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OCEANWATCH

Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound Edition 2020

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Credits

This report was prepared by the Ocean Watch team of the Ocean Wise Research Institute (formerly the Coastal Ocean Research Institute), part of the Ocean Wise Conservation Association. Please visit oceanwatch.ca to read the report online and to see the rest of our work.

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DAVID SUZUKI FOUNDATION
One nature.

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Artificial Reef Society of BC

Atl'ka7tsem/Howe Sound Biosphere Region Initiative

Atl'ḵa7tsem/Howe Sound Marine Reference Guide

Bowen Island Community School

British Columbia Bird Studies Canada

British Columbia Ferry Services

British Columbia Institute of Technology

Carbon Accounting

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About This Report

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In 2017, the first Ocean Watch Howe Sound report was released. It provided an overview of the health of the coastal marine environment throughout the Sound, grouped under seven themes. Today, as we rapidly move towards 2021 and the United Nations Decade of Ocean Science for Sustainable Development, we are pleased to release the Ocean Watch Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound Edition 2020. This update speaks to a number of key UN Sustainable Development Goals (SDG), including, most prominently, SDG 14, *life below water*, but also SDG 11, *sustainable cities and communities*, SDG 13, *climate action*, and perhaps most importantly, SDG 17, *partnerships to achieve the goal*.

Here we have built upon the solid framework used in the first edition, and have made adjustments, additions and revisions. The 2020 edition can be read in isolation; however, to avoid repetition, context and background from the 2017 report have not been repeated. Where possible, figures showing data

Sunset in Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound. (Credit: Rich Duncan) and trends from the 2017 report have been updated, so the entire data set can be seen in one place. However, discussion of the data refers only to the most recent years. To see what was written earlier please view the 2017 report, available online at oceanwatch.ca/howe-sound.

We approached the 2017 authors to provide updates. However, in some cases, the original authors were unable to take part, thus new authors and reviewers contributed their time and have been acknowledged accordingly in each article.

Where possible, we provide both Skwxwa7mesh Uxwumixw/Squamish Nation and English place names based on information available at squamishatlas.com. The names we use are our best efforts to be accurate and respectful. The Ocean Watch Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Edition 2020 should be viewed as a living document subject to review and change as advised by First Nations knowledge holders.

Recommended Actions

A key part of this update was revisiting the recommended actions made in the 2017 report, and providing information, where available, on what has progressed. Every article, where applicable, now includes a review of previously recommended actions in the section *What’s been done since 2017?* Presenting previously recommended actions in this way provides insight on how actions are being progressed in the Sound, aided by easily accessible information and recommendations.

Protect Howe Sound flotilla (Credit: Topo Films)

Report Structure

We continue to use the seven themes applied previously. However, the order of these themes has been rearranged. Given the all-pervading impacts of climate change on community and ecosystem health, the *Oceanography and Climate Change* theme is now renamed *Climate Change and Oceanography*, and articles in this theme appear first in the report. Subsequent themes are ordered as follows: *Species and Habitat; Seafood; Clean Water; Coastal Development and Livelihoods; Sense of Place and Wellbeing; and Stewardship and Governance.*

Figure 1. The seven themes for this report, under which all articles have been grouped.

Climate Change

Climate Change and Oceanography is fronted by two new articles: Climate change in the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound region, which provides a high-level overview of what climate change is and how it is likely to impact Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound; and The path to zero carbon municipalities, which provides concrete actions municipalities and higher levels of government can take to champion the move to zero carbon emissions. In addition, a third new article, Ocean acidification, explains how changes in the ocean's pH (acidity) could impact marine species.

Most articles throughout the report now have a new subheading: How will climate change impact this species/habitat/topic (e.g., sea stars)? These short sections provide a high-level overview of how climate change is impacting every single aspect of life in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound and highlight that even where a "healthy" status is given, strong actions continue to be needed to maintain ecosystem or species health because of anticipated impacts from climate change.

Health Ratings

In the 2017 report, the Ocean Health Index (OHI) was used in addition to the Ocean Watch health ratings given to each article. For the 2020 report, the OHI has not been used because its inclusion in the previous report introduced some confusion – which health index should be used? Which was more relevant for the Sound?

In this report, we present only the Ocean Watch health ratings (Critical, Caution, Healthy, and Limited Data/Not Rated) to provide a clear interpretative assessment. In addition, we have included a new trend indicator to reflect on progress made (or not) since 2017. An upward arrow alongside the rating indicates positive actions have been taken, but the overall trend does not yet warrant an upward shift in rating. A downward arrow indicates a lack of actions although the overall trend does not warrant a downward shift in rating.

For increased transparency, a committee of researchers and community members was formed to assign the ratings. A minimum of three people assigned a rating for each article based on their understanding of the information presented. Where the ratings assigned by committee members differed, the members worked together until a consensus rating was achieved.

Articles

In addition to the new articles noted above, we have three additional new articles: Pinnipeds within *Species and Habitat*; and Plastics, and PollutionTracker within *Clean Water*. Pinnipeds was raised as a candidate for inclusion because of the presence of harbor seals in the Sound, and their importance for top level species in the food web – killer whales. Plastics was included because of the pervasive nature of this material in our oceans, while PollutionTracker is a conservation tool designed to monitor chemical contaminants in the marine environment along the entire B.C. coast, providing oversight of the Sound's historically contaminated waters. Additionally, lingcod and rockfish, previously presented as separate articles, have been combined in the updated article Critical Fish Stocks for this edition.

Despite best attempts, no update for Cultural Continuity and Squamish Nation Stewardship were available at the time of print. We therefore decided it was prudent to leave these articles out until such time as full updates can be provided and added online.

Methods

Oftentimes, people like to know a little bit more about what they are reading – where did the data come from? How was it collected? Who collected it? Has the collection method been consistent over the years? We added a new section to every article outlining the methods, which can be found at the end of the text in each article. They are not intended to be scientifically reproducible, but instead, to offer insight into where the information came from.

We hope you will find the 2020 update to be comprehensive, transparent and accurate and are excited to continue supporting the community of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound to improve the health of the coastal marine environment.

We welcome feedback on the accuracy of the content (oceanwatch@ocean.org).

Executive Summary: overview and future directions

Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is a coastal fjord in the Salish Sea, just north of the bustling city of Vancouver, British Columbia (Figure 1). Lying within the unceded territory of the Skwxwú7mesh Úxwumixw/Squamish Nation, the Sound is home to flourishing communities, and is a Traditional Knowledge hub, a biodiversity hotspot and a recreational playground.

Historically, industrial activities and development in the Sound left the water polluted and the environment damaged. However, significant efforts in recent decades have improved the health of the fjord and allowed valued species to recover.

Administered by 10 local government bodies and Skwxwú7mesh Úxwumixw/Squamish Nation, communities throughout the Sound have been working together for a number of years to create a vision of collaborative restoration, protection and sustainable growth for this unique geographic area. Today, momentum is as strong as ever, and many initiatives are coming to fruition. Careful management of the precious resources in this fjord remain necessary to ensure a sustainable future for the environment and the people who call this jewel “home.”

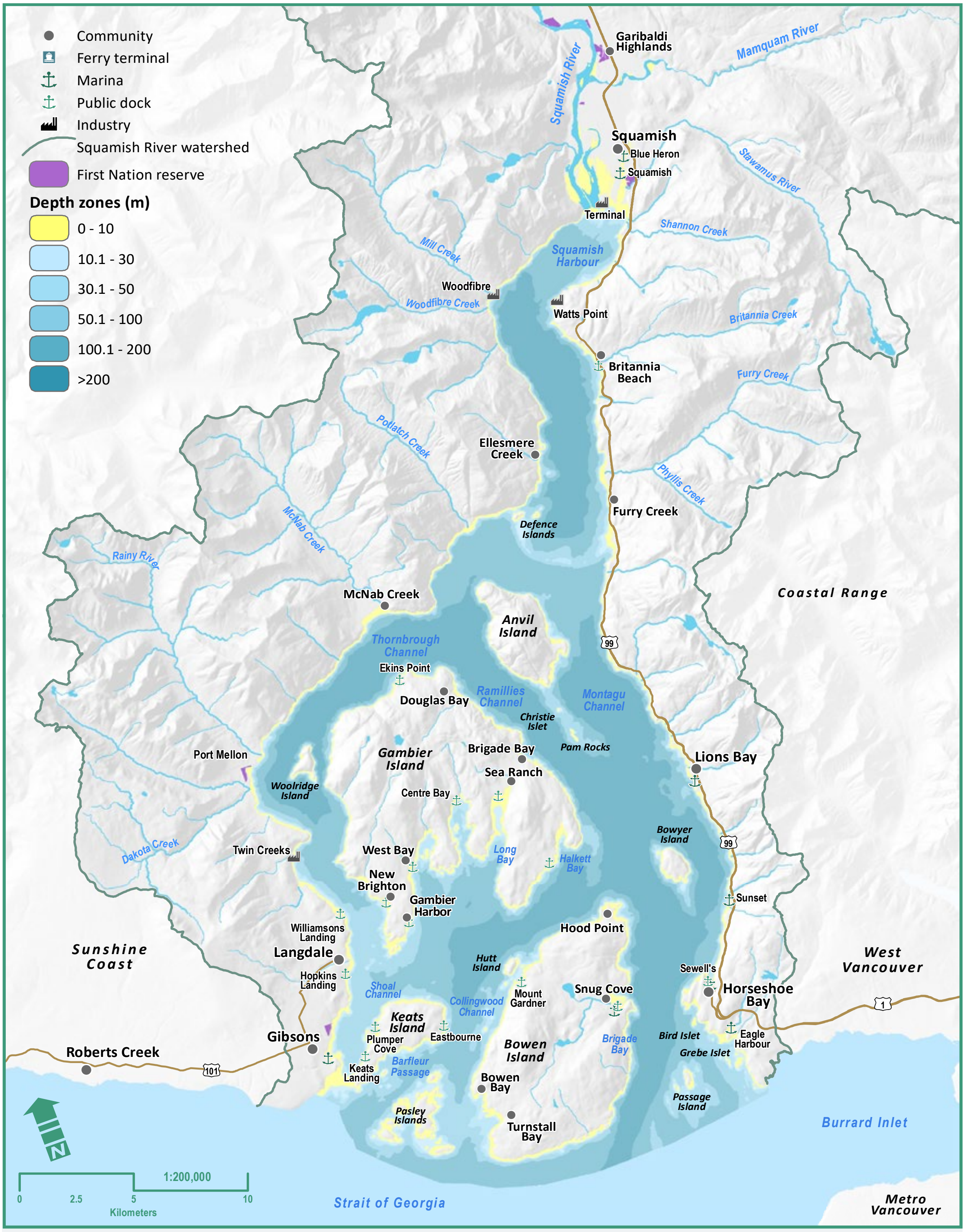

Figure 1. Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, depicted by the gray lines. The watershed that feeds into Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound extends north-east and is therefore not shown in its entirety.

Ocean Wise Research Institute

Novel Research. Meaningful outcomes. Actionable solutions.

The Ocean Wise Research Institute (formerly the Coastal Ocean Research Institute) is home to a dynamic team of conservation scientists, delivering a blend of cutting-edge research and novel conservation tools. Our researchers ply the waters of Canada's three oceans, tracking the impacts of plastics, chemicals, habitat destruction, noise and climate change.

Orange sea pen, *Ptilosarcus gurney*, Porteau Cove.
(Credit: Lee Newman)

We work to protect at-risk whales, salmon, glass sponge reefs and the traditional seafoods of coastal Indigenous communities, and acknowledge the power of knowledge in effecting positive change.

When the Ocean Watch Howe Sound Edition was published in 2017, we knew that we had something useful. In bringing together those knowledge keepers, thinkers, and stewards who contributed to the 2017 report, we felt palpable energy. Curiosity, love of place and a desire for change intersected in a singular conversation, with the resulting Ocean Watch compendium providing a foundation for species protection, ecosystem recovery and sustainable communities in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

This Ocean Watch Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound Edition (2020) adds a new dimension to the 2017 report, by adding a tracking element to evaluate progress made in the intervening three years.

We are indebted to all those who contributed to this unique conservation tool, and thankful for all the hard work done to recover and protect this very special place – Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

– Peter Ross, PhD, Vice-President of Research,
Executive Director of the Ocean Wise Research Institute

Ocean Watch Health Ratings 2020

This report provides an update to the Ocean Watch Howe Sound Edition (2017). It provides both a status report and an assessment of progress made over the past three years.

The Ocean Watch ratings offer an easy, visual way to understand what is happening with the health of different indicators throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. The green *healthy* rating is what we want to attain for all indicators; however, in most cases, more work is needed to advance in that direction.

