Species and Habitats

A sea anemone on the artificial reef Annapolis. (Credit: Eli Wolpin)

Summary

Historically, the unique species and habitats of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound were subjected to industrial contamination, which saw habitats degraded or destroyed and many species decline or simply disappear.

However, thanks to dedicated hard work from community members through to local, provincial and federal governments to clean up the water and restore habitats, many of these species, including top-level predators such as killer whales, have made an astounding comeback. Unfortunately, some species are still struggling to rebound, such as sea stars, marine birds, lingcod and rockfish. For others, the status remains uncertain, such as some species of salmon and forage fish.

Important conservation actions have been taken to address some of the damage, restore key habitats and protect species. For example, efforts are ongoing to establish new eelgrass beds, continue restoration of the Squamish Estuary, and afford new protections to glass sponge reefs with the creation of marine refugia. However, the impetus cannot stop as new threats, such as climate change and an increasing human population, put pressure on the Sound's ecosystems. To effectively protect key species and habitat, actions to address climate change, with consistent, comprehensive monitoring, are necessary.

Ocean Watch Health Rating

HEALTHY 1) The status is healthy according to available data, 2) the trend is positive if known, 3) some data are available, and/or 4) actions to address or mitigate are well underway and are known to be effective. Actions should be taken to maintain positive status and/or trend.

CAUTION Status, trend, data, and/or actions provide contradictory or inconclusive information. Actions are needed to move into positive status and trend and avoid negative status and trend.

CRITICAL 1) Impacts or issues are high risk or have resulted in a low or vulnerable status, 2) improvements are uncertain, minor, or slow, and/or 3) actions to address or mitigate are non-existent, vague, or have low effectiveness. Actions are needed to move into positive status and trend.

LIMITED DATA/ NOT RATED Not rated due to the nature of the article, or there are not enough data to produce an assessment.

ARTICLE + 2020 RATIONALE	2017	2020
PLANKTON No data is presented in this update; however, a pilot plankton study using the same sites as Stockner et al. (1977) was undertaken in summer/fall of 2019, as per recommendations from the 2017 report.	⊖	⊖↑
FORAGE FISH There is a lack of monitoring and data on forage fish in Átl'ḵa7tsem/Txwnéwu7ts/ Howe Sound. Consequently, despite information from citizen scientists, gaps exist; thus, an analysis of trends and population status is not possible.	⊖	⊖ !
SEA STARS For some sea star species, numbers remain low and wasting disease is still observed. However, other species appear relatively common, yet are still susceptible to wasting disease. The risk to these species is likely to increase because of climate change impacts.	⊗	⊗
SALMON There is a lack of comprehensive data or stock assessments for wild salmon species in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Status and trends are inconclusive for hatchery species.	⊗	! ⊗
CRITICAL FISH STOCKS (PREVIOUSLY ROCKFISH, LINGCOD) No increasing trends have been observed; however, there are some positive signs, such as sightings of schools of juvenile yellowtail rockfish. Improvements are minor or slow; enforcement of rules and laws needs improvement.	⊗	⊗

ARTICLE + 2020 RATIONALE	2017	2020
MARINE BIRDS Globally, considerable declines have been observed in marine bird populations due to impacts from climate change and habitat destruction. In the Sound, an Important Bird Area (IBA) was extended; however, the IBA offers no legal protection.		
EAGLES There is considerable annual variation in bald eagle counts, with counts in the last three years being similar to the last ten years, but lower compared to earlier periods.		
PINNIPEDS NEW Better management has led to increased numbers since the 1970s, and monitoring continues. However, pressure from climate change will likely impact recovering numbers, and population estimates would benefit from more frequent monitoring.		
CETACEANS An increase in large whale numbers and a decrease in small cetacean numbers has been reported. Much forward movement on actions has been taken.		
EELGRASS Efforts to restore and transplant eelgrass are ongoing; however, more work is needed as not all transplants are successful.		
GLASS SPONGES Considerable advances in knowledge have been made; however, glass sponges remain vulnerable to mechanical damage and climate change.		
ANNAPOLIS Increases in the number of marine animals but decreases in marine plants and moss animals (bryozoa) have been noted. Ongoing monitoring is needed.		
SQUAMISH ESTUARY Many positive actions are being taken to repair this critically important habitat; however, monitoring of these efforts is needed to measure their impacts.		

Plankton: the foundation of the food web

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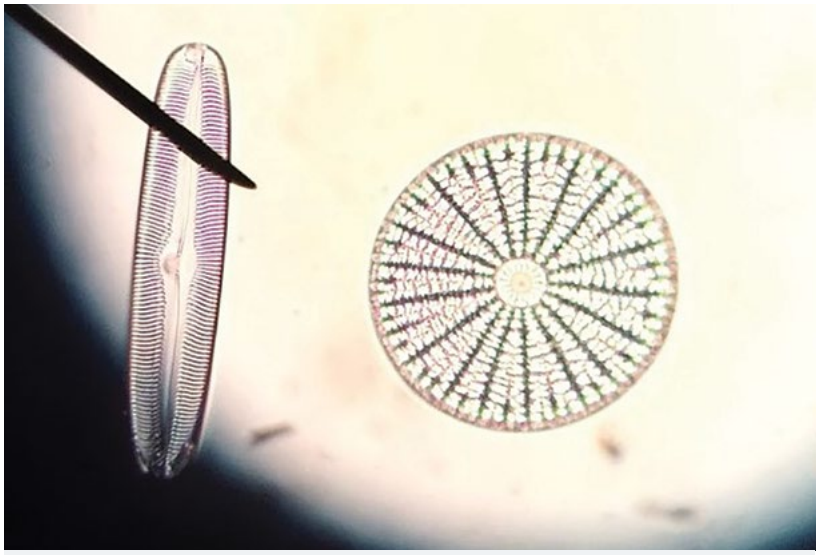
What is happening?

Plankton forms the basis of the Átl'ka7tsem/Txwnéwu7ts/Howe Sound food chain and is therefore vital for the ecosystem. However, plankton has not been studied in detail in Alt'ka7tsem/Howe Sound since the early 1970s. Therefore, due to the lack of data, the Ocean Watch Howe Sound Edition (OWHS) 2017 Plankton article made two key recommendations. First, that survey work be implemented using the Fisheries and Oceans Canada (DFO) sampling sites from the 1970s, so that comparisons over time can be made. Specifically, surveys were suggested to measure changes in water quality as well as plankton species and productivity. Second, it was recommended to make plankton baseline records and monitoring a requirement for coastal development projects.



Plankton under a microscope. Pennate (left) and centric (right) diatoms. (Credit: Bridget John)

Based on these recommendations, plankton surveys have been planned throughout Átl'ka7tsem/Txwnéwu7ts/Howe Sound during 2019. The surveys are a pilot study (i.e., an initial, not full-scale, study). They will be a part of the Átl'ka7tsem/Howe Sound Marine Reference Guide (MRG), which aims to bring together information about the area (see Resources). The MRG arose from the OWHS 2017 Action Plan (see Resources).

What is the current status?

At the time of writing (October 2019), data from planned plankton surveys were not yet available. However, these pilot surveys are being carried out to assess the feasibility, time, and cost of a full-scale sampling protocol, which, if it goes ahead, will be conducted in 2020.

Plankton samples will be collected from two depths at seven sites within Átl'ka7tsem/Txwnéwu7ts/Howe Sound – 1, 4, 5, 6, 7, 8 and 10, because sites 2, 3 and 9 are duplicates (Figure 1), in line with data sampling methods used by Stockner et al. 1977[1]. In addition, another sampling site south of Chá7elkwnech/Gambier will be included for the purpose of providing baseline data (site 11). In order to measure changes, the survey will collect standard physical, chemical and biological parameters; and phytoplankton and zooplankton biomass, dominant species and primary productivity.[2]

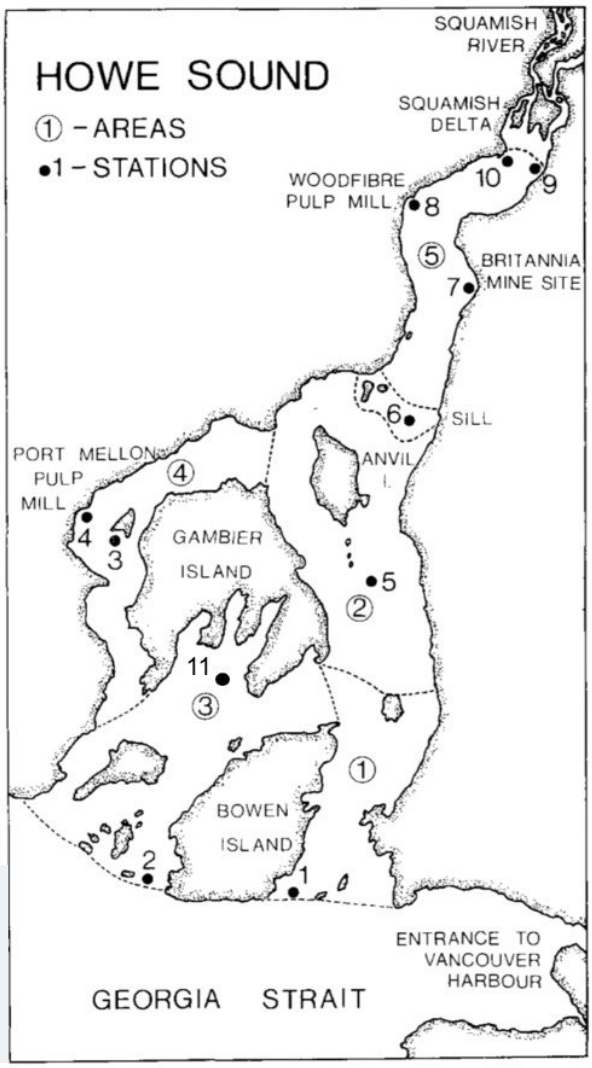


Figure 1. Map of Átl'ka7tsem/Txwnéwu7ts/Howe Sound showing original plankton sampling stations from the 1970s, to be re-sampled in the current pilot study. Small black circles indicate the location of sampling stations. Large open circles with numbers show the sampling zone, as defined by Stockner et al. 1977.[1] Dashed lines indicate the boundaries between zones. Original figure from Stockner et al. 1977.[1] Station 11 has been added in addition to the other original stations to act as a control site.

Through photosynthesis, phytoplankton sequesters CO_2 from the atmosphere and transfers it to the deep ocean, as well as producing oxygen.[3] Zooplankton feed on phytoplankton, and in turn feed animals higher up the food chain (e.g., invertebrates, fish). Dominant phytoplankton and zooplankton species will be examined to elucidate if there has been a change since the 1970s. Even small changes in distribution and abundance of plankton can have important effects on climate, biodiversity and ecosystem services, as well as food web implications. If changes are observed, follow-up questions to investigate potential causes and cascade effects will be important to ask.

Data will be presented on the MRG website as it becomes available (see Resources).

What are the potential impacts of climate change on plankton?

The previous article outlined potential impacts of climate change on plankton. Both ocean acidification and ocean warming were pinpointed as potential issues for plankton. For example, increasing ocean acidification will impact species that produce calcium carbonate structures, which many plankton species do, reducing their ability to produce these structures and impacting their survival. Increasing ocean temperatures will favour the survival of species that are more tolerant of warmer conditions, potentially changing the distribution and abundance of plankton and impacting the species that rely on these plankton for food. More details can be found in the relevant articles on ocean acidification and ocean warming.

Phylum Euglenophyta, *Phacus* species. (Credit: Bridget John)

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
GOVERNMENT ACTIONS AND POLICY	
Conduct a survey, preferably utilizing the same DFO stations in the 1970s, so valid comparisons of decadal changes can be made. This survey should include standard physical, chemical (nutrients, oxygen) and biological (dominant species, phytoplankton and zooplankton biomass, and primary productivity) parameters. What species are being lost or gained (i.e., changes in biodiversity) due to climate change, and what are the changes in plankton/ecosystem productivity?	This action is being addressed via the planning and execution of this pilot plankton survey in Átl'ka7tsem/Txwnéwu7ts/Howe Sound, using the same DFO stations and sampling methods as used in the 1970s study. If the pilot study is feasible, a full-scale study will be carried out in 2020 that will inform a baseline inventory of plankton species in the Sound, with a view to creating the basis for regular plankton monitoring. Water quality studies are being carried out at the east Kw'émkw'em/ Defence Island and Nínich Kw'émkw'em glass sponge reef bioherm (site 6, Figure 1).
Information on zooplankton, an important food source for many small fish, is lacking and should be conducted similar to an on-going study on zooplankton seasonal succession in another fjord, Rivers Inlet, up the B.C. coast.	The above plankton study will examine dominant zooplankton species to elucidate if there has been a change since the 1970s.
Continue the practice of testing water quality in front of the Port Mellon pulp mill (HSPP) to determine if the present mill is meeting provincial and federal marine foreshore water standards.	HSPP is required to monitor the waste water it releases into the Sound. HSPP has implemented an Environmental Effects Monitoring program, in accordance with the evolving Pulp and Paper Effluent Regulation.[4] This monitoring occurs on a three-year cycle. The most recent reporting occurred in 2018 (see Pulp Mill Effluent, OWHS 2020 for more details).
If a Liquefied Natural Gas (LNG) terminal at the old Woodfibre site is approved, then an extensive survey will be needed to determine the "before" or baseline inventory and continued monitoring if it begins operations.	Plankton samples will be collected from two depths at seven sites within Átl'ka7tsem/Txwnéwu7ts/Howe Sound. Sampling site 8 is very near to the Woodfibre site (see Figure 1, map of sampling sites).

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- Keep an eye out for unusual blooms and continue to ask what they are and why are they occurring in the Sound.
- True colour satellite imagery, useful for monitoring coccolithophore blooms and turbidity, can be viewed in near real time on NASA's Worldview (https://worldview.earthdata.nasa.gov). The satellite images will be the "webcam" for active citizen science groups that are interested in on-going plankton events in the Sound.

Government Actions and Policy:

- Make baseline inventory and regular monitoring of plankton (the key food resource for all higher trophic levels) a requirement for coastal development projects, so that any changes in production, diversity, or timing can be assessed.
- Collect important historical data on the Sound (before scientists and other groups retire) and archive the data in a government data centre.
- NEW Fund baseline monitoring of plankton (the key food resource for all higher trophic levels) so that any changes in production, diversity, or timing can be assessed.

Methods

Data was not yet available for this update. However, plankton samples and biological, chemical and physical parameters are being sampled in the near future (2019) by Bridget John, Research Assistant, Atl'ḵa7tsem/Howe Sound Marine Reference Guide, using methods in Stockner et al. 1977.[1] Further updates about this research project will be available on the Marine Reference Guide website (see Resources).

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

Atl'ḵa7tsem/Howe Sound Marine Reference Guide
https://howesoundguide.ca/
https://makeway.org/project/howe-sound-atlkitsem-marine-reference-guide/

Ocean Watch Action Plan
http://oceanwatch.ca/howesound/welcome/action-plan/

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Sea Stars: wasting disease is ongoing

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What is happening?

Sea star wasting disease (SSWD) has been a serious issue along the entire Pacific Northwest coast, including in the waters of Átl'ka7tsem/Txwnéwu7ts/Howe Sound, since the major mortality event of 2013. One of the key issues caused by SSWD is the decrease in biodiversity (see Resources) in areas that are impacted.

Sun star, *Solaster stimpsoni*. (Credit: Lee Newman)

What is the current status?

Throughout Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, numbers for most sea star species remain low but stable. Sunflower stars (*Pycnopodia helianthoides*) and sun stars (*Solaster* spp.) continue to be very rare. When they are observed, they are small (approximately 10 cm across or smaller). Throughout their range, sunflower stars are not showing signs of recovery.[1–3] Initially, there was speculation that sunflower stars may have moved to deeper, colder water to escape the disease. Unfortunately, a 2019 survey found very low numbers in both shallow and deep habitats.[1]

The cascade effects of sea star wasting on other species within the community continue to persist. Green sea urchins are still extremely abundant compared to the years before SSWD (Figure 1). Without the high abundance of sunflower stars, their key predators, sea urchins are free to consume kelp, creating urchin barrens in areas where dense kelp beds previously existed.[4–6]

Dead seastars found on a shoreline. (Credit: Tracey Saxby)

SSWD is ongoing at low levels. In Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, there continue to be sightings of afflicted sea stars at low levels, particularly for the mottled star (*Evasterias troschelii*) which remains common. For most other sea star species, numbers are modest but stable. However, the leather star (*Dermasterias imbricate*) is very common; its numbers increased on many areas of the coast following wasting disease; however, it is not immune to wasting disease.

A virus is associated with SSWD in sunflower stars.[7] However, the disease is not associated with a virus in other sea star species.[8] Instead, there is likely a combination of factors that cause SSWD. These factors can differ from one species to another, and from one location to the next.[8] As a silver lining, surviving sea stars have demonstrated genetic adaptation, suggesting they may be able to evolve to cope with the disease.[9,10] However, with SSWD still present in the environment, it is not clear whether sea stars will ever fully recover, or whether populations will continue to be reinfected.

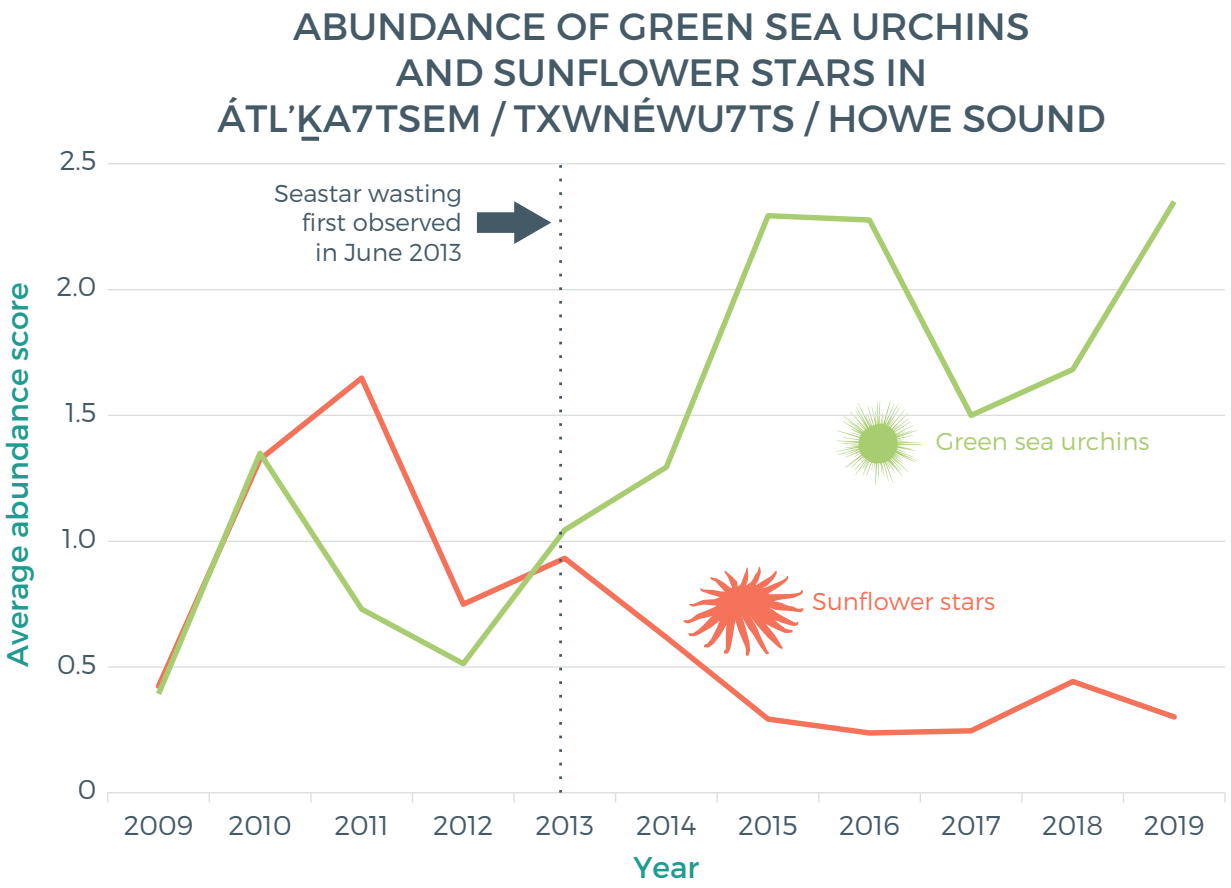
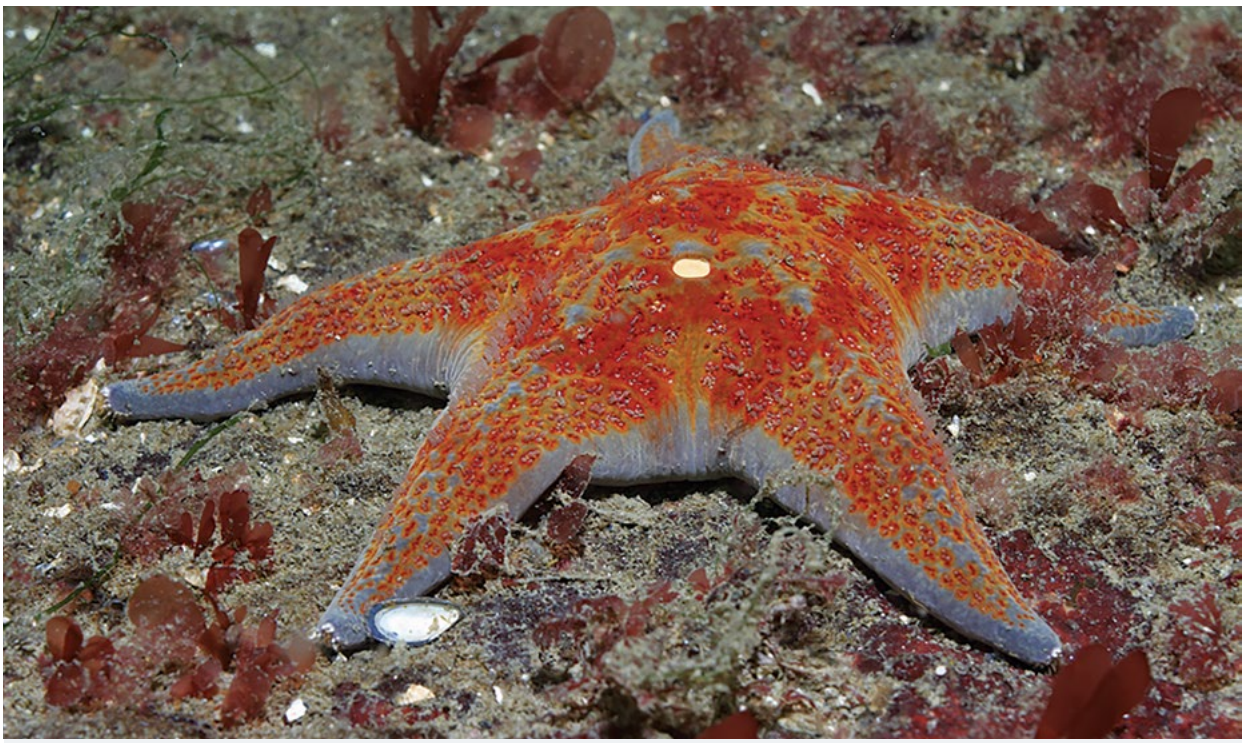


Figure 1. Following the outbreak of sea star wasting disease in 2013 (indicated by the red dashed line), the abundance of sunflower stars declined while the abundance of green sea urchins increased drastically. These data are from roving dive surveys at 116 sites in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound during which abundance was scored using the following scale: 0 = none; 1 = 1–9 individuals; 2 = 10–24 individuals; 3 = 25–49 individuals; 4 = 50–99 individuals; 5 = 100–999 individuals; 6 = >1000. n = 992 surveys. (In the 2017 Sea Stars article, the dataset used covered the entire B.C. coast. Here, we use Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound specific data).

What are the potential impacts of climate change on sea stars?

There is growing evidence that SSWD is related to warming ocean temperatures. Unusually warm temperatures in 2014 and 2015 are linked with peak declines in sunflower stars[1] and some populations of purple stars (*Pisaster ochraceus*).[11] In both species, increased temperature intensifies and accelerates the progression of the disease.[1,11–13] Initial observations of SSWD occurred in the same year (2013) as the *Blob*[i] appeared in the Pacific Ocean, which was followed by the warmest El Niño on record.[6,14] However, the timing and severity of SSWD outbreaks are not always predictable based on temperature,[11] and interactions between wildlife diseases and climate change are complex.[15] In general, marine diseases are likely to become more frequent and less predictable in a warming ocean.



Echinoderm. (Credit: Lee Newman)

i) The Blob - a marine heatwave that occurred in the North Pacific Ocean, starting in late 2013. See Resources for further information.

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
If you see a sick or dying sea star, please submit your observations to the UC Santa Cruz monitoring site (see Resources). Your observations can help researchers track disease spread and understand the potential causes and consequences of sea star wasting. If applicable to your organization, encourage company-wide participation in this citizen science project.	Almost 50 observations have been submitted to the above monitoring site from Átl'ka7tsem/ Txwnéwu7ts/Howe Sound alone.
GOVERNMENT ACTIONS AND POLICY	
Increase public education about sea star wasting disease to encourage participation in citizen science projects, and personal actions to help decrease overfishing, pollution, habitat damage and stressors.	The previous Ocean Watch Howe Sound Edition (2017) increased public awareness throughout the Sound, although this was not a government action.
If studies reflect the need, classify sea stars as Imperiled Species by the *Species at Risk Act*.	In Canada and the USA, discussions continue regarding whether to list sunflower stars as endangered. Thus far, they have not been given this official designation. Researchers and conservationists continue to work on a sea star recovery and monitoring strategy, but because of the complexity of factors causing the outbreak, defining a specific approach remains a challenge.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- NEW Actions to mitigate climate change will promote sea star recovery and decrease the probability of other wildlife disease outbreaks in the future.

Government Actions and Policy:

- Financially support ongoing research projects and assess the need for additional research. Support further studies specifically on the cause(s) of sea star wasting disease.
- NEW List sunflower stars as endangered in Canada and the USA, at provincial, federal or international levels.
- NEW Support and fund researchers and conservationists in Canada and the USA to continue to work on a sea star recovery and monitoring strategy.

Methods

Data presented in Figure 1 were collected from 992 roving dive surveys conducted by the Howe Sound Conservation and Research Team at 116 sites in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound between 2009 and 2019. The abundance of all fish, invertebrates and algae encountered were scored (0 = none; 1 = 1–9 individuals; 2 = 10–24 individuals; 3 = 25–49 individuals; 4 = 50–99 individuals; 5 = 100–999 individuals; 6 = >1000). Sea stars with signs of wasting were noted, and the diameter of sunflower stars was measured whenever possible. Data are managed using the Pacific Marine Life Surveys database.

