral tradition inform and guide our management approach[1].

Reciprocity is another core principle of our indigenous laws. This is a responsibility to show gratitude and be active stewards of the lands and waters that support us. Both respect and reciprocity inform the harvesting protocols and practices within our Territory. People must properly prepare for harvesting. Respect for natural resources is demonstrated through taking only what we need. This includes harvesting only what we need, fully utilizing what is harvested and not overharvesting. Our protocols dictate that people are aware, knowledgeable and respectful of the environment where they harvest in the Territory. For example, herring can be disturbed quite easily and we have protocols for minimizing the use of powerboats and other noisy equipment during a herring spawn. It is also important, out of respect and protocol, not to be distracted while out harvesting. It is our responsibility to be aware of the surroundings, the weather, and the possible implications of any actions. Respect and reciprocity also inform Territorial protocols and practices, including those that require consent to access specific areas within our Territory.

With these principles and laws, comes the responsibility to help those in need, to share, to teach people about our legal system and the proper way to act. It is also our obligation to inform others about our rights and responsibilities regarding specific areas that are looked after by specific decision makers within the Kitasoo/Xai'xais people. We stress that, as Kitasoo/Xai'xais peoples, we have the right and responsibilities to steward the land and waters of our Territory, including the responsibilities to protect species against irresponsible gathering or harvesting of aquatic life, against trophy hunting or other harvesting that is dissociated from the intentional and respectful use of plants and animals.

In the remainder of this document, Part 1 provides background information that contextualizes the management plan. Section 1.1 reviews some of the main stressors on Pacific herring populations, Section 1.2 provides a historical and economic context for herring fisheries, and Section 1.3 describes the current status and our use of spawning areas in our territory. Section 1.4 reviews our involvement in marine spatial planning and the importance of spatial protection in our management approach. Part 2 outlines the management plan.

PART I - BACKGROUND

1.1 Stressors on herring populations

(a) Climate change and fisheries

The abundance of Pacific herring and other forage fishes fluctuates over time, largely in response to environmental shifts that affect food supply and growth rates[3]. Some of these fluctuations occur in response to natural climate cycles, such as El Niño and the Pacific Decadal Oscillation, but long-term climate change caused by our greenhouse gas emissions is projected to strongly influence the abundance and distribution of Pacific herring and other marine resources used by First Nations[4]. At the same time, industrial fisheries have a long history of exploiting forage fish at high rates. The problem stems largely from the fact that herring and other forage fishes aggregate in schools that are large and dense, especially during spawning. Consequently, industrial fisheries have been managed to allow high catch rates and to remain economically viable, even when population abundances are very low, until a crash occurs. The end result is that natural variability causes Pacific herring and other forage fishes to fluctuate in abundance over time—even in the absence of fishing—but fisheries amplify the strength and increase the frequency of declines[3].

Scientists increasingly recognize that climate change and fisheries are not independent stressors. Rather, the effect of one exacerbates the effect of the other on individual species and entire ecosystems[5,6]. For instance, ocean warming may amplify vulnerability to disease[7], reduce growth rates (in part by decreasing prey availability)[8], and diminish the extent of kelp and sea grass beds[9], which herring need for egg deposition and development. Additionally, many fish species associated with warmer water are expected to shift north[10], which might expose Pacific herring to more competitors and potential predators. Further, ocean acidification—a direct consequence of the ocean absorbing our carbon dioxide emissions—could have additional indirect effects (via changes to the food web) or direct impacts on herring[11]. These are the sorts of stressors that reduce the capacity of herring—and fish populations in general—to withstand exploitation levels that might have been sustainable in the past.

Given climate change and ocean acidification, herring fisheries must become more conservative. Additionally, marine protected areas that exclude large-scale exploitation should be used as management tools for sustainability in the face of changing ocean conditions[12,13].

(b) Predators

Predation by marine mammals is a potential stressor on herring populations. Indeed, some marine mammals that eat herring—such as sea lions, seals and some whales—have become more abundant in British Columbia since the mid-1990s. Their increased abundance reflects the end of commercial whaling and of culling programs intended to eliminate seals, sea lions and other species that compete with commercial fisheries. Research in the west coast of Vancouver Island did not find evidence that the recent rise in marine mammal abundance has increased *overall* predation rates on herring. The reason is that, although marine mammals have increased, fish species that consume herring have declined, and the net effect is an overall decrease over time of predation rates on herring[14].

For the Central Coast, DFO's stock assessment models estimate that natural mortality of herring rose sharply between 2001 and 2008 but has been declining since[15]. Our observation, however, is that the number of seals and sea lions in our territory has increased during the last five years. Additionally, various predatory fishes that currently occupy warmer waters to the south are predicted to shift their distribution northwards in response to climate change[4,10]. Further research is needed to understand potential cumulative impacts of fisheries and predator-inflicted mortality on herring populations.

Accordingly, biomass targets used for fishery management need to be conservative to allow for uncertainty in predator-inflicted mortality.

(c) Impacts of vessel noise on spawning herring

Our traditional knowledge has long recognized that herring are easily disturbed by noise and human activities. Accordingly, our indigenous laws prohibit disruptive behaviours around spawning and harvesting sites[1]. That is, we minimize our use of sonars and engines and avoid unnecessary noises near spawning herring. Scientific research also recognizes that motorized vessels disturb herring[16]. Therefore, noise disturbance and its disruption of spawning behaviour is yet another potential impact of commercial fisheries, and a stressor that we manage carefully in our own fisheries.

(d) Short-term information perspectives

Scientific fisheries data often are mired in short-term perspectives[17]. We see this problem as a threat to herring because, without a meaningful baseline, fishery managers with Fisheries and Ocean Canada (DFO) may misinterpret the current state of herring populations and therefore be misled into poor management decisions. We illustrate this concern with two examples.

First, DFO may interpret a strong spawning event confined to the main portion of Kitasu Bay—our most important spawning area—as indicative of increasing herring abundance. Our intergenerational knowledge, however, tells us that—prior to 1950—cumulative spawning activity by the Kitasu Bay stock extended from the bay itself into adjacent areas, including east into Myers Pass and north to upper Laredo Inlet (Fig. 1). Unfortunately, the snapshots of data obtained by DFO during the 1930s and 1940s fail to capture this historical spawning distribution (Fig. 2). Strong spawning events in Laredo Inlet and Myers Pass have become increasingly rare since the 1950s. Therefore, we see spawning activity confined to the main portion of Kitasu Bay as indicative of diminished herring abundance.

Second, we know that in Kitasu Bay and other spawning areas herring aggregate in large numbers during mid to late March prior to spawning, yet many individuals in those aggregations are merely staging. That is, they remain in the area for only a few days before moving on to spawn elsewhere. Because such staging often occurs when DFO is conducting test sets for pre-season assessment, it may lead to inflated local biomass estimates and poor management decisions.

Fig. 1. Cumulative extent of spawning areas in Kitasoo/Xai'xais territory prior to 1951, as experienced by Kitasoo/Xai'xais traditional knowledge holders. Source: Kitasoo/Xai'xais archives.

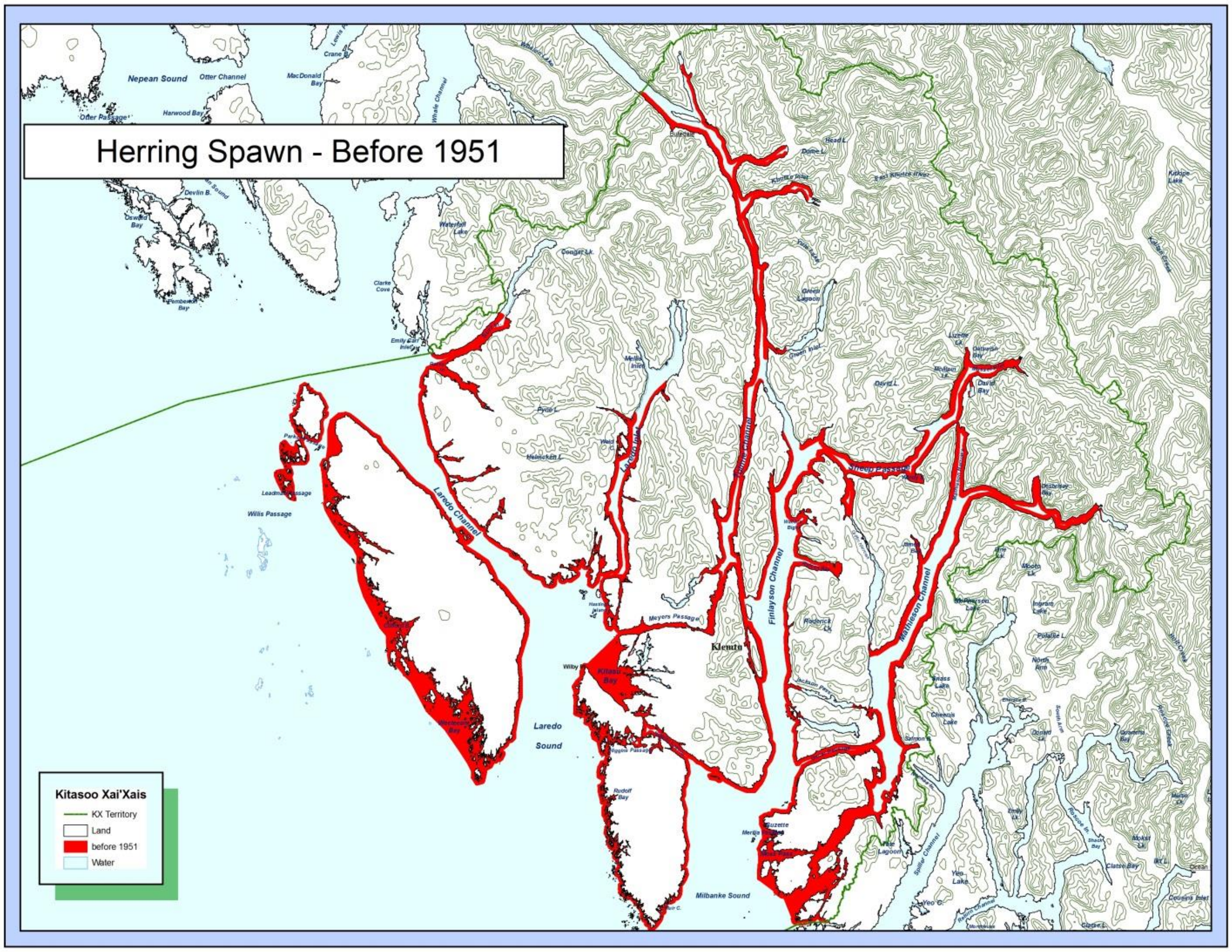
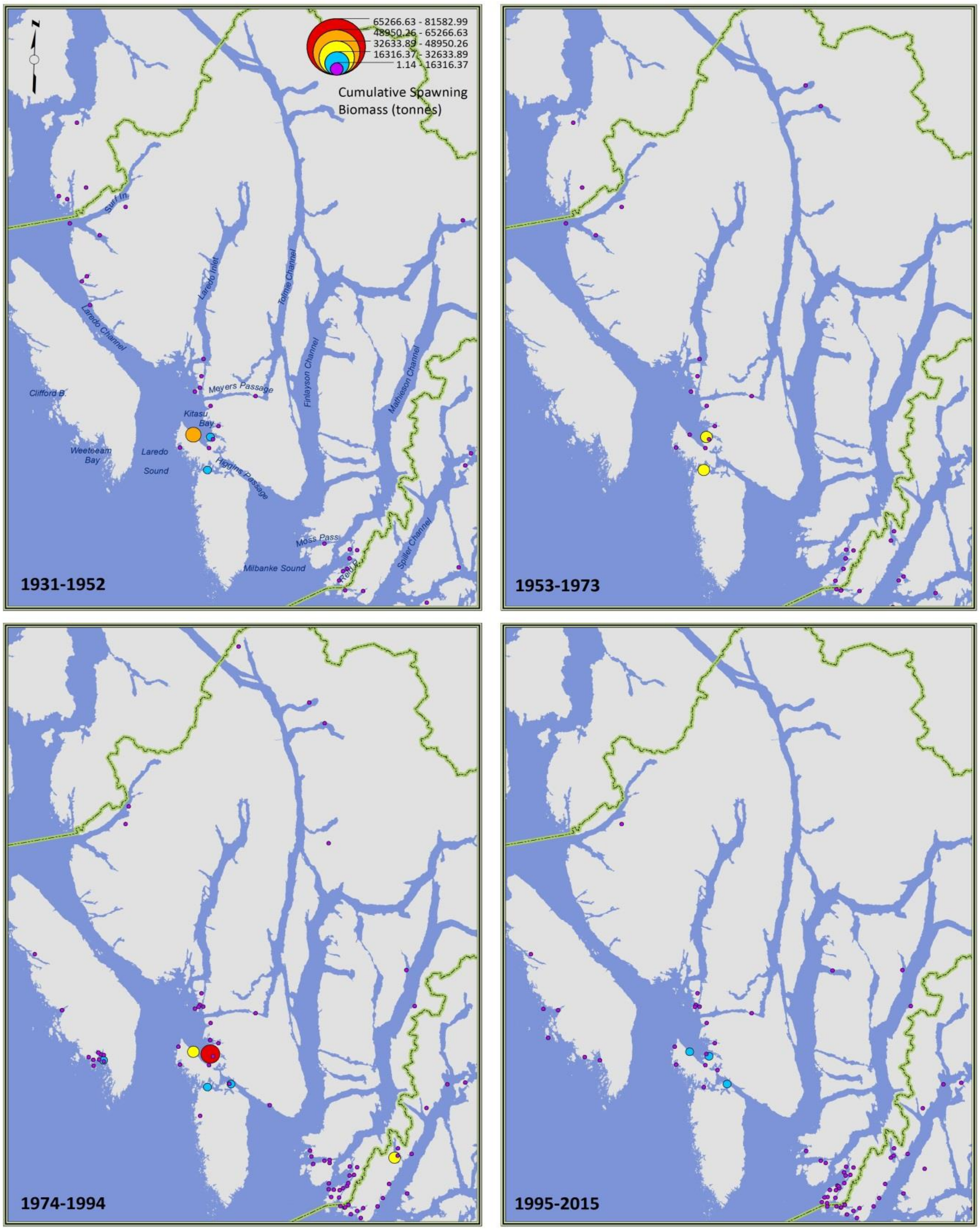