In addition to the four ratings used in the 2017 report (healthy, caution, critical, limited data/not rated), here we have added *improving*, as shown by an upward arrow, and *declining*, as shown by a downward arrow. These arrows indicate that even if the health rating has not changed since the 2017 report, positive forward action has been taken, or conversely, actions have regressed.

Twenty-eight articles from the 2017 report have been reassessed. Six articles are new for this 2020 edition. Despite best attempts, no update for Cultural Continuity and Squamish Nation Stewardship were available at the time of print. Thus, no ratings are given for these two articles.

Ocean Watch Health Rating Legend

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.

Table 1. Health ratings for each article. The health rating for 2017 and 2020 are shown for comparison. A rationale is provided for the 2020 health ratings.

Climate Change and Oceanography	2017	2020
CLIMATE CHANGE NEW Climate change is a global issue, not just specific to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. The problems facing the Sound are complex and multi-faceted. Globally, there is limited progress to reduce drivers of climate change.		⊗
ZERO CARBON COMMUNITIES NEW Canada is one of the 10 countries responsible for the most greenhouse gas emissions in the world. Not enough is being done to reduce these emissions nationally, or globally. Transforming communities to zero carbon emissions is necessary.		⊗
OCEAN WARMING Globally, record-breaking temperatures continue to occur, which directly impacts ocean temperatures. Ocean warming is causing ecosystem-wide changes. Data specific to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is limited.	(!) ⊗	⊗ ⊖
OCEAN ACIDIFICATION NEW Ocean acidification has direct impacts on marine species and habitats. A lack of data exists for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, although monitoring is being implemented to address this gap.		(!) ⊖
SHORELINE EROSION/ SEA LEVEL RISE Sea level rise and storm surges will continue to negatively impact shorelines in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound; however, the degree of impact will vary depending on location in the Sound.	(!)	(!) ⊗
STREAM FLOWS Large interannual variations are observed. A shift in timing of peak flows will have effects on other species.	(!)	⊗
SQUAMISH FLOOD PLANNING Significant progress has been made on the recommended actions from the 2017 report; however, there is still considerable work to be done, and that relies on funding and implementation continuing.	⊗ (!)	⊗ (!) ↑

Species and Habitat	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.	⊗	⊗
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.		(!)

Species and Habitat (continued)	2017	2020
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.	! ✗	! ⊖ ↑
Seafood		
SPORT FISHING Pressure on fish stocks continues to increase from the rising popularity of sport fishing. There is a lack of monitoring to support stock management and enforcement of regulations.	!	! ↓
SHRIMP/PRAWN FISHERY Stocks have been declining since 2015, resulting in fishery closures. Industry is trying to decrease bycatch mortality.	!	!
Clean Water		
BRITANNIA MINE Some improvements have been seen following wastewater treatment; however, exceedances of water quality guidelines are still occurring.	!	!
PULP MILL MARINE EFFLUENT Dioxin and furan contamination in sediment and benthic life is decreasing following regulations but is still detected.	!	! ↑

Clean Water (continued)	2017	2020
WRECKED, ABANDONED, AND PROBLEM VESSELS The passage of Bill C-64 has increased resources available for removal of vessels; however, this is a complex issue and further refining of legislation is necessary.	!	! ↑
POLLUTIONTRACKER NEW Dioxin and furan concentrations are high, especially in mussels, when compared with other areas along the B.C. Coast. Metals continue to be detected in sediments, sometimes above sediment quality guidelines.		!
PLASTICS NEW Plastics are ubiquitous in our oceans, causing concern around entanglement and ingestion by marine animals. However, within the Sound data for plastics and microplastics is lacking.		⊖ ⊗
Development		
COASTAL DEVELOPMENT With rapid growth occurring in the region, and subsequent development, sustainable management is key.	!	!
LARGE VESSEL TRAFFIC The volume of large vessel traffic has not changed significantly. However, not all shipping traffic is represented. Risks from vessel traffic continue. Future development may increase vessel numbers. Efforts are being taken to decrease impacts on cetaceans.	!	! ⊖
TOURISM AND RECREATION Demands for activities and resources is high, creating pressure on ecosystems, and there is no sign of growth slowing. This growth requires sustainable management, and there is movement towards this, but more needs to be done.	✓ !	!
Sense of Place		
CITIZEN SCIENCE There are a large number of citizen science activities in the Sound.	✓	✓
OUTDOOR LEARNING There are a large number of outdoor educational organizations and opportunities in the Sound, with an increasing emphasis on Traditional Knowledge.	✓	✓

Stewardship and Governance	2017	2020
MARINE PROTECTED AREAS Positive actions have been taken, with the creation of new marine refugia to protect glass sponge reefs and the expansion of the important bird area (IBA). However, the IBA offers no legal protection.		
COMPREHENSIVE PLANNING Recent accomplishments suggest positive improvements, but a need for continued collaboration and communication is essential.		

Progress on Recommended Actions from 2017

The Ocean Watch Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Edition (2020) details progress on recommended actions from each article in the 2017 edition. Many actions were identified as having advanced, but many more still require further work. Only a single action in the whole report regressed (Sport fishing), while the heath rating assessment for seven articles also regressed (Ocean Warming, Shoreline Erosion/Sea Level Rise, Stream Flows, Squamish Flood Planning, Marine Birds, Sport Fishing, Tourism and Recreation). Below are some examples of actions that have progressed. Details on specific actions are available in each article. Actions specifically from the 2017 Action plan that have been addressed are denoted below with **2017 ACTION PLAN**.

The Ocean Watch Howe Sound Workshop 2019 asked participants to identify key themes for moving forward on actions related to climate change (click here to see the workshop report). The suggested themes were similar to those used in the 2017 Action Plan. As such, these themes have been used here to group all past and current actions. Additional themes were added to capture the diversity of topics presented. Actions are grouped into the following themes:

- research;
- protect and restore;
- educate and engage;
- legislation;
- funding;
- monitor key indicators;
- greenhouse gas reductions.

Research

Research informs conservation actions. Examples of progress include:

- A pilot plankton sampling study was carried out in 2019 (data not available for the 2020 report).
- The Ocean Wise Research Institute’s Howe Sound Conservation and Research Team continues to build on their 40-plus years of research work in the Sound’s waters, conducting investigations on glass sponge reefs, environment DNA (eDNA), critical fish stock monitoring, recording biodiversity, and many other research and monitoring projects to support conservation.
- The B.C. Cetacean Sightings Network (BCCSN) supports the Whale Report Alert System (WRAS), which provides large vessel pilots and captains with information so they can take steps to reduce risk of impacting whales while they are transiting the area.

Protect and restore species and habitats

While great steps have been taken to protect species and fragile habitats, more work is needed especially as climate change continues to impact the marine environment. Examples of progress include:

- **2017 ACTION PLAN** Ongoing eelgrass transplants throughout the Sound.
- **2017 ACTION PLAN** An increase in protected areas or conservation areas, including the extension of the English Bay/Burrard Inlet Important Bird Area part way into the Sound, and the formation of eight new marine refugia to encompass nine glass sponge reefs, bringing the total number of protected glass sponge reefs in the Sound to 11.
- Restoration of natural habitats, including the Central Estuary Restoration Project in the Squamish estuary; and restoration of waterfowl habitat to aid population recovery.
- Restriction of activities in areas of ecological importance, e.g., banning all commercial, recreational and Food, Social and Ceremonial (FSC) bottom contact fishing activities, in glass sponge reef complexes.

Decorated warbonnet, *Chirolophis decorates*, Porteau Cove. (Credit: Lee Newman)

Education and Engagement

Determined as a key priority for increasing awareness on environmental issues throughout the Sound, education and engagement increases the likelihood of behavioural changes, leading to a more invested and conservation-focused community. An example of actions progressed include:

- **2017 ACTION PLAN** The creation of a Marine Reference Guide (MRG) project in order to support decision making.
- **2017 ACTION PLAN** The Ocean Watch Task Force (OWTF), comprising representatives from local government bodies, planning staff, NGOs, and First Nations, was formed after the 2017 report release. The OWTF was instrumental in creating a strategic plan (2019– 2021) to guide local governments in taking collaborative, cohesive action.
- The Ocean Watch Howe Sound Edition (2017) report provided a summary of many aspects of ecological health specific to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, the likes of which was not previously available.
- The Ocean Watch team raised awareness through community events and outreach, for example the Howe Sound Ocean Watch Workshop held in 2019, and presenting to students.
- The Ocean Watch reports (2017 and 2020) provide informative resources, such as the Integrated Flood Hazard Management Plan for Sḵwx̱wú7mesh/Squamish, location of signage in areas of ecological importance and many others.

Legislation

Legal protections and best practice guidelines offer opportunities to protect the coastal environment. This theme encompasses decisions and guidance from government or government agencies. Examples of progress include:

- **2017 ACTION PLAN** The Squamish bylaw to reduce single-use plastics.
- **2017 ACTION PLAN** The formation of eight marine refuge areas to encompass nine additional glass sponge reefs placed under voluntary protection in 2017.
- An amendment to the B.C. Sport Fishing Regulations will likely soon require a biodegradable escape mechanism, or “rot cord,” on all recreational prawn and crab traps, allowing bycatch to escape; decreased recreational daily catch limit for prawns; and prawns with eggs are no longer allowed to be kept since April 2018.
- Boating requirements including speed and location restrictions and increasing the distance between boats and cetaceans.
- Development of bylaws for coastal development (i.e., Squamish Floodplain bylaw).

Funding

Funding is imperative in supporting other key themes, such as research, protection and restoration, etc. Without funding, this work would rely on volunteers and be much more difficult to achieve in a timely manner. An example of actions progressed include:

- **2017 ACTION PLAN** Different levels of government funding support various initiatives, for example the Tenderfoot Creek Hatchery, Eagle Watch, the Marine Reference Guide, Squamish River Watershed Society initiatives, Squamish estuary restoration work, some of the Howe Sound Conservation and Research Team’s work, and many more.
- Other funding, for example philanthropists, non-governmental organizations, etc., support many other projects that promote conservation within the Sound, e.g., funding the Ocean Watch reports by the Sitka Foundation and North Family Foundation.

Monitor key indicators

This category encompasses many citizen science activities, as well as baseline monitoring and ongoing monitoring of oceanographic conditions. An example of actions progressed includes:

- **2017 ACTION PLAN** Ongoing water quality and streamflow monitoring, such as waste-water quality monitoring by Howe Sound Paper and Pulp Mill and to monitor Britannia Mine; PollutionTracker sediment samples; continuous river flow monitoring at Daisy Lake by BC Hydro; ocean temperature and acidification monitoring.
- Observations of cetacean sightings submitted via the WhaleReport app or to Wild Whales; monthly bird count data submitted to various websites and apps; counts of spawning salmon; beach cleanup data; and many others.

Greenhouse gas reductions

This category is new for 2020; however, it is a very important addition. All aspects of our environment are impacted by climate change (Figure 2). Reducing greenhouse gas emissions is key to curbing the negative impacts we are already seeing.