A literature scan using the terms "sea star wasting syndrome" and "sea star wasting disease" was carried out. We also considered our own personal observations, as well as anecdotal evidence shared with us by Neil McDaniel, Andy Lamb, Marc Chamberlain and Jan Kocian.

Acknowledgements

Thank you to Neil McDaniel, Andy Lamb, Marc Chamberlain and Jan Kocian, for generously sharing sea star observations with Ocean Wise and other researchers, and Donna Gibbs for processing the data and producing Figure 1. We would also like to thank the Sitka Foundation for their ongoing support of biodiversity monitoring by the Howe Sound Conservation and Research Team.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

The Blob
El Niño patterns contributed to long-lived marine heatwave in North Pacific. 2016.
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UC Santa Cruz monitoring
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Forage Fish: the importance of citizen science

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What is happening?

Forage fish, such as herring (*Clupea pallasii*) and eulachon (*Thaleichthys pacificus*), are important species in Átl'ka7tsem/Txwnéwu7ts/Howe Sound's ecosystem, providing food for many animals higher up the food chain. In recent years there has been an increased focus on improving our knowledge on the state of forage fish populations and on improving management practices for these species. Citizen science groups, non-profit organizations, and government bodies have all realized the key role that forage fish play in the ecosystem. As such, these organizations have allocated time and funds to increase research and restoration of these species and their habitats.

Herring eggs found in the west Átl'ka7tsem/Txwnéwu7ts/Howe Sound coastal area. (Credit: John Buchanan).

What is the current status?

Pacific Herring *(Clupea pallasii)*

Citizen scientist John Buchanan has been diligently observing and recording herring spawn in Átl'ka7tsem/Txwnéwu7ts/Howe Sound for the last nine years. Herring spawn surveys were conducted on four dates in both 2017 (January to March) and 2018 (February to April), and three dates in 2019 (January to May), covering an area from Kw'ech'ténm/McNab Creek to the south, continuing up the west coast of Átl'ka7tsem/Txwnéwu7ts/Howe Sound, to the Squamish Terminals (see Figure 1).[1] All surveys yielded sightings of herring spawn at various locations. The first spawn of the year is typically the smallest event. The fourth survey in 2018, undertaken on April 8, was particularly notable, being the densest spawning event observed during this survey in almost a decade.[1] Video footage also shows huge masses of herring spawn found at Foulger Creek on this date, just south of the Woodfibre site (see Resources).

Surveys conducted in 2019 showed similar observations to 2017 and 2018. The Foulger Creek area was densely spawned, while a small area of herring spawn was observed at Squamish terminals and other areas along the coast. New spawning was observed at Foulger Creek during two surveys (March and May), indicating two separate spawning events occurred. These surveys add to multiple years of data where a gap previously existed, giving important insight and helping establish trends of herring spawn activity along the west coast of Átl'ka7tsem/Txwnéwu7ts/Howe Sound inlet.

The harvest of herring roe is deeply seated in the history of the Skwxwú7mesh Úxwumixw/Squamish Nation. Herring roe is a central food in the traditional diet, and harvesting is a culturally significant practice.[2] However, over the past century, this practice has been discontinued because of the impacts of shoreline development and industrialization, as well as certain Canadian laws that forbid First Nation peoples from leaving reserves, thus prohibiting various cultural practices.[2] To help restore this tradition and pass the knowledge to younger generations, hemlock boughs were hung in the water in the vicinity of Nexen Beach in upper Átl'ka7tsem/Txwnéwu7ts/Howe Sound by members of the Skwxwú7mesh Úxwumixw/Squamish Nation, with advice and guidance from elders.[2] The boughs were found to be densely spawned when retrieved.[2]

Citizen science data on herring spawn collected over the last decade has been and continues to be invaluable, contributing to the overall picture of the health of the marine environment in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. The return of herring to these waters has meant that traditional practices can once again be passed down to future generations and herring roe can be harvested.[2]

Based on modelling and monitoring data, herring spawn biomass in the Strait of Georgia stock region showed a strong increasing trend from 2010–2016. However, biomass has since shown a decreasing trend.[3,4] This drop of more than 50% over four years

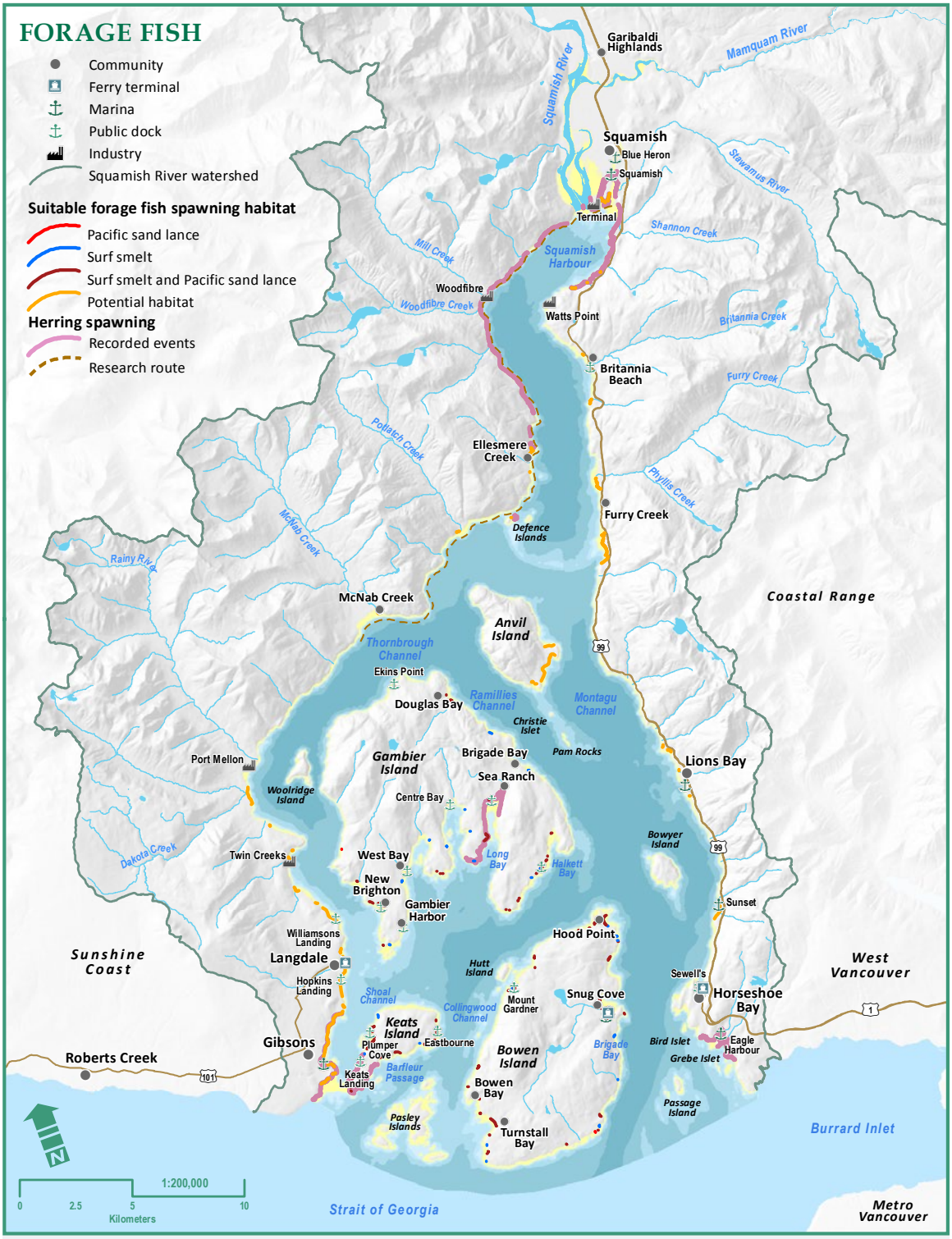

Figure 1. Forage fish spawning habitat and recorded herring spawning locations (data supplied by DFO, 1941–2002; citizen scientists on Bowen Island, 2015; Islands Trust, 2018; Friends of Forage Fish; and John Buchanan).[10]

highlights the need for careful conservation of this important forage fish. Monitoring and stock assessment are focussed on the aggregate migratory stock,[i] thus these trends are not specific to Átl'ka7tsem/Txwnéwu7ts/Howe Sound. No data on herring spawn in Átl'ka7tsem/Txwnéwu7ts/Howe Sound has been available from DFO since the previous Ocean Watch Howe Sound (OWHS) 2017 edition.

Herring spawn on hemlock boughs. (Credit: John Buchanan).

Eulachon *(Thaleichthys pacificus)*

Since 2004 concerns surrounding eulachon stocks resulted in long-term harvest closures of eulachon for both commercial and recreational purposes.[5] In B.C., three distinct populations of eulachon have been assessed under the *Species at Risk Act* (SARA): two are "Endangered"[ii] (Fraser River and Central Pacific Coast populations) and one is of "Special concern"[iii] (Nass/Skeena Rivers population).[6] The Squamish River is listed as a probable eulachon spawning river, under the Central Pacific Coast population grouping.[6] There is no current information on eulachon in Átl'ka7tsem/Txwnéwu7ts/Howe Sound.

i) Aggregate migratory stock – summed index stocks for the Strait of Georgia region.

ii) Endangered – species facing imminent extirpation or extinction.

iii) Special concern – species which may become threatened or endangered because of a combination of biological characteristics and identified threats.

Northern Anchovy *(Engraulis mordax)*

After excitement over anchovy sightings hit the news in 2015 and 2016[7,8] there remains little to no data on anchovy numbers returning to Átl'ka7tsem/Txwnéwu7ts/Howe Sound. Anecdotal evidence of schooling anchovy in Átl'ka7tsem/Txwnéwu7ts/Howe Sound was recorded on video in two instances in 2017, in May and September (see Resources). In January and October 2018, conservationist Bob Turner of Nexwlélexwem/Bowen Island, spotted large schools of anchovy accompanied by a raft of hungry predators (see Resources). After a decade of no sightings (OWHS 2017), there is a clear need for more studies into the numbers and movements of this important species.

Pacific sand lance *(Ammodytes hexapterus)* and surf smelt *(Hypomesus pretiosus)*

These species are important forage for predators such as seabirds, other fish, and marine mammals. As both species are beach spawners, they are especially sensitive to coastal development, shoreline modification and other anthropogenic foreshore disturbances.[9] Various groups (i.e., the Islands Trust Conservancy, Bowen Island Conservancy, the David Suzuki Foundation, the Pacific Salmon Foundation, and the B.C. Shore Spawners Alliance) are conducting ongoing research to learn more about critical beach spawning habitat and ways to improve management practices for Pacific sand lance and surf smelt. For example, the Islands Trust Conservancy is conducting forage fish spawning habitat assessments on various islands throughout the Strait of Georgia, while the B.C. Shore Spawners Alliance is working to protect critical beach spawning habitats and document spawning beaches.

What are the potential impacts of climate change on forage fish?

The use of hard armouring (e.g., seawalls and riprap) to combat sea level rise is a primary threat to the survival of forage fish due to resulting coastal squeeze, i.e., loss of intertidal habitat necessary for spawning (see Shoreline erosion and sea level rise, OWHS 2020).

In recent years, elevated ocean temperatures have been linked to the higher abundance of Northern anchovy in the Salish Sea;[11] however, this positive correlation is likely to exist only up to a certain temperature threshold. Changes in sea surface temperature and ocean acidification may potentially impact egg and/or larval survival and could result in changes in the timing of spawning. This, in turn, would have roll-on effects on species relying on forage fish as prey.[11] Climate change could also affect the timing, amount and types of prey available to forage fish.

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Support research, monitoring and protection of forage fish habitats and water quality.	• BC Shore Spawners Alliance held a workshop in June 2018 showing volunteers how to identify and map forage fish spawning sites (run by Ramona de Graaf). • Islands Trust Conservancy undertook Forage Fish Habitat Assessments for Bowen, Gambier and Keats Islands in 2014, and have continued with other Gulf Islands (most recently in 2019 on North Pender, James and Sidney Islands). • Sea to Sky Cultural Journeys program teaching school kids about harvesting herring roe. John Buchanan has continued to keep records of herring spawn activities throughout the west coast of the Sound.
GOVERNMENT ACTIONS AND POLICY	

Prioritize and fund research, monitoring and protection of forage fish habitats.	• The Coastal Restoration Fund, an Oceans Protection Plan initiative, was announced in May 2017. In May 2018, the fund awarded two grants to groups operating in Átl'ka7tsem/Txwnéwu7ts/Howe Sound.
	  • $1.3 million over five years, awarded to the Sea Change Marine Conservation Society (in partnership with the Canadian Coast Guard and DFO). The grant was awarded to assist in the restoration of eelgrass and estuarine habitat for Pacific salmon and forage fish in four areas, one being Átl'ka7tsem/Txwnéwu7ts/Howe Sound (alongside the Gulf Islands, Burrard Inlet and Sechelt).[12]
	  • $1.5 million over five years, awarded to the Squamish River Watershed Society (in partnership with Canadian Coast Guard & DFO). The project aims to restore coastal habitats by "re-establishing freshwater connection to the estuary" supporting salmon recovery and improving water quality and habitat for other fish and wildlife.[13] See Salmon article, OWHS 2020 for more info.
	  • A national program (Strategic Program for Ecosystem-based Research and Advice) has been developed by DFO in order to help identify ecosystem-based approaches to management strategies. This approach will assist in considering impacts of climate change and will hopefully bring a better understanding of the collective role that forage fish have in the ecosystem, leading to more appropriate management decisions/strategies.
	• Bill C-68, an amendment to the *Fisheries Act*, came into effect August 28, 2019. The provision allows for extra protections and considerations to be made with respect to fish stocks, fish habitat and conservation of marine biodiversity, among other things.[14]
	• Green Shores for Coastal Development – Credits and ratings voluntary program for minimizing environmental impact of waterfront development. This program was awarded funding in Jan/Feb 2019 from Natural Resources Canada as part of the Federal Climate Change Adaptation Program.[15] The shoreline is key spawning habitat for many forage fish, and soft-shore development options can help reduce egg mortality.[16]

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- NEW Be aware of beaches near you that are used as spawning beaches by forage fish. Take care not to disturb these areas.

Government Actions and Policy:

- Monitor and enforce the legislation (B.C. Land Act) that prohibits changes below the high tide line without lease or license of occupation.
- NEW Increase funding in support of monitoring forage fish numbers and distribution in Átl'ka7tsem/ Txwnéwu7ts/Howe Sound.

Kelp greenling forage fish. (Credit: Eli Wolpin)

Methods

Since 2010, citizen scientist John Buchanan of the Squamish Environment Society (SES) has conducted annual herring spawn surveys in late winter and early spring along the west coast of Átl'ka7tsem/ Txwnéwu7ts/Howe Sound. In 2018-2019, herring spawn surveys were conducted by boat on four dates in 2018 (February to April), and three in 2019 (January to May). The surveys commenced in the south around Kw'ech'ténm/McNab Creek and finished in upper Átl'ka7tsem/Txwnéwu7ts/Howe Sound around the Squamish Ferry Terminal, or Stawamus Creek, in the north. John conducts surveys of the rocky shores and seaweed beds, documenting his findings with photographs, videos and coordinates on maps, taking note of any significant findings or other observations of note.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

John Buchanan Resources
January 2017. Herring Report #1
https://www.youtube.com/watch?v=ZmYVsjMRuVQ
February 2017. Herring Report #2
https://www.youtube.com/watch?v=Jt1emUPgE98
March 2017. Herring Report #3
https://www.youtube.com/watch?v=hMThXebOpzE
March 2017. Follow-up to Report #3
https://www.youtube.com/watch?v=wWM21LT7xZg
April 2018. Herring spawn report #4
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Accessed October 17, 2019.

Ramona de Graaf, June 2016. BC Shore Spawners Alliance work https://youtu.be/H-8F67Acxlc. Accessed September 24, 2019.

Reeltime M, 2017. Massive school of anchovies in Howe Sound, May 2017 https://youtu.be/xgNKco-h1-s. Accessed October 17, 2019

Taylor, A 2017. Howe Sound Anchovy, October 2017 https://youtu.be/qQ9-yv1F28g. Accessed October 17, 2019

Coastal Squeeze
https://oceanwatch.ca/howesound/wp-content/uploads/sites/2/2016/11/diagram-coastal-squeeze-BRANDED.png

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1 Buchanan, J. Howe Sound herring survey report #1-4. www.squamishenvironment.ca/tag/john-buchanan/ (2018).

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6 COSEWIC. COSEWIC assessment and status report on the Eulachon, Nass/Skeena Rivers population, Central Pacific Coast population and the Fraser River population Thaleichythys pacificus in Canada. *Species at risk public registry* www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/eulachon-3-rivers.html (2011).

7 Shepherd, J. Anchovy return in huge numbers to Howe Sound. *North Shore News* https://www.nsnews.com/news/anchovy-return-in-huge-numbers-to-howe-sound-1.2336492 (2016).

8 Pemberton, K. Anchovy schools are back in session, with 'phenomenal numbers' spawning in Howe Sound. *Vancouver Sun* https://vancouversun.com/news/local-news/anchovy-schools-are-back-in-session-with-phenomenal-numbers-spawning-in-howe-sound (2016).

9 BC Government. *Environmental guidelines for urban and rural land development in British Columbia, fact sheet #21, Coastal forage fish.* (2014).

10 Beaty, F., van Riet, W., Wareham, B. & Schultz, J. Howe Sound/Atl'ka7tsem Map. (2019).

11 Duguid, W. D. P. *et al.* Historical fluctuations and recent observations of Northern Anchovy Engraulis mordax in the Salish Sea. *Deep. Res. Part II Top. Stud. Oceanogr.* 159, 22–41 (2019).

12 Fisheries and Oceans Canada (DFO). Government of Canada makes significant Coastal Restoration Fund investments in British Columbia through the Oceans Protection Plan. www.canada.ca/en/fisheries-oceans/news/2018/05/government-of-canada-makes-significant-coastal-restoration-fund-investments-in-british-columbia-through-the-oceans-protection-plan.html (2018).

13 Fisheries and Oceans Canada (DFO). Government of Canada makes a significant Coastal Restoration Fund investment in the Squamish River Estuary through the Oceans Protection Plan. https://www.canada.ca/en/fisheries-oceans/news/2018/05/government-of-canada-makes-a-significant-coastal-restoration-fund-investment-in-the-squamish-river-estuary-through-the-oceans-protection-plan.html (2018).

14 Fisheries and Oceans Canada (DFO). *Fish and fish habitat protection policy statement.* http://www.dfo-mpo.gc.ca/pnw-ppe/policy-politique-eng.pdf (2019).

15 Green Shores. Green shores funding announcement. https://stewardshipcentrebc.ca/Green_shores/news/green-shores-funding-announcement/ (2019).

16 De Graaf, R. *Valdes Island, British Columbia Surf smelt and Pacific sand lance Spawning Habitat Suitability Assessments.* (2017).

ADDITIONAL INFORMATION

Buchanan, J., 2019. Email communication with Howe Sound Biosphere Region Initiative Society, Squamish Environment Society on behalf of John Buchanan, July 18, 2019.

Critical Fish Stocks: an update on rockfish and lingcod

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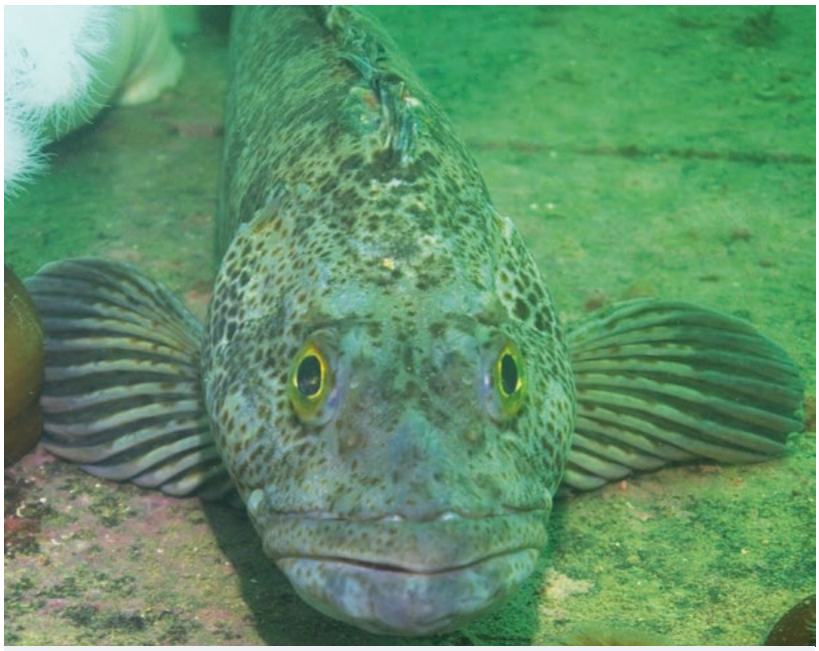
What is happening?

Despite various commercial and recreational fishing closures, lingcod and rockfish populations in Átl'ka7tsem/Txwnéwu7ts/Howe Sound have been depleted for many years and show little sign of recovery. Ongoing monitoring of both groups is vital to assess the impact of protection measures on populations and determine if further conservation measures need to be taken.



Lingcod, *Ophiodon elongatus*. (Credit: Laura Borden)

What is the current status?

Lingcod

Over the last three years (2017–2019), the lingcod population in Átl'ka7tsem/Txwnéwu7ts/Howe Sound has shown no pattern of increase or decrease in abundance based on annual egg mass surveys (see Methods). The 2017 and 2018 surveys were in line with long-term average abundance of egg masses, while 2019 surveys were slightly lower (Figure 1). However, fluctuations such as this have occurred in previous survey years.

Data collected about egg mass size (an indication of the age of female lingcod) showed a slight change in the abundance of large egg masses, produced by the oldest females (those with higher offspring viability). Additionally, there has been no updated Fisheries and Oceans Canada (DFO) stock assessment for the Strait of Georgia (including Átl'ka7tsem/Txwnéwu7ts/Howe Sound) lingcod since 2014.

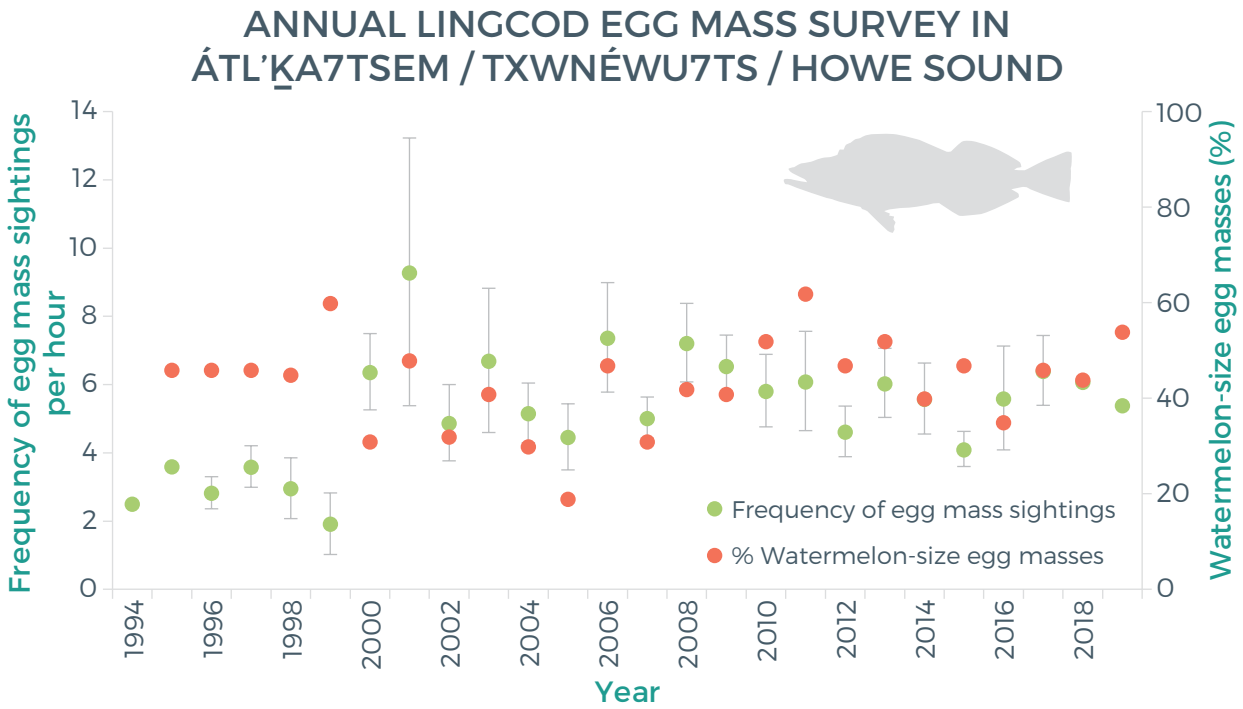


Figure 1. Frequency of egg mass sightings per hour and percentage of watermelon-size egg masses (produced by females at least five years old) in Átl'ka7tsem/Txwnéwu7ts/Howe Sound 1994–2019.

Rockfish

Monitoring of rockfish populations and abundance in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound has been ongoing (see Methods). Although no overall trend of increasing rockfish abundance can be identified, for example, because of fluctuations in the number of observers, two important changes were documented in 2017 and 2018. First, in 2017, large schools of juvenile yellowtail rockfish were observed throughout Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

This followed on the heels of young-of-year[i] yellowtail rockfish (*Sebastes flavidus*) seen in high abundance along the outer coast of Vancouver Island and the central coast in 2016 (see Rockfish, Ocean Watch B.C. Coast Edition 2018). This population of yellowtail rockfish has persisted in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound through the first half of 2019.

Second, in 2017 and 2018, sightings of juvenile black rockfish *(Sebastes melanops)* were made at Hutt Island and Lhákw'tich/Bowyer Island. Black rockfish were extirpated from Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound during the 1960s and were later reintroduced at Sḵ'íẁitsut/Point Atkinson in the early 2000s. Although this population has had successful year classes[ii] since their reintroduction, sightings of yearling juveniles in 2017 was an indication of the first successful year class (2016) since approximately 2010. Sightings of black rockfish further north of Sḵ'íẁitsut/Point Atkinson is an important indication that the population may be growing and spreading further into Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

Quillback rockfish, *Sebastes maliger.* (Credit: Laura Borden)

What are the potential impacts of climate change on these species?