Herring Spawn - Before 1951
Kitasoo Xai'Xais
KX Territory
Land
before 1951
Water
Nepean Sound
Laredo Channel
Laredo Sound
Finlayson Channel
Meyers Passage
Milbanke Sound
Klemtu

Fig. 2. Cumulative spawning biomass (tonnes) of herring during 1931-1952 (upper left panel), 1953-1973 (upper right panel), 1974-1994 (lower left panel) and 1995-2015 (lower right panel), as depicted by DFO survey data for 1-kilometre-long segments of shoreline. Larger symbols and warmer colours depict greater biomass (see legend). (Data points from adjacent segments sometimes overlap.) The green line denotes the boundary of Kitasoo/Xai'xais territory. Note the limited spatial extent of these data compared to traditional knowledge observations in Fig. 1.



1.2 History and current status of Pacific herring fisheries in our Territory and surrounding areas

Indigenous people have fished Pacific herring for thousands of years. Prior to European colonization, we were numerous and developed advanced fishing technologies yet—thanks to the indigenous laws that have always guided our stewardship practices—we did not deplete herring or other resources[1,2,18].

Our hereditary chief structure is a form of marine tenure, in which chiefs are responsible for the proprietorship, stewardship, management and inter-generational knowledge of specific areas. Their long-term experience, knowledge and perspective on the state of a resource are important tools for deciding whether fishery closures are required for conservation. When managing herring, we are concerned not only about that species alone, but have always been aware that, without herring, the whole ecosystem—including many of the larger fishes that we eat—would also suffer[1]. Scientists agree with us[19]. Consistent with this view, our harvest focuses on herring eggs, a practice less likely to impact herring stocks than fisheries that kill reproductive adults. We have always known this, and a recent scientific analysis corroborates our traditional knowledge[20].

Commercial fisheries that kill spawning adults, however, have operated in British Columbia since 1877[21]. Until 1967, these were reduction fisheries. That is, herring were caught to be processed into fish meal and oil, which determined where fishing occurred. The reason is that herring become less oily—and therefore less profitable from a reduction fishery standpoint—as they approach spawning. Consequently, reduction fisheries intercepted migrating herring before spawning began and therefore exploited mixed stocks[22]. And they did so unsustainably. Between 1954 and 1967, the annual exploitation rate in British Columbia averaged about 62% of the estimated biomass[23], removing up to 250 thousand tonnes in one year and driving most populations into sharp decline[21]. To promote recovery, the federal government halted commercial fishing, but only from 1967 through 1971[21].

Kitasoo/Xai'xais members recall commercial fishermen arriving in Kitasu Bay unannounced and without consultation in the early 1970's. These commercial fishermen set gear and accessed herring in ways that significantly interfered with the traditional food fisheries relied upon by our members since time immemorial.

In 1972, commercial fisheries resurged, this time targeting herring for roe at a harvest rate of 20% of the forecasted biomass. Roe quality and fishery profit are greatest when fish are about to spawn. Therefore, roe fisheries target herring near or within their spawning locations, potentially concentrating their impacts on distinct stocks[22]. Today, roe fisheries continue to account for most commercial exploitation of herring on the Pacific West Coast. However in the Central Coast, the higher commercial exploitation in recent years is on herring egg harvest.

Commercial fisheries for spawn on kelp (SOK) occupy a small share of the current market. Unlike roe fisheries, they do not target reproductive adults and, instead, harvest eggs deposited on kelp. Consequently, they are much more sustainable than roe fisheries[20]. The Kitasoo/Xai'xais and our neighbouring First Nations mostly practice SOK commercial fisheries. These can be closed pond, in which pre-spawning adults caught by seine are placed inside a fish pen with suspended kelp blades for egg deposition, and fish are released after spawning, or open pond, in which frames or lines with suspended kelp blades and no netting are placed among free-swimming herring that are actively spawning. In both cases, the harvest consists of kelp blades covered in herring eggs.

Our commercial SOK fishery is closed pond, and we have observed that aggregating herring inside the pen triggers a spawning event that propagates among free-swimming herring in the area. Closed ponding tends to produce a higher egg grade and profit than open ponding, but does so at a potential risk to herring. Susceptibility to disease and physical damage increases with crowding in the pens[24]. Herring on their first spawning season (new recruits) may be particularly vulnerable to viral hemorrhagic septicemia virus (VHSV). A study in Prince William Sound, Alaska, found that risk of contracting VHSV peaked after four to eight days of ponding, and recommended low fish densities inside pens, excluding new recruits from pens (which may be impractical to implement), and releasing fish immediately after spawning[24]. Another risk is that, unless pens are designed to exclude predators, closed ponding may increase predation on herring from sea lions or other predators. Open ponding tends to yield lower grade of product, but also has less risks of physical damage and disease to herring[24]. Our fishery for food, social and ceremonial purposes (FSC) is open pond, with hemlock boughs often replacing kelp as the substrate for egg deposition.

(a) Herring eggs and our trade economy

The financial revenue provided by our commercial SOK fishery is a modern manifestation of the traditional economic role that herring eggs have played in supporting our local economy through trade with neighbouring Nations. For instance, in an archived interview, the late elder Mary Ann Mason, who was born in 1921, described trade as "…the only way we really ate." Her statement referred to the critical role of herring eggs for trading with neighbouring Nations for oolichan grease. Mary Ann Mason elaborated: "That's why we go all out getting sea weed and herring eggs. Because from up at Kitimaat they trade us with grease. And those villages that have the oolichan rivers, we trade that to, it is either dried, salted, or smoked or even frozen[1]."

Written records corroborate the historical importance of herring eggs for trade. For instance, Hudson Bay Company employee William Fraser Tolmie wrote in his diary when stationed at Fort McLoughlin, on Campbell Island[1]: "Saturday, March 7, 1835 - 8 canoes of Neecelowes [Neasloss, a Kitasoo hereditary chief name] Indians have arrived in the Sound and encamped about 3 miles from the fort I supposed in Pine Bay - they have come for the purpose of collecting and trading herring spawn."

In our modern context, both commercial SOK fisheries and the use of herring eggs for trade are vital in supporting our local economy.

(b) Traditional harvests for multiple species during herring season

Our stories, indigenous laws and harvesting practices reflect our awareness that herring drive the abundance and distribution of other species in the ecosystem. During herring season at primary spawning areas like Kitasu Bay, we not only harvest herring eggs but also set longlines for halibut and red snapper (Yelloweye rockfish)—often baited with fresh herring—as our catch rates for groundfish increase that time of year. After spawning activity is over, we hunt surf scoters and other sea ducks which linger in large numbers feeding on herring eggs. This integration of herring egg harvest, longlining for groundfish and hunting for sea ducks is an expression of the nutritional and cultural wealth that herring season provides for us, and of what we risk to lose when herring fisheries are mismanaged.

1.3 Herring spawning areas in Kitasoo/Xai'xais Territory

Herring stocks that are genetically distinct and adapted to specific spawning areas appear to have been common in the past[25]—prior to the declines caused by reduction fisheries—but are less prevalent today[26,27].