Impacts of greenhouse gas emissions

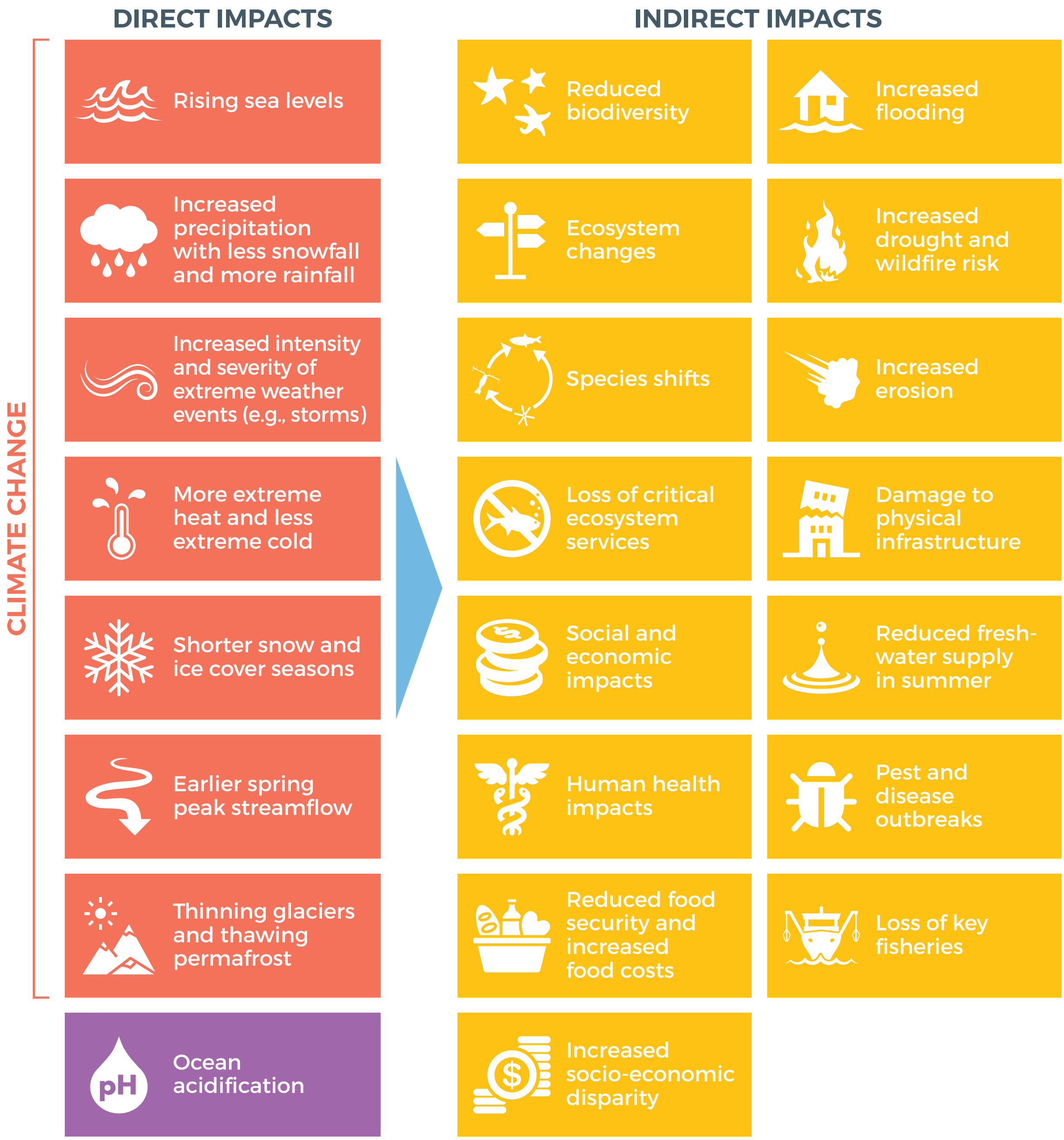

Figure 2. The increased concentration of greenhouse gases in our atmosphere results in direct climate change impacts (orange) and ocean acidification (purple), which then lead to indirect impacts. (yellow).

2020 Key Issues

Moving forward, momentum and collaboration between individuals, community groups, NGOs, local governments and First Nations needs to increase. Further actions are required to continue working towards a healthy Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound marine environment. The list below highlights new and outstanding issues, which are addressed by the new Action Plan.

1. The species, habitats and ecosystems in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound interact in complex ways that we do not yet fully understand. Continued research efforts are needed to further our understanding of these complex biological relationships so that recommended actions do not accidentally have unintended negative consequences.
2. Pressure from population growth, tourism, and development (both land-based building and future increases in vessel traffic) are all impacting the marine environment. Increased collaborative efforts to protect and restore species and habitats is essential.
3. Education and engagement around some of the key issues facing the environment today, in particular climate change, is needed to encourage the necessary behaviour changes and coordinated stewardship efforts.
4. Legal protection is lacking for some protected areas, e.g., Important Bird Areas. Additionally, enforcement of regulations, such as fishing restrictions within glass sponge reef marine refugia, is difficult at best due to a lack of resources at various government levels.
5. Although many initiatives have good funding at present, securing continuity in funding can be difficult, meaning some initiatives must be put aside.
6. A lack of baseline data to monitor trends in species, habitats and ecosystems continues to be an issue, e.g., wild salmon, plankton, forage fish. Equally, monitoring data to evaluate whether protection and restoration efforts are having the desired outcome either do not exist, are not readily available or are held by different groups.
7. Climate change is impacting every aspect of the environment in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Coordinated, community-wide actions are needed to decrease greenhouse gas emissions.

Action Plan

The full report includes updates on past recommended actions as well as detailing new recommended actions, where applicable. Not all actions here are specifically listed within articles; however, after compiling and assessing actions, it was apparent that higher-level recommendations were necessary. This action plan summarizes actions into broad themes to provide an overview and focus on implementation of actions.

Action 1. Research

INCREASE KNOWLEDGE OF THE LOCAL AREA AND SPECIES THROUGH RESEARCH.

1. Conduct baseline studies and ongoing monitoring of key indicator species and habitats to guide conservation actions.
2. Conduct ongoing monitoring of the impacts of climate change and ocean acidification to support adaptation and action.
3. Address key knowledge gaps that develop as knowledge increases.
4. Improve availability and sharing of data.
5. Increase participation and engagement of First Nations knowledge holders in Western science.

Action 2. Protect and Restore

PROTECT AND RESTORE MARINE SPECIES, HABITATS AND ECOSYSTEM SERVICES.

1. Create and implement a coordinated strategy for managing growth (population, tourism, development growth) sustainably throughout the Sound, to reduce impacts on the marine environment.
2. Increase the proportion of area protected within the Sound, with a particular focus on beach spawning habitat and critical habitats.
3. Work with the Federal, Provincial, First Nations and local governments to refine Bill C-64 to clarify the laws applied to abandoned, wrecked or problem vessels so location (on land or at sea), marine debris and waste management issues arising are covered.
4. Reduce entry of pollutants into the marine environment (e.g., plastics and microplastics, harmful chemicals and wastewater).

Action 3. Educate and Engage

INCREASE AWARENESS AND EDUCATION AND ENSURE CONSISTENT MESSAGING ON ENVIRONMENTAL ISSUES.

1. Work with First Nations and local governments to increase education and understanding of critical environmental issues, such as climate change, within municipal staff. Ensure key resources are shared between local governments and have uniform messaging.
2. Increase education and awareness around environmental knowledge and best practices. Include Traditional Knowledge in these education opportunities, and where applicable, ensure they are taught by Skwxwú7mesh Úxwumixw/Squamish Nation members.
3. Increase opportunities for Skwxwú7mesh Úxwumixw/Squamish Nation members to connect to Traditional Knowledge in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Further meaningful reconciliation efforts are needed.
4. Continue to work collaboratively on reconciliation with First Nations.

Action 4. Legislation

DRIVE HIGH-LEVEL CHANGE USING OFFICIAL CHANNELS (E.G., GUIDELINE, POLICY, BYLAW) APPROPRIATE TO THE CIRCUMSTANCES.

1. Implement appropriate regulations to curtail actions that are detrimental to the environment (e.g., pesticides, pollutants, boating, development).
2. Strengthen protections for vulnerable ecosystem components including legal protection, e.g., Important Bird Areas.
3. Explore the option of citizens or First Nations working with government agencies (e.g., a ranger program or something akin to the Coastal Guardian Watchmen Program).

Action 5. Funding

FINANCIALLY SUPPORT CONSERVATION ACTIONS AND ENSURE STRICTER ENFORCEMENT.

1. Strategically fund priority projects for protection of vulnerable species and restoration of critical habitats.
2. Support ongoing, and new, long-term data collection initiatives.
3. Allocate resources to clean-up activities (e.g., wrecked, problem and abandoned vessels; plastics and contaminants; shoreline cleanups and appropriate disposal or recycling, especially after storm events).
4. Incentivize transitions towards environmentally friendly practices and products, e.g., a zero carbon economy.
5. Commit more resources to enforcement.

Action 6. Monitor

COLLECT LONG-TERM DATA TO IDENTIFY TRENDS, SUPPORT DECISION MAKING, AND EVALUATE THE OUTCOME OF ACTIONS TAKEN.

1. Conduct long-term observations of key species and habitats, and potential hazards (e.g., pollutants).
2. Make information easily available to support decision making, e.g., through the Marine Reference Guide.
3. Create a centralized hub to make group information and data easily accessible and searchable, to increase group participation and data use.

Action 7. Greenhouse Gas Reductions

DECREASE GREENHOUSE GAS EMISSIONS AND MOVE TOWARDS ZERO CARBON MUNICIPALITIES TO ALIGN WITH RECOMMENDED REDUCTIONS IN GLOBAL GREENHOUSE GAS EMISSIONS, E.G., IPCC, PARIS AGREEMENT, COPENHAGEN ACCORD.

1. Invest in efficient, regular public transit options in the Sea to Sky corridor.
2. Invest in renewable energy and green infrastructure.
3. Where not already done, local governments should declare a climate emergency to enable council and staff to dedicate the resources required to immediately reduce community-wide GHG emissions.
4. Conduct a baseline GHG emission inventory for each community to identify the largest emitters, with ongoing monitoring and reporting of community-wide emissions beginning in 2020 to track success.
5. Work with large businesses to advise on how to decrease their carbon footprint.
6. Create a climate action plan to prioritize policies and actions that will be most effective at reducing community-wide GHG emissions. Identify challenges and opportunities and establish key evaluation criteria to evaluate success.

Scalyhead sculpin, *Artedius harringtoni*, at Porteau Cove. (Credit: Lee Newman)

Action Plan Leadership

Subsequent to the release of the 2017 report, the Ocean Watch Task Force (OWTF) was created to implement the previous Action Plan. In 2019, the OWTF created a Strategic Plan to guide local governments, fulfilling their agreed goals (terms of reference).

The 2020 Action Plan reflects how far we have come, as a community, in the last three years. Nonetheless, opportunities still exist to improve the health of the coastal marine environment in Atl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Continued, collaborative efforts across government, First Nations, organizations and individuals are key to ongoing success. The update presented above aims to guide these efforts. In addition, further leadership actions that could be taken include:

a) Create a steering committee representing First Nations, government, business, communities, NGOs and other sectors to oversee and guide this work.

b) On an as needed basis, create ad-hoc committees focused on progressing strategic priority actions.

c) Establish a formal network of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound government staff and First Nations to update and exchange information on marine environmental issues, and share resources and information arising from this work.

d) Appoint a sustainably funded project director/coordinator to track progress, prepare annual plans and reports, manage committees and the suggested network, and organize workshops and seminars on priority topics related to the marine environment.

A diver with copper rockfish, *Sebastes caurinus*, in the foreground at Whytecliff Park. (Credit: Lee Newman)

Climate Change and Oceanography

Climate activist, Greta Thunberg, speaking at the World Economic Forum, Davos, Switzerland, January 2019. (Credit: Flickr)

Summary

In recent years, societal awareness of climate change and its pervasiveness has increased dramatically. Harnessing that awareness and turning it into positive action to reduce and eliminate carbon emissions is going to give our planet – and our oceans – its best fighting chance.

Globally and locally, we are seeing direct impacts through rising sea levels, warming ocean temperatures, ocean acidification, changing stream flows, more intense storms, wildfires, droughts and floods. In addition, we are also seeing indirect impacts, e.g., storms destroying eelgrass beds; salmon and forage fish spawning habitat lost to coastal squeeze or washed away by floods, resulting in low numbers for some species; the persistence of sea star wasting disease with warming water temperatures.

Encouragingly, communities and citizen science groups are becoming even more determined to protect species, habitats, and human communities in the face of climate change. Notwithstanding this positive movement, further actions are essential to protect our communities, oceans, and our planet. Recommended actions aimed at all levels of society, from the individual through to federal government, are provided.

> **"You must unite behind the science. You must take action. You must do the impossible. Because giving up can never be an option."**
>
> **GRETA THUNBERG**

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
CLIMATE CHANGE NEW Climate change is a global issue, not just specific to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. The problems facing the Sound are complex and multi-faceted. Globally, there is limited progress to reduce drivers of climate change.		
ZERO CARBON COMMUNITIES NEW Canada is one of the 10 countries responsible for the most greenhouse gas emissions in the world. Not enough is being done to reduce these emissions nationally, or globally. Transforming communities to zero carbon emissions is necessary.		
OCEAN WARMING Globally, record-breaking temperatures continue to occur, which directly impacts ocean temperatures. Ocean warming is causing ecosystem-wide changes. Data specific to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is limited.		
OCEAN ACIDIFICATION NEW Ocean acidification has direct impacts on marine species and habitats. A lack of data exists for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, although monitoring is being implemented to address this gap.		
SHORELINE EROSION/ SEA LEVEL RISE Sea level rise and storm surges will continue to negatively impact shorelines in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound; however, the degree of impact will vary depending on location in the Sound.		
STREAM FLOWS Large interannual variations are observed. A shift in timing of peak flows will have effects on other species.		
SQUAMISH FLOOD PLANNING Significant progress has been made on the recommended actions from the 2017 report; however, there is still considerable work to be done, and that relies on funding and implementation continuing.		