A recent literature review detailed the impacts of climate change on a variety of marine species found along the B.C. coast, including rockfish and lingcod.[1] Rocky reef habitat – important for both rockfish and lingcod – is amongst the habitats most vulnerable to climate change impacts,[2] including variations in the

i) Young-of-year – fish born in the past year.

ii) Year class – the fish in a stock born in the same year.

resilience, sensitivities, responsiveness, and non-stationarity of the biota. Additionally, the change in severity of natural climate cycles (El Niño Southern Oscillation, Pacific Decadal Oscillation) may negatively affect recruitment success in these species as changes in plankton composition occurs. However, recent recruitment events (noted above) that co-occurred with high temperatures, complicate projections. This is particularly impactful for rockfish, which have infrequent year classes owing to their long maturation time frame. In Átl'ka7tsem/Txwnéwu7ts/Howe Sound, no rockfish year classes of any great strength in numbers have occurred since the 2011 climate regime shift, in contrast to the millennial (1999–2010) climate regime that saw strong recruitment of multiple species of rockfish. (Note: yellowtail rockfish are born offshore in the open ocean, not in Átl'ka7tsem/Txwnéwu7ts/Howe Sound).

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Support the annual rockfish/lingcod abundance/egg mass survey by spreading awareness and contributing dive surveys to the Vancouver Aquarium.	Citizen science participation has remained strong for both surveys – public talks to promote surveys and discuss conservation of critical fishes have been conducted by Ocean Wise staff.
Commit more resources to monitoring rockfish populations in Rockfish Conservation Areas (RCAs) with suitable habitat.	New assessment of effectiveness of existing RCAs and proposal for improvements have been undertaken (DFO: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2019/2019_022-eng.pdf)

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (Ocean Watch Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- Follow fishing closures for the recreational fishery and report any illegal fishing to 604-666-3500 (1-800-465-4336). Even if not involved in fishing, educate yourself on fishing practices so you are able to report poaching.

Government Actions and Policy:

- Commit more resources to monitoring and enforcing compliance with fishing regulations in RCAs.
- Work with the Vancouver Aquarium to help encourage awareness of and participation in the annual Lingcod Egg Mass Survey.
- Simplify regulations in the RCAs.
- Increase public education and awareness of closures to commercial and recreational fisheries, and the status of rockfish/lingcod populations.
- NEW Follow up on the 2019 DFO assessment of existing RCAs to adjust boundaries or move RCAs to better protect suitable rockfish habitat where deemed necessary.
- NEW Establish citizen enforcement officers throughout the Sound, who are granted limited enforcement powers, such as checking catch size, species, and fishing method, and handing out fines for fisheries infringements.

Methods

Data for both the lingcod egg mass survey and rockfish abundance survey were collected by citizen scientist divers and Ocean Wise staff. The rockfish abundance survey, conducted yearly from August to October, asks divers to record information about rockfish seen during a dive (see Resources).

The lingcod egg mass survey, centring on February each year, asks divers to record key pieces of information (see Resources).

Information on potential impacts of climate change on these critical fish stocks was collected using a limited search on Google Scholar for articles including the keywords: climate change, rockfish, lingcod. The most recent literature review of this topic for the B.C. Pacific coast was used as the best representative for the current state of climate change impacts on the B.C. marine environment, with references to an extensive list of studies providing in-depth details not discussed here.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

Rockfish abundance survey
https://research.ocean.org/survey/rockfish

Lingcod egg mass survey
https://research.ocean.org/survey/lingcod.

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Salmon Enhancement Efforts: a hatchery perspective

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What is happening?

Since the late 1980s, Pacific salmon stocks throughout Canada and the U.S. have been subject to decline, influenced by climate change, habitat degradation, over-fishing and pathogens[i].[1,2] In Átl'ka7tsem/Txwnéwu7ts/Howe Sound, Pacific salmon (*Oncorhynchus* sp.) are important species socially, culturally and economically. There are concerted efforts from community all the way through to federal-level government to conserve and restore salmon populations throughout the Átl'ka7tsem/Txwnéwu7ts/Howe Sound

Pink salmon, *Oncorhynchus gorbuscha*. (Credit: Tracey Saxby)

i) Pathogens – Disease-causing agent

watershed (see Salmon, Ocean Watch Howe Sound Edition [OWHS] 2017). However, the current lack of comprehensive, local data on wild salmon populations in Átl'ka7tsem/Txwnéwu7ts/Howe Sound is a key challenge in moving these efforts forward. This lack of information has also led to the primary focus of this article being hatchery enhancement efforts.

What is the current status?

Citizen science groups play an important role in protecting and restoring salmon habitat (See Citizen Science, OWHS 2020). For example, the Bowen Island Fish and Wildlife Club (BIFWC) monitor the health of local creeks, work on restoration projects in impacted waterways and engage with schools and communities to educate about salmon conservation.[3] There has also been mobilization on multiple projects in the Skwxwú7mesh/Squamish area aimed at reducing threats to salmon populations and restoring habitat, undertaken by the Squamish River Watershed Society and the Squamish Streamkeepers Society, amongst others.

Tenderfoot Creek Hatchery, funded and run by Fisheries and Oceans Canada (DFO), and the Bowen Island Terminal Creek Hatchery, run by BIFWC, under the supervision of DFO, are playing a key role in salmon conservation and restoration in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. Adult females are caught before laying their eggs. The eggs are harvested and cared for at these salmon hatcheries, before being released as juveniles. Bowen Island Hatchery produce chum and coho for release yearly, and pink during odd years.[3]

Hatchery-raised salmon theoretically have higher survival rates than their wild counterparts, due to experiencing fewer environmental impacts (e.g., flooding, predation, lack of nutrition); however, this is not conclusive.[4] Conditions during the young salmons' early marine period impacts their growth, and in turn their survival rates, and this can vary between and within years.[5] Regardless, these programs are an effective tool to help increase salmon populations.

There are currently no comprehensive escapement[ii] data or stock assessment programs available for Átl'ka7tsem/Txwnéwu7ts/Howe Sound salmon populations. Instead, DFO salmon stock assessments occur for the entire Strait of Georgia Conservation Unit[iii]. The limited data that are available in Átl'ka7tsem/Txwnéwu7ts/Howe Sound for five Pacific salmon species (i.e., Chinook, chum, pink, coho and sockeye) show high variability between years with no clear trends in the numbers of adult salmon returning to spawn in the Sound's rivers. Information on individual species is detailed below.

ii) Escapement – the number of salmon that are not caught in fisheries (commercial, recreational, ceremonial) and return to their freshwater spawning areas.

iii) Conservation Unit – a group of salmon that is isolated enough from other groups that the population would struggle to repopulate if extirpated.

Chinook salmon *(Oncorhynchus tshawytscha)*

Overall, Strait of Georgia Chinook populations appear to be bouncing back from historic lows noted in 2009. Chinook returns have doubled since the program started in 2014. The Tenderfoot Creek Hatchery Chinook brood program produces over 200,000 smolts[iv] and fry[v] that are released back to their natal rivers each spring.[6] All returning adults, used as brood stock, are caught via tangle nets or set nets in the Cheakamus, Mamquam, Ashlu, Shovelnose, and Elaho river systems.

DFO staff capture brood stock via nets, before transferring to hatchery grounds. (Credit: Jordan Uittenbogaard)

Hatchery staff have observed strong returns of hatchery-bred adults in all enhanced river systems in 2018 and 2019.[6] For the first time since the program began, in 2018 and 2019, many large four- and five-year-old returning hatchery fish were observed and caught by hatchery staff in the aforementioned rivers, and intercepted in recreational fisheries along the B.C. coast.[6] Not enough data have been collected to assess the overall success of the hatchery programs; however, preliminary observations suggest the program is on track to meet the intended conservational goals of bringing the populations back to historical levels.[6]

Juvenile chum salmon getting ready to be released at the Bowen Island Hatchery. (Credit: Bowen Island Hatchery; Bowen Island Fish and Wildlife Club. Reproduced with permission from Tim Pardee.)

Outside of hatchery data collected by Tenderfoot staff, no concrete escapement data for Átl'ka7tsem/Txwnéwu7ts/Howe Sound are available. Most stock status is calculated using details from hatchery staffs' daily catches during the Chinook brood program (July-September). Sḵwx̱wú7mesh Úxwumixw/Squamish Nation conduct a dead-pitch program[vi] during spawning season to better estimate escapement data and determine population health.

Conversely, in the Cheakamus River, a tributary to the Squamish River, a B.C. Hydro study from 2018 showed that estimates for Chinook salmon have followed the trend of low-abundance years since 2014.[7]

iv) Smolts – a young salmon, when it becomes the adult silvery color and migrates to the ocean for the first time.

v) Fry – small, young fish that are just emerging from their gravel nest.

vi) Dead-pitch program – population assessment program where carcasses are recovered to get population numbers.

Chum salmon *(O. keta)*

The Tenderfoot Hatchery began a long-term chum stocking program in 2012 in response to low stocks in the Squamish River system (Figure 1). This program identifies suitable watercourses for an enhancement period, whereby chum fry are released annually for four years. At the conclusion of the four years, another suitable watercourse is selected, and the program continues. Enhanced watercourses are more accessible, with appropriate habitat for chum salmon. Data from 2017 onwards have not yet been analyzed. Chum returns remain below the long-term average; however, with the introduction of hatchery chum throughout the Átl'ka7tsem/Txwnéwu7ts/Howe Sound watershed, chum returns in the area are increasing, especially in urban settings.[6] Additionally, as of November 2019, the recreational chum salmon fishery was closed.[8]

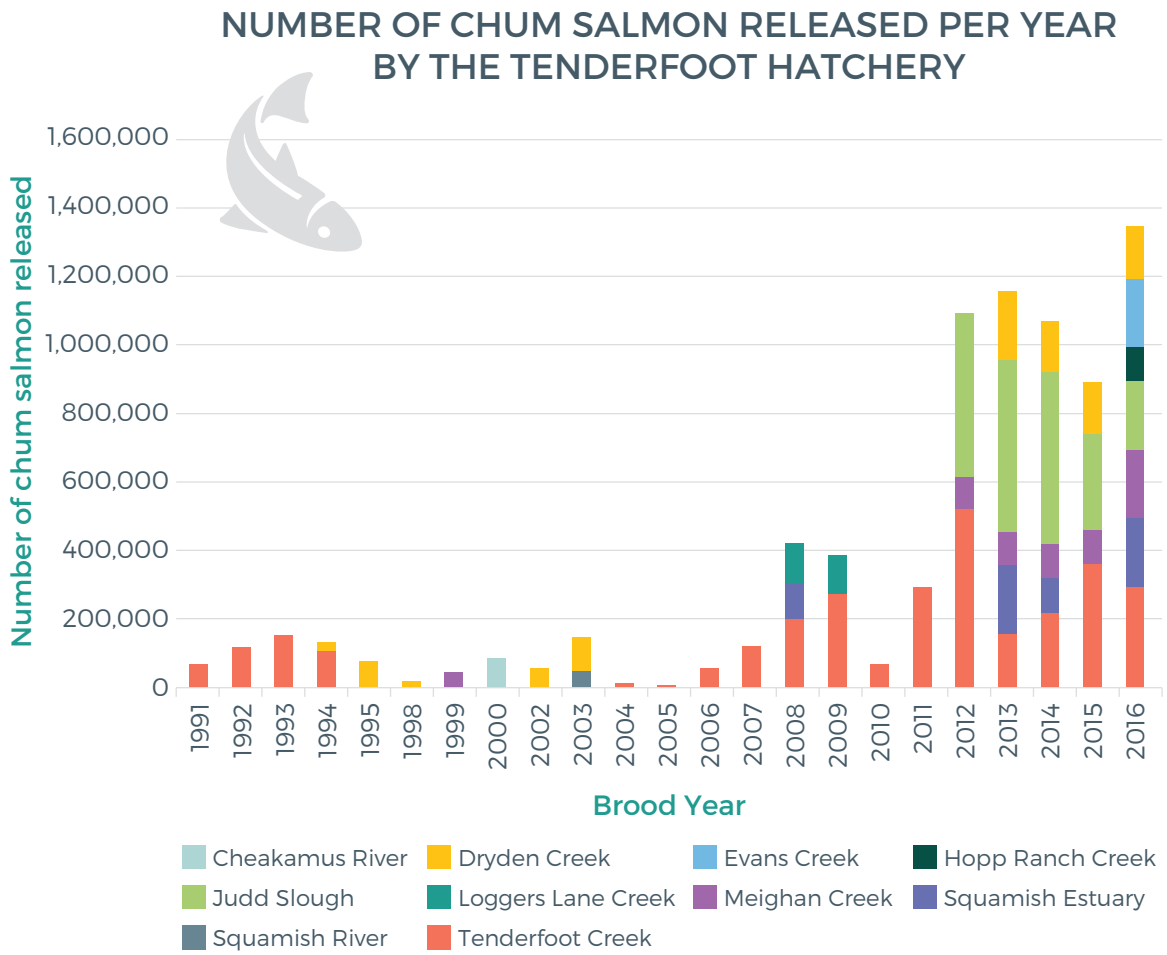

Figure 1: Number of chum salmon released per year at sites within Tenderfoot Hatchery's stocking program. Note increased efforts in 2012, aligned with the start of the chum stocking program.

Pink salmon *(O. gorbuscha)*

Pink salmon return to spawn every two years. The population occurring throughout Átl'ka7tsem/Txwnéwu7ts/Howe Sound return in odd years.[9] In 2013 and 2015, large returns of pink salmon (*Oncorhynchus gorbuscha*) were recorded in the Squamish River by Tenderfoot Hatchery staff, prompting the unheard-of opening of a commercial fishery for this species in the area in 2013 (see Salmon, OWHS 2017). However, due to a lack of comprehensive data, DFO scientists decided it was not prudent to allow a commercial fishery to continue.[10] The fishery was shut down in August 2015.[11]

Data from the Cheakamus River indicate there has been a decline in juvenile pink salmon abundance since 2015[7] with lower returns in 2017. In 2019, pink salmon returns rebounded in some river systems compared to 2017. Within the 2019 hatchery production plan for the Átl'ka7tsem/Txwnéwu7ts/Howe Sound area, there is a target to transfer 100,000 pink salmon eggs to the Tenderfoot Hatchery.[12]

After spawning occurs, young of year (YOY) salmon[vii] leave the watershed early the following year (even-numbered years). For 2012 and 2014, data from the Cheakamus River showed the mean abundance of YOY pink salmon to be unusually high compared to the previous and subsequent years (Figure 2).[7] Estimates of YOY abundance were generated using a standard model[viii] that estimates weekly abundance. Despite observations in rivers, no escapement data are available. Annual monitoring is ongoing by B.C. Hydro to gauge the impacts of the hydroelectric dam on fish populations of the Squamish River.

In September 2019, B.C. Hydro reduced the flow from Daisy Lake Dam into Cheakamus River, an event known as "ramping"[ix]. This ramping event caused water levels to fall, resulting in the stranding of hundreds of pink salmon.[13] Ramping down, in combination with low rainfall, resulted in large numbers of pink salmon dying off before spawning, potentially impacting future numbers.[14]

DFO catching broodstock. (Photo credit: Jordan Uittenbogaard)

vii) Young of Year (YOY) - salmon born within the past year.

viii) Standard model – BTSPAS Mark-recapture model, see Bonner and Schwarz 2011 for more information.

ix) Ramping – changing of the level of stream discharge by an upstream hydroelectric facility.

Coho salmon *(O. kisutch)*

Coho escapement and return data are collected via passive count methods in Tenderfoot Creek, using a counting fence (see Methods). Based on these data, the coho stock status is considered healthy, with fairly consistent survival of hatchery fish for the past decade.[10] Some coho stocks have seen dramatic decreases in returns due to high river levels upon their migration, in part due to flooding events and ramping. The Mamquam and Ashlu river systems have seen a decrease in numbers of returning adults due to high waterflows from these flooding events for the past five years.[10]

Sockeye salmon *(O. nerka)*

Sockeye data are limited to some sockeye observations by hatchery staff in 2016 to 2019 during Chinook brood capture.[10] The sockeye recreational fishery was opened in August 2018 for areas within Átl'ka7tsem/Txwnéwu7ts/Howe Sound (Subareas 28-1, 28-2 and 28-7), with a limit of four fish per day.[15]

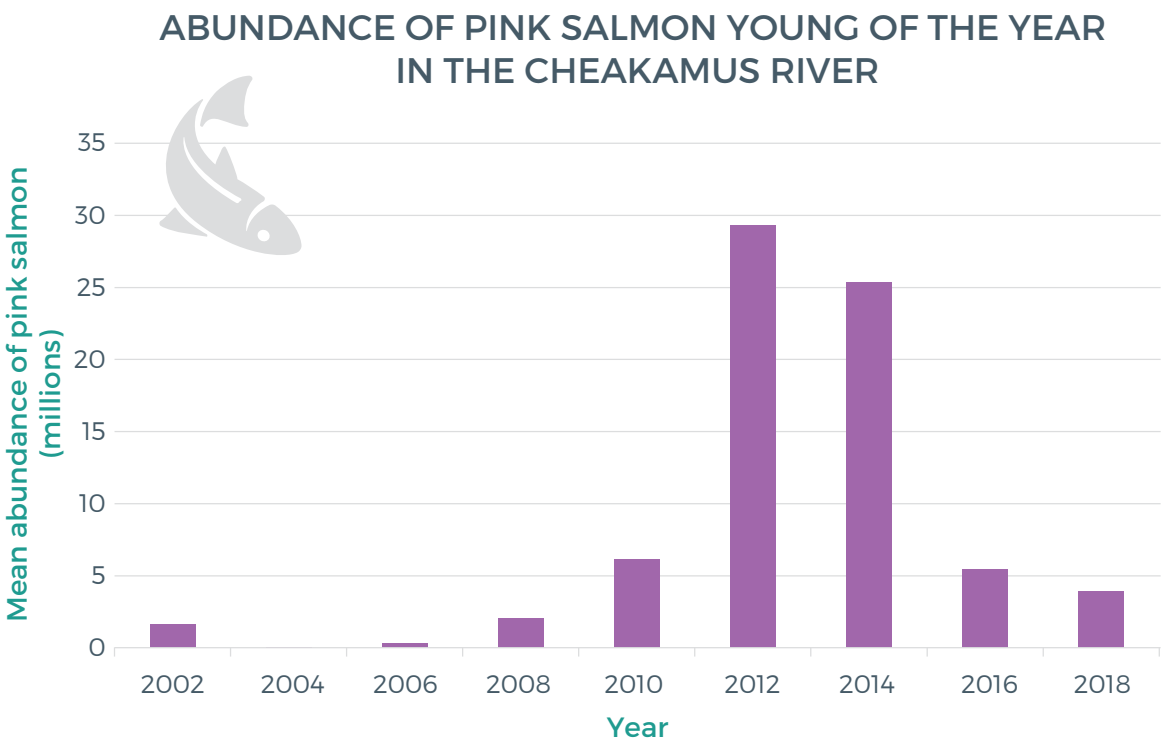

Figure 2. Mean annual abundance estimates of young of year (YOY) pink salmon collected bi-yearly in the Cheakamus River from 2002 to 2018, adapted from Lingard 2018.

Success Story

ELAHO RIVER PROJECT
CHINOOK SALMON RESTORATION AND RELEASE

Industrialization in the Elaho River area in the 1960s-70s resulted in blockages of part of the river canyon by large boulders and debris, impacting the flow regime of the river. The blockages effectively prevented salmon migration in the Elaho Valley watershed, leading to local extinction. Blasting to remove the boulders and restore key Chinook habitat was undertaken in November 2017 and September 2018 by Sḵwx̱wú7mesh Úxwumixw/Squamish Nation, Squamish River Watershed Society, and DFO, with funding from the Fish Habitat Restoration Initiative Fund and Pacific Salmon Foundation (see photos below of this location on different dates). Additional funding was received in 2019 from the B.C. Salmon Restoration and Innovation Fund.

The large boulder blocking the river.
(Credit: Edith Tobe and Global Rock Works, 2019)

The boulder after it had been blasted apart.

Boulder fragments were moved to allow water flow to resume.

After the removal of the blockages from the river, a plan to introduce Chinook fry from Shovelnose Creek began in July 2019, when 5000 hatchery-raised Chinook fry were released into the upper Elaho River. Additional fry will be released each spring from the Tenderfoot Hatchery into this waterway to restore a natural spawning population of Chinook throughout the reaches of the Elaho River. Currently, 10,000 Shovelnose smolts are being reared to be released into the upper Elaho in May 2020.[6] Monitoring will be required to establish whether the barrier removal was effective, and whether the population has been re-established successfully.

What are the potential impacts of climate change on salmon species?

Pacific salmon has been identified as one of the most vulnerable species groups to climate change in B.C.[2] Ocean warming and changes in river water conditions, including temperature, timing and discharge levels (see Streamflow, OWHS 2017) were identified as the greatest threats due to impacts on migration, growth and survival of various life stages. Salmon that spend more time in freshwater (i.e., river-type[x] Chinook) have been experiencing higher population declines than those that spend less time in freshwater (i.e., pink, chum, river-type sockeye, and ocean-type Chinook), suggesting that climate change will have different impacts on different species.[9] Other threats include ocean acidification (see Ocean Acidification, OWHS 2020) that could have impacts on the food web by limiting prey availability and potentially increase harmful algal blooms that could trigger mass fish kills.[2]

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Join local restoration efforts to help monitor and maintain freshwater salmon habitat.	• A number of restoration efforts have been made in the Squamish River and central Squamish Estuary in the last three years. Details can be found in Squamish Estuary, OWHS 2020. Examples include the Central Estuary Restoration Project (CERP), which is ongoing, and repair and maintenance of channel intakes at Ashlu Creek. See Resources for more information, and links to the Squamish River Watershed Society (SRWS) website (www.squamishwatershed.com). • Since the publication of the previous report, another citizen science project, in conjunction with DFO, relating to salmon, commenced (2019). Various creeks within Howe Sound with salmonid-bearing habitat are monitored for temperature by volunteers from various Streamkeeper groups. Additional details can be found in Citizen Science, OWHS 2020.

x) River-type – young fish remain in fresh water longer than the ocean-type and are therefore larger when entering saltwater. Adults return earlier to fresh water than the ocean-type and remain there longer before spawning.[14]

2017 ACTION	ACTION TAKEN
GOVERNMENT ACTIONS AND POLICY	
Increase focus on data collection in order to get accurate, high-quality counts of spawners. Use tagging methods over visual counts where feasible.	• In 2018, a new five-year Wild Salmon Policy Implementation Plan was released by DFO with the assistance of public consultation. This plan aims to standardize monitoring in order to assess salmon stocks more accurately. Notably, it concludes that the goals can only be achieved with the support and collaboration of the community. • DFO is developing a new parentage-based tagging system that could enable higher accuracy and greater coverage of juvenile salmon identification. • Pacific Salmon Explorer – An online tool is being developed by the Pacific Salmon Foundation that incorporates data on salmon populations and habitats into an interactive map (www.salmonexplorer.ca). Five regions on the B.C. coast are covered: Nass, Skeena, Central Coast, Fraser, and Vancouver Island & Mainland Inlets. The latter two are still in progress, with Howe Sound falling under the Mainland Inlets region. A link is provided in Resources. Funding for this project was provided by government, community groups and philanthropic donors.
1. Increase support for community habitat restoration efforts including spawning channels, rearing channels, reconnection of side channels and weirs. 2. Reclaim and rehabilitate estuary habitat that has been modified by past development. 3. Promote and fund the rehabilitation of modified rivers and streams such that salmon habitat is enhanced. This includes promoting shaded riparian areas to help maintain cooler stream temperatures. 4. Recognize the importance of estuary habitat for spawning and rearing salmon.	Applies to all four actions • The Coastal Restoration Fund has provided support to two community groups operating in the Sound (SRWS and SeaChange Marine Conservation Society) in part to restore estuarine habitat for Pacific salmon. • Research and remediation efforts have increased in the area with the support from Government (as detailed in "What is being done" above).
Continue to monitor water quality and treatment, and support ongoing remediation at Britannia Mine.	Golder Associates continues to undertake environmental monitoring in the vicinity of the historical contamination site, on behalf of the provincial government.
Increase monitoring and enforcement of fishery limits, openings and closures.	According to the Integrated Fisheries Management Plan 2018-2019, the current compliance strategy aims to utilize technology to monitor and to work with stakeholders to improve regulatory compliance.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- Monitor fishery status and limits. Ensure you are fishing within current regulations.
- Eat sustainable seafood, look for the Ocean Wise symbol in restaurants and grocery stores.

Government Actions and Policy:

- Protect all estuary habitats from residential, commercial, or industrial development.
- Increase public education on the status of salmon, and how people can help salmon stocks recover.
- NEW Establish citizen enforcement officers throughout the Sound, who are granted limited enforcement powers, such as checking catch size, species, and fishing method, and handing out fines for fisheries infringements.

Methods

All coho and chum estimates are approximated using counting fences. Counting fences are placed instream, blocking the width of the river, apart from a small diversion channel. The migrating salmon must swim through this narrower channel, where they are counted. The diversion channels often have a white bottom, in contrast to the salmon, making them easier to count.

Chinook status stock methodology is based on catch per unit efforts of hatchery netting program. Dead-pitch numbers are also used. Long-term monitoring in remote river systems such as the Elaho River will include environmental DNA (eDNA) sampling to determine the extent of usage in the upper reaches by all life stages of chinook salmon.

A brief literature scan was undertaken using ResearchGate and Google Scholar to find new articles relating to salmon and climate change, released since 2017. Key words used included a combination of salmon, climate change, B.C., Canada, Pacific, ocean acidification.

Resources

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A pink salmon stranded after a ramping event in the Stawamus River, Squamish. (Credit: Tracey Saxby)

Marine Birds: Important Bird Area expanded into the Sound

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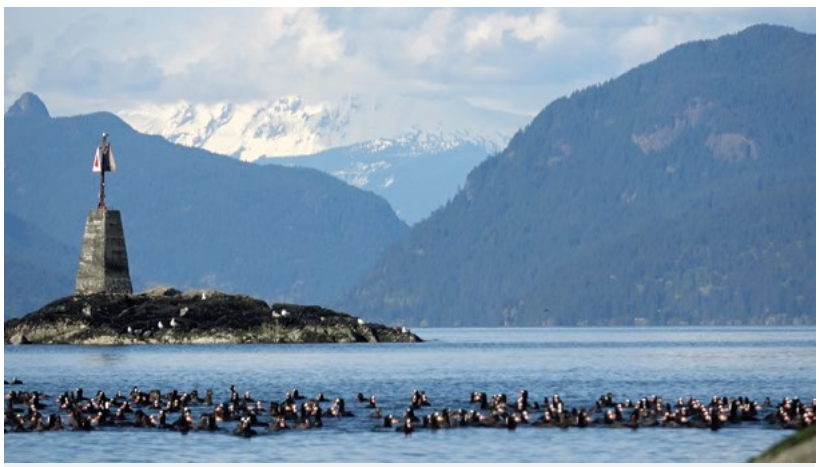
What is happening?

A recent report, informed largely by citizen-science data, estimated a decline of 2.9 billion birds throughout North America since 1970.[1] There have been anecdotal reports of declining bird numbers throughout Átl'ka7tsem/Txwnéwu7ts/Howe Sound over recent years. Extensive, regular, long-term data collected by citizen science groups and birding enthusiasts not only assists in conservation efforts but contributes important information that helps identify and confirm these types of trends.