Recent research suggests that the size and age of fish at spawning aggregations have an west-east gradient, where larger and older fish are found farther west (at more exposed, outer shore sites). Notably, male and female fish in Spiller Channel were significantly younger than fish from all other sites. Clifford Bay and Kitasu Bay had the oldest fish, with higher proportions of fish at age 6 through 9 than other spawning areas, whereas Spiller Channel was mostly comprised of fish age 3 through 5 (Fig. 4)[42]. These results are consistent with substock distinctiveness that we have long believed to exist through observations that some spawning areas are consistently more productive than others, and that spawn timing is site specific. Continued research on spatial differences in age composition and size of fish will potentially provide valuable insight into optimizing how harvests are allocated in space and into adaptive spatial conservation strategies. Interestingly, prior to this research, hereditary chief Charlie Mason from Klemtu told the researchers that herring would be smaller in the eastern spawning areas of the central coast and get larger as they moved west with the largest being at Aristazabal Island (Clifford Bay). This is yet another example of Traditional Ecological Knowledge (TEK) being supported by science.

The number of active spawning areas in our Territory has declined dramatically since the onset of industrial fisheries (Figs. 1-3). As elaborated below, in recent years there have been only five primary spawning areas: Kitasu Bay, east Higgins Pass, Clifford Bay, Weeteeam Bay, and the combined waters of Moss Pass and Reid Pass (Fig. 3). Additionally, secondary areas—where spawn is less abundant and occurs later in the season (and therefore missed by DFO data displayed in Figs 2 and 3)—remain active in Mathieson Channel, Finlayson Channel and Surf Inlet.

(a) Kitasu Bay—a most significant spawning area

Kitasu Bay (Figs. 1-3) stands out as a spawning location of high significance to our culture and economy, one we have occupied and fished every year without fail for many centuries. Archaeological evidence suggests that Grant Anchorage in Higgins Pass, just south of Kitasu Bay, has been occupied continuously over the last 3500 years[28]. Marvin Island, at the south end of Kitasu Bay, has always been a seasonal camp for the primary purpose of harvesting herring eggs. Archaeological evidence corroborates our use of Marvin Island in the past [29], and the island remains extremely important today. In a 2004 interview, hereditary chief Percy Starr referred to Kitasu Bay as a "real sacred spot for the people here." He explained that, during his upbringing, there were up to 30 families living at Marvin Island for five to six weeks during herring egg harvest season. Through our SEAS program (Supporting Emerging Aboriginal Stewards: http://emergingstewards.org/), we now take our youth to Marvin Island, where we teach them about our indigenous laws, herring and our relationship to marine resources. To this day, Kitasu Bay continues to produce over 95% of the herring eggs we use for FSC. It also is a current source of monetary revenue; since 1976, we have operated a closed pond SOK commercial fishery that alternates between Kitasu Bay and East Higgins Pass. Critically, we view Kitasu Bay as a source population. That is, it produces individuals that return to spawn in Kitasu Bay, and individuals that disperse to spawn elsewhere, thereby contributing to regional abundance

Fig. 3. Cumulative spawning biomass (tonnes) of herring during 2000-2004 (upper panel), 2005-2009 (middle panel) and 2010-2015 (lower panel), as depicted by DFO survey data. See legend to Fig. 2 for additional details.

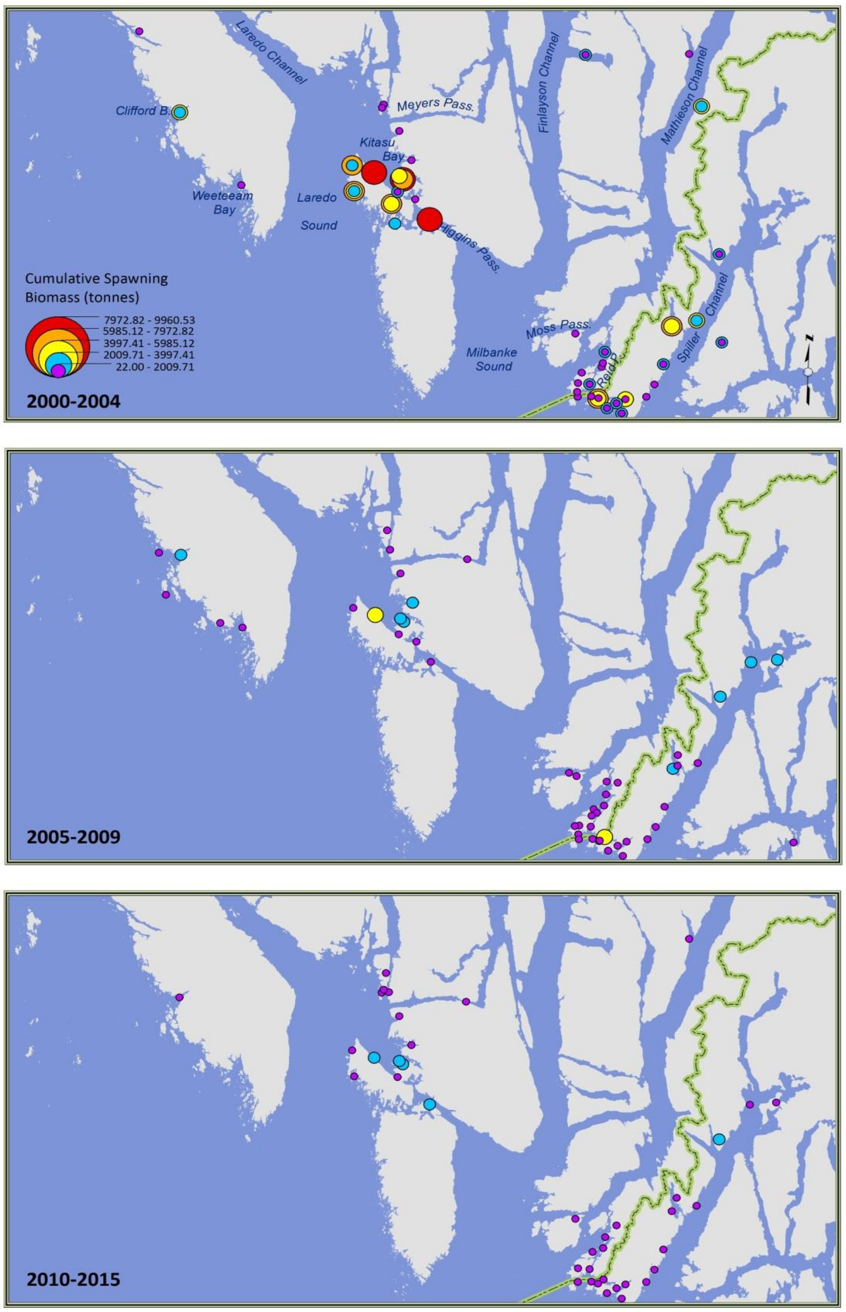
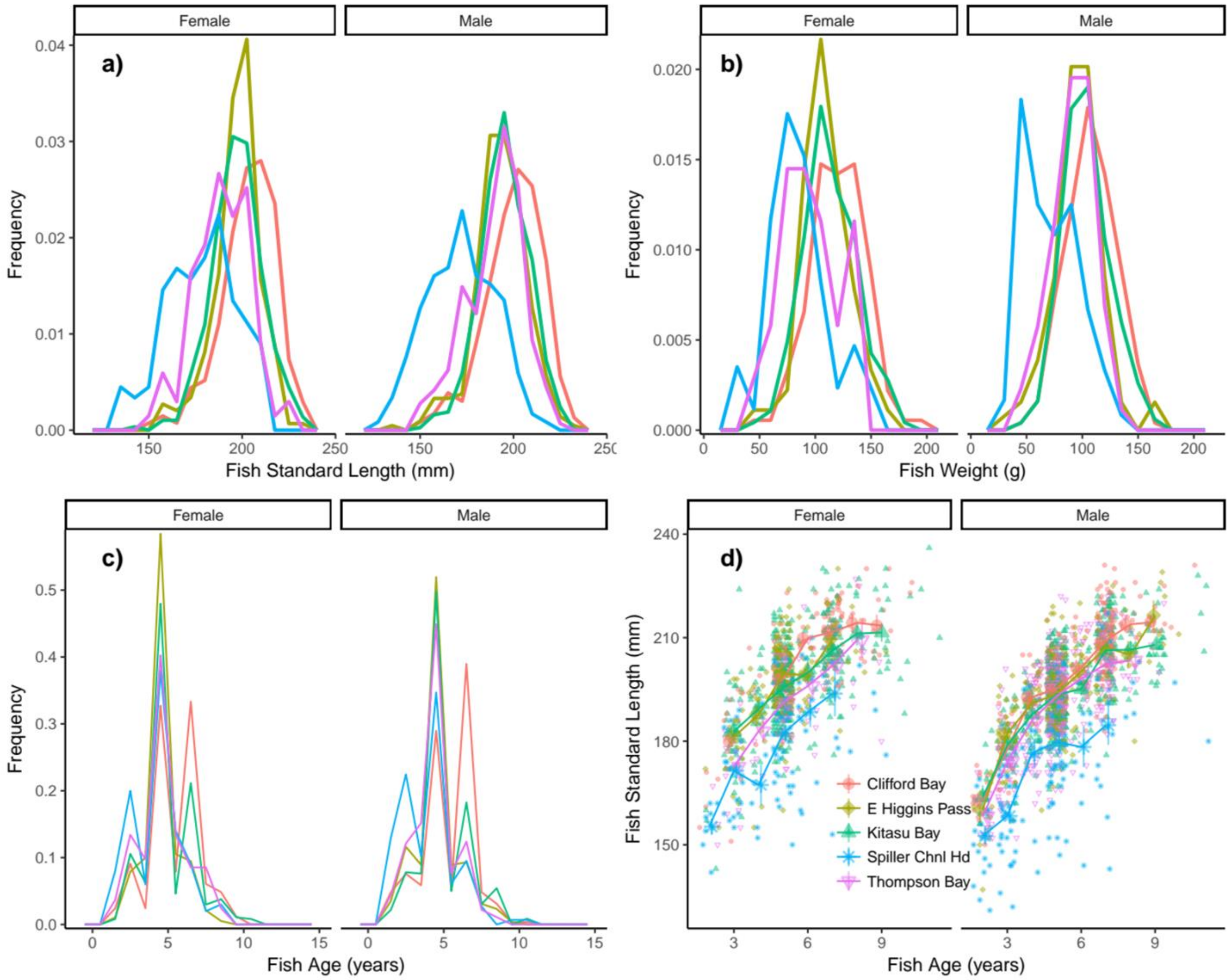


Fig. 4 Results of recent research on spatial differences in size and age[42]: a) Frequency of male and female fish lengths (mm) sampled at all five study locations b) Frequency of male and female fish weights (g) sampled at each of the study locations. Only mature or ripe, as opposed to spent, female fish were included in this plot. c) Frequency (number of fish divided by sample size) of male and female ages sampled at each location. d) Male and female fish length (mm) at age at each location. The small points are raw data; the large points and error bars represent mean size for each age. Length-at-age was chosen over weight-at-age because a female fish will lose weight, but not length, after expelling her eggs.