Climate Change in the Átl’ḵa7tsem / Txwnéwu7ts / Howe Sound Region

“Our dependency on the earth to ensure life for all resources, animals and human beings has been taught through the generations.”

KÚKWPI TA̓YA (CHIEF LEONARD ANDREW), LÍL̓WAT NATION
FROM “WHERE RIVERS, MOUNTAINS AND PEOPLE MEET”.
REPRODUCED WITH PERMISSION FROM THE SQUAMISH LÍL̓WAT CULTURAL CENTER

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Climate change refers to shifts in long-term (i.e., 30 years or greater) patterns of weather, including variations in temperatures, precipitation levels and/or extreme weather events. And while climate changes naturally over long periods, it is now clear that human activities have been responsible for the majority of warming experienced over the past 150 years[i].[1]

Increasing concentrations of greenhouse gases (GHG) in our atmosphere, most notably carbon dioxide (CO_2)[ii] – along with land use changes such as urbanization, affecting how much carbon natural systems can remove from the atmosphere – have been quickly changing Earth’s climate in recent times. GHGs do not interact with shortwave radiation (or light energy) coming from the Sun to Earth. The Earth converts this light energy into longwave radiation (or heat energy). When heat moves away from the Earth, GHGs absorb and quickly re-emit some of this outgoing longwave radiation. In other words, these gases trap heat and lead to a warmer planet. This phenomenon is known as the greenhouse effect, which is natural and essential for sustaining life as we know it on our planet.

i) The Intergovernmental Panel on Climate Change (IPCC) states that the level of likelihood of this statement being true is greater than 95%.

ii) Other GHGs emitted by human activities include methane, nitrous oxide and hydrofluorocarbons (HFCs).

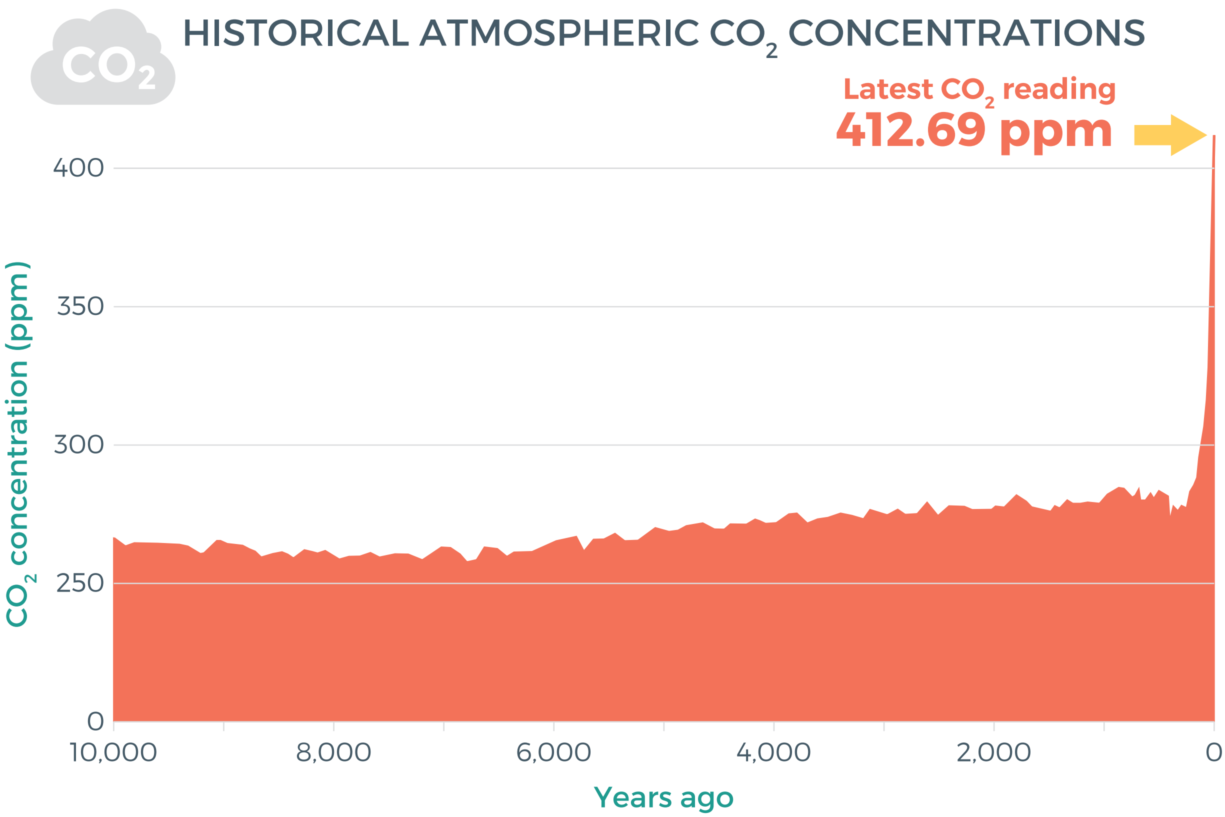

Figure 1. Historical atmospheric CO_2 concentrations from 10,000 years ago until present. Current levels are measured at the Mauno Loa observatory on Hawai'i. Go to https://scripps.ucsd.edu/programs/keelingcurve/ to see the real time concentration.

Recent (i.e., post-1950s) atmospheric CO_2 levels have increased dramatically compared to historical levels over the last 10,000 years (Figure 1). In 2016, CO_2 levels in the atmosphere surpassed 400 ppm and failed to return below this value. This is the first time this has occurred in the last 800,000 years[2], and likely the first time it has occurred since the Pliocene Epoch (between 2.6 and 5.3 million years ago).[3]

Many aspects of the climate system are highly complex and uncertain, and some are still not fully understood. However, the reality of anthropogenic[iii] climate change is simply scientific fact. A full discussion of energy budgets, GHGs, the greenhouse effect, positive feedback cycles[iv] and other relevant concepts can be found in excellent and readily available climate change resources (see Resources).

iii) Anthropogenic – human-caused.

iv) Positive feedback cycles – cycles that amplify the warming effects of increased GHGs. Common feedbacks include water vapour (which is a GHG that increases in concentration as air temperatures increase); albedo feedbacks (i.e., less snow and ice makes the earth less reflective allowing more heat to be absorbed by the oceans); forest fires; permafrost melting; and loss of ocean life.

Past climate change

Reliable global temperature information has been available since approximately 1880, at which point there were enough weather stations around the world to confidently estimate global temperatures. Older records exist (both human records and paleoclimate data[v]), but these involve greater uncertainties. Since pre-industrial times, average global temperatures have risen by approximately 1.0°C.[4] Northern areas, such as the Canadian Arctic, have warmed, and continue to warm, considerably faster compared to areas closer to the equator. Most inland areas have warmed faster than coastal areas in part because oceans are a large heat sink. For example, northeastern B.C. has experienced greater average temperature increases than Vancouver Island.

Average air temperatures in Canada have increased by approximately double the global average.[5] Since 1900, air temperatures in southwestern B.C. have increased by approximately 1.2°C, with winter temperatures

School strike for climate change, Vancouver, B.C., September 27, 2019. (Credit: Brett Vo)

v) Paleoclimate data – information about the climate at any given time in the past. These data can come from tree rings, ice cores, sediment samples, and other evidentiary sources.

(Figure 2, top) increasing faster than summer temperatures (Figure 2, bottom). Additionally, the rate of temperature increase has been occurring faster since 1951 (red lines in Figure 2) in both winter and summer.

Precipitation is much more variable compared to temperature because it can change considerably between nearby locations and can vary greatly from year to year. This makes it hard to discern clear trends. However, precipitation has generally increased globally over the past 100 years, partially because a warmer atmosphere holds more water vapour.[6] Specifically, in the Pacific Northwest, part of the difficulty in measuring precipitation changes is that there are major climatic cycles, namely the El Niño Southern Oscillation[vi] and the Pacific Decadal Oscillation[vii], that cause significant variations in precipitation levels.

Overall, data for B.C. indicate a precipitation increase of approximately 5%.[7] Historical trends in winter (Figure 3, top) and summer precipitation (Figure 3, bottom) show an increase in precipitation overall, but since 1951, there has been a decrease in winter precipitation (blue lines). There is low confidence in these trends because of such factors as noted above (e.g., annual and geographical variation). Climate change also affects the phase of precipitation: more rain and less snow have implications for snowpack, aquifers and stream flows.

Ocean temperatures are also increasing (see Ocean Warming, OWHS 2020). Thermal expansion[viii] and melting glaciers are driving sea level rise (see Shoreline Erosion, OWHS 2020). With increased atmospheric CO_2 concentrations, oceans are also becoming more acidic (see Ocean Acidification, OWHS 2020). Ocean acidification is a separate issue from climate change, but both are linked to increases in CO_2.

vi) El Niño Southern Oscillation (ENSO) – irregular, periodic variations in wind and sea surface temperatures over much of the Pacific Ocean, which impact climate in surrounding areas.

vii) Pacific Decadal Oscillation (PDO) – a recurring pattern of ocean-atmosphere climate variability centred over the Pacific basin.

viii) Thermal expansion – water increases in volume as it warms.

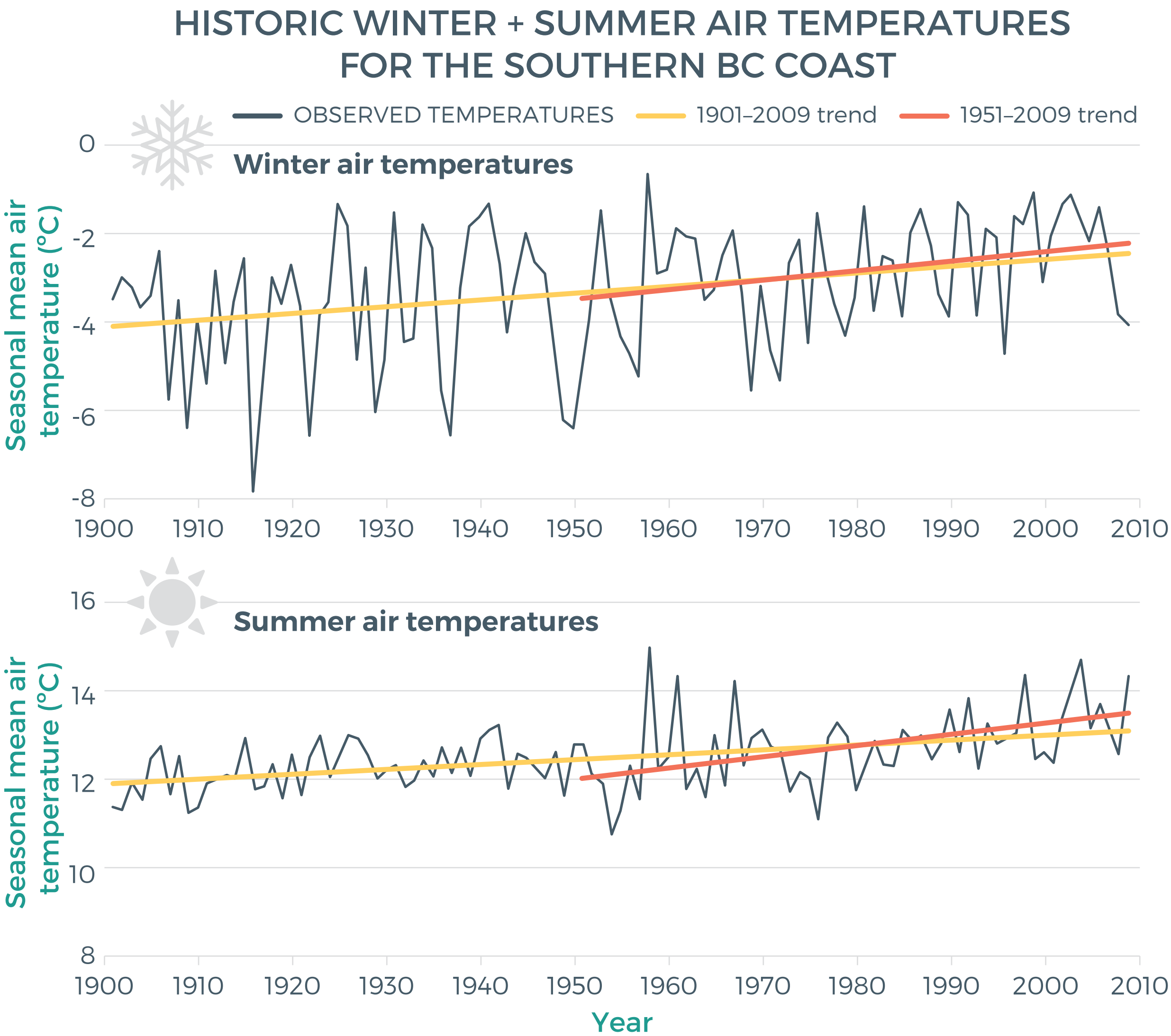

Figure 2. Historical winter (top) and summer (bottom) air temperature time series for the south coast region of B.C., which includes Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Adapted with permission from PCIC, 2013).