A surf scoter, *Melanitta perspicillata* flock at Worlecombe in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. (Credit: Bob Turner)

Shorebird[i] numbers in Canada have decreased by 37.4% and are in need of urgent conservation action.[1,2] Waterbird[ii] numbers have decreased by 21.5%.[1] These large declines are attributed to habitat loss and degradation, collisions with man-made structures (e.g., cars, windows), decreased prey, and increased predation and disturbance from non-native species such as domestic cats and dogs. Climate change is also contributing to population declines by negatively changing habitats and impacting crucial plants and prey.[1]

What is the current status?

Many waterfowl[iii] species were on the brink of extinction during the last century in North America.[1,2] However, conservation actions have led to a 56% increase in their numbers.[1] By identifying the causes of waterfowl decline (pesticides, hunting, loss of key wetland habitat), effective management strategies were able to directly address these concerns.[2,3]

Two Important Bird Areas (IBAs) are located within the Átl'ka7tsem/Txwnéwu7ts/Howe Sound region (Figure 1). The English Bay – Burrard Inlet IBA was enlarged in January 2019 to include part of Átl'ka7tsem/Txwnéwu7ts/Howe Sound, including Nexwlélexwem/Bowen Island and areas in south-eastern Átl'ka7tsem/Txwnéwu7ts/Howe Sound (see Marine Protected Areas, Ocean Watch Átl'ka7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020). The extension of the IBA was spearheaded by members of the Pacific Wild-Life Foundation, who collected data to inform a recommendation for the B.C. IBA advisors.[4,5]

The expansion of the English Bay – Burrard Inlet IBA was warranted due to large numbers of surf scoters (*Melanitta perspicillata*), Barrow's goldeneyes (*Bucephala islandica*) and marbled murrelets (*Brachyramphus marmoratus*) recorded in the area (Figure 2).[4] These birds are considered globally significant as "congregatory species". These IBAs are home to a significant proportion of the global populations of these species.[4] Other significant species identified in these IBAs include the western grebe (*Aechmophorus occidentalis*) and the local subspecies of great blue heron (*Ardea herodias fannini*).[4]

Átl'ka7tsem/Txwnéwu7ts/Howe Sound was formerly home to a significant number of western grebes during winter, however this species declined throughout the Salish Sea by about 95% from 1975 to 2010.[6] This means the remaining population is regarded as important to conserve. The local subspecies of great blue heron is considered nationally significant; the two IBAs noted above are home to a large concentration of breeding pairs.[7] The status of specific species is detailed below.

i) Shorebirds – birds that live along the shoreline, e.g., sandpipers, plovers, oystercatchers.

ii) Waterbirds – birds that live on or around water, e.g., seabirds, herons, marsh birds.

iii) Waterfowl – birds that live in or around water that are hunted for sport (game birds), e.g., ducks, geese, swans.

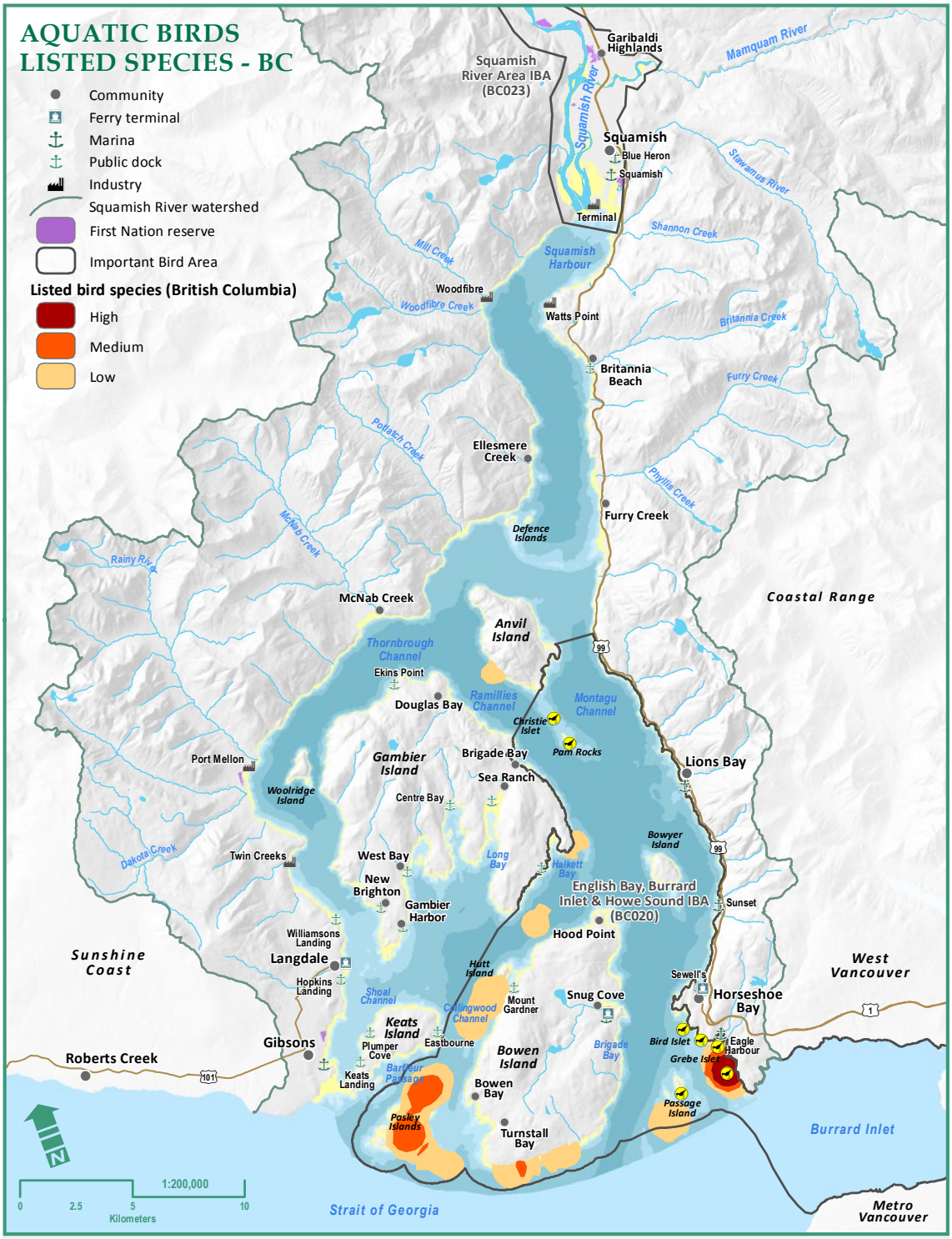


Figure 1. The English Bay – Burrard Inlet Important Bird Area, including its expansion into Átl'ka7tsem/Txwnéwu7ts/Howe Sound that occurred in January 2019. Heat map shows recorded densities of listed bird species in the area. Yellow bird symbols represent the location of known bird colonies within the IBA.

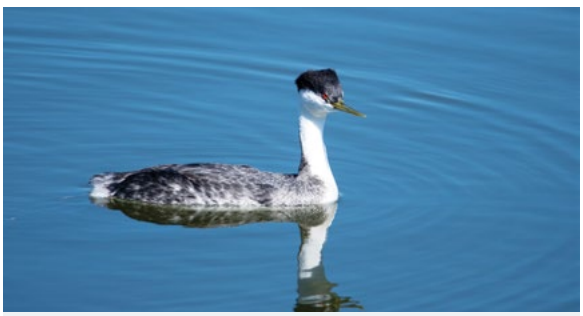
Western grebe
(Aechmophorus occidentalis)

STATUS: Listed as Special Concern[iv] by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the *Species at Risk Act* (SARA).[6] Red listed[v] in B.C. with a target of doubling the population.[vi]

DISTRIBUTION AND HABITAT: Found throughout western Canada year-round,[6] they winter in marine waters along the southern coast of B.C., and nest mainly in southern Alberta, Manitoba, and Saskatchewan.

POPULATION: Nation-wide, the current population has seen a large decrease since around 1970.[5]

THREATS: Non-breeding marine sites birds are threatened mainly by declines in fish prey, as well as pollution.[8,9]



Western grebe. (Credit John Bakes)

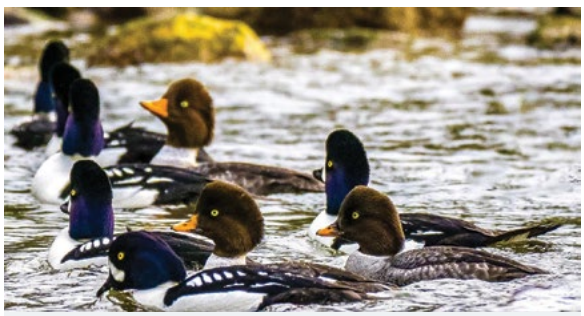
Barrow's goldeneye
(Bucephala islandica)

STATUS: The B.C. bird conservation strategy has an objective to maintain their current population. This is a species of note in the North American Waterfowl Management Plan (NAWMP) as having a high conservation value and/or monitoring requirement.[3]

DISTRIBUTION AND HABITAT: These sea ducks have a confined distribution.[10] Two populations – an eastern and a western – are found in Canada. The western population is much larger.[10] The Salish Sea is an important habitat for these species during winter, providing nearshore coastal habitat, including within Átl'ka7tsem/Txwnéwu7ts/Howe Sound.[11]

POPULATION: Population estimates have been stable for the past two decades.[12]

THREATS: This species is threatened by loss of nesting habitat and disturbance from development.[10]



A flock of Barrow's goldeneye. (Credit: John Bakes)

iv) Special Concern species have characteristics that make them particularly sensitive to human activities or natural events, e.g., very restricted habitat or food requirements.

v) Red listed animals, plants and ecological communities have been identified as at risk of extirpation (local extinction) or extinction.

vi) Bird conservation strategy, Region 5: North Pacific Rainforest – http://publications.gc.ca/collections/collection_2013/ec/CW66-316-2-2012-eng.pdf

Surf scoter
(Melanitta perspicillata)

STATUS: Blue-listed[vii] in B.C., with a target to increase the population (unspecified amount). Recognized as a priority species in the NAWMP.[3]

DISTRIBUTION AND HABITAT: There are two populations of this sea duck recognized in North America – an eastern and a western.[12] High numbers of the western population winters around the Salish Sea, including Átl'ka7tsem/Txwnéwu7ts/Howe Sound.[4] They feed on Pacific herring (*Clupea pallasii*) eggs seasonally, and this food source is important during their spring migration.[4,13] Herring have been returning to Átl'ka7tsem/Txwnéwu7ts/Howe Sound in recent years (see Forage Fish, OWHS 2020), meaning that the area provides an important feeding habitat along the coast during migration.[4]

POPULATION: There are currently insufficient counts and data available to give good population or trend estimates for scoters.[13] However, the available data indicates scoter numbers in western Canada have remained fairly constant over the last two decades.[13,14]

THREATS: Largely unknown, but likely include changes in prey availability and pollution, such as oil spills on marine sites and effects of climate change and hydroelectric development on their boreal forest breeding habitat.[13,14]

Marbled murrelet
(Brachyramphus marmoratus)

STATUS: Listed as Threatened[viii] in Canada, and Endangered[ix] (International Union for Conservation of Nature [IUCN]) globally.[16] Red-listed in B.C. with an objective to recover the population to 1970 levels. Also listed as Vulnerable[x] on the Wild Species List, Canada (2015), and on the State of North America's Birds Watch list (2016).

DISTRIBUTION AND HABITAT: Canada is home to over one quarter of the global population of marbled murrelets. High numbers have been recorded in Átl'ka7tsem/Txwnéwu7ts/Howe Sound during winter surveys, indicating this is an important habitat location.[4,17]

POPULATION: A less conspicuous species for which there is little historical data.[14] However, limited surveys have indicated a decline in abundance since the 1970s.

THREATS: The largest threat is loss of old-growth coastal forest nesting habitat.[4,16–18] Other concerns include nest predators, marine pollution, entanglement and declines in the quality of marine prey.[16,18,19]

vii) Blue-listed animals, plants and ecological communities are of special concern.

viii) Threatened species are likely to become endangered if limiting factors are not addressed.

ix) Endangered species are considered to be facing imminent extirpation (local extinction) or extinction.

x) Vulnerable species are at moderate risk of extirpation.

Great blue heron subspecies
(Ardea herodias fannini)

STATUS: Listed as Special Concern in Canada[7] and Blue-listed in B.C., with targets to assess and maintain the current population.

DISTRIBUTION AND HABITAT: This wading bird frequents shorelines and marshes.[15] They are non-migratory and live in an isolated area constrained by mountain ranges.[7] This sub-species is found only in coastal B.C. A coastal wetland bird, many nest in marshes and woodlands near eelgrass (*Zostera marina*) meadows and marine shorelines.

POPULATION: The population is small and has seen large decreases since the 1970s.[15]

THREATS: This subspecies is threatened by bald eagle predation and loss of feeding and nesting habitat from development.[7,15] Threats to the nesting sites include impacts of development on nesting trees, as well as on adjacent feeding sites that often include eelgrass beds, a habitat that has been destroyed in the region in the past. Hopefully with eelgrass restoration efforts around Átl'ka7tsem/Txwnéwu7ts/Howe Sound, there will be increases in suitable nesting habitat (see Eelgrass, OWHS 2020).[15]

Great blue heron. (Credit: John Bakes)

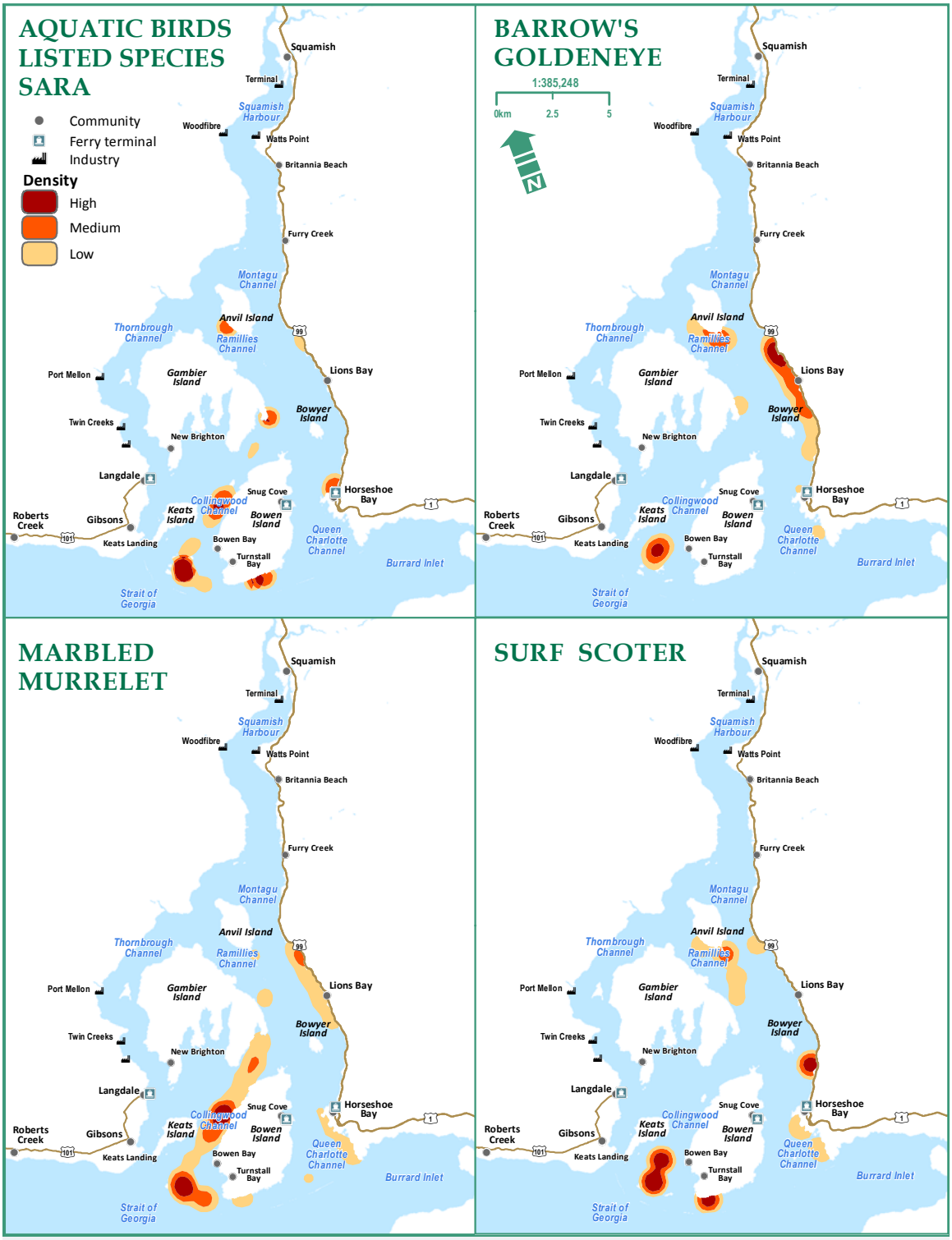


Figure 2. Densities of birds within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Top left: Density of SARA-listed marine birds. Top right: Density of Barrow's goldeneye. Bottom left: Density of marbled murrelet. Bottom right: Density of surf scoter.

Dedicated citizen scientists are keeping their eyes on these and other birds in the Sound, collecting crucial data for various organized bird counts such as:

THE GREAT BACKYARD BIRD COUNT (GBBC), held once a year. In 2019, there were 22 participants in the Squamish-Lillooet District, and 60 different species counted. The most numerous marine species observed were the Canada goose (*Branta canadensis*) (177), followed by gulls (multiple species) (50), Barrow's goldeneye (*Bucephala islandica*) (40), and mallard (*Anus platyrhynchos*) (38).

THE BC COASTAL WATERBIRD SURVEY (BCCWS) are monthly counts undertaken by the Bowen Island Nature Club, Squamish Birders program, Lighthouse Park Preservation Society and the Pacific WildLife Foundation, among others. All contribute data to the BC Coastal Waterbird Survey counts.

THE NORTH AMERICAN BREEDING BIRD SURVEY (NABBS). The Squamish Environment Society (SES) sponsors the Squamish NABBS and provides count data for analysis. In 2018, 47 species were reported, totalling over 500 birds[xi] for the Sḵwx̱wú7mesh/Squamish area. This dataset was used in the 2019 report "Decline of the North American Avifauna."[1]

THE AUDUBON CHRISTMAS BIRD COUNT (CBC). The SES hosts the annual CBC for the area. In the 2018/2019 CBC, 24 participants were recorded for the Sḵwx̱wú7mesh/Squamish District, 24 participants for the Sunshine Coast, 155 for Vancouver and 16 participants for Whistler. CBC data were used in the 2019 report "Decline of the North American Avifauna."[1]

xi) https://www.pwrc.usgs.gov/BBS/PublicDataInterface/index.cfm. See Methods for how these surveys are carried out. See Resources for more information on these groups.

What are the potential impacts of climate change on marine birds?

As temperatures rise and habitats are lost, some species are shifting their range, changing their behaviour, and losing large numbers from their populations.[1,4] Climate change is triggering increases in sea surface temperature, which results in lower oceanic productivity.[20,21] This means decreasing amounts, or changing locations of available prey species, and potential starvation for many marine birds.[20,21]

A recent case in the North Pacific demonstrated this when, between 2014 and 2016, anomalously warm sea surface temperatures known as "the Blob" (see Resources) occurred that resulted in the death of an estimated one million common murres (*Uria aalge*).[20] The heatwave caused a decrease in phytoplankton biomass. From California to Alaska, evidence from the birds that washed ashore indicated that they had died from starvation.[20]

Eggs and juvenile shorebirds are at risk from climate-related sea level rise and the increased frequency of extreme weather events, which will destroy nesting habitat.[21] Prolonged climate impacts continue to have drastic consequences for many marine birds in B.C., and globally. Habitat restoration and protection will be necessary for the survival of many species.

A flock of Barrow's goldeneye on the shore. (Credit: John Bakes)

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
GOVERNMENT ACTIONS AND POLICY	
Continue to support and facilitate the education, monitoring, and restoration activities of local groups in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. Provide funding assistance and partnership opportunities where feasible.	Funding provided through the B.C. government and the Habitat Conservation Trust Foundation includes some grants for bird habitat. Grants from 2019 can be viewed at: https://hctf.ca/24-community-conservation-projects-receive-pcaf-funding/
Legally recognize and strictly regulate Important Bird Areas as Protected Areas, especially in IBAs that do not have established legal protection (e.g., national and provincial parks). Where this is not feasible, consider conservation easements and agreements, private land stewardship, and land acquisition to ensure protection.	An IBA in English Bay – Burrard Inlet was extended in January 2019 to include part of Átl'ka7tsem/ Txwnéwu7ts/Howe Sound. However, IBAs still do not afford any legal protection.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below.

Individual and Organization Actions:

- Bird watching is one of the fastest growing hobbies in North America. Whether you are a beginner or advanced, you can join one of the annual Christmas Bird Counts that occur in West Vancouver, Bowen Island, Squamish, and the Sunshine Coast, or the more frequent monthly bird counts with the Squamish Environment Society or Lighthouse Park Preservation Society. It is a great way to learn from people who know more than you.
- If you are a knowledgeable birder, you can submit your observations directly through eBird, the online repository for worldwide bird observations managed by the Cornell Lab of Ornithology. Any unusual sightings require an accompanying photograph to be accepted by eBird.
- Keep your practices friendly to marine birds. During the spring and summer, stay away from offshore rocks that are nesting sites for oystercatchers, gulls and cormorants. Never take your dog to these islands.
- During the winter, do not disturb flocks of winter birds along the coastline. You may disrupt their feeding or resting and cause them to waste valuable energy.
- Collect lost nets and traps and plastics on beaches that might trap or kill birds.

Government Actions and Policy:

- Increase monitoring and enforcement of illegal bird harvesting.
- Explore the possibility of increasing the size of the Skwelwil'em Wildlife Management Area or Nature Trust Conservation Area, or create more Wildlife Management Areas to increase protection.

Methods

Data available from 2017 to 2020 were obtained through requests with citizen science groups and online resources.

Methods for creating the density heat-map (Figure 2.) plus an explanation can be found here: https://pwlf.ca/wp-content/uploads/2019/10/Howe_Sound_Report_Final.pdf

BC COASTAL WATERBIRD SURVEY[xii]

The survey occurs monthly from September to May, generally on the second Sunday of every month (+/- two days). Sites occur along a section of coastline, or a bay or inlet, and generally extend to 1 km offshore. Each count site has a mapped area and only birds within the boundaries are counted. Birds must be using the habitat to be counted; birds just flying through the area are not counted. On count days, surveys are conducted within two hours of high tide to standardize timing and ensure birds are close to shore for easy viewing. At some sites, a mid-tide count is acceptable when the shoreline is steeper and the tide does not recede too far. Recording sheets are provided to standardize the information captured.

CHRISTMAS BIRD COUNT[xiii]

Counts take place between December 14 to January 5, yearly. The count areas are pre-established 24 km diameter circles that can be found online[xiv]. Each circle is designated one calendar day within the survey dates. Volunteers follow specified routes through the circle, counting every bird they see or hear all day. Rather than a tally of species, all individual birds are counted.

GREAT BACKYARD BIRD COUNT[xv]

This survey takes place over four count days in February each year. Anyone can take part, from as little as 15 minutes per day. Estimates of how many birds of each species are recorded on a provided checklist along with any photos.

xii) https://www.birdscanada.org/wp-content/uploads/2020/02/BCCWS-Protocol.pdf

xiii) www.audubon.org/conservation/science/christmas-bird-count

xiv) https://audubon.maps.arcgis.com/apps/View/index.html?appid=ac275eeb01434cedb1c5dcd0fd3fc7b4

xv) https://gbbc.birdcount.org/

THE NORTH AMERICAN BREEDING BIRD SURVEY[xvi]

Each year, around June, birds are counted along pre-determined survey routes throughout the US and Canada. Along the survey route, stops are situated approximately 0.5 miles apart, whereby point counts are conducted. The survey generally lasts five hours and commences half an hour before sunrise. Every bird seen or heard within a 0.25 mile radius is counted.

SQUAMISH BIRDERS MONTHLY ESTUARY BIRD COUNT[xvii]

Surveys generally occur on the second Sunday of every month, year-round. The counts are led by local birders, and anyone can participate. Counts generally last four to six hours. A checklist is provided, based on data collected since 1981, and updated over the years. The area is divided into different habitats, and counts must specify what habitat type the birds were seen in.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

CITIZEN SCIENCE SURVEYS AND PROGRAMS

BC Beached Bird Survey, BC Breeding Bird Atlas, Breeding Bird Survey, BC Coastal Waterbirds Survey, BC Coastal Disturbance Project, Urban Bird Program, Window Collision Project (www.birdscanada.org/volunteer/programmap/index.jsp?lang=EN&targetpg=bcprograms)

APPS TO RECORD AND UPLOAD DATA

Ebird, NestWatch, Christmas Bird Count, GBBC, iNaturalist, Merlin

HOW TO BIRD-SAFE YOUR WINDOWS

https://birdsafe.ca/

www.allaboutbirds.org/news/why-birds-hit-windows-and-how-you-can-help-prevent-it/

IMPORTANT BIRD AREA LINKS

www.ibacanada.org/site.jsp?siteID=BC020

www.ibacanada.org/site.jsp?siteID=BC023

www.bcnature.ca/projects/iba/iba-newsletters/

LINKS TO LOCAL GROUPS

www.squamishenvironment.ca/programs/squamish-birders/

https://ebird.org/hotspots?hs=L292545&yr=all&m=

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Bald Eagles: numbers comparable to past ten years

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What is happening?

During the winter season, bald eagle (*Haliaeetus leucocephalus*) populations in Átl'ka7tsem/Txwnéwu7ts/Howe Sound are diligently observed and recorded by citizen scientists. Counts from three citizen science groups in the Sḵwx̱wú7mesh/Squamish, Brackendale, and lower Átl'ka7tsem/Txwnéwu7ts/Howe Sound areas were reported on previously (see Eagles, Ocean Watch Howe Sound Edition [OWHS] 2017). Depending on the group, the counts have been running anywhere from 15 years to almost four decades and are ongoing today. Counts are conducted in winter (i.e., December or January) around salmon spawning rivers in order to count bald eagles attracted to the salmon carcasses that result from spawning.

Bald Eagle. (Credit: Aroha Miller)

In recognition of the Sound as an important habitat not only for bald eagles but for several migratory bird species as well, the English Bay/Burrard Inlet Important Bird Area (IBA) was extended in January of 2019 to include an area of Átl'ka7tsem/Txwnéwu7ts/Howe Sound. This extension expands as far north as the southern half of Lhaxwm/Anvil Island, down the east side of Chá7elkwnech/Gambier Island, and encompasses Nexwlélexwem/Bowen Island and the Pasley Islands (see Marine Birds, OWHS 2020). However, this IBA does not afford any legal protection.[1]

What is the current status?