The commercial roe herring fleet, however, fished Kitasu Bay from 1972 to 1990. To protect our FSC and commercial SOK fisheries, since 1990 we have used our laws and management responsibilities to exclude the commercial roe herring fleet away from Kitasu Bay, successfully doing so except for six years between 1993 and 2007. Despite these efforts, herring spawn abundance in Kitasu Bay declined in 2005 (relative to the 1988-2004 average) and, on average, has remained depressed (Figs 3, 5). Since 2013, however, herring spawn abundance *appears* to be increasing—to the point that abundance in 2015 reached its highest level since 1992 (Fig. 5a). Although longer-term observations are needed to distinguish whether this increase represents an actual recovery trend rather than the short-term variation that characterizes herring populations, it is notable that signs of potential recovery are less evident at two nearby sites, Spiller Channel[*] and East Higgins Pass, where exploitation by roe fisheries has occurred more frequently in the last two decades (Figs. 5b,c).

The broader ecological importance of Kitasu Bay also is evident in the wildlife it supports. During the 2016 spawning season, predators that aggregate to feed on herring eggs or spawning adults—humpback whales, Steller sea lions, harbour seals, bald eagles, gulls, and other birds (except surf scoters)—were more abundant at Kitasu Bay than at sites with lower herring biomass, such as Higgins Pass and Spiller Channel (after correcting for shoreline-length differences: Fig. 6)[43].

While formal scientific observations are limited to 2016, in recent years we have consistently observed a greater abundance of predators at Kitasu Bay than elsewhere, which likely reflects the fact that we have deterred roe fisheries from this area and allowed the local stock to rebuild. The implication of predator aggregations to mortality rates in Kitasu Bay, however, has yet to be investigated.

Effective spatial management is particularly important for Kitasu Bay, considering recent research showing that spawning aggregations of fish are likely distinct here from populations further east (Fig. 4)[42], and the abundance of wildlife supported by these fish (Fig. 6)[43]. Well informed spatial management strategies can help protect herring stocks from exploitation and provide substantial ecological benefits to the rest of the food web[3].

Hastings Island and Meyers Pass are just north of Kitasu Bay, and we consider herring that spawn in these areas to be part of the Kitasu Bay stock. Though less productive than the main portion of Kitasu Bay, spawning activity at Hastings Island and Meyers Pass has continued through recent decades (Fig. 3); these spawning areas must be managed sustainably to safeguard against poor years within the main portion of Kitasu Bay.

[*]Spiller channel is where our neighbours, the Heiltsuk Nation, conduct their FSC and SOK fisheries.

Fig. 5. Index of herring spawn abundance (length X width X number of egg layers) summed per year at a) Kitasu Bay (DFO section 67e-3) b) Spiller Channel (DFO section 72-2) and c) East Higgins Pass (DFO section 77-2). The index used here differs from the standard spawn index used by DFO in stock assessment models, and is meant to illustrate changes in relative abundance. Vertical lines indicate the year when statistically significant changes in the average index occurred (2005 for Kitasu Bay and East Higgins Pass, 2003 for Spiller Channel), and horizontal lines indicate the statistically significant trends before and after that change. Gray shaded areas represent the 95% confidence interval around these estimates. Note that in 2015 the index in Kitasu Bay reached its highest value since 1992, but longer-term data are required to distinguish a recovery trend from short-term variability. See the Appendix for technical details.

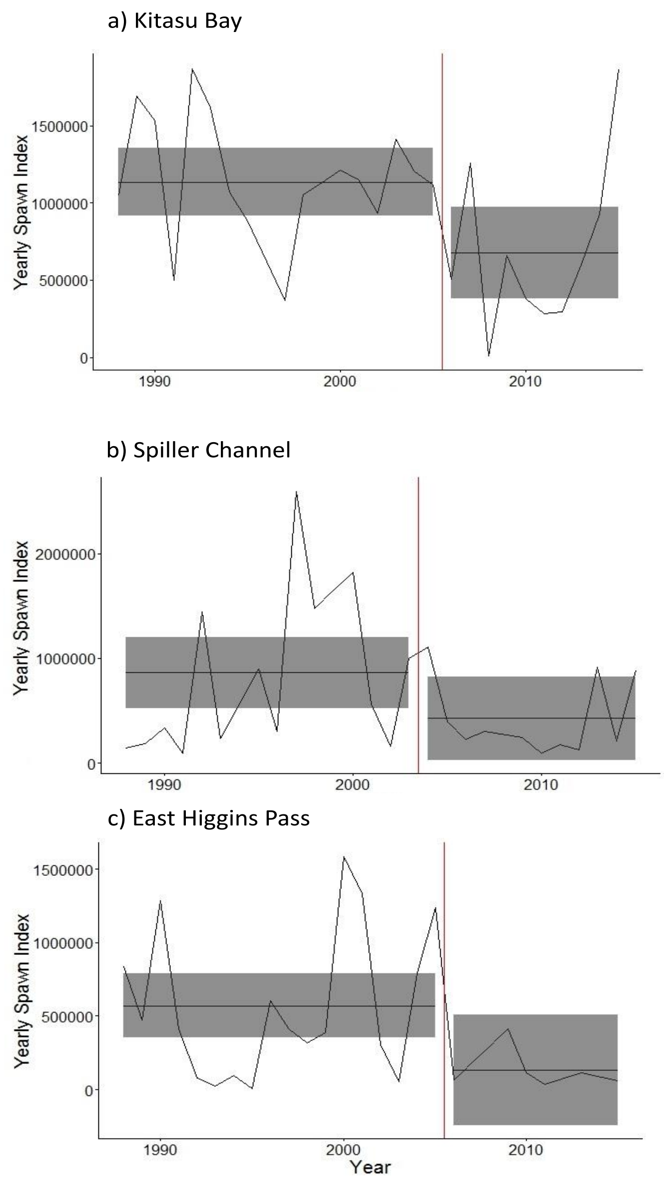
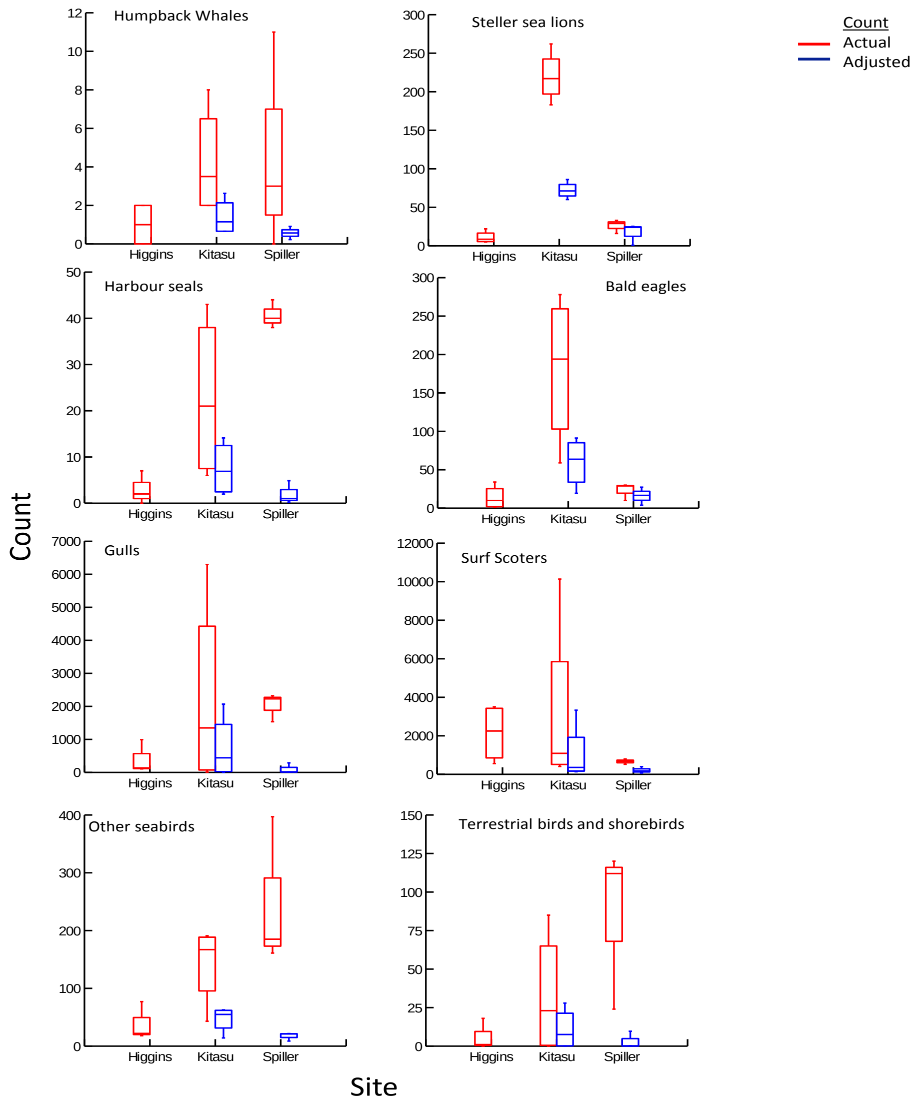


Fig. 6. Daily numbers of predators during the 2016 herring spawning season aggregating at east Higgins Pass, Kitasu Bay and Spiller Channel. Actual counts (red) are total animals counted, whereas adjusted counts (blue) are corrected for relative shoreline length*. Counts took place on 3-4 separate days per site and encompassed the period just prior and during peak spawning activity (Boxes enclose the median (centerline) and 25th and 75th percentiles (boundaries of the box); line caps indicate 10th and 90th percentiles.) (<u>Data</u>: Thompson, M.D., Frid, A., Okamoto, D.K., Salomon, A.K. (2016) Thesis Manuscript in Prep.)



* Shoreline lengths surveyed were: East Higgins Pass= 8,078m=*a*; Kitasu Bay = 24,604m=*b*; Spiller Channel = 71,209m =*c*. Adjusted counts for Kitasu Bay and Spiller Channel are actual counts multiplied by *a*/*b* and *a*/*c*, respectively. East Higgins Pass is the baseline (i.e. shortest) shoreline length and requires no correction.