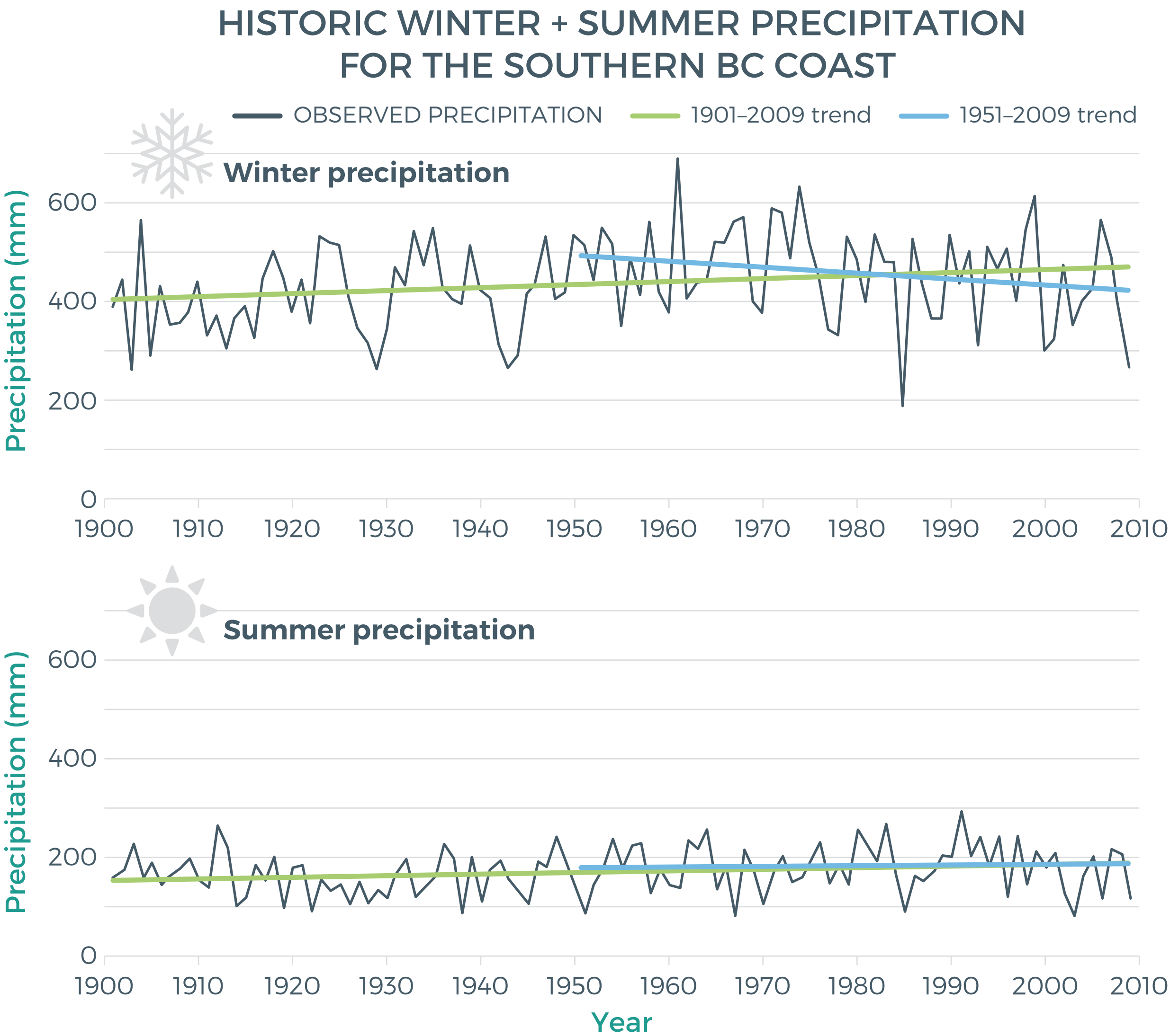

Figure 3. Historical winter (top) and summer (bottom) precipitation for the South Coast region of B.C., which includes Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Adapted with permission from PCIC, 2013).

Future climate change

Projecting future climate changes is a complex and uncertain undertaking. The best tools available for projecting future climates are global climate models (GCMs). These are mathematical representations of the global climate system based on well-established physical and chemical principles. They are now so comprehensive they require super-computing capacities to run.

Once a model has been established and tested, different scenarios can be run to provide estimates of future climate conditions, for example, average and extremes in temperatures and precipitation levels. The scenarios run in these models differ primarily in how many GHGs humans emit and therefore give different projections of climatic conditions. Models may (and do) differ in how they represent various processes (such as how clouds form). Such slight mathematical nuances account for the differences in projections for the same scenarios (illustrated by the shaded areas in Figure 4).

Some predicted results from the Intergovernmental Panel on Climate Change (IPCC) have come from multiple GCMs and consider two emissions scenarios. Based on this work, the future projected changes in temperature until the year 2100, relative to the baseline average (1986 to 2005), are shown (Figure 4). The Representative Concentration Pathway (RCP) 2.6 scenario (Figure 4, blue line) envisions a world with significant global efforts to reduce GHG emissions. By contrast, RCP 8.5 (Figure 4, red line) is "business as usual" scenario, where humanity continues to rely heavily on fossil fuels and there is little international cooperation regarding climate change.[8]

The evidence is clear that global warming is happening and will continue; however, how much warming will occur in the coming decades depends on us (Figure 4). It is impossible to state definitively what is a "maximum acceptable" level of warming. Many scientists and governments believe that 1.5°C is a maximum "safe" acceptable threshold, while some maintain that 2°C is appropriate. However, changes beyond 2°C will result in impacts that are very damaging, and adaptation will be either difficult or impossible. Even a 1.5°C increase in average temperatures will lead to substantial stress on many ecosystems, impacts on resources and huge consequences for many people around the world. Unfortunately, the most vulnerable human populations are typically the least wealthy. Perhaps ironically, it is these people who have the lowest carbon footprints and have contributed the least to climate change.

How climate change is expected to continue specifically in the B.C. South Coast region has been analyzed with outputs from a suite of 30 GCMs, run using multiple emissions scenarios.[7] The median[ix], or average, values (and the 10^{th} to 90^{th} percentile[x] range of pro-

ix) Median – when data points are arranged in order, the median value is that which falls in the middle.

x) 90^{th} percentile – larger than 90% of the datapoints; 10^{th} percentile – larger than 10% of the data points.

jections) are shown below for both temperature and precipitation. Future projections indicate that the region will:

- warm by approximately **1.7°C** (from 1.1 to 2.5°C) in the 2050s, compared to the 1961–1990 baseline;
- become **6%** wetter annually in the 2050s, compared to the 1961–1990 baseline. Increases are projected for winter of 11%, while decreases are projected for summer of 2%.

Not surprisingly, precipitation falling as snow in winter is projected to decrease substantially due to warmer temperatures.

When thinking about projected changes, it is important to consider and plan for a range of potential future scenarios. This helps decision makers prepare for uncertainty, and also encourages people to build resilience into their systems.

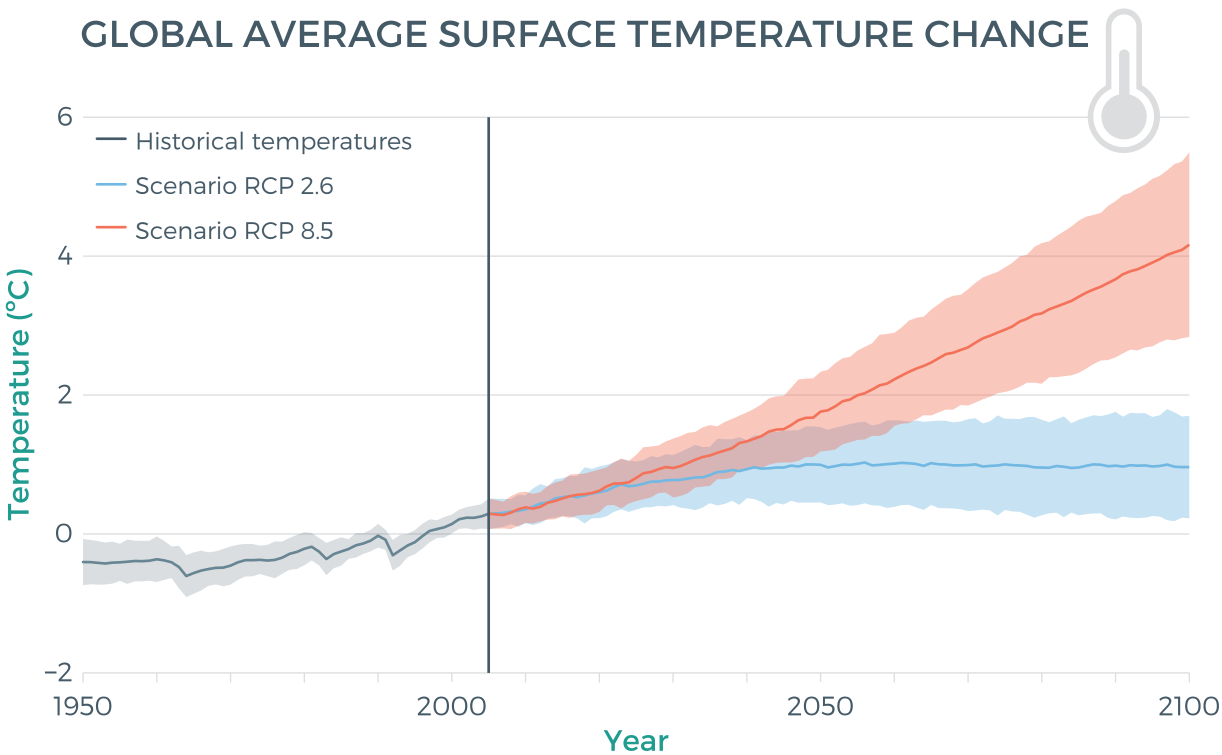

Figure 4. Past (1950–2005) and projected future (2005–2100) temperature changes using a suite of GCM models and two emissions scenarios (RCPs 2.6 and 8.5) relative to the 1986–2005 baseline (from IPCC 2013). In 2100, the RCP 2.6 scenario is approximately 1.5°C above preindustrial temperatures, whereas the RCP 8.5 scenario is 3°C higher, being approximately 4.5°C above preindustrial temperatures. These two scenarios represent substantially different futures with severe global implications. The two scenarios do not start to differ significantly for another 20 to 30 years, around 2050. This is because there are already a lot of GHGs in the atmosphere that will continue to warm the climate for some time, regardless of what action is taken. However, after 2050, the consequences of our actions become apparent as these two scenarios diverge significantly. The shaded areas around the blue and red lines account for differences in projections for the same scenario because of different models used.

Wildfire smoke at the Sea to Sky Gondola. (Credit: Tracey Saxby)

Extreme weather

Climate change does not just mean shifts in averages, but also how often extreme events may occur, and how extreme they may be. Extreme events may include very warm weather, heavy precipitation events, floods and droughts, as well as wildfires (which relate to changes in temperature and precipitation). Projecting shifts in extremes is complex, but a recent study focused on climate change and health includes extensive projection information for the Lower Mainland.[9] Two noteworthy results for the Vancouver area include:

- the number of summer days above 30°C are projected to increase from two days currently to 12 days in 2050;
- the wettest day of the year is expected to deliver 11% more precipitation than it does currently.

Climate change impacts

The changes discussed above will have far-reaching impacts both globally and on local scales, such as in the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region. It is important to remember that an “impact” does not necessarily have to be negative. However, there will likely be more negative than positive impacts associated with climate change because both human and natural systems are designed for a current particular set of conditions, such as temperature and precipitation. The impacts of changes to climate depend heavily on the local and regional contexts. What infrastructure is there currently, and how important is it? How resilient are established systems, biological, physical and social? How much capacity do people have to adapt to change?