During the 2016 to 2019 counts, the number of eagles observed by each citizen science group remained comparable to the previous 10 years (from 2008/09 counts on), with the exception of 2013/14, when markedly more eagles were observed (Figure 1). In each of the three most recent years, fewer than 1500 bald eagles were counted by each individual group. The total number of eagles observed in the three survey areas combined over this period was 1346, 1797 and 2032, respectively, a small increase year after year.

However, there is considerable variation in the number of eagles counted over the years. Therefore, we cannot say that this small year-over-year increase indicates an upward trend in eagle numbers. The number of bald eagles observed in the Lower Howe Sound Christmas Bird Count continues to be low (less than 150 birds per year). For this group, no data for December 2018 was available online at the time of writing (October 2019).

Counts can be affected by weather (e.g., snowy or windy conditions in which eagles seek shelter) and human factors (e.g., number of participants). Despite these uncertainties, the consistent collection of data is valuable, providing important information for understanding winter foraging behaviour of bald eagles and their contributions to the ecological system in Átl'ka7tsem/Txwnéwu7ts/Howe Sound.

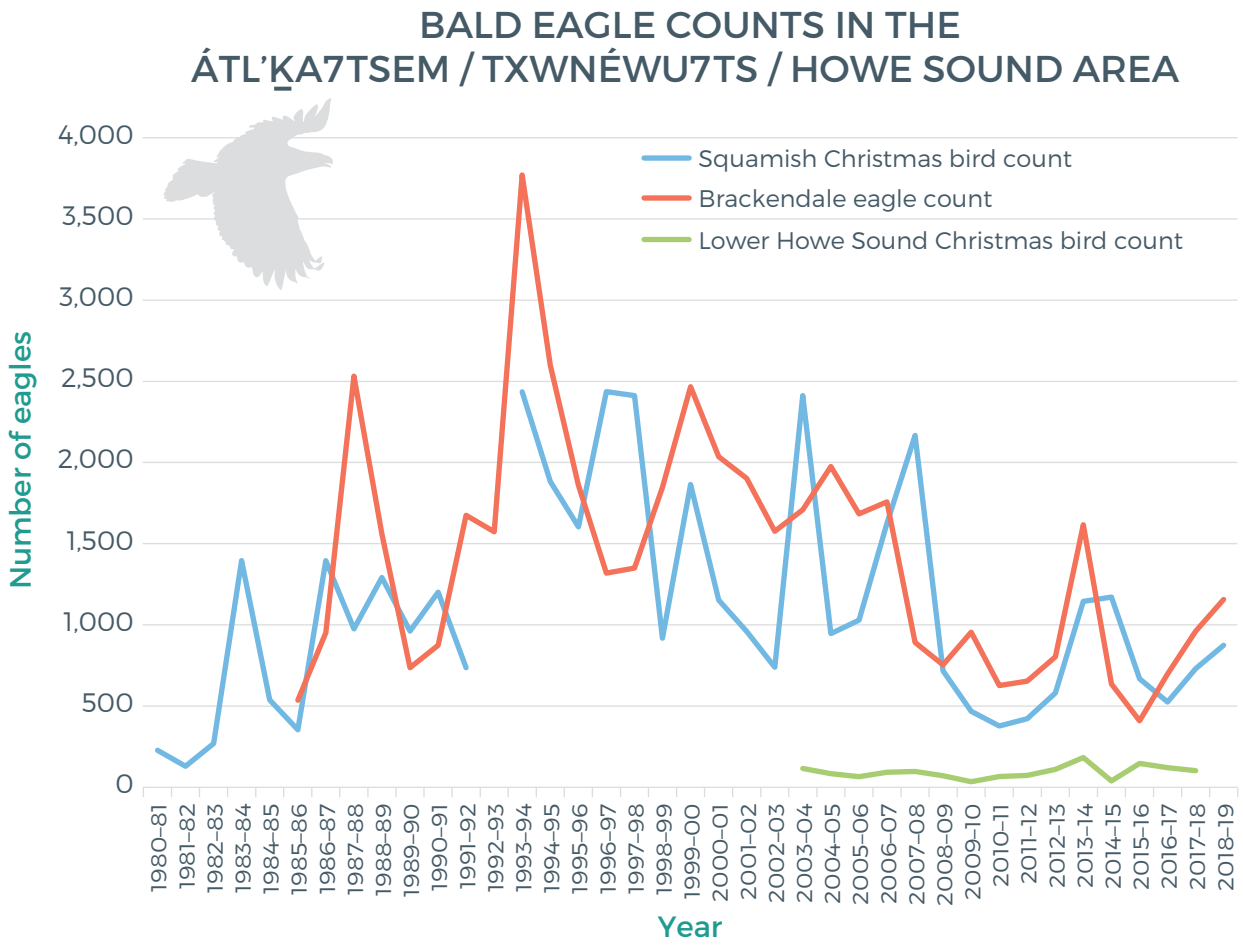
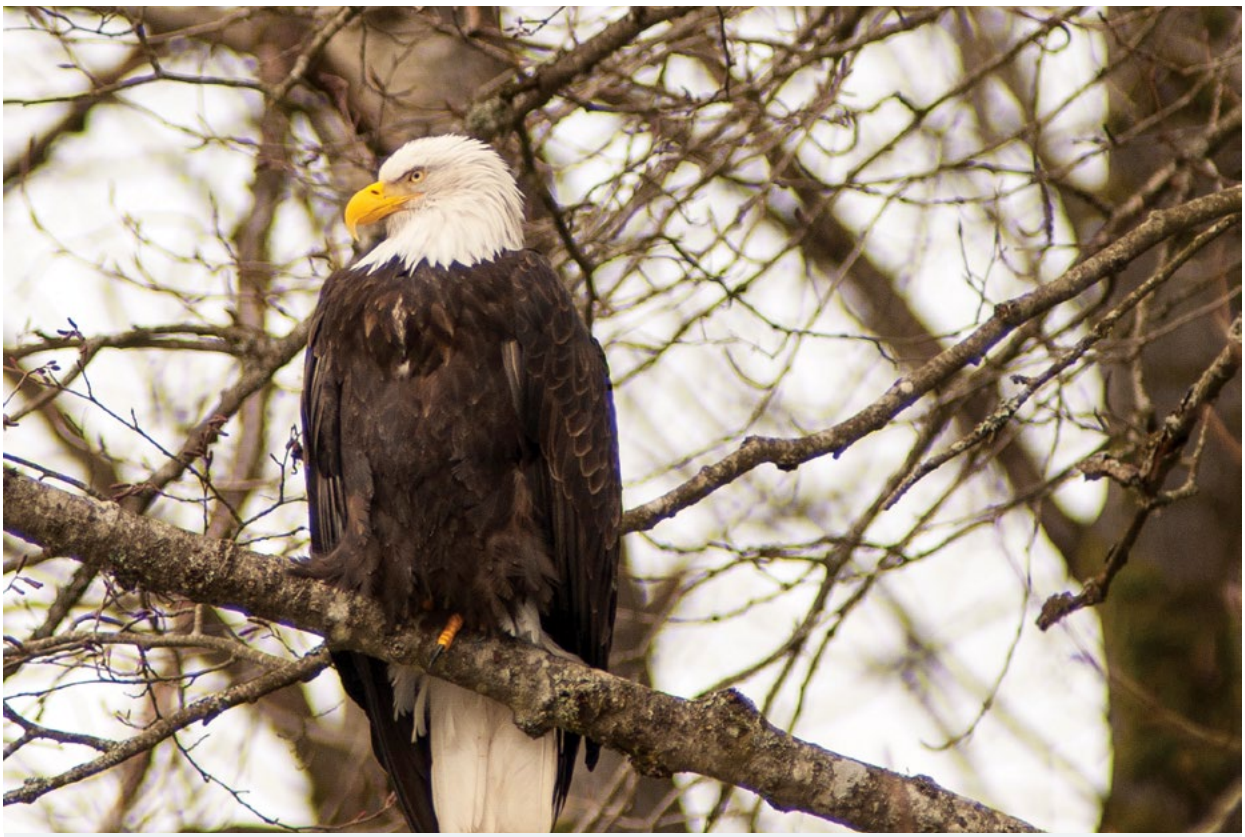


Figure 1. Bald eagle counts by each of three citizen science groups in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound from the early 1980s to 2019 for the Squamish Christmas and Brackendale eagle counts; and from 2002 to 2018 for the Lower Howe Sound group.

How will climate change impact bald eagles?

The predicted increase in storm frequency and intensity will result in more flooding events that remove salmon carcasses from rivers. Numbers of salmon in rivers will be affected by other factors that influence salmon survival and reproduction, such as stream flow and warmer water temperatures (see Stream Flow, OWHS 2017). Consequently, eagles will search elsewhere for salmon or look for other food sources. Movement to follow food sources will likely result in fewer eagles observed at historic winter-feeding sites, a reason given for the record low bird count in January of 2016 (411 eagles) (See Eagles, OWHS 2017).



A bald eagle. (Credit: Rich Duncan)

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Use proper viewing ethics when watching eagles. Do not disturb eagles feeding or roosting.	Supported by Eagle Watch resources, volunteers and signage. https://www.squamishenvironment.ca/programs/eaglewatch/
GOVERNMENT ACTIONS AND POLICY	
Empower local stewardship by increasing public bald eagle education efforts and education of regulations of the *B.C. Wildlife Act*, and locations of eagle nests and Important Bird Areas. Increase enforcement of activities restricted in the *B.C. Wildlife Act*.	Eagle Watch acknowledges the support of the District of Squamish. https://www.squamishenvironment.ca/programs/eaglewatch/
Closely monitor and manage prey species populations, specifically to ensure adequate chum runs are available to support eagle populations.	Fisheries and Oceans Canada (DFO) supports the Tenderfoot Creek Hatchery long-term chum stocking program, which began in 2012. In efforts to protect chum, DFO closed this recreational fishery in Átl'ka7tsem/Txwnéwu7ts/Howe Sound in November 2019 (see Salmon, OWHS 2020).
Legally recognize and strictly regulate IBAs as Protected Areas, especially in IBAs that do not have established legal protection (e.g., National and Provincial Parks). Where this is not feasible, consider conservation easements and agreements, private land stewardship, and land acquisition to ensure protection.	Approximately 50% of IBAs do not overlap with protected areas (e.g., National Parks).[1] In European countries, IBAs offer legal protection.[1]
Legislate against the production and use of harmful chemicals (e.g., Persistent Organic Pollutants [POPs]).	Canada was the first country to sign and ratify the Stockholm Convention, which aims to protect against health and environmental impacts from POPs. Details and links to Canada's work in this area can be found online at: https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-organizations/persistent-organic-pollutants-stockholm-convention.html

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below.

Individual and Organization Actions:

- Learn more about eagles by watching live streaming web cams of eagle nests (see Resources) or by attending Eagle Watch at Brackendale during the winter.
- Use proper viewing ethics when watching eagles. Do not disturb eagles feeding or roosting.
- Know the rules that protect eagles. It is an offense to possess, take, injure, molest, or destroy a bird or its eggs. Eagle nests are protected year-round, whether or not the nest is in use, by the B.C. Wildlife Act. Develop with Care.
- Adopt the best practices guidelines for protecting eagle nests during development that include identification of eagle nests before development and the establishment of a vegetated no-disturbance buffer zone around the nest tree.

Bald eagle. (Credit: Rich Duncan)

Methods

Bald eagle data were accessed from citizen science sites. Sḵwx̱wú7mesh/Squamish bird counts for 2016 to 2018 were accessed online from the Audubon database by filtering for year, location specifics (i.e., Canada, B.C.) and the codes (BCSQ for Sḵwx̱wú7mesh/Squamish and BCHS for Lower Howe Sound.[2] No data for the Lower Howe Sound bird count was available for January 2019. The early January Brackendale eagle count was accessed from the Squamish Environment Society's (SES) website.[3]

Counts are conducted in a single day. The area covered in bird counts was described previously for Squamish/Sḵwx̱wú7mesh and Brackendale (see Eagles, OWHS 2017) as well as Lower Howe Sound (see Marine Birds, OWHS 2017). Advice on etiquette is available from the Eagle Watch Program, run by the SES. Binoculars or telephoto lenses are advised to support viewing.[4] Christmas Bird Counts are organized events and participation requires coordination with the count compiler.[5] Audubon has a published compiler manual to support consistent counts.[6] To create a reliable survey, the Brackendale count also requires trained volunteers.[7]

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Pinnipeds: population stable since the 1990s

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What is happening?

Pinnipeds[i] common to nearshore B.C. waters include harbour seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and Steller sea lions (*Eumetopias jubatus*). Northern fur seals (*Callorhinus ursinus*) and Elephant seals (*Mirounga angustirostris*) are also common to Pacific Canadian waters, but they are observed much less frequently due to their offshore nature and long dive times, respectively. Recently, lone Guadalupe fur seals (*Arctocephalus townsendi*) have been observed on a handful of occasions, which may be related to warm water pulses driven by climate change.

Harbour seals and Steller sea lions, which are the only pinnipeds to currently breed in B.C.[ii], have been monitored during the breeding season (late

Harbour seals are found in many coastal areas. Here, a mother – pup pair are hauled out in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Bob Turner)

i) Pinnipeds – seals, sea lions, and walrus.

ii) Elephant seals have occasionally given birth at Race Rocks near Victoria, but the pups have not survived.

July through August) using standardized breeding season surveys. These surveys began in 1973 when long-standing hunting, culling, and bounty programs ended[iii] and have traced the recovery of these populations over the past 45 years.[1]

Harbour seals are the only pinniped species with established, predictable haul-outs[iv] in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Haul-outs are typically located on nearshore islands, islets, reefs, or sandbars.

Seals are generalist predators that prey on a variety of fish species as well as various cephalopods (small octopus and to a lesser extent squid). In the Strait of Georgia/Salish Sea, this includes primarily Pacific hake (*Merluccius productus*), herring (*Clupea pallasii*), and pollock (*Gadus* sp.). Seasonally important prey include eulachon (*Thaleichthys pacificus*) in early spring and salmon (primarily chum [*Oncorhynchus keta*]) in the fall. The return of forage fish to Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, such as anchovy (*Engraulis mordax*), Pacific sand lance (*Ammodytes hexapterus*), and smelt (*Hypomesus pretiosus*), is also an important source of prey for pinnipeds.

The Strait of Georgia has the greatest density of harbour seals in B.C. and has been the area most surveyed since counts began in 1973.[2] Trends in seal abundance observed in the Strait of Georgia are thought to be representative of other areas in coastal B.C, and counts in the Strait are important for predicting population trends of harbour seals throughout coastal B.C.[1]

Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound is one of five subareas surveyed during a typical Strait of Georgia seal survey (Figure 1), with subareas loosely defined as contiguous areas that can be surveyed during a single tide/time window.

Why are seals in Átl'ḵa7tsem/ Txwnéwu7ts/Howe Sound important?

Harbour seals are the primary prey for Bigg's (also known as transient) killer whales (*Orcinus orca*) in B.C. Bigg's killer whales are listed as threatened under the Canadian *Species at Risk Act* (SARA).[3] A stable and adequate food supply is key to the recovery and survival of the Bigg's killer whale. Harbour seals are therefore a key component of the ecosystem that attract and sustain this apex predator.

iii) Bounty program – financial reward for providing proof of opportunistic, lethal removals (e.g., seal snouts).

iv) Haul-out – a site where seals regularly come ashore.

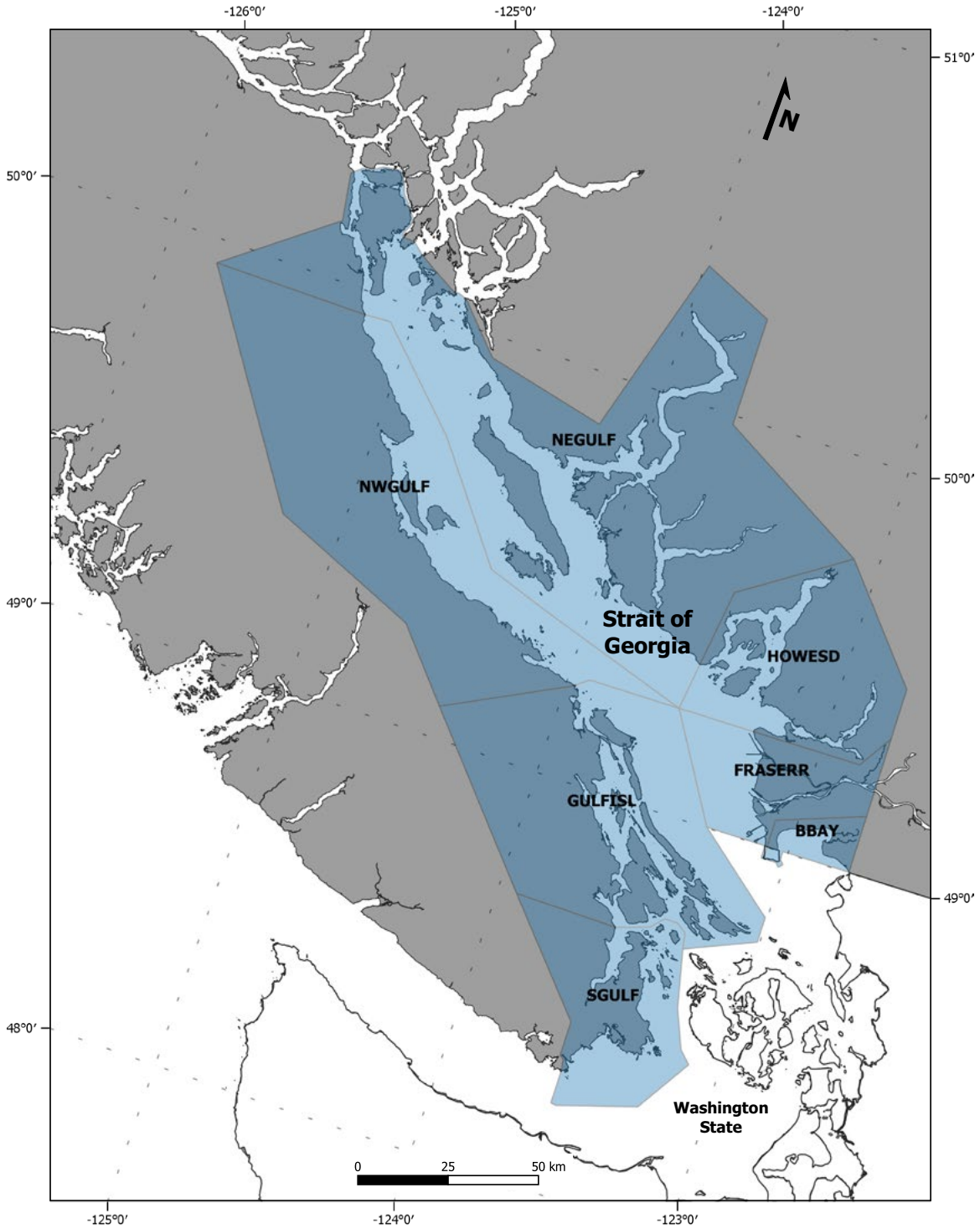


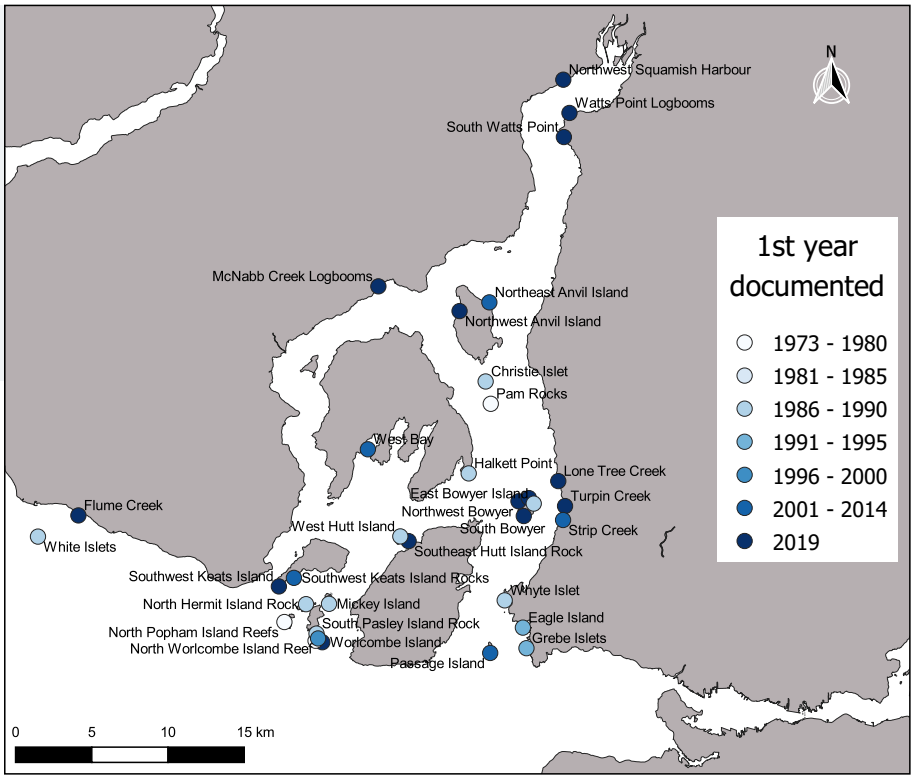
Figure 1. The Strait of Georgia harbour seal aerial survey occurs throughout the blue shaded area. Survey subareas are delineated by grey lines with Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound (HOWESD) located in the mid-eastern portion of the Strait.

Do pinnipeds play a role in First Nations spiritual or cultural heritage?

In the past, B.C. First Nations hunted harbour seals and sea lions for their pelts, meat and oil. Steller sea lion whiskers were used on traditional ceremonial garments.[4] Hunts took place either from the shore or on the water from canoes.[5]

For the Sḵwx̱wú7mesh Úxwumixw/Squamish Nation, specially trained hunters harvested seals and sea lions from Sẇesṕéṗs ta Kwenís, a rocky outcrop off Gibsons Landing on the Sunshine Coast. K̲wiláḵm/Bowen Island was also known as an important sea lion hunting site.[6] These hunts typically took place during evenings or early mornings in summer, using harpoons.[5] Steller sea lions were not recorded at haul-out sites in the Strait during summer months until very recently and were observed in relatively low numbers.[2] Recent observations may therefore reflect sea lions re-occupying traditional habitat described earlier by Sḵwx̱wú7mesh Úxwumixw/Squamish Nation ecological knowledge.

Harbour seals resting on a typical rocky reef haul-out that is easily accessible from the water. Thirty-six harbour seals were observed on this portion of rocky complex in West Bay, Gambier Island, on August 12, 2019. (Credit: Sheena Majewski)



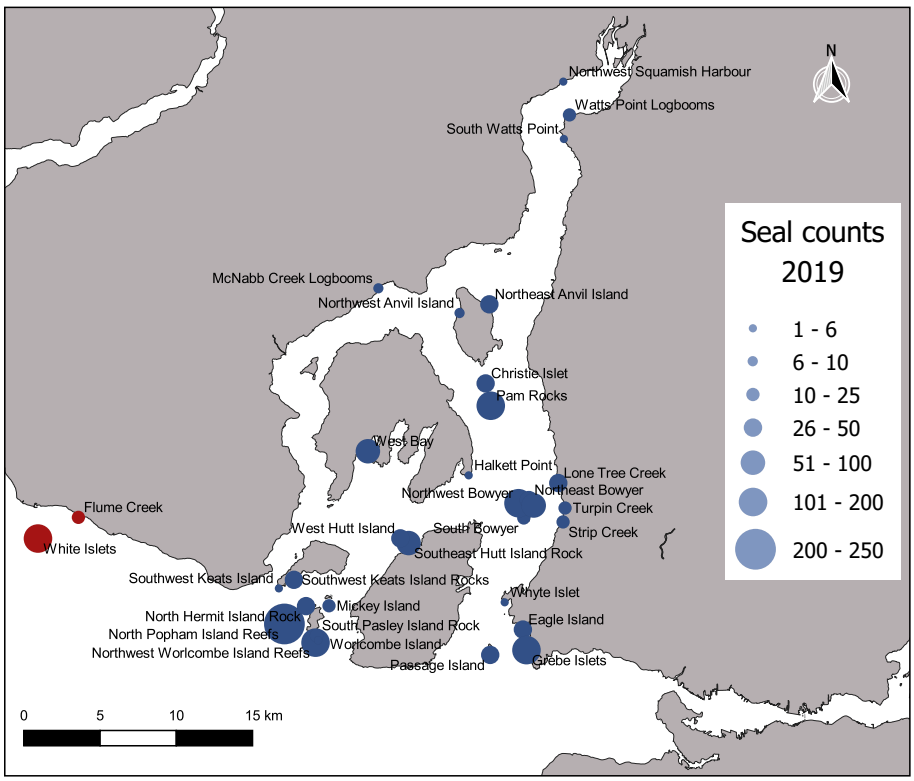


Figure 2. Top panel: Chronology of harbour seal site use in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, 1973 to 2019, for sites occupied during 2019 survey.

Bottom panel: Harbour seal counts at haul-out sites for 2019. Seal abundance is indicated by dot size. Haul-outs within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound proper are indicated by blue dots; sites just outside the survey boundary are indicated by red dots (Flume Creek, White Islets).

What is the current status?

When counts began in the Strait of Georgia in the early 1970s, fewer than 100 seals were observed in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, which was low compared to other subareas in the Strait (Figure 1). Only three haul-out sites were noted in the first surveys: Pam Rocks, North Popham Island Reefs, and North Worlcombe Island Reefs (Figure 2, top panel).

As the overall population in the Strait began to recover following legal protections, so too did the number of seals in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Annual counts throughout the 1980s showed that the initial recovery was almost exponential. Biennial[v] counts followed from 1988 – 2000. By the mid-1990s, growth had slowed and stabilized. Harbour seal counts in the Sound peaked in 1994, with almost 1,000 individuals recorded. Subsequently, numbers ranged between 450 and 700 seals until the year 2000 (Figure 3).