(b) Other primary spawning areas

East Higgins Pass (including Higgins Lagoon: Figs. 1-3) produces herring eggs that are less preferred for FSC because local conditions (tannic water, abundant jellyfish) affect their taste[1]. Nonetheless, Higgins Pass plays a role in supporting the ecosystem and safeguarding our FSC and SOK fisheries against spawning failure at Kitasu Bay. It supported our commercial SOK fishery until recently. The commercial roe fishery exploited it heavily through 2007. From 2008 to 2015 we diverted the roe fishery elsewhere, yet allowed a harvest of 213 tonnes, equivalent to 10 % of the in-season biomass estimate, in 2016. Similar to Kitasu Bay, herring spawn abundance at this site declined in 2005 (relative to the 1988-2004 average) and has remained depressed (Fig. 5c; see also Fig. 3). Historically, spawning activity in this area has spread to west Higgins Pass and adjacent areas of Price Island in some years (Fig. 1). Despite its lower herring abundance, during the 2016 spawning season east Higgins Pass had a larger relative abundance of surf scoters than Kitasu Bay, which points to the ecological importance of this spawning area (Fig. 6).

On the west side of Aristazabal Island, herring continue to spawn in Clifford Bay (including in 2016) and but have not spawned recently at Weeteeam Bay (Fig. 3). At these sites, herring are less abundant and spawn earlier than at Kitasu Bay. Because of their remoteness and greater exposure to weather, they have been fished less intensively by commercial and FSC fisheries.

Moss Pass and Reid Pass continue to be active spawning areas (Fig. 3), including in 2016. These areas were key to our past fisheries, providing the earliest herring eggs of the season and alternative harvest areas when abundance at Kitasu Bay was low[1]. In a 1994 interview, hereditary Chief Percy Starr states that when Kitasu Bay failed to provide enough herring eggs, "… we always went, and I don't know how many times, I went to get my herring eggs out of Reid Pass[1]". Harvesting at Moss and Reid Pass often took place side-by side with our Heiltsuk neighbours[1]. Current herring abundance at Moss and Reid Pass (Fig. 3c), however, reflects overfishing by commercial fisheries and is below our historical baseline (Fig. 1). We have not included our management zoning for Moss and Reid Pass as we are working with our Heiltsuk neighbours in an effort to reach a joint management plan in future for these areas.

(c) Management of spawning areas by hereditary chiefs

The Kitasoo/Xai'xais people, like other coastal First Nations, have always had a governance structure. Throughout our history, spawning areas have been managed according to legal principles and protocols upheld by our hereditary chiefs—the decision makers who own particular pieces of land and bodies of water. As such, they can decide where and when fishery closures should take place within their chiefdom. When harvests are allowed, the chiefs decide when they occur, by whom, by what methods and the maximum catch. But the system is not designed to be exclusive. For instance, hereditary chief Charlie Mason explains that within Kitasu Bay, different areas belonged to different people, but people outside those families could ask permission to harvest resources in that area. Also, chiefs determine the extent to which neighbouring Nations can harvest resources in their chiefdom. Respect, communication, and reciprocity are central to these protocols and practices.

Hereditary chiefs do not make decisions in isolation, as they often seek counsel from elders and other chiefs. The authority of elders is reflected in our oral history and remains current. Charlie

Mason explains that elders know the history of names and therefore continue to play a role in interpreting harvesting laws and resolving disputes about resource ownership.

Today, chiefs continue to enact their roles and responsibilities for the management of herring and other resources. They work with knowledge holders, elders and technical staff from our resource stewardship office to interpret and enforce the indigenous laws that regulate harvesting[1].

1.4 Spatial protection

Our herring management principles derive from our experience that commercial roe fisheries cannot coexist in the same space as our FSC and SOK fisheries. Therefore, we need a spatial management approach in which we sustainably manage and protect the herring stocks of our Territory and the priority of our FSC and SOK fisheries, and where required exclude roe herring fisheries from areas important to conservation, and our culture and economy.

To proactively manage our resources, we have engaged in contemporary marine use planning since 2000[30]. In consultation with our hereditary chiefs and other knowledge holders, we have identified critical herring spawning locations from which to exclude roe fisheries in perpetuity. Since 2010, we have worked to integrate our marine planning process with that of neighbouring Nations—Heiltsuk, Nuxalk and Wuikinuxv—under the umbrella of the Central Coast Indigenous Resource Alliance (www.ccira.ca). We currently are working with other levels of government to implement our plans. Specifically, we first created a Central Coast First Nations Integrated Marine Use Plan[31], which became the foundation for the Marine Planning Partnership (MaPP) with the province of British Columbia (www.mappocean.org). This partnership produced the Central Coast "MaPP spatial plan"[32], which zones allowable uses and protected areas. The MaPP spatial plan is the basis for ongoing discussions with the federal government to establish a network of marine protected areas (MPAs) in the Northern Shelf Bioregion.

MPAs and other forms of spatial fishery closures safeguard against management uncertainty, especially in the face of climate change, and provide baselines against which to gauge fishery effects[12,13]. Evidence from around the globe indicates that spatial fishery closures can promote the recovery and conservation of many species, as long as closures are large, placed in biologically relevant places, enforced for no-fishing compliance, and given enough years for species to recover from exploitation[33]. Atlantic herring are among the species that have shown "dramatic increases in abundance" after spatial fishery closures were implemented in the Scotian Shelf, eastern Canada[34]. Accordingly, we see spatial protection—guided by indigenous laws, traditional knowledge, and science—as a key management tool for herring and other marine resources in our Territory[35].

Effective spatial management and protection requires spatial data. Spatial differences in age and size composition, microchemistry, and genetics will improve our understanding of stock distinctness, providing valuable insight into optimizing how harvests are allocated in space, and into adaptive spatial conservation strategies, including MPAs and other forms of protection. Accordingly, we will continue to support scientific research that includes our traditional knowledge and aims to improve our ability to protect herring stocks on the Central Coast.

PART II - THE KITASOO/XAI'XAIS HERRING MANAGEMENT PLAN

2.1 Objectives

Our indigenous laws and responsibilities require a precautionary approach to resource management[1]; Section 35(1) of Canada's Constitution Act requires conservation and the protection of our fisheries to be priority over other fisheries[36].

Accordingly, here we outline a herring management plan with the following objectives:

1. *To formally and explicitly incorporate indigenous law and the hereditary chief system into joint-management of herring stocks with the federal government and other First Nations.* This objective requires that the authority and responsibilities of our hereditary chiefs are recognized as decision makers with authority that is inherent to us as indigenous peoples, and which cannot be superseded by the fisheries minister.

2. *The recovery, conservation and long-term persistence of diverse Pacific herring populations and of the multi-species interactions that they support in the ecosystem.* Effectively, this means maintaining herring abundance not only to sustain the needs of people, but also the needs of diverse predators, including groundfish, marine mammals, salmon, seabirds and others[1,19-21,37]. This objective requires the protection of key spawning areas from roe fisheries and other major stressors. Maintaining a herring biomass large enough to support and sustain a functional ecosystem is the first priority for management..

3. *Access to herring for FSC fisheries by the Kitasoo/Xai'xais Nation.* Herring provide us with physical sustenance and are inherent to our cultural identity. Managing herring to support sustainable FSC fisheries is essential to our physical and spiritual health[1]. Once the ecosystem role of herring is safeguarded, FSC fisheries have priority over our commercial SOK fisheries.

4. *Access to herring for commercial SOK fisheries by the Kitasoo/Xai'xais Nation*. As modern indigenous people, we live in a contemporary economy and seek local employment opportunities compatible with our conservation ethic and indigenous laws. These economic opportunities include commercial SOK fisheries, which our marine use plans recognize as having much lower ecological impacts than roe fisheries, a view that science corroborates[20]. Once our FSC fisheries are safeguarded, our commercial SOK fisheries are priority over non-indigenous commercial fisheries.

5. *To provide access to herring for non-indigenous fishers when high abundance provides a surplus.* Consistent with the doctrine of priority[36], we define "surplus" as the herring biomass above that required to support the ecosystem[19] and our indigenous fisheries, while allowing a buffer for data uncertainty and the additional stresses of climate change[4] and ocean acidification[11].

To achieve these objectives, we will integrate indigenous laws, traditional knowledge and science as described below.

2.2 Applying fishery models

(a) General issues

We understand that modern fishery models are tools to help managers estimate the abundance of fish we cannot count directly, such as herring, or to distill the essence of how an ecosystem *might* respond to external forces, such as fisheries, but only under the specific conditions or assumptions that the modeller assumes to be true in the "world" of the model. Sometimes these assumptions are well-grounded in reality. Sometimes they are blatant but necessary simplifications. If used thoughtfully, these models may help us address how complex forces for which we have no historical precedent—such as the combined effects of industrial fisheries and climate change—might be altering the ocean[6].

Our position is that—when the objectives and assumptions include our information and perspectives—models can provide useful assistance on how to manage fisheries. If a modeller works in isolation from us, however, chances are that the model will not address questions relevant to our conservation needs.

Herring are a case in point. Prior DFO fishery models have focused primarily on one type of fishery, the roe fishery that kills spawning adults[20]. It was not until recently that scientists outside DFO developed an alternative model that contrasts fisheries that harvest only eggs—as our FSC and SOK fisheries do—against industrial fisheries that harvest spawning adults. The upshot of that alternative model is that fishers can harvest a much higher proportion of eggs than of adults without having significant impacts on the herring population. Accordingly, consistent with our traditional knowledge, scientific analysis and experience, harvest control rules must be much more conservative for the adult than for the egg fisheries[20].

Similarly, traditional knowledge, science, and experience tell us that individual spawning areas likely are distinct stocks. DFO models, however, treat the entire Central Coast as a single stock, thereby ignoring our understanding that management must occur at much finer spatial scales—at the level of individual spawning areas.

To facilitate positive change, we are willing to acknowledge the potential benefits and constraints of fishery models. Accordingly, we have begun to work with fishery scientists who are considering our knowledge and perspective. This collaboration strives to improve fishery models and is consistent with the objectives of our plan.

(b) Limit reference points

Limit reference points (LRPs) are benchmarks (i.e. biomass thresholds) used to assess stock strength and abundance and, where necessary, constrain harvests. Fishery models make assumptions that affect the estimated biomass, and therefore whether a LRP is being met.

For instance, parameter q was introduced in the 2012 DFO stock assessment model to correct for spawn missed by divers during surveys, and has implications for biomass predictions[38]. The 2015 biomass estimate for the Central Coast (areas 6 and 7) that assumes divers miss half the spawn (40,981 tonnes when q=0.5) is nearly half than if assuming divers do not miss any spawn (23,126 tonnes when q=1)[15]. Not surprisingly, parameter q has been controversial, and much work is needed to reduce uncertainty about its value, and about how that value has shifted over time as a consequence of changing methodology or funding limitations that preclude proper field assessments. Therefore, whenever uncertainty exists around a parameter value—q or otherwise—the most conservative biomass estimate should be used to assess whether a LRP has been met.

In sections 2.5 and 2.6 we describe limit reference points for SOK and commercial roe fisheries. These LRPs represent interim criteria. As we continue to work with scientists, we will refine our criteria and continue to revise these LRPs in the future.