Recently, researchers and the District of Squamish partnered to explore what the impacts of climate change will be in the municipality.[10] The near-term (i.e., urgent) and long-term (i.e., not urgent but important to consider) impacts in Sḵwx̱wú7mesh/Squamish are summarized below (Table 1). Although the study did not encompass the entire Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound area, the results are likely to represent the regional impacts. The focus of this work was the Squamish Municipality, so many ecological impacts may be underrepresented or missing.

Wildfire smoke in Squamish. (Credit: Tracey Saxby)

Table 1. Overview of impacts in the District of Squamish. Summarized from Picketts and Hamilton (2016)[10].

IMPACT	DESCRIPTION OF IMPACT AND POTENTIAL ADAPTATION ACTIONS
NEAR TERM PRIORITIES	
Sea level rise (SLR)	The B.C. Government recommends that communities plan for 1 m of SLR by 2100. This level does not consider storm surge flooding. Adaptation approaches relate to protection (e.g., dikes), accommodation (e.g., flood-proofing buildings), retreating (e.g., relocating away from vulnerable areas) and avoiding (e.g., not developing vulnerable areas).
Increased forest fires	Forest fires are increasing in frequency and size in Canada and B.C. due to increased temperatures, changing precipitation and other factors. Adaptation approaches relate to enhanced understanding, identifying high hazard areas and making properties more 'fire smart'.
Extreme precipitation	Climate change is intensifying the hydrological cycle, resulting in more extreme precipitation events that are outside of a normal range. Adaptation approaches relate to infrastructure design and maintenance, and determining if design standards must be changed to account for projected shifts.
LONG TERM PRIORITIES	
Changing river flows	It is difficult to understand the relationship between climate change and river flows (flooding has been increasing in some but not all rivers). More research is needed to determine how to proceed.
Water supply vulnerability	Climate change affects water supply in terms of both quantity and quality. Water conservation is an excellent strategy to address both adaptation and mitigation.
Economic development	Climate has important links to natural resource operations, agriculture, recreation and tourism. Both positive and negative impacts may arise.
Food security	Climate change interacts with food security through ecological impacts (e.g., salmon populations), temperature change (e.g., growing seasons and water demands) and extreme events (e.g., droughts).
Health	Climate change poses both long-term health risks (e.g., air quality and disease vectors) and short-term health risks (e.g., heat waves and fires).

Climate change responses

It is important to consider how climate will change and what can be done to prepare for, adjust to and avoid these changes. There are three principle human responses to climate change:

1. **Climate change adaptation** is fundamentally a process of managing the risks and opportunities brought by climate change and preparing for uncertainty. Adaptation can happen reactively but is generally more effective, less costly and less risky when proactive measures are taken.
2. **Climate change mitigation** focuses on how humans can decrease their long-term effect on the climate. This is accomplished primarily by reducing GHG emissions and enhancing Earth’s natural abilities to sequester GHGs.
3. **Geoengineering**, or direct interference with (aka manipulation of) the climate system to either lower atmospheric GHG concentrations or reduce incoming solar radiation.

We are now at a point in time where the negative impacts of climate change cannot be avoided solely through effective mitigation. *(Recall from Figure 4 that there is a level of continued change that will occur regardless of even the most ambitious GHG reductions.)* Therefore, climate change adaptation is required. That being said, adaptation on its own is not sufficient: there is simply no way that certain systems can adapt to high levels of change. For example, a community may be able to accommodate 1 m of sea level rise, but many areas just could not withstand 3 m of sea level rise. Beyond certain thresholds, a significant percentage of plant and animal species will also face extinction.

Geoengineering is still in its infancy, but it may emerge as another response to climate change alongside significant mitigation and adaptation options. Even strong proponents of geoengineering caution people not to view this response as a panacea – it may only help us to avoid some impacts as we strive to meet ambitious mitigation targets. Moreover, it carries with it a “moral hazard,” that is, society continues to burn fossil fuels and emit carbon dioxide (thus, for example, exacerbating ocean acidification as CO_2 dissolves in seawater) even while geoengineering activity – such as reflecting sunlight back to space — is put in place to lower Earth’s average temperature.

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).

Resources

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

Natural Resources Canada is leading a national assessment of climate change in Canada. The recent "Canada's Changing Climate Report" (Bush and Lemmen 2019) is available from: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR_FULLREPORT-EN-FINAL.pdf

The Intergovernmental Panel on Climate Change (IPCC) is a United Nations body that summarizes and synthesizes the state of knowledge about climate change globally. Find their full assessments and other reports at: https://www.ipcc.ch/

The Pacific Institute for Climate Solutions (PICS) has many educational and informative resources about climate change in B.C. that can be accessed here: https://pics.uvic.ca/

The Pacific Climate Impacts Consortium provides practical climatic information about climate change, models, variability and impacts, available from: https://www.pacificclimate.org/

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The Path to Zero Carbon Municipalities

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What is happening?

We are facing a climate emergency

In September 2018, the Intergovernmental Panel on Climate Change (IPCC) warned that we must take significant action by 2030 in order to limit warming to 1.5° Celsius (C) to avoid worsening the long-lasting and irreversible impacts of climate change. A rapid, far-reaching culture shift is necessary to immediately reduce greenhouse gas (GHG) emissions and minimize impacts on ecosystems and human health.[1]

The growing scientific evidence for climate change is finally having a global social response. In September 2019, more than 6 million people[2] participated in a global climate strike. Inspired by Greta Thunberg's "Skolstrejk för klimatet" (school strike for climate), strikes took place in more than 4,500 locations in 150 countries.[3] Youth are drawing attention to issues of moral responsibility and social justice, highlighting that climate disruptions are

Over 100,000 people gathered in Vancouver B.C. for the global climate strike on 27 September 2019. (Credit: Dr. Timothy J. Raybould) putting billions of people at risk, and disproportionately harming the youngest, poorest, and most vulnerable people who have contributed the least to the problem.[4]

In November 2019, more than 11,000 scientists signed a declaration stating that:

> *“Scientists have a moral obligation to clearly warn humanity of any catastrophic threat and to ‘tell it like it is.’ On the basis of this obligation and the graphical indicators presented below, we declare, with more than 11,000 scientist signatories from around the world, clearly and unequivocally that planet Earth is facing a climate emergency.”*
>
> **WILLIAM J. RIPPLE, CHRISTOPHER WOLF, THOMAS M. NEWSOME, PHOEBE BARNARD, WILLIAM R. MOOMAW, AND 11,258 SCIENTIST SIGNATORIES FROM 153 COUNTRIES.[5]**

More than 475 communities across Canada declared a climate emergency in 2019, including the City of Vancouver, Richmond, Islands Trust Council, Squamish, North Vancouver, West Vancouver, Burnaby, Bowen Island, and Surrey.[5]

The Federal government has also declared a national climate emergency, describing climate change as a “*real and urgent crisis, driven by human activity, that impacts the environment, biodiversity, Canadians’ health and the Canadian economy*” and committing to meet the Paris Agreement targets, as well as deeper reductions to keep global warming below 1.5°C.[6]

Skwxwú7mesh Úxwumixw/Squamish Nation has also declared a climate emergency, and has committed to advocate to all levels of government for climate actions that will reduce Canada’s carbon emissions by 40–60% below 2010 levels by 2030 and to achieve net zero by 2050, to meet the requirements for a stable climate as outlined in the Intergovernmental Panel on Climate Change (IPCC) Report.[7]

To limit warming to 1.5°C, the IPCC report recommends that human-caused emissions of carbon dioxide (CO_2) need to fall 45% below 2010 levels by 2030, and achieve “net zero” by 2050.[1] However, the IPCC’s recommendations have been criticized as too conservative.[8,9] Other scientific studies suggest that limiting warming to 1.5°C will not be sufficient to mitigate climate change impacts to ecosystems and communities.[5,10,11] Climate change is happening much faster than scientists predicted,[1,5,12,13] and new research indicates that climate scientists have consistently underestimated the pace and severity of climate change.[14]

Communities have an opportunity to lead the transition to a zero carbon economy

Communities (i.e., cities, towns, and villages) consume 75% of the world’s energy, and emit 80% of greenhouse gases.[15] Communities are also uniquely positioned to take immediate action to reduce greenhouse gas emissions as decisions on land use, buildings, local transport, and waste are largely controlled at the local level.[16]

Addressing our climate emergency is an unprecedented opportunity to generate new, vibrant economic and social wealth as we transform where our energy comes from and how it is used. It is an opportunity to achieve energy security, develop more sustainable economies and jobs, become better environmental stewards, reduce pollution, improve public health, and enhance our quality of life. Transitioning away from fossil fuels to a zero carbon economy has clear benefits for people and natural ecosystems, and is an opportunity to create a more prosperous and equitable society.[1,16,17,]

> *“The world has seen remarkably fast economic transition in the past and can do so again. We can create 100% renewable energy systems, make our buildings, transport, agricultural and industrial systems zero carbon, minimise waste – and do it remarkably quickly.”*
>
> **– BEYOND ZERO EMISSIONS[16]**

Students from Sḵwx̱wú7mesh/Squamish, B.C. call for immediate climate action at the global climate strike on September 27, 2019. (Credit: Tracey Saxby)

What is a zero carbon community?

A zero carbon community is one that is taking strategic and targeted actions to reduce community-wide greenhouse gas emissions to zero within ten years.[17]

Local governments around the world are leading the way on climate action by setting bold greenhouse gas reduction targets for community-wide emissions, and aligning these targets with the latest climate science and international agreements.[17] Many communities across Canada are already working towards achieving 100% renewable energy goals[18] and zero emissions targets.[19]

The internationally recognized climate change think tank, Beyond Zero Emissions, recommends a ten-year timeframe to transition to zero carbon, stating that:

> *"Without ambition to take this challenge seriously we will fail before we begin. Setting an ambitious target is challenging but also inspires leadership and innovative solutions. Leading communities need to aim high and demonstrate that rapid change is possible."*
>
> **BEYOND ZERO EMISSIONS**[16]

The technology needed to transition to zero carbon already exists. Creating thriving, zero carbon communities is achievable and affordable now.[17] Atl'ḵa7tsem/Txwnéwu7ts/Howe Sound communities have an opportunity to lead this transition to a zero carbon economy, and inspire other communities across Canada.

Collaboration is essential to achieve zero carbon

Climate change is too big and too complex to be addressed by a single entity alone. Identifying solutions and inspiring behaviour change will require collaboration between all levels of government (including First Nations), and profit and non-profit sectors.

Why is it important?

Climate change is already impacting Atl’ḵa7tsem/ Txwnéwu7ts/Howe Sound communities

Canada’s climate is warming twice as fast as the rest of the world, while the Canadian Arctic is warming at three times the global rate. This warming is effectively irreversible on multi-century timescales.[20] The increased concentration of greenhouse gases in our atmosphere has led to the following direct climate change impacts for Canada (Figure 1):

- rising sea levels
- increased precipitation with less falling as snow and more as rain
- increased intensity and severity of extreme weather events
- more extreme heat and less extreme cold
- shorter snow and ice cover seasons
- earlier spring peak streamflow
- thinning glaciers
- thawing permafrost.[21]

Ocean acidification is happening at the same time as climate change, because about a third of the carbon dioxide released from fossil-fuel combustion has dissolved into the upper ocean, making it more acidic. This threatens the survival of organisms such as oysters that make their shells from calcium carbonate, and threatens the health of marine ecosystems.[21] Ocean acidification negatively impacts the ability of oceans to absorb carbon through photosynthesis, creating a positive feedback loop[i] that further contributes to climate change.

Indirect impacts of climate change and/or ocean acidification include, for example:

- reduced biodiversity
- ecosystem changes
- species shifts
- loss of critical ecosystem services
- social and economic impacts
- human health impacts
- reduced food security and increased food costs
- increased socio-economic disparity
- increased flooding
- increased drought and wildfire risk
- increased erosion
- damage to physical infrastructure
- reduced freshwater supply in summer
- pest and disease outbreaks
- loss of key fisheries (Figure 1).[21]

i) Feedback loop – where the output from that system can feedback into the system, resulting in either negative or positive outcomes.

Impacts of greenhouse gas emissions

Figure 1. The increased concentration of greenhouse gases in our atmosphere results in direct climate change impacts (orange) and ocean acidification (purple), which then lead to indirect impacts (yellow). For example, increased intensity and severity of extreme weather events (direct impact) can cause damage to physical infrastructure and social and economic impacts (indirect impacts).[21]

Climate change costs are primarily being borne by municipalities

The costs of adapting to climate change are primarily being borne by municipalities, which own 60% of public infrastructure,[21] posing a significant burden on their often-limited financial capacity. The Federation of Canadian Municipalities and the Insurance Bureau of Canada estimate that an average annual investment in municipal infrastructure and local adaptation measures of $5.3 billion is needed Canada-wide to adapt to climate change.[22] For example, the cost of upgrading dike infrastructure to prepare Metro Vancouver for one meter of sea level rise is estimated to be in the range of $9.5 billion.[22]

The good news is that every $1 invested by communities in local adaptation projects yields an estimated $6 in terms of climate costs avoided.[23] Early action is vital, as it is more cost-effective, and allows communities to take advantage of natural opportunities to upgrade infrastructure and plan for zero carbon communities.[24]

Climate Strike Squamish. (Credit: Tracey Saxby)

What is the current status?