In the early 2000s, survey effort in other areas of B.C. was increased and counts in the Strait of Georgia were reduced to a roughly 5-year rotation. Since 2001,

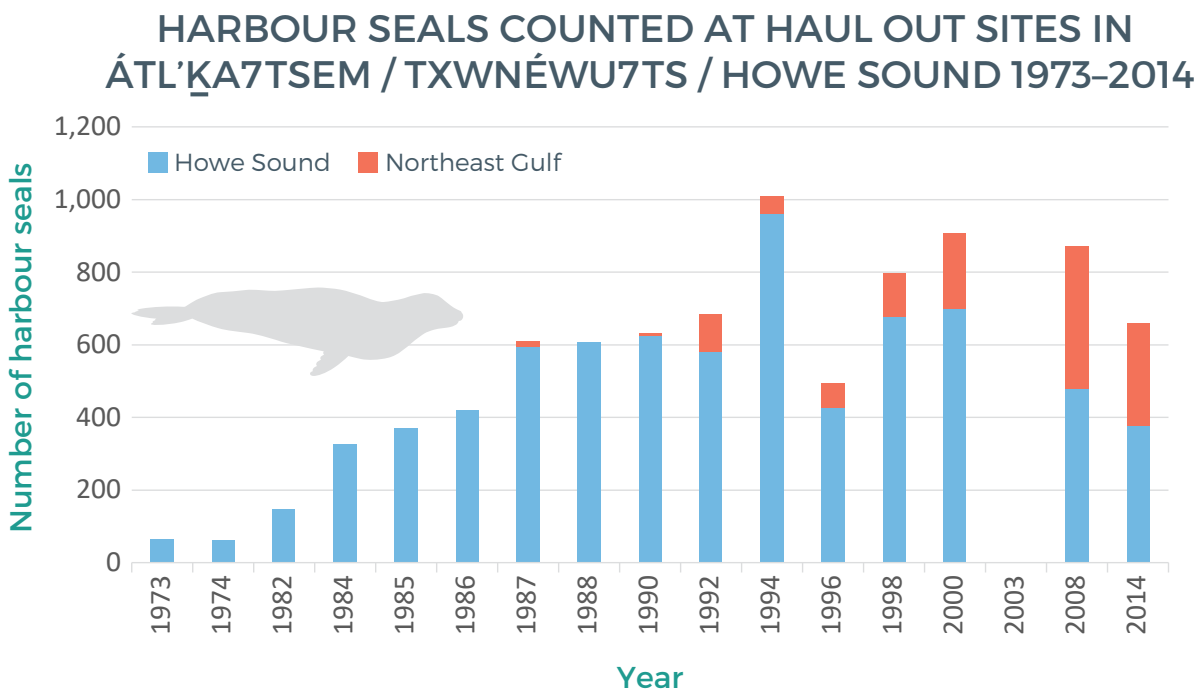


Figure 3. Number of individual harbour seals counted at haul-out sites in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound from 1973 to 2014. Seals were recorded at nearby Northeast Gulf sites beginning in 1978. The Northeast Gulf sites shown represent only two of the nearby sites, not the entire Northeast Gulf area. Initial 2019 counts remain to be validated as of the date of this publication; therefore, the final total is not included here. When available, data will be posted to the Government of Canada Open Data portal: https://open.canada.ca/data/en/dataset/be5a4ba8-79dd-4787-bf8a-0d460d25954c

v) Biennial – every other year.

three counts have been conducted in Átl'ka7tsem/Txwnéwu7ts/Howe Sound: in 2008, 2014 and 2019 (a count in 2003 was abandoned due to bad weather).

Since 2001, seal numbers in the Sound appear to have declined (Figure 3, blue bars), whereas counts at two haul-outs located just outside of Átl'ka7tsem/Txwnéwu7ts/Howe Sound proper (White Islets and Craster Creek/Flume Creek in the Northeast Gulf subarea; Figure 3, red bars) increased. Seals likely make use of these adjoining areas and the Átl'ka7tsem/Txwnéwu7ts/Howe Sound haul-outs interchangeably (Figure 4). When adding seals from those two haul-outs to counts within the Átl'ka7tsem/Txwnéwu7ts/Howe Sound survey boundaries, the counts from 2000, 2008 and 2014 are within the range observed since the early 1990s.

As the total number of seals occupying Átl'ka7tsem/Txwnéwu7ts/Howe Sound has varied over time, so has their relative abundance at each haul-out. Counts at specific sites fluctuate from year to year, with some sites increasing and others decreasing from one survey to the next. Seals have also changed their overall spatial distribution within the Sound over time, sometimes occupying new haul-outs while occasionally abandoning others. Through 2014, harbour seals were documented at 29 different sites within Átl'ka7tsem/Txwnéwu7ts/Howe Sound (blue dots, Figure 4), although not all sites are occupied every survey year. For example, in 2014, seals were counted at 20 sites within the Sound with two of these being new haul-out sites (Strip Creek and Passage Island) and with most seals found at traditional rocky haul-outs easily accessible from the water.

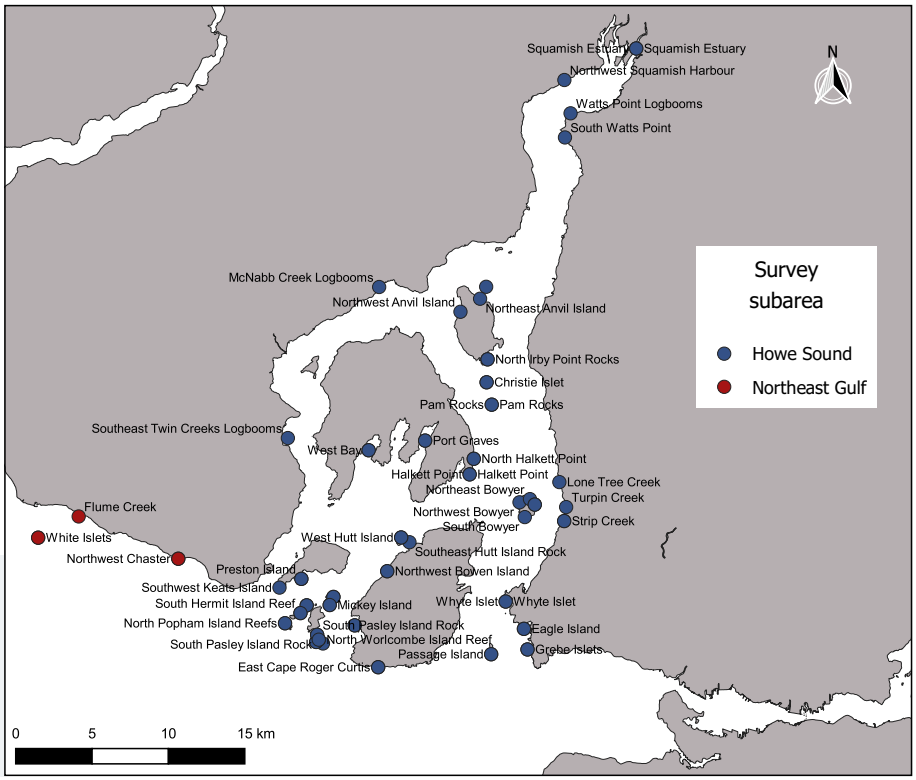


Figure 4. Harbour seal haul-outs documented in the Átl'ka7tsem/Txwnéwu7ts/Howe Sound survey area (blue dots) and three nearby haul-outs to the west of the survey boundary in the Northeast Gulf area (red dots) from 1973 to 2019

2019 Surveys

A surprising shift was observed in the distribution of harbour seals in the 2019 survey. Seals were counted at 34 sites, 14 more haul-out sites compared to the previous survey in 2014. Thirteen of these sites were new haul-outs (Figure 2, top panel). This was the largest increase in the number of new haul-out sites documented in a single survey in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. It is unlikely that all of the new sites were occupied for the first time in 2019, so the large increase in site use may reflect the five-year interval between surveys. However, the new sites differed from traditional sites in Átl'ka7tsem/Txwnéwu7ts/Howe Sound in that they were awkward to haul out on, being located on steep slopes and large boulders.

Although seals were present in large numbers at haul-outs in Átl'ka7tsem/Txwnéwu7ts/Howe Sound in 2019, they were more spread out than in any survey conducted in the past 35 years. There is nothing to suggest that the new sites are being used due to overcrowding at more established haul-outs. More likely is that seals have shifted their distribution in response to fine-scale changes in distribution or abundance of prey, disturbance from anthropogenic sources or, more likely, in response to predation pressure by killer whales. These changes in haul-out patterns are co-occurring with increases in the frequency of Bigg's killer whale sightings (see Cetaceans, Ocean Watch Átl'ka7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020). As the primary prey of Bigg's killer whales, seals may now be selecting haul-out sites that reduce the risk of predation.

Harbour seals observed using non-traditional haul-out sites, such as boulders and cliff-sides, which are less accessible from the water. Twenty-one harbour seals were counted on this section of steep shoreline on the northwest side of Boyer Island on August 12, 2019. (Credit: Sheena Majewski)

What is being done?

Harbour seals in Átl'ka7tsem/Txwnéwu7ts/Howe Sound and pinnipeds in B.C. are not actively managed by DFO; however, they are protected under the Marine Mammal Regulations of the *Canadian Fisheries Act*[vi]. The regulations prohibit disturbing pinnipeds in the water or on land, including approaching them or attempting to feed, interact, trap, mark, or cause them to move from the immediate vicinity. Permits are required to carry out research or other scientific or educational work with pinnipeds. Pinniped surveys are typically conducted each year on a portion of the B.C. coast (see Methods), and a B.C. coastwide harbour seal assessment is scheduled to be produced in 2021.

What are the potential impacts of climate change on pinnipeds?

Pinnipeds are vulnerable to climate change in both the terrestrial and marine environments. Haul-outs are used for resting, breeding, and for pupping, and these important areas may be lost due to impacts of sea-level rise causing coastal squeeze[vii] (see Shorelines, OWHS 2017), erosion, and increasing impacts from storm surges (see Shorelines, OWHS 2020), which can cause pups to separate from their mothers. Conversely, flooding of low-lying coastal areas may open up previously inaccessible habitat.[7]

Pinnipeds feed primarily on fish and cephalopods, with forage fish being a key component of their diet. Forage fish are known to dive to deeper water or move further offshore when ocean temperatures increase beyond their optimal range. This forces pinnipeds to follow their prey by either swimming further offshore, and in the process using more energy, or by requiring them to dive deeper, potentially beyond their physiological capabilities. This leaves pinnipeds vulnerable to nutritional stress from the extra energy expended to forage for food[8] and also more vulnerable to predation by killer whales.

Changes in ocean temperature, salinity and acidity can favour plankton species that cause harmful algal blooms (HABs). The toxins produced by HABs can make pinnipeds sick or even result in death. Changes in ocean processes in general can also result in an increased incidence of disease.[7,8]

vi) https://laws-lois.justice.gc.ca/eng/Regulations/SOR-93-56/index.html

vii) Coastal squeeze – a loss of intertidal habitat and species due to rising sea levels.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). Additional actions also follow.

Individual and Organization Actions:

- Always keep your distance from seals/sea lions, especially during breeding season.
- If you see a marine mammal in distress (injured, stranded, entangled), keep people and animals away and report it to the Ocean Wise Marine Mammal Rescue Centre on 604-258-SEAL (7325), or to DFO at 1-800-465-4336, or on marine VHF radio channel 16.
- Alternatively, if you see someone abusing a marine mammal, you can also call DFO on their 24-hour hotline, 1-800-222-TIPS (8477), or Marine VHF radio channel 16.

Government Actions and Policy:

- Continue to fund the monitoring and research of pinnipeds in the Strait of Georgia, including Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.
- Use best-available scientific evidence to inform whether seal/sea lion management is practical or will produce the intended results.
- Create more Marine Protected Areas (MPAs) to protect pinnipeds from human activities and haul-out sites from climate change impacts.

Methods

DFO staff based out of the Pacific Biological Station have been undertaking harbour seal counts in Átl'ka7tsem/Txwnéwu7ts/Howe Sound for almost 50 years. Aerial surveys are flown with fixed-wing aircraft in late July through August during pupping when the greatest proportion of animals are expected to haul out ashore and be available to be counted. Within Átl'ka7tsem/Txwnéwu7ts/Howe Sound, the entire coastline is surveyed, including all exposed rocks/reefs, at an airspeed of 200 km/h (125 miles/h). High-resolution digital overhead photographs are taken from 180 m (~600 feet) for later counting. Surveys are also flown during specific time windows and during select tide conditions as the number of seals hauled out is strongly related to the tide, with the highest number of seals hauled out around the lowest tide of the day. The survey protocol allows surveys to be as consistent as possible from year to year and from one area of the B.C. coast to the next. As there are only a handful of survey windows available each year, the entire coast cannot be flown in a single year and, therefore, defined areas are surveyed on a rotational basis.

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Cetaceans: sightings on the rise

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What is happening?

In the previous report (see Cetaceans, Ocean Watch Howe Sound Edition [OWHS] 2017) data up to and including 2015 showed cetaceans (whales, dolphins and porpoises) were making a triumphant comeback to Átl'ka7tsem/Txwnéwu7ts/Howe Sound. This strong comeback persists today.

Harbour porpoise. (Credit: Ocean Wise)

What is the current status?

Since 2016, reports of cetaceans to the B.C. Cetacean Sightings Network (BCCSN) have continued to increase. In 2018, the BCCSN received 335 sighting reports from the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound area, submitted by 116 volunteer observers (Figure 1).

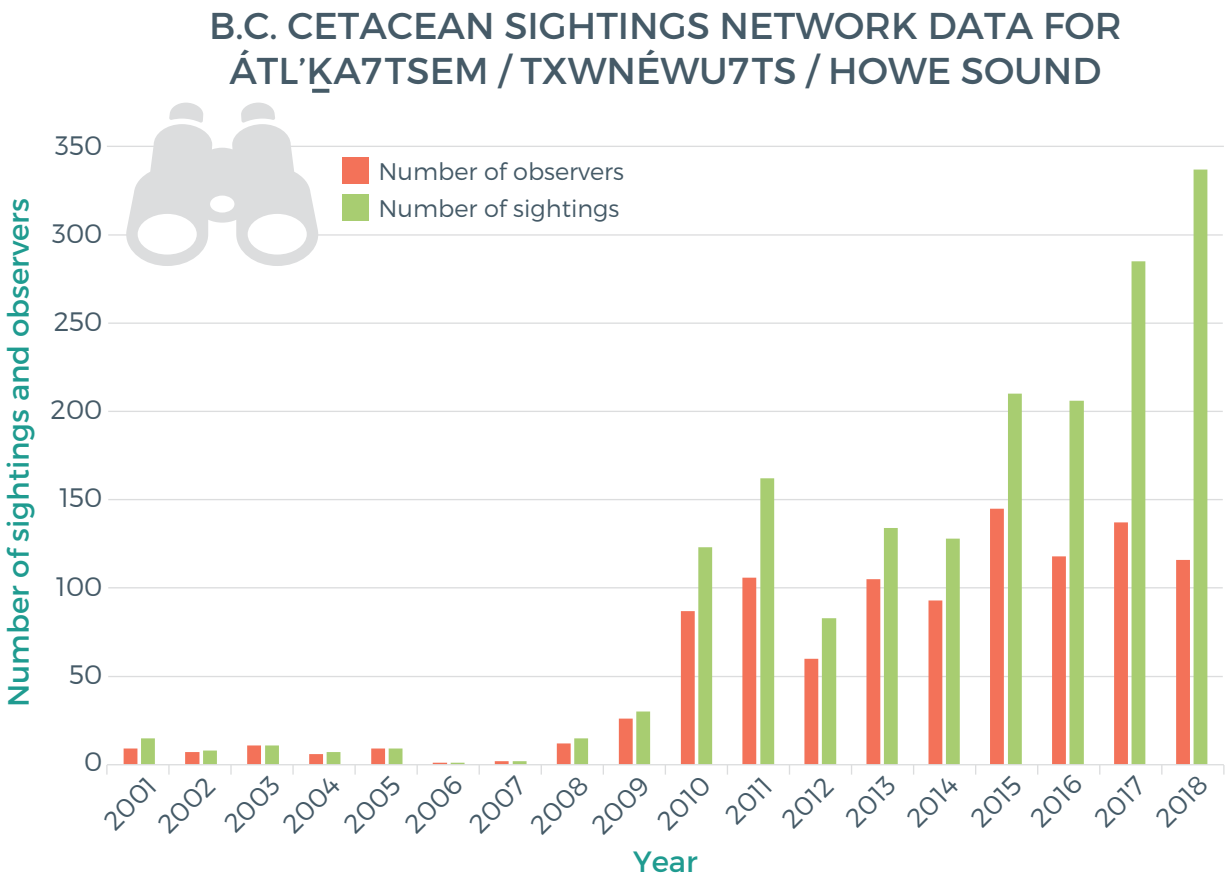

Figure 1. Total number of observers and number of cetacean sightings reported to the BCCSN in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound by year.

Killer whales (*Orcinus orca)* were the most commonly reported large cetacean in 2018, with 190 reports submitted to the BCCSN. Since 2015, there has been a 60% increase in killer whale sightings in the area, with considerably more sightings reported west of Chá7elkwnech/Gambier and Lhaxwm/Anvil Islands compared to 2015 (Figure 2).

Whenever possible, the BCCSN identifies individual killer whales using photos submitted with sighting reports. In 2018, the majority of sightings where individuals could be identified belonged to the marine mammal-eating Bigg's (transient) killer whale population. The increased presence of Bigg's killer whales could be an indication of a healthy harbour seal (*Phoca vitulina*) population in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. Harbour seals are a major prey item for Bigg's killer whales, making up of over 50% of their diet. Bigg's killer whales will also target other small cetaceans and pinnipeds (i.e., seals, sea lions), and occasionally hunt smaller baleen whales such as minkes (*Balaenoptera acutorostrata*).[1]

By contrast, resident killer whales (both northern and southern resident populations) are salmon specialists. The majority of their diet is comprised of large, nutrient-dense Chinook (*Oncorhynchus tshawytscha*).[2] Fish-eating northern resident killer whales made only a single, brief foray into Átl'ka7tsem/Txwnéwu7ts/Howe Sound in 2018. Chinook salmon runs

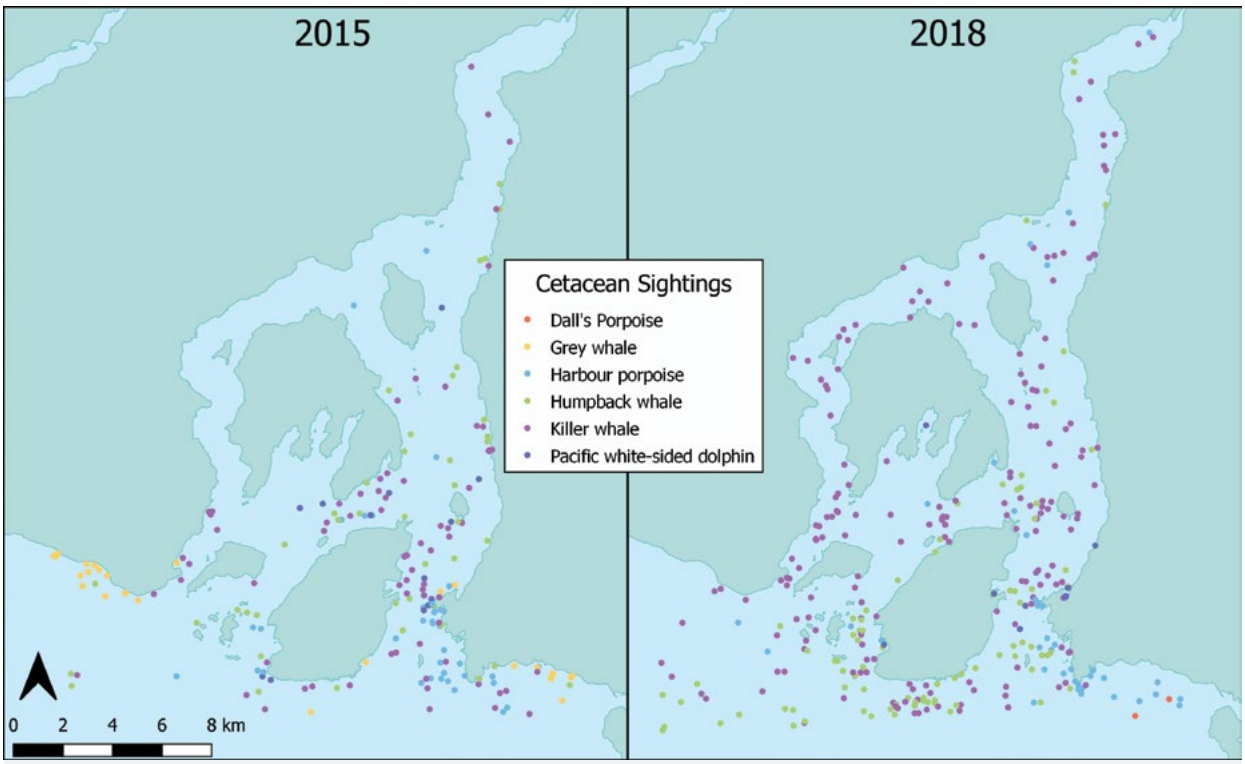

Figure 2. Cetacean sighting reports submitted to the BCCSN in 2015 (left panel) compared to 2018 (right panel), by species. One point on the map is equivalent to one cetacean sighting.

Humpback whale in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. (Credit: Rhys Sharry)

in Átl'ka7tsem/Txwnéwu7ts/Howe Sound have been depleted since the 1970s and 1980s[3] and could explain the near absence of resident killer whales from Átl'ka7tsem/Txwnéwu7ts/Howe Sound waters.

Humpback whales (*Megaptera novaeangliae*) were the second most frequently reported large cetacean, with a total of 87 reports in 2018 (Figure 3). This number has more than doubled since 2015. Historically, the Strait of Georgia was the seasonal home for 100-150 humpbacks. However, this population was eradicated by intensive whaling activities in 1907. Since 1907, humpbacks had been virtually absent from Átl'ka7tsem/Txwnéwu7ts/Howe Sound until 2008 when they began reappearing in large numbers. Humpbacks are now recovering to near historical levels in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. These sightings are likely a reflection of the overall increase in humpback abundance in the Strait of Georgia. In addition, habitat restoration efforts in Átl'ka7tsem/Txwnéwu7ts/Howe Sound have increased the abundance of forage fish such as herring (*Clupea pallasi*) and northern anchovy (*Engraulis mordax*), two major prey items for humpback whales.[4]

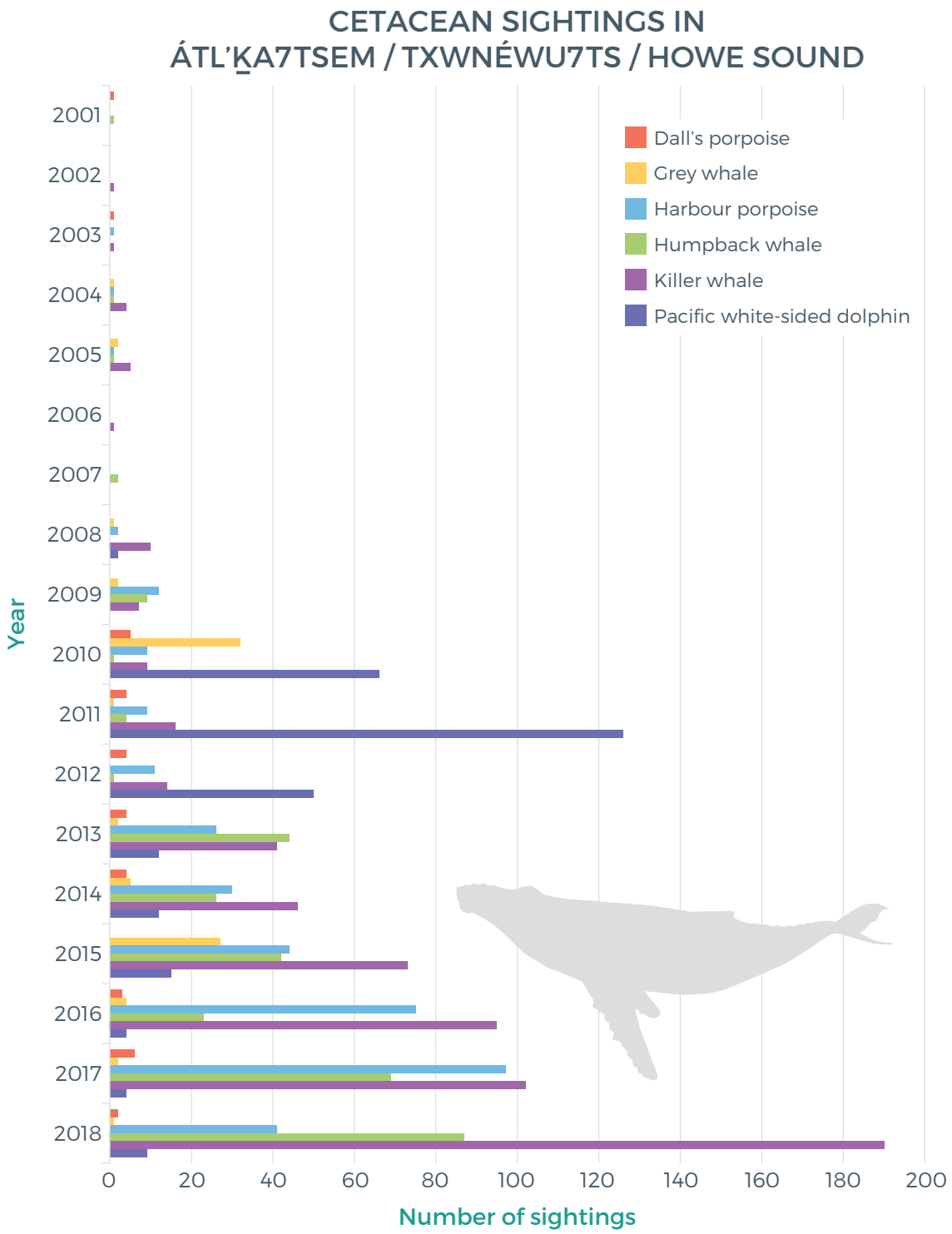

Figure 3. Cetacean sightings in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound from 2001–2018, by species.

Harbour porpoises (*Phocoena phocoena*) were the most commonly reported small cetacean (i.e., any dolphin/porpoise other than killer whales, typically under six feet in length) in 2018 (Figure 3). However, this number has decreased by 58% from the previous year. There was a surge in Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) sightings between 2010 and 2012, but this trend has not continued (Figure 3). One explanation for the decrease in small cetacean sightings may be the increased abundance of Bigg's killer whales, which are the primary predators of both harbour porpoise and Pacific white-sided dolphins.[1] Additionally, a change in the abundance or distribution of preferred prey for small cetaceans (e.g., forage fish such as Pacific sand lance, *Ammocytes haxapterus*) may be occurring.

Increased melting of the Pemberton icefields in recent years[5] will likely alter forage fish habitat and recruitment by affecting salinity, sedimentation and temperature.[6] Forage fish could also be losing access to critical spawning habitat due to increased shoreline development in Átl'ka7tsem/Txwnéwu7ts/Howe Sound, an issue potentially exacerbated by sea level rise, storm surges, and extreme weather due to climate change.