2.3 Primary spawning areas

Primary spawning areas are fundamental to the spatial management zones of our Territory (Section 2.4). They are sections of our Territory with consistent spawning activity, historic or current, such that:

1. They play a key role in supporting the ecosystem role of herring.

2. They are important to our FSC and SOK fisheries, including:

    (a) Depleted areas we currently do not fish but harvested historically and would harvest in the future after their recovery

    (b) Areas we currently harvest but require further recovery

    (c) Areas we must protect for conservation and FSC purposes.

As elaborated earlier (Section 1.3) our primary spawning areas are Kitasu Bay, East Higgins Pass, Clifford Bay, Weeteeam Bay, and the combined waters of Moss and Reid Pass. We have not included our management zoning for Moss and Reid Pass as we are working with our Heiltsuk neighbours in an effort to reach a joint management plan in future for these areas.

2.4 Spatial management zones

Implementation of our herring management plan is based on the following spatial management zones:

Table 1. Spatial management zones for herring.

		Allowable herring fisheries		
Management zone	**Location**	***FSC***	***Commercial SOK***	***Commercial Roe***
Core Habitat Protection Zones	Sublocations within primary spawning areas (Fig. 7).	yes	no	no

Communal Protection Zone	Kitasu Bay (Fig. 7)	yes	yes	no

(a) Core Habitat Protection Zones

1. These are spatial fishery closures at all primary spawning areas that encompass critical habitat, as identified by our local knowledge and DFO's spatial data on high concentrations of cumulative spawn[*] (Fig. 7).

2. These zones extend from the intertidal zone to 300 metres offshore or across the length of narrow channels (i.e. <300 metres-wide).

3. All commercial fishing activities—including our own use of closed ponds for SOK—cannot occur within these zones.

4. FSC is permitted in core habitat protection zones.

(b) Communal Protection Zone

This zone encompasses Kitasu Bay (Fig. 7) and is to be managed as follows:

1. Roe herring fisheries and other non-indigenous commercial fisheries are excluded.

2. All SOK commercial fishery activities, including placement of closed ponds and capture of fish, are excluded from the Core Habitat Protection Zone south of Wilby Point (Fig. 7).

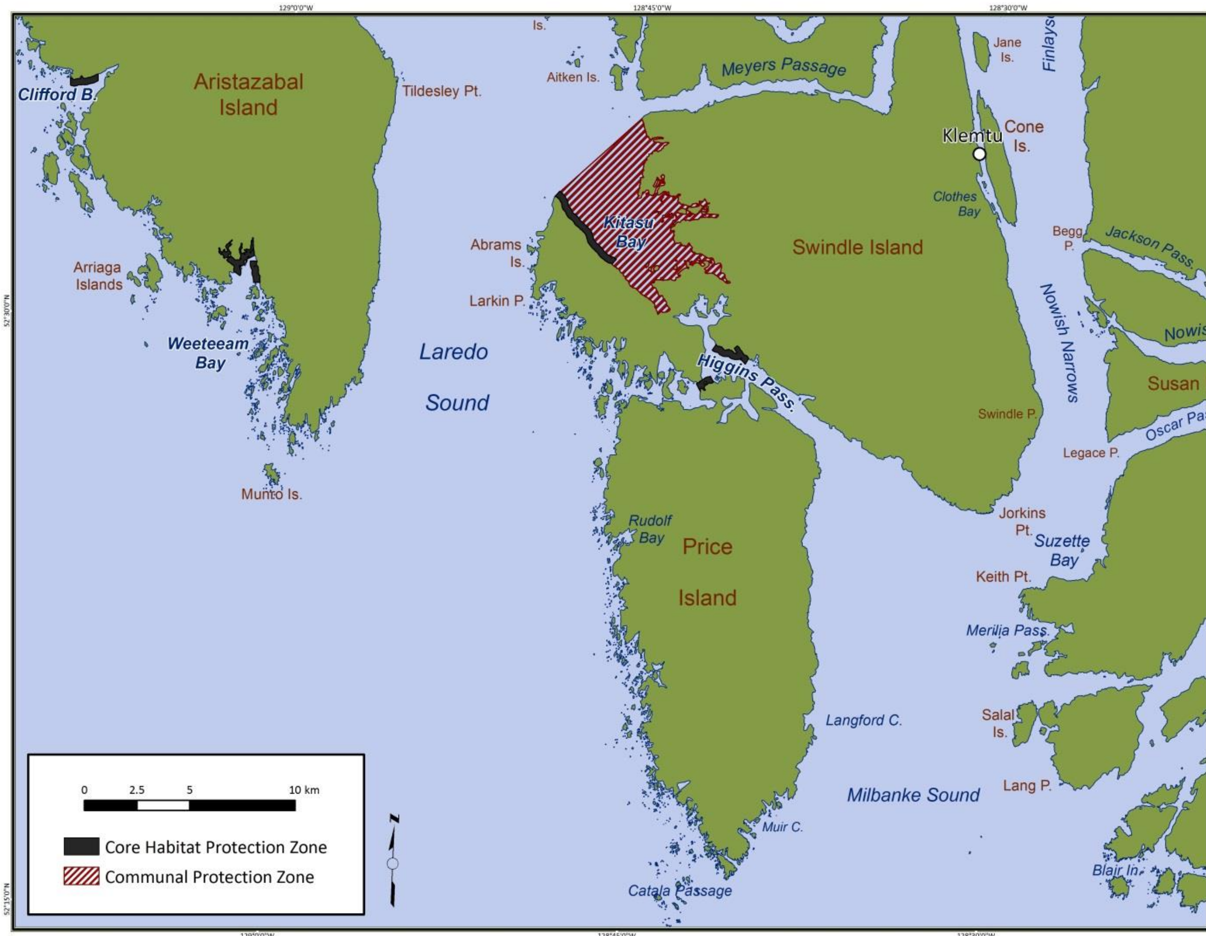
3. SOK and FSC fisheries within Kitasu Bay are managed according to criteria described in section 2.5.

4. No moorage of large vessels in Kitasu Bay during spawning season without prior approval from Kitasoo/Xai'xais

5. Uplands of Kitasu Bay and Higgins Pass are protected from industrial land uses as part of the Spirit Bear Conservancy developed by Kitasoo/Xai'xais and the Province of B.C. We will continue to enforce these land use restrictions to protect herring habitat within the intertidal zone.

[*] http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/bcmaph-eng.html

Fig. 7. Spatial management zones at primary spawning areas. Kitasoo/Xai'xais will continue to work with the Heiltsuk Nation regarding the location of Core Habitat Protection Zones in Moss and Reid Pass.



2.5 Management of FSC and commercial SOK fisheries

(a) Opening of FSC fisheries

We reiterate that our management objectives prioritize conservation and the needs of the ecosystems first (maintaining herring abundance for people and other species dependent on herring), followed by our right to pursue FSC fisheries. Accordingly, FSC fisheries will occur only where and when the judgement of hereditary chiefs and DFO's pre- and in-season biomass assessments indicate that FSC harvest can occur without impacting conservation and the ecosystem role of herring,. As they become available in the future, we will also consider ecosystem-based fishery models that include our information and perspective as additional criteria for managing our FSC fisheries.

(b) Limit reference point for commercial SOK fisheries

Allowing SOK commercial fisheries to occur on any given year requires a two-tier decision process involving a LRP. Specifically:

1. Commercial SOK fisheries cannot occur at any spawning area unless herring biomass for DFO statistical areas 6, 7 and 8 (combined) is ***17,600 tonnes*** or greater. This interim LRP is as identified in the Central Coast First Nations Integrated Marine Use Plan[31]. It was determined by collective discussions between Central Coast First Nations, which drew from the long-term observations and judgement of hereditary chiefs, expertise of marine planning committees, and community workshops. As detailed in section 2.2, when different biomass estimates are generated from alternative assumptions about uncertain parameter (e.g. q=1 vs. q<1), deciding whether the LRP was met should be based on the most conservative estimate. Also, as we continue to work with scientists we will refine our criteria and revise this LRP accordingly.

2. When biomass for the Central Coast exceeds the LRP, SOK commercial fisheries may open at specific locations, *contingent* on the criteria and approval of hereditary chiefs, which will be informed by pre- and in-season assessments at the scale of individual spawning areas. As they become available in the future, we will consider ecosystem-based fishery models that include our perspective as complementary decision tools for our commercial SOK fisheries.

(c) Minimizing damage to fish from commercial SOK fisheries

Within the Kitasu Bay Communal Protection Zone and any other areas where they may occur in the future, commercial SOK fisheries are managed to reduce physical damage and disease transmission within ponds[24]. Specifically:

1. Do not over-crowd fish inside closed ponds.

2. Release fish from ponds immediately after spawning.

3. Use closed ponding designed to exclude sea lions and other predators. Given the large abundance of sea lions and other predators at Kitasu Bay during spawning season (Fig. 6), this management action is critical.

(d) General management criteria for commercial SOK and FSC fisheries

1. Do not fish without permission from hereditary chiefs.

2. Close or reduce FSC and/or SOK fisheries if information integrated from traditional knowledge and science, pre- or in-season, warns that herring abundance is insufficient to withstand harvest.

3. Leave product with thin layers of herring eggs in the water to hatch.

4. Do not shoot sea lions or conduct other hunting activities that spill blood on the water during spawning season, as these activities disrupt spawning[1].

5. Minimize use of sonars and engines near spawning herring, and be as quiet as possible while setting ponds or hemlock boughs[1].

2.6 Roe herring fishery management

(a) Limit reference points

Outside Kitasu Bay and Core Habitat Protection Zones, allowing commercial roe fisheries to occur on any given year requires the following two-tier decision process:

1. Commercial roe fisheries cannot occur anywhere in Kitasoo/Xai'xais territory unless herring biomass for DFO statistical areas 6, 7 and 8 (combined) exceeds ***37,600 tonnes***. This interim LRP is as identified in the Central Coast First Nations Integrated Marine Use Plan[31]. It was determined by collective discussions between Central Coast First Nations, which drew from the long-term observations and judgement of hereditary chiefs, expertise of marine planning committees, and community workshops. Critically, the LRP is consistent with the precautionary approach that is required in the face of uncertainty in fishery data and model outputs, and the need to mitigate synergistic impacts and effects of fisheries, climate change and ocean acidification. As detailed in section 2.2, when different biomass estimates are generated from alternative assumptions about uncertain parameter (e.g. q=1 vs. q<1), deciding whether the LRP was met should be based on the most conservative estimate. Also, as we continue to integrate our traditional knowledge and experience with ongoing scientific work, we will refine our criteria and revise this LRP accordingly.

2. When biomass for the Central Coast exceeds 37,600 tonnes, commercial roe fisheries may open at specific locations outside protected zones, *contingent* on the criteria and approval of hereditary chiefs, which will be informed by pre- and in-season assessments at the scale of individual spawning areas.

3. As we continue to work with scientists and traditional knowledge holders, in the future we will refine our criteria and provide specific LRPs for individual spawning areas that will help inform whether fisheries in that area can occur.