Canada is not on track to achieve our greenhouse gas reduction targets

Canada is one of the top ten polluting countries in the world, producing 1.58% of total worldwide greenhouse gas emissions in 2016 (Figure 2),[25] with per capita emissions more than 2.5 times higher than the G20[ii] average.[26]

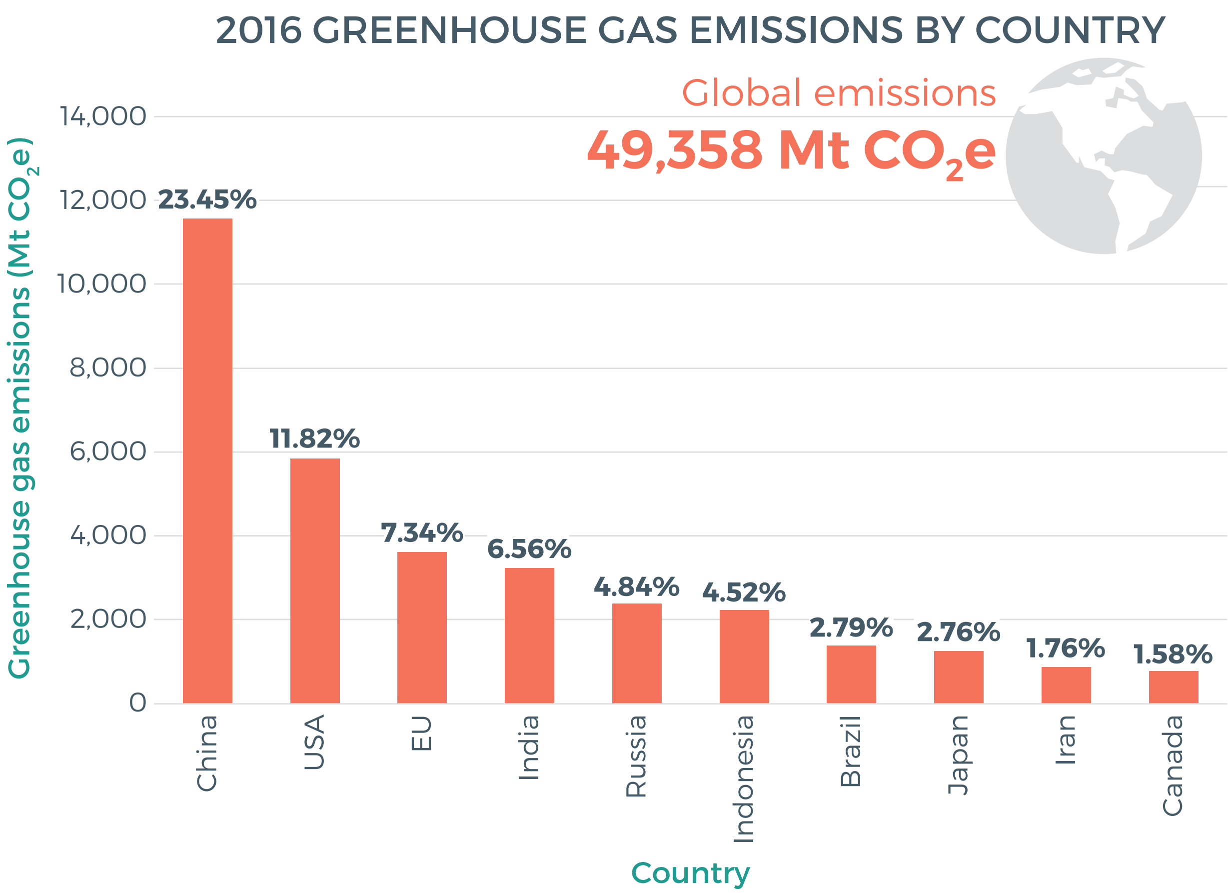


Figure 2. Canada is amongst the top ten producers of greenhouse gas emissions in the world. SOURCE: Climate Watch (2018)[26]

ii) The G20 comprises 19 countries and the European Union. The 19 countries include: Argentina, Australia, Brazil, Canada, China, Germany, France, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the United Kingdom, and the United States.

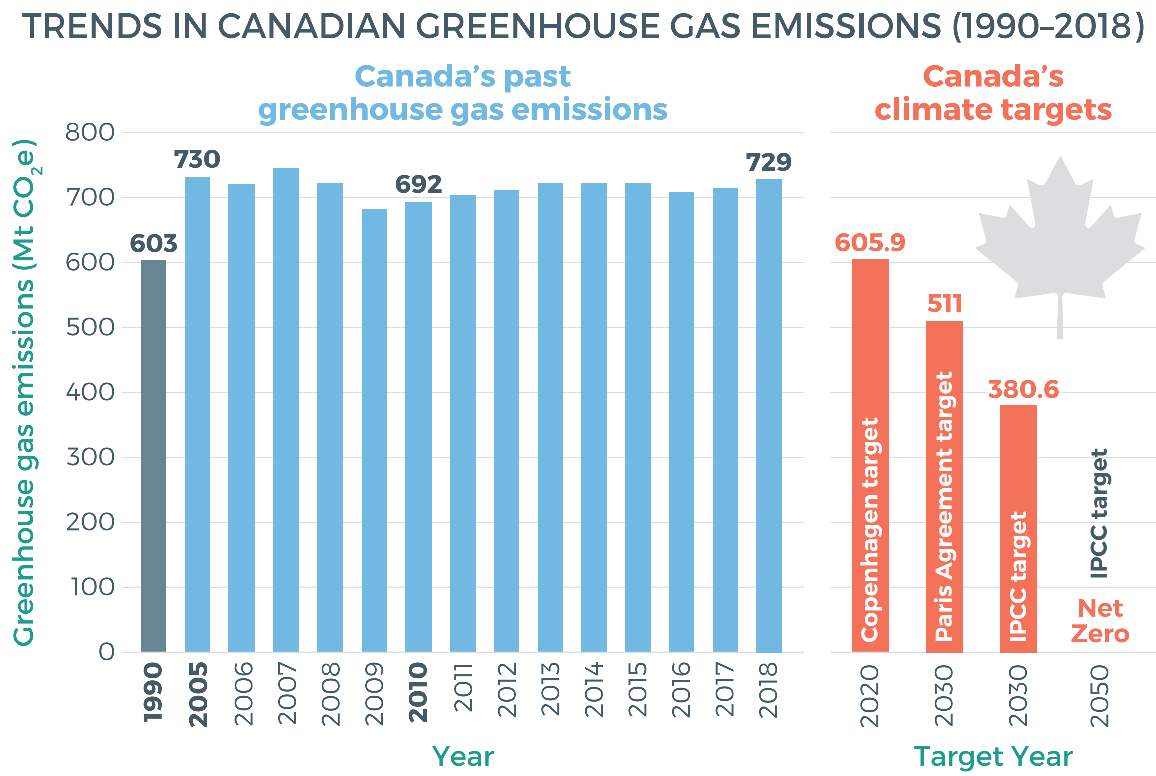


Figure 3. Canada’s annual greenhouse gas emissions have increased by 20.9% since 1990, and emissions have resumed an increasing trend since 2016.[28] To achieve the Copenhagen targets for 2020, Canada needs to reduce emissions 17% below 2005 levels to 605.9 Mt CO_2e.[31] To achieve the Paris Agreement target for 2030, Canada needs to reduce emissions 30% below 2005 levels to 511 Mt CO_2e.[31] To achieve the latest IPCC recommended targets, Canada needs to reduce emissions 45% below 2010 levels to 380.6 Mt CO_2e by 2030 and net zero by 2050.[1] Adapted from Environment and Climate Change Canada (2020).[28]

In 2018, Canada’s total greenhouse gas emissions increased to 729 megatonnes (Mt) of CO_2 equivalent (CO_2e),[iii] which averages out to 19.67 tonnes of CO_2 equivalent per person.[27,28] Since 1990, Canada’s total greenhouse gas emissions have increased by 20.9%, and while emissions have been relatively static since 2005, the last three years have shown an increasing trend (Figure 3).[28] Canada has missed every greenhouse gas emissions reduction target it has set since 1992,[29] and is not on track to achieve any of the greenhouse gas reduction targets outlined below:[27]

- 17% below 2005 levels by 2020 (Copenhagen Accord 2009); [30]
- 30% below 2005 levels by 2030, with a long-term goal of 80% below 2005 levels by 2050 (Paris Agreement 2015);[31]
- Canada has yet to adopt the latest targets recommended by the IPCC report of 45% below 2010 levels by 2030, and “net zero” by 2050.[1]

In 2018, an assessment of climate policies worldwide revealed that Canada’s current policies would lead to more than 5.1°C of warming by 2100 if they were adopted globally.[31] Since then, the Federal government has committed to: phase out coal power plants;[32] implement a nationwide carbon price starting at CAD $20 per tonne of CO_2e in 2019[33] and increasing annually; and enact the Canadian Energy Regulator Act (CERA)[34] to oversee the energy sector. The 2019 Climate Transparency assessment for Canada notes that despite these improvements to federal policies, Canada is still not on track to achieve emissions reductions compatible with 1.5°C of warming to prevent irreversible impacts of climate change.[27] The Parliamentary Budget Office has recommended that the federal carbon tax needs to increase by an additional CAD $50 a tonne by 2030 to meet the Paris Agreement.[35]

iii) CO_2 equivalent or carbon dioxide equivalent (CO_2e), is a standard unit for measuring carbon emissions. The idea is to express the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of warming. Greenhouse gases that are included in CO_2e are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

What is being done?

Comparison of climate actions and climate targets for Atl'ḵa7tsem/Txwnéwu7ts/Howe Sound municipalities and regional districts

Several municipalities around Atl'ḵa7tsem/Txwnéwu7ts /Howe Sound have now declared a climate emergency, and updated their climate targets to reflect the latest IPCC recommendations of 45% below 2010 levels by 2030, and "net zero" by 2050.[1] We have compared specific climate commitments for municipalities around Atl'ḵa7tsem/Txwnéwu7ts/Howe Sound (Table 1) and reviewed current climate targets (Table 2).

Table 1. Comparison of climate commitments for municipalities and regional districts around Atl'ḵa7tsem/Txwnéwu7ts/Howe Sound.[6,56–74] SCRD – Sunshine Coast Regional District. SLRD – Squamish-Lillooet Regional District.

YES | NO | IN PROGRESS

CLIMATE ACTIONS	BOWEN ISLAND	GIBSONS	LIONS BAY	SQUAMISH	VANCOUVER (CITY OF)	WEST VANCOUVER	WHISTLER	ISLANDS TRUST	SCRD	SLRD
Declared a climate emergency	Yes	No	No	Yes	Yes	Yes	No	Yes	No	No
Created a climate emergency response plan	No	No	No	Yes	Yes	In progress	In progress	No	No	No
Have set climate targets	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Have set climate targets equal to (or higher than) the 2019 IPCC recommendations of 45% greenhouse gas reduction by 2030 and net-zero by 2050	No	No	No	Yes	Yes	Yes	No	No	No	No
Climate action has been identified as a strategic priority	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Climate change rally. (Credit: Brett Vo)

Table 2. Current climate targets for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound municipalities and regional districts. SCRD – Sunshine Coast Regional District. SLRD – Squamish-Lillooet Regional District.

COMMUNITY	TARGETS
Bowen Island	33% below 2007 levels by 2020[37]
Gibsons	7% below 2007 levels by 2030[38]
Lions Bay	20% below 2007 levels by 2020[41]
Squamish	45% below 2010 levels by 2030
	100% below 2010 levels by 2050[44]
Vancouver	33% below 2007 levels by 2020
	50% below 2007 levels by 2030
	Carbon neutral before 2050[46]
West Vancouver	45% below 2010 levels by 2030
	100% below 2010 levels by 2050[47,48,49]
Whistler	33% below 2007 levels by 2020
	80% below 2007 levels by 2050
	90% below 2007 levels by 2060[50]
Islands Trust	
Keats Island	33% below 2007 levels by 2020
	85% below 2007 levels by 2050
Gambier Island	33% below 2007 levels by 2020
	85% below 2007 levels by 2050[51,52]
SCRD	7% below 2007 levels by 2031[37,53]
SLRD	33% below 2007 levels by 2020
	80% below 2007 levels by 2050[54,55]

How are we currently tracking greenhouse gas emissions?