Residents of Átl'ka7tsem/Txwnéwu7ts/Howe Sound are enthusiastic participants in the BCCSN, and these contributions have created a unique dataset to inform cetacean trends in the area. However, one cannot rule out the possibility that the trends seen in Átl'ka7tsem/Txwnéwu7ts/Howe Sound are reflective of observer effort and not due to changes in species abundance and composition. The area with the highest density of sighting reports is from Sḵ'íẁitsut/Point Atkinson to Ch'axáy/Horseshoe Bay and the surrounding area (Figure 4), one of the areas of highest human population density in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. Although the number of Átl'ka7tsem/Txwnéwu7ts/Howe Sound observers reporting to the BCCSN has remained steady since 2015, it is possible that these observers have improved their ability to detect cetaceans, or have established the habit of reporting more consistently, resulting in an increase in sighting reports. Smaller cetaceans may also be observed less frequently than larger cetaceans such as killer whales and humpbacks due to their small size or elusive nature.

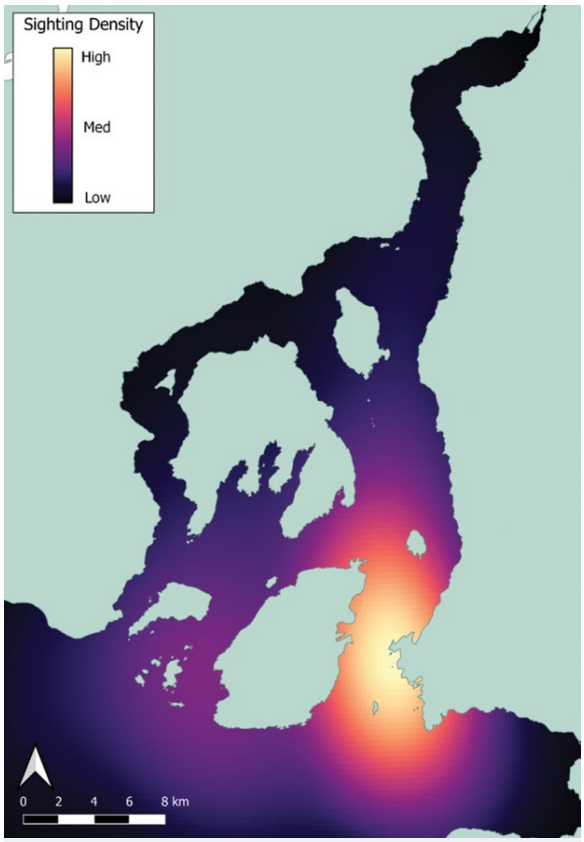

Figure 4. Density of cetacean sightings reported to the BCCSN from 2016 to 2019.

What are the potential impacts of climate change on cetaceans?

Climate-driven weather pattern variations have been linked to massive die-offs and shifts in distribution of plankton, fish and marine mammals.[7] Changes in weather systems and wind patterns off the B.C. coast can cause marked fluctuations in the production of phytoplankton that form the base of many aquatic food webs (see Plankton, OWHS 2017). This can affect the distribution and abundance of zooplankton and forage fish, causing significant changes in the distribution of humpbacks and other baleen whales.[4]

Warmer water temperatures resulting from climate change may disrupt the synchronization between phytoplankton production and zooplankton, the main grazers of phytoplankton, thus affecting growth and survival of animals higher up the food web. Changes due to timing mismatches in the food web are likely to have serious implications for marine mammals.[7] Warmer water may result in a northward shift in both the distribution of marine mammals and their prey.[4] A northward shift in prey distribution will mean longer migration paths for baleen whales that undertake long-distance migrations from their tropical breeding grounds to high-latitude feeding grounds, and therefore increased energy expenditure.[7]

Construction of hard shore armouring (e.g., sea walls, dikes) and other shoreline development in Átl'ka7tsem/Txwnéwu7ts/Howe Sound could reduce coastal refuges for forage fish and degrade spawning habitat by blocking the natural erosion of material that creates spawning substrate.[8] A reduction in forage fish abundance in Átl'ka7tsem/Txwnéwu7ts/Howe Sound would likely result in a decrease in the number of cetaceans and other marine mammals in the area.

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Report cetacean sightings using the WhaleReport app, available for iOS and Android devices on the iTunes and Google Play stores.	In addition to contributing to conservation-based research, sighting reports alert mariners of large commercial vessels to the presence of cetaceans in the area so they can take measures to reduce the risk of collision or disturbance (i.e., slowing down or altering their course). As of August 2019, over 1,500 alerts have been generated using sighting reports submitted via WhaleReport.
GOVERNMENT ACTIONS AND POLICY	
Provide large-vessel captains with resources so they can safely transit waters when whales are in the area.	The WhaleReport Alert System now effectively does this.
Legislate against the production and use of single-use plastic.	Canada to ban single-use plastics and hold companies responsible for plastic waste as early as 2021.[9]
Legislate mandatory safe-distance for vessels from cetaceans.	New regulations (2019): • Boats must stay 400 m away from orcas or killer whales in Southern Resident Killer Whale critical habitat. • Boats must stay 200 m away from killer whales in other B.C. waters. • Boats must stay 100 m from all other cetaceans (e.g., humpback whales, harbor porpoises). • Boats must stay out of certain sections of Swiftsure Bank, off the east coast of Saturna Island and south-west of North Pender Island.Visit http://bewhalewise.org/ for more information on regulations.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below.

Individual and Organization Actions:

- When viewing cetaceans from a boat, follow the Be Whale Wise Guidelines to avoid disturbing or displacing them.
- Purchase sustainable ocean wise seafood. In your business, ensure food sold or supplied is sustainable (if applicable).
- Purchase products that do not contain harmful toxins such as Persistent Organic Pollutants (POPs).
- Recycle and properly dispose of garbage to prevent marine debris that can be harmful if ingested, or cause entanglement. Ensure workplaces are equipped with proper disposal options.
- Minimize the use of plastics, especially single-use plastics.

Government Actions and Policy:

- Monitor pollutant levels, enforce and where necessary amend pollution regulations.
- Monitor and when warranted restrict fishing to protect the prey resources of cetaceans in Átl'ḵa7tsem/ Txwnéwu7ts/Howe Sound.
- Continue to update *Species at Risk Act* (SARA) reports on a regular basis to reflect current status of species.
- Continue to aid and support population studies of Species At Risk, or potential Species At Risk.
- Continue to support and facilitate growth of the Marine Mammal Response Network to ensure timely and safe incident responses coast-wide.
- Increase public education regarding species of cetaceans, the risks they face, and how the public can help. Continue to support children and youth educational programs.
- Support citizen science and grassroots initiatives related to cetacean conservation.
- Empower local communities by ensuring they are educated on the proper actions to take in the event of an oil spill. Provide the required resources for communities to safely respond and assist in the event of a spill.
- Facilitate the creation of ecosystem-based species management plans in order to help ensure a sustainable predator-prey balance.

Methods

Our understanding of cetacean abundance and distribution in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound and other parts of the province is largely based on sightings provided to the BCCSN by a volunteer network of coastal citizens and mariners. Data are collected by observers and reported in a standardized way via phone, email, mailed logbook entry, WhaleReport smartphone application or webform. Committed observers are recruited through educational presentations and training workshops on cetacean and sea turtle identification, natural history and conservation. The data collected are reviewed for accuracy and filtered to remove multiple sightings of the same animal(s) at the same time and location. The BCCSN database, which now contains over 116,000 sightings, enables the protection of essential habitat, highlights areas of high risk to these vulnerable species and allows for targeted outreach and mitigation.

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Eelgrass: transplants and restoration for critical habitat

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Cynthia Durance, Precision Identification

What is happening?

Selecting eelgrass (*Zostera marina*) restoration sites requires understanding the history of sediment, water quality and eelgrass distribution in bays and estuaries (Figure 1), as well as past, current and future human use patterns and potential climate change impacts. Experts rely upon a combination of spatial datasets (e.g., maps of eelgrass distribution, suitable spawning habitat for forage fish, sea-level rise vulnerability), and local and traditional ecological knowledge to inform their decision-making.

Eelgrass transplant monitoring on Port Graves, Gambier Island, 2018. (Credit: Coastal Photography Studio)

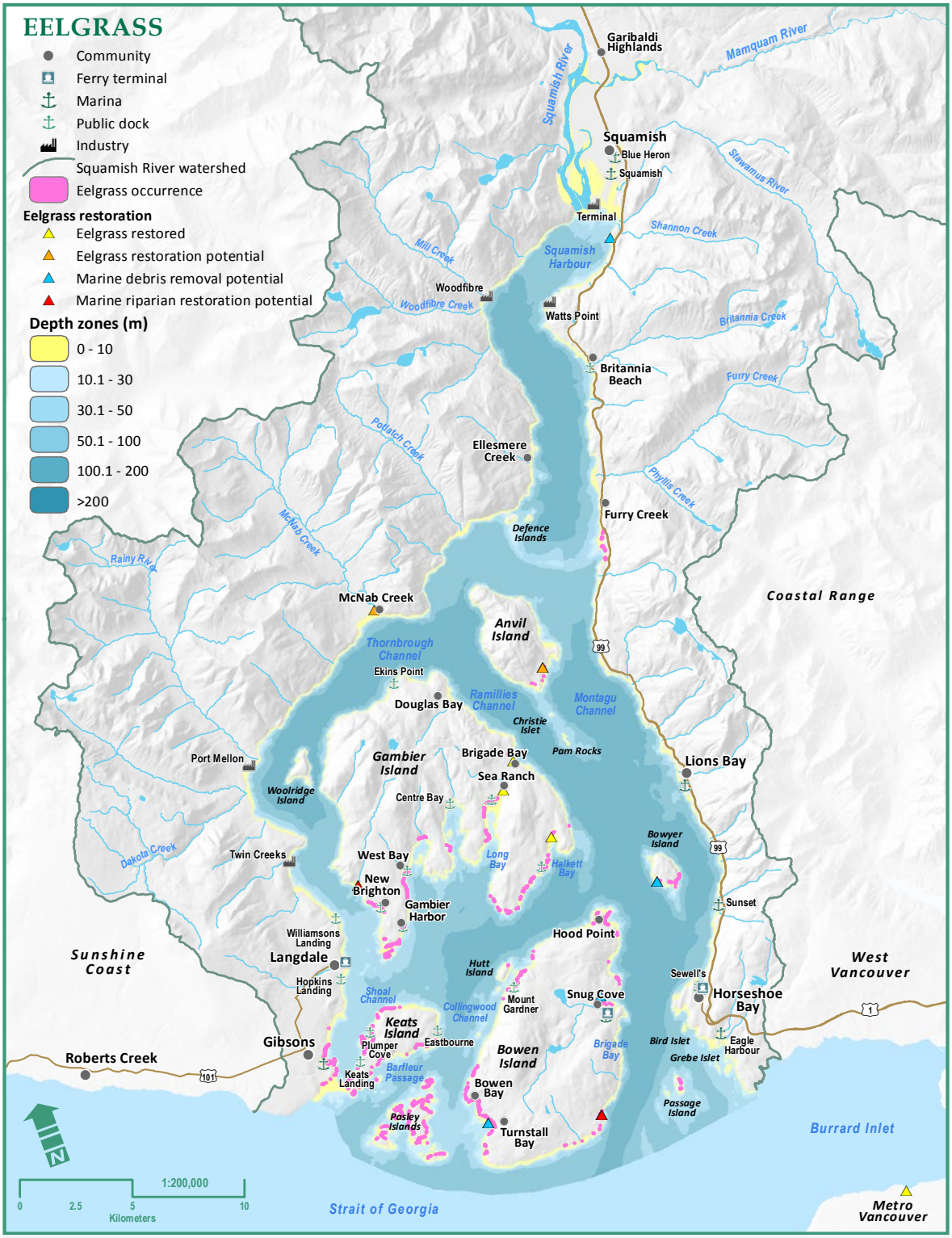
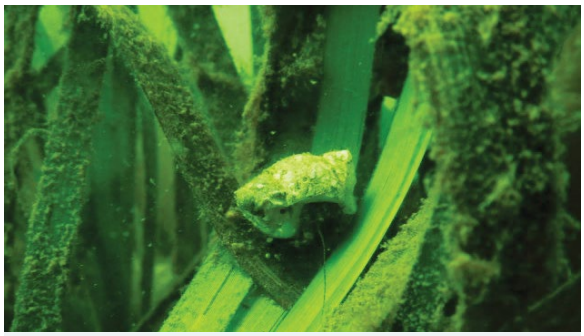


Figure 1. Eelgrass occurrence throughout Átl'ka7tsem/Txwnéwu7ts/Howe Sound.[1]

What is the current status?

Since 2017, there have been seven eelgrass transplants in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound: five on Cha7elkwnech/Gambier Island, one on Keats Island and one on Nexwlélexwem/Bowen Island (Table 1). Monitoring of transplant sites occurs every six months for three to five years following the initial transplant, with results showing mixed success across sites thus far. Additional transplants and restoration activities are planned throughout Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound in the coming years.



A hermit crab on an eelgrass blade. (Credit: Coastal Photography Studio)

In 2017, SeaChange Marine Conservation Society (see Resources), a key player in the restoration of eelgrass habitat, amongst other marine and watershed protection activities they conduct, was awarded funding through Fisheries and Ocean's Canada (DFO) Oceans Protection Plan. This funding helps support restoration of nearshore habitat throughout the Salish Sea. The Salish Sea Nearshore Habitat Recovery Project (see Resources) is now in its third of five years and has four focal regions: Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, sḏilw̓ət/Burrard Inlet, Sechelt Inlet, and the Gulf Islands. Restoration activities include marine riparian revegetation, eelgrass restoration, and underwater debris removal in shallow water areas where eelgrass might grow.

Throughout the project's duration, SeaChange conducts annual community meetings in all four of these regions, in collaboration with local residents and knowledge holders, to identify and assess potential restoration sites. Together, SeaChange and residents of each regional community determine the best sites on which to focus their restoration efforts. Identified sites are then surveyed by SeaChange staff. In Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, 110 sites were initially identified for potential restoration. After two community meetings, this list was whittled down to 21 and then 12 sites to survey. Upon conducting the habitat surveys in 2018 and 2019, nine sites were identified as suitable for eelgrass recovery.

Eelgrass was mapped in 2012-2014 for the islands within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound (Islands Trust Conservancy 2019) and in front of Gibsons (Moonstone Enterprises). In 2019, the Marine Reference Guide (MRG) mapped eelgrass distribution for the Sound's mainland (see Resources). Researchers found minimal eelgrass along the Sea-to-Sky Corridor, and healthy meadows along West Howe Sound's shoreline. This distribution pattern is likely associated with the prevalence of steep, rocky shorelines and the impact of log storage along the shorelines, both of which restrict eelgrass growth. Updated eelgrass maps that include the Islands Trust surveys will be a layer in the online interactive MRG map (anticipated release date, Fall 2020).

Table 1. Eelgrass transplants in Átl'ka7tsem/Txwnéwu7ts/Howe Sound since 2017.

DATE OF TRANSPLANT	NUMBER OF TRANSPLANTED SHOOTS	DATES OF MONITORING	SHOOT DENSITY[¤]: NATIVE BED	SHOOT DENSITY[¤]: TRANSPLANT	LEAF AREA INDEX (LAI): NATIVE BED	LEAF AREA INDEX* (LAI): TRANSPLANT	STATUS OF TRANSPLANT SUCCESS	OBSERVED THREATS
CHÁ7ELKWNECH/GAMBIER, HALKETT BAY								
July 2016	1061	August 2018	7.3	7	7.8	5.3	Good	
August 2018	525	April 2019	9.4	7.5	2.8	2.3		
		August 2019	8.2	12.5	4.8	10		
CHÁ7ELKWNECH/GAMBIER, BRIGADE BAY								
October 2018	468	April 2019	9.7	5.1	2.5	1.2	Poor	Nearby breakwater may be decreasing water circulation and nutrients to transplant.
		August 2019	8.9	4.2	4.6	3.1		
CHÁ7ELKWNECH/GAMBIER, LONG BAY								
October 2018	990	April 2019	9.1	3.9	3.3	0.8	Moderate	May be exposed to strong southerly winds.
		August 2019	12.7	6.8	6.6	5.7		
KEATS ISLAND, PLUMPER COVE								
March 2019	782	August 2019	15.7	15.4	11.9	16.9	Good	Near recreational dock in a B.C. park
CHÁ7ELKWNECH/GAMBIER, COTTON BAY								
March 2019	600	August 2019	14.6	20.8	13.2	20.1	Good	Former log storage area.

¤ shoot density is the number of shoots per square metre (shoots/m^2)

* where, Leaf Area Index (LAI) is a measurement of the productivity of an eelgrass bed, with higher numbers indicating greater productivity. It is calculated as: (mean shoot density/m^2 × mean shoot leaf width × mean shoot width height ÷ divided by 1000).

What are the potential impacts of climate change on eelgrass?

Climate change will impact eelgrass through three principle mechanisms: ocean warming, sea level rise and winter storms. Warming sea surface temperatures often enable the growth of plankton and macro-algae, which compete with eelgrass for light and habitat. This effect is amplified in sheltered bays and estuaries where high nutrient inputs and low water circulation further encourage macroalgal growth. Ocean warming can also interact with high salinity patterns caused by droughts to increase the prevalence and intensity of seagrass (*Labyrinthula zostera*) wasting disease.[2]

As shallow water becomes deeper due to sea level rise, eelgrass will need to migrate shoreward so it can remain in the photic zone (i.e., where the sun's rays can still penetrate to allow photosynthesis). However, if the substrate has changed because of shoreline modifications (e.g., sea walls), this migration becomes more difficult or impossible, and habitat is lost. This phenomenon is known as coastal squeeze (see Resources).

The increasing frequency and intensity of winter storms allows extreme wind and wave energy to be carried to the nearshore where it can uproot plants, reducing eelgrass density during its slowest growing season. Collectively, these climate-change-associated pressures challenge eelgrass growth and survival year-round.

Despite these vulnerabilities, eelgrass can help buffer nearshore ecosystems from another climate change impact: ocean acidification. Because eelgrass photosynthesizes (i.e., converts carbon dioxide plus the Sun's energy into food and oxygen), it can buffer the acidity of its local environment. This helps the small grazing invertebrates (e.g., isopods[i], sea hares[ii]) that shelter in eelgrass meadows to persist, despite a change in acidity. Eelgrass can likely provide this buffering effect up to a certain acidity threshold, beyond which neither plant nor invertebrate fares well.[3]

During field observations in 2019, SeaChange divers observed declines in the densities of eelgrass beds compared to the earlier 2012-2014 surveys.[4] While the direct cause of these declines is uncertain, cumulative effects from land and water activities are hypothesized to be a dominating factor in changing eelgrass distribution and density throughout the Salish Sea.

i) Isopods – an order of crustaceans that live in the sea.

ii) Sea hares – A group of marine gastropod molluscs belonging to the Anaspidea clade.

Success Story

In 2017, the Bowen Island Municipality obtained a 30-year tenure (Licence of Occupation) for Mannion Bay with the intent to restore the socioecological integrity of the bay. Thus followed several years of intensive revitalization work led by the municipality, together with community groups and provincial and federal ministries. Activities involved providing education on public and environmental safety requirements associated with keeping boats in the bay; increasing registration enforcement for mooring buoys and anchored vessels; and removing non-complying or untenured mooring buoys (21), vessels (5), floating dock structures (7) and more than 3400 kg of subtidal debris.

Because of this extensive work, SeaChange crews are now able to return to Mannion Bay to begin filling in the eelgrass meadows where problem vessels and structures had disturbed them.

For a map of the License of Occupation and more details visit:
https://www.bowenislandmunicipality.ca/mannion-bay

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Participate in eelgrass restoration activities and encourage your organization to participate.	Since 2017, seven eelgrass transplants have occurred throughout Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.
Join or contribute to funding eelgrass restoration efforts. Eelgrass habitat needs to be monitored and mapped every three to five years to evaluate changes over time.	In 2019, the Marine Reference Guide (MRG) mapped eelgrass distribution for the Sound's mainland.
GOVERNMENT ACTIONS AND POLICY	
Continue to financially support community eelgrass restoration and monitoring practices within Howe Sound. Ensure monitoring and mapping is occurring every three to five years and updated data is made widely available.	In 2017, SeaChange Marine Conservation Society was awarded funding through the Department of Fisheries and Ocean's Oceans Protection Plan to conduct eelgrass restoration. This funding is now in its third of five years and has four focal regions: Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, sə̓lilw̓ət/ Burrard Inlet, Sechelt Inlet, and the Gulf Islands.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- Protect eelgrass by learning where eelgrass beds are located.
- Familiarize yourself with Howe Sound islands' eelgrass mapping initiatives.
- Shoreline landowners can minimize the impact of docks by using light-penetrating materials and using shared community docks rather than private docks.
- Shoreline owners can maintain trees, shrubs and ground cover plants close to the shore to reduce erosion and detrimental sedimentation.
- Avoid boating or anchoring in eelgrass beds.
- NEW Use the howesoundconservation.ca map to find eelgrass distribution in the Sound.
- NEW Anchor and install mooring buoys deeper than 7 m to reduce the likelihood of scouring the seafloor and ripping out eelgrass shoots.
- NEW Use mid-line floats in mooring buoys to reduce damage to benthic sediments.
- NEW Encourage environmentally friendly marine dumping and sewage treatment infrastructure.

Government Actions and Policy:

- Support and facilitate community education and stewardship involving the importance of eelgrass, the threats eelgrass faces, and how coastal citizens can help.
- Consider relocating log boom tenures or reducing size and restoring eelgrass beds.
- Prohibit shoreline armouring near eelgrass.
- Create protected zones for eelgrass areas identified as important. Within these areas; restrict removal of backshore native plants, encourage a "no anchor zone," restrict the installation of non-light-penetrating docks, and restrict the implementation of new logging operations.
- Allow no new tenures in eelgrass habitat or habitat suitable for eelgrass restoration.
- NEW Learn from local governments who have obtained jurisdiction over the foreshore using Licence of Occupations (Bowen Island Municipality), Recreational Water Leases (Town of Gibsons), or Head Leases (District of West Vancouver) to manage water use and remove problem vessels and subtidal debris.

Methods

For the duration of its restoration project, SeaChange is monitoring each restoration site every six months, for up to five years following transplant events. Divers record underwater videos before and after each transplant, and also record a before and after video of the harvest site (i.e., from where the eelgrass plants used in the transplant were taken). When monitoring transplant sites, divers take additional underwater videos of each site and measure shoot density and blade width and height within a minimum of fifteen 0.25m^2 quadrats. When analyzing the data, season is factored in because light availability in the spring and winter impacts shoot density.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

SeaChange Marine Conservation Society
https://seachangesociety.com/

Salish Sea Nearshore Habitat Recovery Project
https://seachangesociety.com/salish-sea-nearshore-recovery-project/

Marine Reference Guide
https://howesoundguide.ca/

Coastal squeeze infographic
https://oceanwatch.ca/howesound/wp-content/uploads/sites/2/2016/11/diagram-coastal-squeeze-BRANDED.png

Howe Sound/Atl'ka7tsem Map
howesoundconservation.ca/mapapp

References

1 Beaty F, van Riet W, Wareham B, Schultz J. Howe Sound/Atl'ka7tsem Map [Internet]. Ocean Wise and David Suzuki Foundation; 2019. Available from: http://howesoundconservation.ca

2 Kaldy JE. Effect of temperature and nutrient manipulations on eelgrass Zostera marina L. from the Pacific Northwest, USA. J Exp Mar Bio Ecol [Internet]. 2014;453:108–15. Available from: http://dx.doi.org/10.1016/j.jembe.2013.12.020

3 Hughes BB, Lummis SC, Anderson SC, Kroeker KJ. Unexpected resilience of a seagrass system exposed to global stressors. Glob Chang Biol. 2018;24:224–34.

4 Islands Trust Conservancy. Ecosystem maps (pdfs) [Internet]. 2019. [cited 2019 Sep 5]. Available from: http://www.islandstrustconservancy.ca/initiatives/mapping-our-ecosystems/ecosystem-maps-pdfs/

Glass Sponge Reefs: fragile habitats require further protection

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What is happening?

Glass sponge reefs only occur in B.C.'s Pacific coastal waters. Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound has some of the best, most intact sponge reefs in all of B.C. The reefs in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound are the only ones that are shallow enough to reach by air diving; all other known reefs occur at much greater depths and require technical diving[i] or use of a remotely operated vehicle (ROV) to access. This aspect alone makes these Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound reefs extremely unique and comparatively accessible.

Research diver lighting up a sub-adult yellowtail rockfish over a glass sponge reef. (Credit: Adam Taylor)

i) Technical diving – all diving methods that exceed the limit for depth (> 40 m/ 130 ft) and/or time imposed for recreational scuba diving. Technical diving often requires the use of special gas mixtures other than compressed air, for breathing, as well as staged decompression stops when ascending.

A quillback rockfish on a glass sponge reef, Ḵw'émḵw'em/Defense Islands. (Credit: Adam Taylor)

What is the current status?

Considerable advances in our knowledge of glass sponge reefs in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound have occurred. The Howe Sound Conservation and Research Team of Ocean Wise has spent decades monitoring the glass sponges in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. One report examined changes over time at the inshore Nínich Ḵw'émḵw'em/East Defence Island sponge reef (bioherm[ii]).[1] Over a decade of scuba diving at this bioherm led to a somewhat novel view of the dynamics of bioherm formation and persistence. Work documenting these reefs spanning decades had led to the opinion that cloud sponges (*Aphrocallistes vastus*), one species of glass sponge of which many genera exist, are very slow growing, and the geologically stable reef base includes many intact sponge skeletons. However, this study revealed a rapid collapse of dead skeletons and a geologic base largely consisting of skeletal fragments.[1]

Additionally, the shallowest fringe of this reef has crept out over bedrock. Bioherms at this site have typically formed on glacial till (cobbles) because the Ḵw'émḵw'em and Nínich Ḵw'émḵw'em/Defence Islands protrude from the inner sill of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, a glacial relic that consists of glacial till deposits. This reef is so close to the shore that it abuts the solid rock of ridges projecting from the island and has crept up onto that solid bedrock.

ii) Bioherm – ancient organic reef of mound-like form built by a variety of marine invertebrates and calcareous algae.

Furthermore, some rapid tissue collapse of particular sponges was observed when mortality occurred.[1] Encouragingly, restoration work using staked transplants (fragments of sponges that were damaged and broken lose from reefs by downrigger gear) illustrated relatively rapid (i.e., within months) growth and reattachment to secure stakes. Similarly, the recovery of sponge growth from loose fragments with stabilized positions in debris drifts[iii] illustrates a living pattern, in effect, suggestive of tissue persistence. These sponge bushes are effectively single cells within a skeletal framework of silica (glass) spicules[iv]. Fragments that include intact tubes or pumping units can resume growth under favorable conditions and with stable positioning, such as in debris drifts.

Because Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound is so steep-sided and rugged, bottom trawling with chains and trawl doors attached to nets has not occurred where the sponge reefs exist. This is in stark contrast to the Strait of Georgia, where a half century of trawling for Pacific cod (*Gadus macrocephalus*) has left scoured remnants of the geologically stable reef bases, with some living reef structures.[2] These bases were protected in 2016 by bottom-contact fishing closures in case future settlement of planktonic propagules of glass sponges can facilitate the recovery of reefs at those locations.