(b) Exploitation rates and other management criteria

1. When commercial roe fisheries are allowed, their exploitation rate will be 7% of the estimated herring biomass inside the spawning area (stocklet biomass). Exceptions may be made in years of high abundance, as determined by pre-season assessment and the judgement of hereditary chiefs, when the exploitation rate may increase to 10%. These rates are as identified in the Central Coast First Nations Integrated Marine Use Plan[31].

2. To determine whether fisheries may open at a given site, in-season assessments will use soundings, test sets on fishable aggregations, spawn flights conducted three to four days per week, and may consider previous years' spawning estimates as reference criteria. Additionally, hereditary chiefs will use their long-term understanding of local resources to judge whether a fishery closure is required.

3. The targeted exploitation rate of 7–10% for any commercial roe herring fishery within a spawning area will be reduced proportionally to account for any FSC or SOK fisheries that occur within that same spawning area for that year.

2.7 Conservative fisheries management in the face of climate change

We have been watching the ocean change rapidly in recent decades in response to climate change. Scientists predict that these changes will decrease our access to Pacific herring and other marine resources[4]. Therefore, we must ramp up our precautionary approach as ocean conditions continue to shift. Effectively, this means monitoring ocean change—both from the standpoint of science and our traditional knowledge—and decreasing exploitation rates from non-indigenous fisheries first, and indigenous fisheries next, if the available information indicates the need to curtail our fisheries.

2.8 Administration of Fisheries

1. The Kitasoo/Xai'xais resource stewardship board—which includes hereditary chiefs and technical staff—will be responsible for pre- and in-season management decisions, in communication and collaboration with DFO.

2. The Kitasoo/Xai'xais Stewardship programs, including the Guardian Watchmen and co-management programs, will monitor and enforce compliance of spatial and aspatial management decisions regulating FSC, SOK and roe herring fisheries, including the permanent roe fishery closures at the Kitasu Bay Communal Protection Zone and at Core Habitat Protection Zones (Fig. 7).

3. The Kitasoo/Xai'xais encourage protocols with commercial operators to better promote the management and conservation of the herring stocks and the implementation of sustainable fisheries in our Territory.

4. Food fishery permits and transport permits must be obtained from the Kitasoo/Xai'xais Band office. Only members of our Nation will receive such permits.

2.9 Addressing some salient scientific gaps

We support scientific research that aims to respect and include our traditional knowledge. Below we list some scientific gaps that, if addressed, could improve future versions of our management plan. (For additional scientific issues in need of research see the Ocean Modelling Forum report[39].)

1. We need formal, robust analyses of how reductions in biomass affect the spatial extent of spawn and egg layer thickness, and therefore the quality and quantity of eggs harvested for FSC and SOK.

2. Understanding stock distinctness at the scale of individual spawning areas is a critical gap which, when filled, would help us improve spatial management. Ongoing analyses by researchers at the University of British Columbia (Wade Smith) and the University of Washington (Lorenz Hauser and his lab) are using microchemistry and genetic tools to assess stock distinctness in the Central Coast. Also, an SFU researcher (Dan Okamoto) is conducting field research and developing models to examine the implications of managing herring at the scale of individual spawning areas[42].

3. Parameter *q* was introduced in the 2012 DFO stock assessment model to correct for spawn missed by divers during spawn surveys, and has implications for biomass predictions[38]. Research is needed to estimate *q* more rigorously.

4. There is large spatial variability in depth of spawn. We know little about the causes of such variability and how it relates to egg survival. Results from 2016 field research conducted out of Simon Fraser University[43] suggest that egg survival at deep spawning sites (≥ 30 m deep) is very low and that a majority of eggs are unfertilized, which has potential implications for stock assessment models.

5. Fisheries often truncate size and age structure, with possible implications for reproductive potential at the population level[40]. A better understanding of size and age structure in relation to fishery pressure is needed to inform management decisions. For instance, DFO data suggest that herring of ages 8 to 10+ were more common in the Central Coast between the late 1980s and early 2000s than before or after that period[41]. The extent to which this observation reflects fishery exploitation or other causes has yet to be examined.

6. We do not know the extent to which predator-inflicted mortality as a consequence of increasing numbers of sea lions and other predators may be affecting herring populations in the Central Coast. Filling this data gap may help improve stock assessment models.

7. More generally, DFO's 2015 stock assessment report[15] states that "For all stocks, the uncertainty around the natural mortality estimates is very high in recent years." Given that natural mortality is an important parameter in stock assessment models and projections, better estimates are needed.

8. While the general effects of climate change and ocean acidification on marine ecosystems are receiving much scientific attention, not enough is known about how these stressors may specifically affect Pacific herring in our Territory and in the Central Coast, either directly or indirectly via larger ecosystem changes[10,11]. For instance, we know that weight-at-age of herring has been declining in the Central Coast[15], but little is known about the potential contribution of changing ocean conditions to shifts in body condition and resulting fecundity. Filling these sorts of knowledge gaps would help inform whether our management decisions need to become even more conservative. At the very least, we need programs that monitor changing ocean conditions at spatial and temporal scales relevant to the management of individual spawning areas.

Disclaimer

This plan is intended to inform and guide herring management decisions and herring resource harvesting in Kitasoo/Xai'xais Territory. The Kitasoo/Xai'xais rely upon and exercise aboriginal title, rights and responsibilities, including ownership, jurisdiction, stewardship and management over the lands, waters and resources, including the marine spaces, throughout our Territory.

The Kitasoo/Xai'xais acknowledge that the Heiltsuk Nation rely upon and exercise aboriginal title and rights, including ownership, jurisdiction and management over the lands, waters and resources, including the marine spaces throughout their territory. The Kitasoo/Xai'xais also acknowledge that Heiltsuk assert aboriginal title and rights to portions of the lands and waters within this management plan, and acknowledge that herring is an important species to the Heiltsuk. The Kitasoo/Xai'xais will continue to work collaboratively with the Heiltsuk, (and other First Nations of the Central Coast), to find mutually acceptable ways of collaboratively managing herring, particularly as it relates to those herring stocks and spawn locations on which we rely and share responsibilities for this and future generations.

While this plan is an exercise of our inherent and constitutional rights and responsibilities it is not intending to describe, define, amend or deny the full extent of our inherent or Aboriginal rights, title and responsibilities, or the title, rights and responsibilities of any other Nation.

This plan is not an acknowledgement of Crown title and rights and those who rely on Crown licences.

This plan does not limit or prejudice the positions of the Kitasoo/Xai'xais may take in any negotiations or legal or administrative proceedings.

References

1 Kitasoo/Xai'xais. Indigenous Law Archives. (2016).

2 McKechnie, I. *et al.* Archaeological data provide alternative hypotheses on Pacific herring (Clupea pallasii) distribution, abundance, and variability. *Proc. Natl. Acad. Sci. U. S. A.* **111**, E807-E816, doi:10.1073/pnas.1316072111 (2014).

3 Essington, T. E. *et al.* Fishing amplifies forage fish population collapses. *Proc. Natl. Acad. Sci. U. S. A.* **112**, 6648-6652, doi:10.1073/pnas.1422020112 (2015).

4 Weatherdon, L., Ota, Y., Jones, M., Close, D. & Cheung, W. Projected Scenarios for Coastal First Nations' Fisheries Catch Potential under Climate Change: Management Challenges and Opportunities. *PLoS One* **11(1): e0145285**, doi:doi:10.1371/journal.pone.0145285 (2016).

5 Planque, B. *et al.* How does fishing alter marine populations and ecosystems sensitivity to climate? *J. Mar. Syst.* **79**, 403-417, doi:10.1016/j.jmarsys.2008.12.018 (2010).

6 Cheung, W. W. L. *et al.* Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems. *Nature Climate Change* **3**, 254-258, doi:10.1038/nclimate1691 (2013).

7 Miller, K. M. *et al.* Infectious disease, shifting climates, and opportunistic predators: cumulative factors potentially impacting wild salmon declines. *Evol. Appl.* **7**, 812-855, doi:10.1111/eva.12164 (2014).

8 Tanasichuk, R. W. Influence of biomass and ocean climate on the growth of Pacific herring (Clupea pallasi) from the southwest coast of Vancouver Island. *Canadian Journal of Fisheries and Aquatic Sciences* **54**, 2782-2788, doi:10.1139/f97-181 (1997).

9 Okey, T. A., Agbayani, S. & Alidina, H. M. Mapping ecological vulnerability to recent climate change in Canada's Pacific marine ecosystems. *Ocean Coastal Manage.* **106**, 35-48, doi:10.1016/j.ocecoaman.2015.01.009 (2015).

10 Cheung, W. W. L., Brodeur, R. D., Okey, T. A. & Pauly, D. Projecting future changes in distributions of pelagic fish species of Northeast Pacific shelf seas. *Prog. Oceanogr.* **130**, 19-31, doi:10.1016/j.pocean.2014.09.003 (2015).

11 Haigh, R., Ianson, D., Holt, C., Neate, H. & Edwards, A. Effects of Ocean Acidification on Temperate Coastal Marine Ecosystems and Fisheries in the Northeast Pacific. *PLoS One* **10(2)**, doi:doi:10.1371/journal.pone.0117533 (2015).

12 Green, A. L. *et al.* Designing Marine Reserves for Fisheries Management, Biodiversity Conservation, and Climate Change Adaptation. *Coast. Manage.* **42**, 143-159, doi:10.1080/08920753.2014.877763 (2014).

13 Micheli, F. *et al.* Evidence That Marine Reserves Enhance Resilience to Climatic Impacts. *PLoS One* **7**, doi:10.1371/journal.pone.0040832 (2012).

14 Schweigert, J. F., Boldt, J. L., Flostrand, L. & Cleary, J. S. A review of factors limiting recovery of Pacific herring stocks in Canada. *ICES Journal of Marine Science: Journal du Conseil* **67**, 1903-1913, doi:10.1093/icesjms/fsq134 (2010).

15 DFO. Stock Assessment and Management Advice for BC Pacific Herring: 2015 Status and 2016 Forecast. *DFO Can. Sci. Advis. Sec. Sci. Resp. 2015/038.* (2015).

16 De Robertis, A. & Handegard, N. O. Fish avoidance of research vessels and the efficacy of noise-reduced vessels: a review. *ICES Journal of Marine Science: Journal du Conseil* **70**, 34-45, doi:10.1093/icesjms/fss155 (2013).

17 Pauly, D. Anecdotes and the shifting baseline syndrome of fisheries. *Trends in ecology and evolution* **10**, 430 (1995).

18 Lepofsky, D. & Caldwell, M. Indigenous marine resource management on the Northwest Coast of North America. *Ecological Processes* **2**, 1-12, doi:10.1186/2192-1709-2-12 (2013).