How will climate change impact glass sponge reefs?

The Nínich Ḵw'émḵw'em/East Defence Island inshore bioherm study[1] included observation of mortalities associated with the El Niño climate events of 2009/2010 and 2015/2016. Tissue recovery and rapid growth appeared correlated with La Niña events, so future study needs to include monitoring of climate patterns and recording of ocean water conditions.

iii) Debris drifts – stable piles of fallen sponges.

iv) Spicule – a minute, slender, sharp-pointed body, typically present in large numbers.

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Install a safe and permanent moorage for dive boats at glass sponge reef sites.	The Marine Life Sanctuaries Society (MLSS) and partners have installed the base of what will be a permanent mooring buoy at the Halkett Marine Park sponge reef at Halkett Pinnacle. This will provide safe moorage and safe access for divers to the sponge garden on a ridge contiguous with the deeper sponge reef. Citizen science documentation of that garden and reef is anticipated, with the cooperation of commercial dive boat operators, and with web data reports and scientific assistance from Ocean Wise Research Institute, similar to the Annapolis Reef in Halkett Bay.
GOVERNMENT ACTIONS AND POLICY	
Implement full protection of glass sponge reefs throughout all of Átl'ka7tsem/Txwnéwu7ts/Howe Sound.	In March 2019, DFO announced the closure of the nine documented glass sponge reef complexes in Átl'ka7tsem/Txwnéwu7ts/Howe Sound to bottom-contact fishing. Furthermore, 21 additional possible reef sites in eight distinct areas in Átl'ka7tsem/Txwnéwu7ts/Howe Sound were mapped in the DFO report[3] that preceded the public review process. Those sites have since been surveyed in a DFO ROV research cruise in May 2019; publication of results is anticipated in 2020.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below.

Individual and Organization Actions:

- Contribute to citizen science projects in order to monitor glass sponge growth at the inshore Kw'émkw'em/Defence Island sponge reef.
- Report illegal fishing and trapping to DFO within sponge closure areas.
- Take the padi course developed to teach safe diving practice around sponge reefs before diving around sponge reefs.
- Familiarize yourself and others with locations of sponge reefs throughout Átl'ka7tsem/Txwnéwu7ts/Howe Sound, specifically if bottom contact fishing or mooring your vessel.

Government Actions and Policy:

- Encourage local education and awareness of the importance of sponge reefs, and the risks they face.
- Advertise the uniqueness of the opportunity to dive a sponge reef using compressed air in Átl'ka7tsem/Txwnéwu7ts/Howe Sound.
- Support local citizen science projects, and formal studies aimed at understanding and monitoring glass sponge reefs.
- Restrict bottom contact fishing throughout all glass sponge reefs in Átl'ka7tsem/Txwnéwu7ts/Howe Sound.

Methods

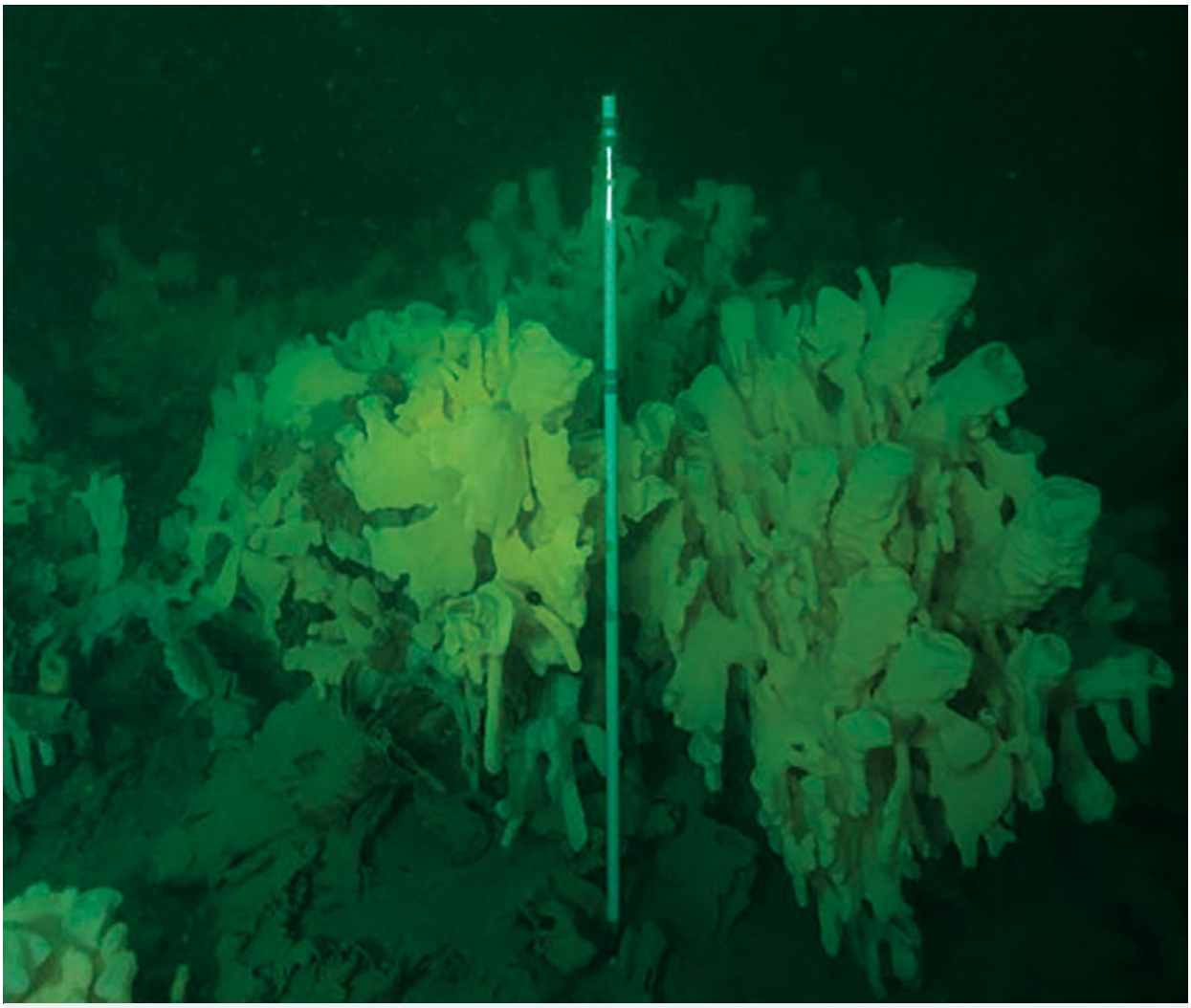
The study by Marliave et al.[1] drew on more than a decade of scuba diving at the Nínich Kw'émkw'em/East Defence Island bioherm by the Howe Sound Conservation and Research Team of Ocean Wise. This research included the installation of bar-coded marker stakes (i.e., multicoloured lines on the stakes to allow identification of each stake), transplants of loose fragments from fishing gear damage, and substrate depth survey transects with an avalanche probe.

References

[1] Marliave JB, Borden LA, Schultz JA, Gibbs DM, Dennison GJ. Formation, persistence and recovery of glass sponge reefs: a case study. 2018; Available from: https://tinyurl.com/su606uz

[2] Dunham A, Archer SK, Davies SC, Burke LA, Mossman J, Pegg JR, et al. Assessing condition and ecological role of deep-water biogenic habitats: Glass sponge reefs in the Salish Sea. Mar Environ Res [Internet]. 2018;141:88–99. Available from: https://doi.org/10.1016/j.marenvres.2018.08.002

[3] Fisheries and Oceans Canada (DFO). Glass sponge aggregations in Howe Sound: locations, reef status, and ecological significance assessment [Internet]. 2018. [cited 2019 Dec 9]: DFO Canadian Science Advisory Secretariat Science Response 2018/032; Available from: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ScR-RS/2018/2018_032-eng.html



Glass sponge reef marked by a bar-coded stake. (Credit: Adam Taylor)

Former HMCS Annapolis: artificial reef harbours many species

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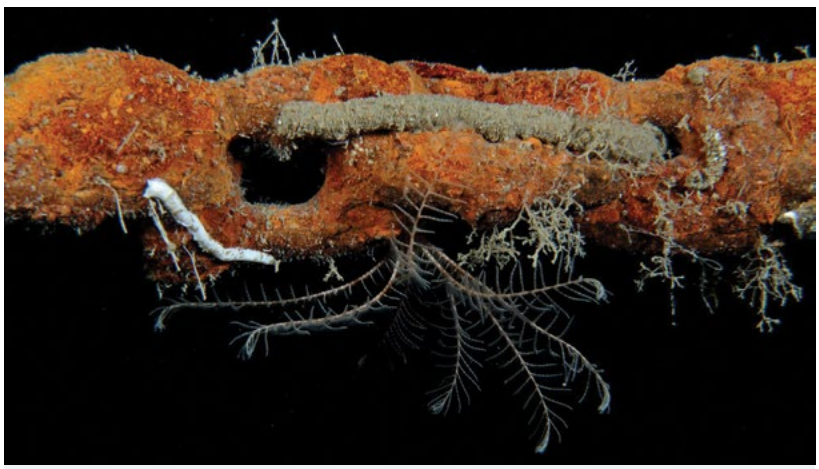
NB: The Ocean Watch Howe Sound Edition [OWHS] 2017 Annapolis article incorrectly stated the length of this vessel as 370 metres long. It is in fact 371 feet, or 113 metres long.

What is happening?

In 2015, the Annapolis, a decommissioned naval ship, was sunk in Ch'á7elsm/ Halkett Bay, on the south-east of Chá7elkwnech/Gambier Island to create an artificial reef. Due to historical log boom storage in this area, habitat potential was reduced compared to other nearby sites. The sinking of the Annapolis was thus designed to provide usable habitat to increase species abundance and diversity in the area, and is monitored by the Artificial Reef Society of BC (ARSBC) through their citizen science program, the Annapolis Biodiversity Index Study (ABIS) (see Resources). By early 2016, nearly 50 different marine species had made the Annapolis home (see Annapolis, Ocean Watch Howe Sound Edition [OWHS] 2017).



Marine organisms populating the Annapolis. (Credit: Lee Newman)

What is the current status?

Artificial reefs provide habitat that attracts sea life, from the smallest invertebrates to large fish. One important feature of the Annapolis is its similarity to habitat that attracts rockfish and lingcod, two groups of fish with low population numbers in Átl'ka7tsem/Txwnéwu7ts/Howe Sound (see Critical Fish Stock, OWHS 2020). The number of rockfish species observed on the Annapolis has increased; however, yelloweye rockfish (*Sebastes ruberrimus*) have not yet been observed during 2019 dives (Table 1).

Table 1. Presence (+)/absence (–) of rockfish species observed during dives on the Annapolis between 2015 to 2019.

YEAR	COPPER	QUILLBACK	YELLOWTAIL	YELLOWEYE
2015 (from May 21)	+	+	–	–
2016	+	+	–	+
2017	+	+	+	+
2018	+	+	+	+
2019 (up to March 9)	+	+	+	–

The results of the ABIS project over the past few years are very promising, with some exciting discoveries such as lingcod (*Ophiodon elongatus*), yelloweye rockfish, gravid copper (*S. caurinus*) and quillback rockfish (*S. maliger*), and midshipman (*Porichthys notatus*), as well as many invertebrate discoveries. In the past four years, sponges and tunicates have begun to settle. Most recently, 161 species have been recorded as using the Annapolis for habitat. Most of these species are small invertebrates and algae. Two small species of encrusting sponge have been identified. However, the number of plant and moss animal species recorded during dives has decreased. It is unclear whether this is a natural fluctuation. All other animal groups have increased in abundance, with some more than doubling the number of species present, for example molluscs and echinoderms (Figure 1). Ongoing monitoring is necessary and continues via a BC Parks Enhancement Funding Grant to support the ABIS.

The ship has not been down long enough to suggest any trends of future settlement. However, early observations indicate that there are currently more marine species in the area inhabiting the Annapolis than there were before the ship was sunk.

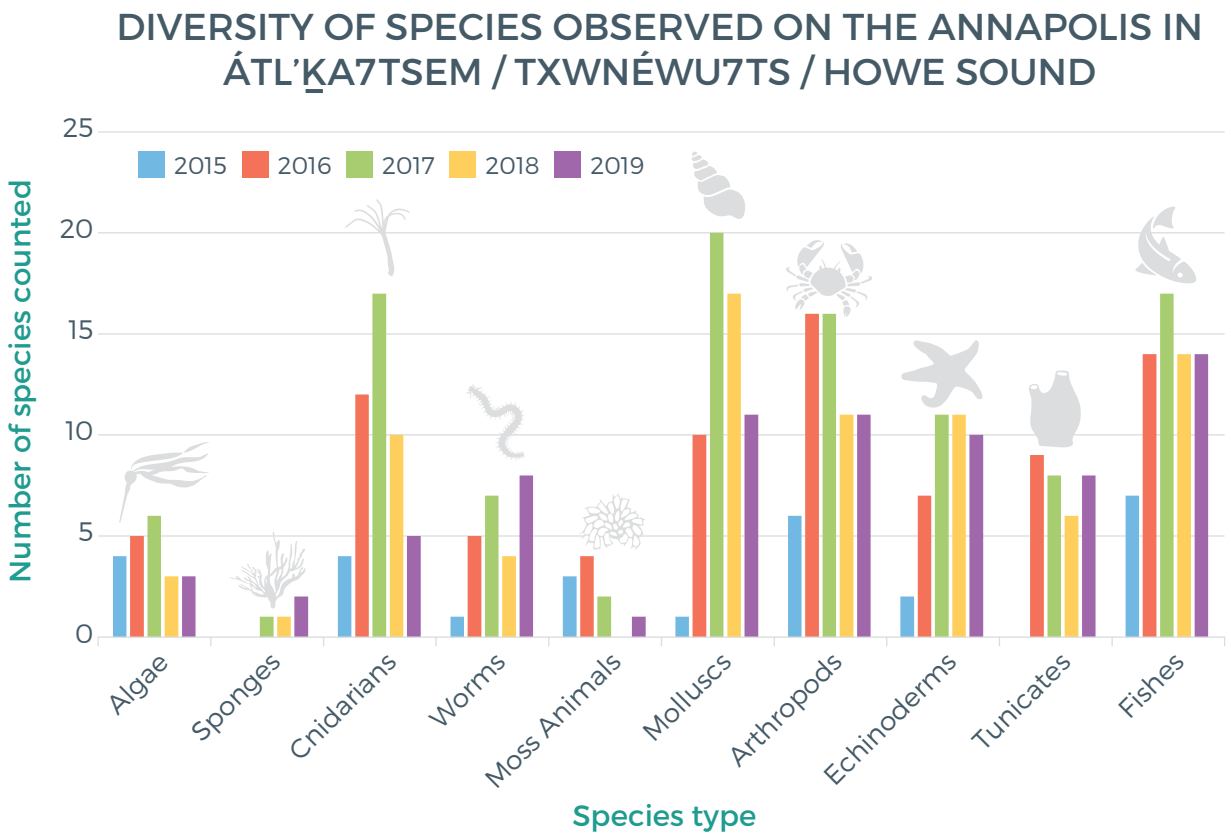


Figure 1. Number of species in different categories observed on the Annapolis since it was sunk in April 2015. Data for 2015 is from May 21. Data for 2019 includes dives conducted up to early March (the project completion date). All other years are full calendar years.

What are the potential impacts of climate change on the Annapolis?

Climate change impacts are unlikely to directly affect the Annapolis as an artificial reef. However, direct impacts may be seen on the species that use this habitat. Further details about climate change impacts on particular species can be found in the relevant articles (e.g., Critical Fish Stocks, OWHS 2020).

Divers on the Annapolis. (Credit: Diane Reid)

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
GOVERNMENT ACTIONS AND POLICY	
Support citizen science efforts.	The 2018 (August) to 2019 (March) term for the ABIS project was funded by BC Parks.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as NEW also follow.

Individual and Organization Actions:

- Learn about the monitoring project through the ARSBC website.
- NEW If you are a diver, take the course offered by Ocean Wise to improve your identification skills (see Resources).

Government Actions and Policy:

- Monitor and assess the effectiveness of artificial reef habitat.

Methods

Data has been collected by voluntary divers as a part of the ARSBC's citizen science program, the ABIS.[1]

For the 2018/2019 term (August to March), ABIS was funded by BC Parks. A total of five dive trips involving 16 divers was possible in this time. The divers covered all exposed areas of the ship over the course of these dives, including port and starboard breezeways, hangar, antenna deck, flying bridge, foredeck and aft deck areas. Other areas explored and documented included some interior areas such as #1 Mess, forward Capstan Room, Halfdeck, Operations area, and Burma Road (the main corridor that runs through the interior of the ship from bow to stern). Some dives occurred around the circumference of the ship where the hull meets the bottom. Some areas below decks still require examination, e.g., the Cafeteria, Galley, Sick Bay and some of the Mess areas below Burma Road.

Divers are encouraged to record their marine life findings using video or photography, and report these to Donna Gibbs (donna.gibbs@ocean.org). Donna is a marine taxonomy specialist, who uses these images and videos to identify the species and/or groups (phyla) represented.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

Marine Life Identification for Divers course
https://ocean.org/marine-life-identification-for-divers/

Artificial Reef Society of BC (ARSBC)
https://artificialreefsocietybc.ca/index.html

Annapolis Biodiversity Index Study (ABIS)
http://www.artificialreefsocietybc.ca/annapolis-project-abis.html

References

1 Artificial Reef Society of British Columbia. Annapolis: Project ABIS [Internet]. 2019 [cited 2019 Aug 30]. Available from: http://www.artificialreefsocietybc.ca/annapolis-project-abis.html

Squamish Estuary: reconnecting ocean and river

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What is happening?

The Squamish estuary is located at the confluence of the Squamish River and the northern end of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Over the past century, the estuary has undergone numerous changes including infilling to create the townsite of Squamish, construction of roads, rail, and industrial ports and logging. Today, less than 50% of the original estuary remains (see Squamish Estuary, Ocean Watch Howe Sound Edition [OWHS] 2017).

Organizations such as the Squamish River Watershed Society (SRWS) have been working to restore the estuary. Activities include reconnecting tidal

A view down Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, with the Squamish Estuary shown in the bottom right. (Credit: Rich Duncan)

channels to the river through installation of culverts across roads and a man-made berm[i]; removing brownfields[ii]; and, wherever possible, restoring habitat for fish and wildlife. The goal of restoration is to re-establish a healthy, vibrant and resilient estuary that can withstand sea-level rise and climate change, and remain an important breeding and rearing ground for migratory and resident species, including the myriad of birds that inhabit the estuary, such as the iconic bald eagle (*Haliaeetus leucocephalus*) and the blue heron (*Ardea herodias*), as well as migratory salmon. A healthy, thriving estuary is central to supporting the wealth of species that use this beautiful habitat.

What is the current status?

In 2017, the SRWS, together with Sḵwx̱wú7mesh Úxwumixw/Squamish Nation and Fisheries and Oceans Canada (DFO), began work on the Central Estuary Restoration Project (CERP). Past industrialization and development continue to limit habitat function and fish access in the Squamish estuary. For example, the training berm is "flushing" juvenile salmon into Átl'ka7tsem/Txwnéwu7ts/Howe Sound faster than they would otherwise migrate, potentially impacting their survival.

CERP is a three-phase project designed to reconnect and restore estuary habitat to support the outmigration of Pacific salmon, especially Chinook (*Oncorhynchus tshawytscha*). Chinook is the main prey species of southern resident killer whales (*Orcinus orca*),[1] an iconic B.C. species that is currently in serious decline. In addition to improving access and habitat for Pacific salmon, other ecosystem benefits will likely occur. Examples include improvements to water quality; flood mitigation and coastal resilience; increased sediment deposition and carbon sequestration potential; and increased support of known species at risk within the project area due to improved habitat quality.

The three phases of CERP are broken down as follows:

PHASE 1. Upgrade the existing culverts in the training berm to improve fish access;

PHASE 2. Modify the lower section of the training berm to reconnect the lower estuary; and

PHASE 3. Install a flow control device under the Canadian National Railway (CN) rail spur to re-water historical channels.

Work on Phase 1 commenced in 2018. Phase 1 focused on replacing an underperforming culvert crossing with a larger fish-friendly crossing. The most effective location for the culvert upgrade was determined based on modelling of sediment transport and a 2D flood model of the Squamish River.[2] Of the nine culverts installed over the past 20 years, the best location for the upgrade was determined to be the third culvert from the north end. This culvert was a twin 1.2-

i) Berm – a flat strip of raised land bordering a body of water.

ii) Brownfield – a former industrial or commercial site.

Construction preparing for the new box culverts. (Credit: Squamish River Watershed Society)

m diameter corrugated steel pipe that was installed in the early 1990s. This culvert was replaced with a 3 m x 3 m concrete box culvert that would permit flow, and thus fish passage, for over 80% of the daily tidal exchange.

During construction, inflows from the river were obstructed with a cofferdam[iii]. However, the site could not be completely isolated and was inundated by daily tides. Consequently, work was limited to the low tide periods each day. Riprap[iv] was placed at the inlet and outlet of the box culvert to limit scouring of the channel during tidal exchange. Upon completion, the cofferdam was removed, and water began flowing from the river to the estuary.

Prior to construction work beginning, an extensive monitoring program was undertaken to establish baseline data. This included monitoring for fish passage and presence; water parameters such as salinity, pH, temperature and dissolved oxygen; and vegetation colonization. Monitoring will continue during 2020 and into 2021 to establish the effectiveness of the culvert upgrade.

Design and planning for Phase 2 (realignment of the spit to open up over 77 hectares of tidal habitat for juvenile Chinook salmon) and Phase 3 (to install flow control structures under the CN Spur Line to improve water quality and fish habitat in the Cattermole Slough/Bridge Pond) are underway for 2019/2020. Once approvals and permits are received, physical works should commence from 2021.

The SRWS takes a holistic approach towards watershed management and considers the entire water-

iii) Cofferdam – a temporary enclosure in or around a body of water that allows the water to be pumped out, creating a dry environment for construction to take place.

iv) Riprap – large boulders and rocks.

shed when working on restoring fish productivity and habitat. Work in the Squamish estuary is directly tied to restoration activities the SRWS and other organizations have undertaken throughout the watershed to improve fish habitat, in particular for steelhead (*O. mykiss*) and salmon. Examples of work the SRWS have been a part of since 2017 include restoration activities in the upper Elaho River, where physical barriers to salmon migration were removed; and restoration of fish habitat in the Ashlu, Shovelnose and Cheakamus rivers, which were impacted by logging, dikes, hydro-electric facilities and roads. All of these rely on a healthy estuary for juvenile salmonids to migrate through on their way to the ocean.

A concurrent project is examining the greenhouse gas offsetting potential of the Squamish estuary salt marsh habitats. Salt marshes cover approximately 180 ha of Squamish estuary. Salt marsh ecosystems are globally recognized as important "Blue Carbon," or ocean carbon, sinks. Their management, restoration and protection can help to offset impacts that would occur if they were destroyed or altered by development.[3,4] The SRWS is investigating both the blue carbon potential of the Squamish estuary and the changes in carbon sequestration capacity from constriction in the area of the training berm. Results will inform local carbon storage capacity and rates of sequestration, which will contribute to an overall understanding of carbon dynamics of the Squamish estuary.

A box culvert installed in the dike to increase connectivity between the Squamish River and the estuary. (Credit: Edith Tobe)

What are the potential impacts of climate change on the Squamish estuary?

Rising sea levels will inundate low-lying areas, including estuaries, and alter the tidal range. Ocean acidification may change the salinity of these brackish water areas, rendering them unsuitable for some, and more suitable for other species. Increased precipitation could lead to an increase in water and stormwater run-off, increasing erosion processes and introducing larger volumes of nutrients and/or pollutants into the estuary. Increased freshwater input could also alter the salinity in estuaries.[5]

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Increase educational and awareness campaigns that support widespread understanding of the importance of estuary health to all life in Átl'ka7tsem/Txwnéwu7ts/Howe Sound.	Signage has been posted by the SRWS and other organizations along various trails within the Squamish estuary.
GOVERNMENT ACTIONS AND POLICY	
Continue to support and facilitate education, monitoring and restoration activities of local groups in Átl'ka7tsem/Txwnéwu7ts/Howe Sound. Provide funding assistance and partnership opportunities where feasible.	DFO has partnered with SRWS and provided staff support on the CERP.
Reclaim and rehabilitate estuary habitat that has been modified by past development.	This is being achieved for example by the work of the SRWS, e.g., CERP as outlined above; the Nature Conservancy of B.C. is working to enhance B.C. estuaries (see: https://www.naturetrust.bc.ca/our-projects/enhancing-bc-estuaries); Skwxwú7mesh Úxwumixw/Squamish Nation is actively involved in estuary restoration projects.
Recognize the importance of estuary habitat for spawning and rearing salmon.	DFO has partnered with the SWRS to restore and reconnect the estuary to improve habitat function and fish access.

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below.

Individual and Organization Actions:

- Volunteer individually or as an organization with one of the local environment groups (i.e., Squamish Streamkeepers, Squamish Environment Society, Squamish River Watershed Society, or Squamish Climate Action Network) and learn about the estuary on a walk with any of these organizations.
- Report ecological information to local citizen science programs (see Citizen Science, OWHS 2020).

Government Actions and Policy:

- Increase educational and awareness campaigns that support widespread understanding of the importance of estuary health to all life in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Ensure accurate and comprehensive information is available and reviewed by area planners and decision makers.
- Explore the possibility of increasing the size of the Skwelwil'em Wildlife Management Area or create more Wildlife Management Areas to increase protection throughout the estuary.
- Protect all estuary habitats from residential, commercial, or industrial development.

Methods

Restoring, protecting and enhancing natural habitats, such as the Squamish estuary, often fall on local non-profit organizations or First Nations. The works described here are the result of decades of collaboration, pushing political priorities within the federal and provincial mandates, and having patience to wait for projects to be realized. For more information on the Squamish estuary, please refer to the SRWS website (see Resources). Additional information and background have been provided by Edith Tobe, Executive Director of the SRWS.

Resources

This list is not intended to be exhaustive. Omission of a resource does not preclude it from having value.

Squamish River Watershed Society
https://www.squamishwatershed.com/

References

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2 Kerr Wood Leidal. 2018. Squamish Estuary Qualitative Sediment Transport Analysis. completed December 21, 2018.

3 Laffoley, D. & Grimsditch, G. (eds). *The management of natural coastal carbon sinks. Natural England Commissioned Report NECR033.* (2009).

4 McLeod, E. *et al.* A blueprint for blue carbon: Toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. *Frontiers in Ecology and the Environment* vol. 9 552–560 (2011).

5 US Environmental Protection Agency (EPA). Climate adaptations and estuaries. https://www.epa.gov/arc-x/climate-adaptation-and-estuaries (2016).

Signage on a walk within the Squamish estuary. (Credit: Aroha Miller)