19 Pikitch, E. *et al.* Little Fish,Big Impact: Managing a Crucial Link in Ocean Food Webs. *Lenfest Ocean Program. Washington, DC.* , 108 pp (2012).

20 Shelton, A. O., Samhouri, J. F., Stier, A. C. & Levin, P. S. Assessing trade-offs to inform ecosystem-based fisheries management of forage fish. *Scientific Reports* **4**, doi:10.1038/srep07110 (2014).

21 DFO. *Pacific Herring*, <http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/hertags/pages/indicator-eng.htm> (1994).

22 Hourston, A. S. Homing by Canada's west-coast herring to management units and divisions as indicated by tag recoveries. *Canadian Journal of Fisheries and Aquatic Sciences* **39**, 1414-1422 (1982).

23 Ware, D. M. Life-history characteristics, reproductive value, and resilience of Pacific herring (*Clupea harengus pallasi*). *Canadian Journal of Fisheries and Aquatic Sciences* **42**, 127-137 (1985).

24 Hershberger, P. K., Kocan, R. M., Elder, N. E., Marty, G. D. & Johnson, J. Management of Pacific herring spawn-on-kelp fisheries to optimize fish health and product quality. *North Am. J. Fish Manage.* **21**, 976-981, doi:10.1577/1548-8675(2001)021<0976:mophso>2.0.co;2 (2001).

25 Speller, C. F. *et al.* High Potential for Using DNA from Ancient Herring Bones to Inform Modern Fisheries Management and Conservation. *PLoS One* **7**, e51122, doi:10.1371/journal.pone.0051122 (2012).

26 Hay, D. E., McCarter, P. B. & Daniel, K. S. Tagging of Pacific herring Clupea pallasi from 1936-1992: a review with comments on homing, geographic fidelity, and straying. *Canadian Journal of Fisheries and Aquatic Sciences* **58**, 1356-1370, doi:10.1139/cjfas-58-7-1356 (2001).

27 Beacham, T. D., Schweigert, J. F., MacConnachie, C., Le, K. D. & Flostrand, L. Use of Microsatellites to Determine Population Structure and Migration of Pacific Herring in British Columbia and Adjacent Regions. *Trans. Am. Fish. Soc.* **137**, 1795-1811, doi:10.1577/t08-033.1 (2008).

28 Simonsen, B. O. Archaeological Investigations in the Hecate Strait-Milbank Sound Area of British Columbia. (National Museum of Man, Ottawa, 1973).

29 Maxwell, J. & Scott, D. Archaeology Assessment of Meyer Passage, Kitasu Bay and Higgins Passage. (Report to the Kitasoo/Xai'xais Nation, Klemtu, 2000).

30 Kitasoo/Xai'xais. Marine Resource Strategy. *Kitasoo/Xai'xais archives.* (2002).

31 CCIRA. Central Coast First Nations Integrated Marine Use Plan. (2011).

32 MaPP. Central Coast Marine Plan. *http://mappocean.org/central-coast/central-coast-marine-plan/* (2015).

33 Edgar, G. J. *et al.* Global conservation outcomes depend on marine protected areas with five key features. *Nature* **506**, 216-+, doi:10.1038/nature13022 (2014).

34 Fisher, J. A. D. & Frank, K. T. Changes in finfish community structure associated with an offshore fishery closed area on the Scotian Shelf. *Marine Ecology Progress Series* **240**, 249-265, doi:10.3354/meps240249 (2002).

35 Frid, A., McGreer, M. & Stevenson, A. Rapid recovery of Dungeness crab within spatial fishery closures declared under indigenous law in British Columbia. *Global Ecology and Conservation* **6**, 48-57, doi:http://dx.doi.org/10.1016/j.gecco.2016.01.002 (2016).

36 DFO. *An Integrated Aboriginal Policy Framework*. (Communications Branch, Fisheries and Oceans Canada, 2007).

37 Willson, M. F. & Womble, J. N. Vertebrate exploitation of pulsed marine prey: a review and the example of spawning herring. *Rev. Fish. Biol. Fish.* **16**, 183-200, doi:10.1007/s11160-006-9009-7 (2006).

38 Martell, S., Schweigert, J., Haist, V. & Cleary, J. Moving towards the sustainable fisheries framework for Pacific herring: data, models, and alternative assumptions; Stock Assessment and Management Advice for the British Columbia Pacific Herring Stocks:2011 Assessment and 2012 Forecasts. *DFO Can. Sci. Advis. Sec. Res. Doc. 2011/136.*, xii+151 pp (2012).

39 Levin, P. S., Francis, T. B. & Taylor, N. G. Thirty-two essential questions for understanding the social–ecological system of forage fish: the case of Pacific Herring *Ecosystem Health and Sustainability* **2**, doi:e01213. doi:10.1002/ehs2.1213 (2016).

40 Froese, R. Keep it simple: three indicators to deal with overfishing. *Fish. Fish.* **5**, 86-91, doi:10.1111/j.1467-2979.2004.00144.x (2004).

41 DFO. Pacific herring preliminary data summary for Central Coast 2016. *DFO Science, PBS, Nanaimo* (2016).

42 Okamoto, D. McGreer, M., Thompson, M. and Frid, A. Sampling of Pacific herring in the Central Coast for size, age, genetics and tissue analysis: Summary of work conducted in 2017 (2017)

43 Thompson, M.D. Causes and Consequences of Pacific Herring (Clupea pallasii) Deep Spawning Behaviour. Simon Fraser University. (2017)

Appendix: Estimating herring spawn abundance over time at Kitasu Bay, Spiller Channel and Higgins Pass

(By Madeleine McGreer and Alejandro Frid)

This appendix describes the data and statistical methods used to produce Fig. 5, and restates results in more technical terms.

Data and Methods

DFO uses dive and surface surveys to collect data at the level of spawn "events", or patches of herring spawn on the water. Their data include the length (parallel to the shore), mean width (perpendicular to the shore), and average egg density (in layers of herring eggs) per kilometer of coastline (Hay and McCarter 2015; Fort et al. 2013). We accessed these data online for Kitasu Bay (section 67-3), Spiller Channel (section 72-2), and East Higgins Pass (section 77-2). We constrained the time series to begin in 1988, when the primary field methodology shifted from surface surveys to more reliable dive surveys.

For each site (statistical sub-area) and year, we summarized herring spawn abundance into a unit-less “yearly spawn index”. This index should not be confused with the "spawn index" used in the age-structured and escapement stock assessment models. For each 1 km segment of coastline (Hay and McCarter 2015), we multiplied the average length, median width, and mean number of egg layers within the spawning beds in that segment. For each year, we then summed these values across the coastline of the site, thus obtaining one yearly spawn index per year at each site of interest. Some surveys lacked data for width or average egg layers within the spawn event. For these missing data, we used the median width and median number of egg layers estimated for other spawn events within the given site and year.

We used “changepoint” analysis to detect statistically significant shifts in the mean of a time series (Killick et al.2015), thereby identifying the specific year when the spawn index changed at each site. We constrained these analyses to detect at most one change point.

For each site, we then used piecewise linear regression[1] to assess differences in temporal trends in spawn index before and after the change points. The predictors were census year and a Boolean variable indicating whether the census occurred before or after the change point. We used AIC model comparisons to simplify models, keeping models with the lowest AIC, when delta AIC was 2 or more, and keeping models with the lowest degrees of freedom in cases where the delta AIC was less than 2.

[1]A piecewise regression analyzes the trends before and after a change point within a linear model by including a Boolean variable indicating whether data were collected before or after the change point.

Results and Discussion

Significant change points in the 1988-2015 spawn index time series occurred during 2005 in Kitasu Bay, 2003 in Spiller Channel, and 2005 in East Higgins Pass. That is, at each site the spawn index significantly decreased after those years (Fig. 5 in main text). However, there were no statistically significant trends over time before or after the change point at any location (Fig. 5 in main text; Tables A1, A2).

Though not statistically significant, visual inspection of data suggests an increasing trend in herring spawn abundance at Kitasu Bay since 2013—to the point that abundance in 2015 reached its highest level since 1992 (Fig. 5a in main text)—while signs of potential recovery are less evident in Spiller Channel (Fig. 5b in main text) and absent in Eastern Higgins Pass (Fig. 5c in main text). Longer-term observations are needed to distinguish whether the recent increase at Kitasu Bay is an actual recovery, perhaps in response to spatial protection, rather than the short-term variation that characterizes herring populations.

Table A1. AIC tables comparing piecewise regression models with a change point * year interaction (“Change in Trend”), no interaction but with year as a factor (“No Change in Trend”), and with only the breakpoint as a factor (“No Trend”). The response variable is the spawn index (length*width*egg layers) summed over the whole location per year.

Kitasu Bay

Model	**df**	**AIC**	**delta AIC**
Change in Trend	5	814.312	1.354993
No Change in Trend	4	814.957	1.999994
No Trend	3	812.957	0

Spiller Channel

Model	**df**	**AIC**	**delta AIC**
Change in Trend	5	772.7781	0.6251666
No Change in Trend	4	772.153	0
No Trend	3	772.7142	0.5612542

East Higgins

Model	**df**	**AIC**	**delta AIC**
Change in Trend	5	699.2551	2.943657
No Change in Trend	4	697.4841	1.172701
No Trend	3	696.3114	0

Table A2. Best linear piecewise regression models for Kitasu Bay (DFO section 67e-3), Spiller Channel (DFO section 72-2), and East Higgins Pass (DFO section 77-2). The response variable in this regression is spawn index (length*width*egg layers) summed per section per year. After model selection procedures, only the break point effect was supported at all three sites. The effect of the change point can be interpreted as the magnitude of the change past 2005 in Kitasu Bay (section 67e-3) and East Higgins Pass (section 77-2) or 2003 in Spiller Channel (section 72-2). The interaction between the change point and census year can be interpreted as the change in trend after the change point.

Response Variable	**Predictor**	**Coefficient**	**Std Error**	**t-value**	**p-value**
Kitasu Yearly Spawn Index	Intercept	1134264	107246	10.576	6.52E-11
	Change Point	-455458	179456	-2.538	0.0175
Spiller Channel Yearly Spawn Index	Intercept	861649	164648	5.233	2.30E-05
	Change Point	-436549	253131	-1.725	0.0975
East Higgins Pass Yearly Spawn Index	Intercept	568988	104911	5.424	1.90E-05
	Change Point	-434992	209822	-2.073	0.0501

References for the Appendix

Fort C, Daniel K, Thompson M (2013). Herring Spawn Survey Manual. Fisheries and Oceans Canada.

Hay D E, and McCarter P B (2015). Herring spawning areas of British Columbia: A review and geographic analysis and classification. Fisheries and Oceans Canada.

Killick R, Haynes K and Eckley IA (2015). *changepoint: An R package for changepoint analysis*. R package version 2.2, http://CRAN.R-project.org/package=changepoint.