Local government reporting: Climate Action Revenue Incentive Program (CARIP)

Local governments in Canada have been world leaders in climate action since as early as 1988.[36] Since 2007, 187 of 190 local governments have signed on to the B.C. Climate Action Charter, which is a voluntary agreement between the B.C. government, the Union of B.C. Municipalities, and each local government signatory to take action on climate change.[37]

Under the Charter, local governments commit to:

- become carbon neutral in their corporate operations;
- measure and report community-wide greenhouse gas emissions; and
- create more complete, compact, and energy efficient communities.

The B.C. Climate Action Charter is non-binding, and there are no accountability mechanisms or legislated targets to significantly reduce emissions at the municipal level. While many Atl’ḵa7tsem/Txwnéwu7ts/Howe Sound municipalities report corporate emissions every year through the CARIP, which enables them to receive a grant equivalent to 100% of the carbon tax they pay,[38] most municipalities are not independently reporting community-wide greenhouse gas emissions (Table 3). This is partially due to budget and staff capacity constraints, particularly for smaller communities, and partially due to the lack of complete data available to easily track emissions at the local level.

Transportation is one of the biggest sources of carbon pollution in Atl’ḵa7tsem/Txwnéwu7ts/Howe Sound communities. The solution is to get people out of their gas-powered cars and into electric cars, or to use more public transit and active transportation such as biking and walking. Photo: iStock

Table 3. Comparison of CARIP reporting and specific climate adaptation actions taken by municipalities and regional districts around Atl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[37–55] SCRD – Sunshine Coast Regional District. SLRD – Squamish-Lillooet Regional District.

YES | NO | IN PROGRESS | NOT APPLICABLE

CLIMATE ACTIONS	BOWEN ISLAND	GIBSONS	LIONS BAY	SQUAMISH	VANCOUVER (CITY OF)	WEST VANCOUVER	WHISTLER	ISLANDS TRUST	SCRD	SLRD
Have signed the BC Climate Action Charter to become carbon neutral in corporate operations and to reduce community-wide emissions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reported corporate emissions in 2018/2019	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reported community-wide emissions in 2018/2019	No	No	No	Yes	Yes	No	Yes	No	No	No
Climate Action is incorporated into the Official Community Plan (OCP)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	In progress (iv)
Have a corporate greenhouse gas reduction plan	No	No	No	Yes	Yes	Yes	Yes	Yes	In progress	No
Have a community-wide climate action plan	Yes	No	No	Yes	Yes	Yes	Yes	No	In progress	No
Have a community energy and emissions plan	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes
Have an integrated community sustainability plan	No	Yes	No	No	Yes	No	Yes	Not applicable	No	Yes
Have a regional growth strategy	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Yes	No	Yes
CLIMATE ADAPTATION ACTIONS LISTED IN CARIP FOR 2018										
Risk and vulnerability assessments	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Risk reduction strategies	Yes	Yes	No	Yes	Yes	No	Yes	No	No	Yes
Emergency response planning	Yes	Yes	No	Yes	Yes	Yes	Yes	Not applicable	No	Yes
Asset management	Yes	Yes	No	Yes	Yes	Yes	Yes	Not applicable	Yes	No
Natural/eco asset management strategies	Yes	Yes	No	No	Yes	Yes	No	Not applicable	No	No
Infrastructure upgrades (e.g. stormwater system)	Yes	Yes	No	Yes	Yes	Yes	No	Not applicable	Yes	No
Beach nourishment projects	No	Yes	No	No	No	Yes	No	No	No	No
Economic diversification initiatives	Yes	Yes	No	Yes	Yes	No	Yes	Not applicable	Yes	No
Strategic and financial planning	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Cross-department working groups	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Official community plan policy changes	No	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Changes to zoning and other bylaws and regulations	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Incentives for property owners (e.g. reducing stormwater run-off)	Yes	No	No	No	Yes	No	Yes	Yes	No	No

iv) Climate Action is incorporated into one of four of the SLRD’s Official Community Plans, for Electoral Area D. Updates are in progress for the other three Official Community Plans.

Provincial government reporting: Community Energy and Emissions Inventory (CEEI)

The Community Energy and Emissions Inventory (CEEI) provides a framework for tracking and reporting emissions from buildings, local transport, and waste to support local governments to meet their commitments under the BC Climate Action Charter (Figure 4).[39]

CEEI reports were first made available by the Province for every municipality in BC in 2007, 2010, and 2012,[40] with a more limited data set published every year since 2012 as part of the Provincial Greenhouse Gas Emissions Inventory.[41] The 2013–2017 data sets only include emissions from buildings and waste, as the Climate Action Secretariat does not have access to accurate community-level transportation data. The Province is currently exploring options to collect information on annual vehicle use at the community level.[42]

CEEI reporting is reliant upon data providers (e.g., utilities) and the Province to complete the rigorous data collection, analysis, and reporting required. There is often a significant time lag between data reporting and data availability, for example, 2017 data was published in 2019.

Federal government reporting: National Inventory Report (NIRs)

Every year since 2003, Canada has prepared a National Inventory Report (NIR)[28] to report sector-based emissions, and submitted it to the United Nations Framework Convention on Climate Change (UNFCCC).[43] Although NIRs include 'chapters' for each province and territory, the Province of BC generates its own Provincial Inventory Reports (PIR), which is largely based on the NIR.

These data overlap with CEEI reporting on buildings, transport, and waste; however emissions are calculated using different data, scope boundaries, and a different methodology, and also include emissions from industry, agriculture, and oil & gas production (Figure 4).

What aren't we measuring? Consumption-based emissions inventory (CBEI)

A consumption-based emissions inventory (CBEI) calculates emissions associated with the production, transportation, use, and disposal of goods and services consumed by communities, such as food, clothing, electronics, services, and flights (Figure 4).[44]

In 2014, C40 Cities initiated a study to measure consumption-based greenhouse gas emissions from 79 cities from around the world, including Vancouver.[45] Upstream emissions from the goods and services that cities consume can be more than double the emissions currently measured through traditional territorial or sector-based emissions inventories. Consumption-based emissions associated with residents in wealthy, industrialized countries, such as Canada, are 2–4 times higher than the global average.[64,65]

Limiting emissions calculations to the CEEI or NIR frameworks means that additional emissions associated with consumption of goods and services are not being measured. The British Columbia Institute of Technology is currently piloting a project called the *ecoCity Footprint Tool* in ten communities across B.C. to identify each community's ecological footprint and create a consumption-based emissions inventory.[46]

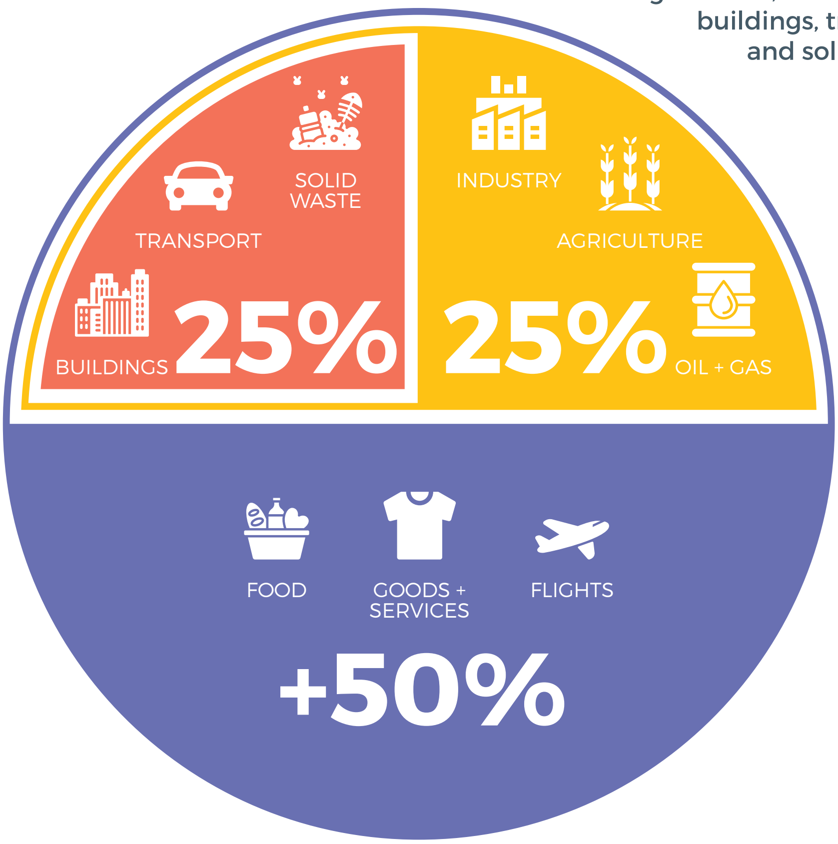
What is and isn’t being measured?

Community Energy Emissions Inventory (CEEI)

The Provincial government tracks and reports greenhouse gas emissions produced by buildings, transport, and solid waste.

National Inventory Report (NIR) (Territorial or sector-based emissions)

The Federal government tracks and reports greenhouse gas emissions calculated by sector, e.g., industry, agriculture, oil + gas, plus buildings, transport, and solid waste.



Consumption-Based Emissions Inventory (CBEI)

Greenhouse gas emissions associated with the production, transportation, use, and disposal of products and services consumed by a community. These emissions are not currently being tracked by the Provincial or Federal governments.

Figure 4. A simplified comparison of methodologies to measure greenhouse gas emissions: Community Energy Emissions Inventory (CEEI) measures emissions from buildings, transport, and solid waste, which comprises approximately 25% of total emissions. The National Inventory Report measures sector-based emissions that overlap and build on CEEI, and includes emissions from industry, agriculture, and oil and gas; however, this still only comprises approximately 50% of total emissions. Nearly 50% of emissions associated with the production, transportation, use, and disposal of food, goods, and services are not currently measured, which is why we need to begin measuring emissions using Consumption-Based Emissions Inventory (CBEI) to track total emissions at the local, provincial, and federal level of government.

Independent municipal greenhouse gas emissions reported by Atl’ḵa7tsem/Txwnéwu7ts/Howe Sound communities

To reduce local greenhouse gas emissions, it is fundamental to understand where these emissions are coming from. Some communities in Atl’ḵa7tsem/Txwnéwu7ts/Howe Sound have chosen to conduct independent community-wide greenhouse gas emission inventories, using the CEEI framework to track emissions from buildings, transport, and solid waste. Whistler has been tracking emissions almost every year since 2010,[47] while Sḵwx̱wú7mesh/Squamish recently conducted an independent emissions inventory for 2017 (Figure 5).[48] Metro Vancouver is currently developing annual reporting of greenhouse gas emissions as part of its *Climate 2050* strategy, using the CBEI framework.[49]

Tracking local greenhouse gas emissions is critical to support evidence-based climate action planning. By tracking emissions, municipalities can identify where emissions are coming from, and pass policies that strategically reduce those emissions. By tracking emissions annually, it allows municipalities to evaluate whether specific policies and public engagement campaigns are effective, or if more needs to be done. Local governments are much more agile than Provincial/Federal government, and can adopt and test new policies quickly. Tracking emissions also enables local governments to engage with stakeholders and decision-makers, and inspire behaviour change among their constituents.

We compare the example greenhouse gas emissions inventories for Sḵwx̱wú7mesh/Squamish (2017), Whistler (2018), and West Vancouver (2010) (Figure 5). Emissions cannot be compared directly between these municipalities because the inventories were completed in different years and used different methodologies. Even so, it is clear that vehicles and buildings are the two biggest sources of greenhouse gas emissions for all three communities (Figure 5). This information provides a clear direction for strategic climate action planning. For example, what policies can municipalities pass to support the transition from gas-powered cars to electric cars? How can municipalities improve public transit and support active transportation? How can municipalities incentivize a rapid transition to zero-emission energy and heating in new and existing buildings?

What about emissions from industry and agriculture?

Greenhouse gas emissions from industry and agriculture are often outside of municipal control, and will require policies and taxes/incentives from the provincial and/or federal governments. However, municipalities can still play a role by engaging in conversation with local industries and local agriculture, to ask what they are doing to reduce carbon pollution, which can often dwarf community-wide emissions. Municipal councils can also lobby the provincial and federal governments to support new policies and taxes/incentives to reduce local emissions from industry and support regenerative agricultural practices.

Greenhouse gas emission inventories

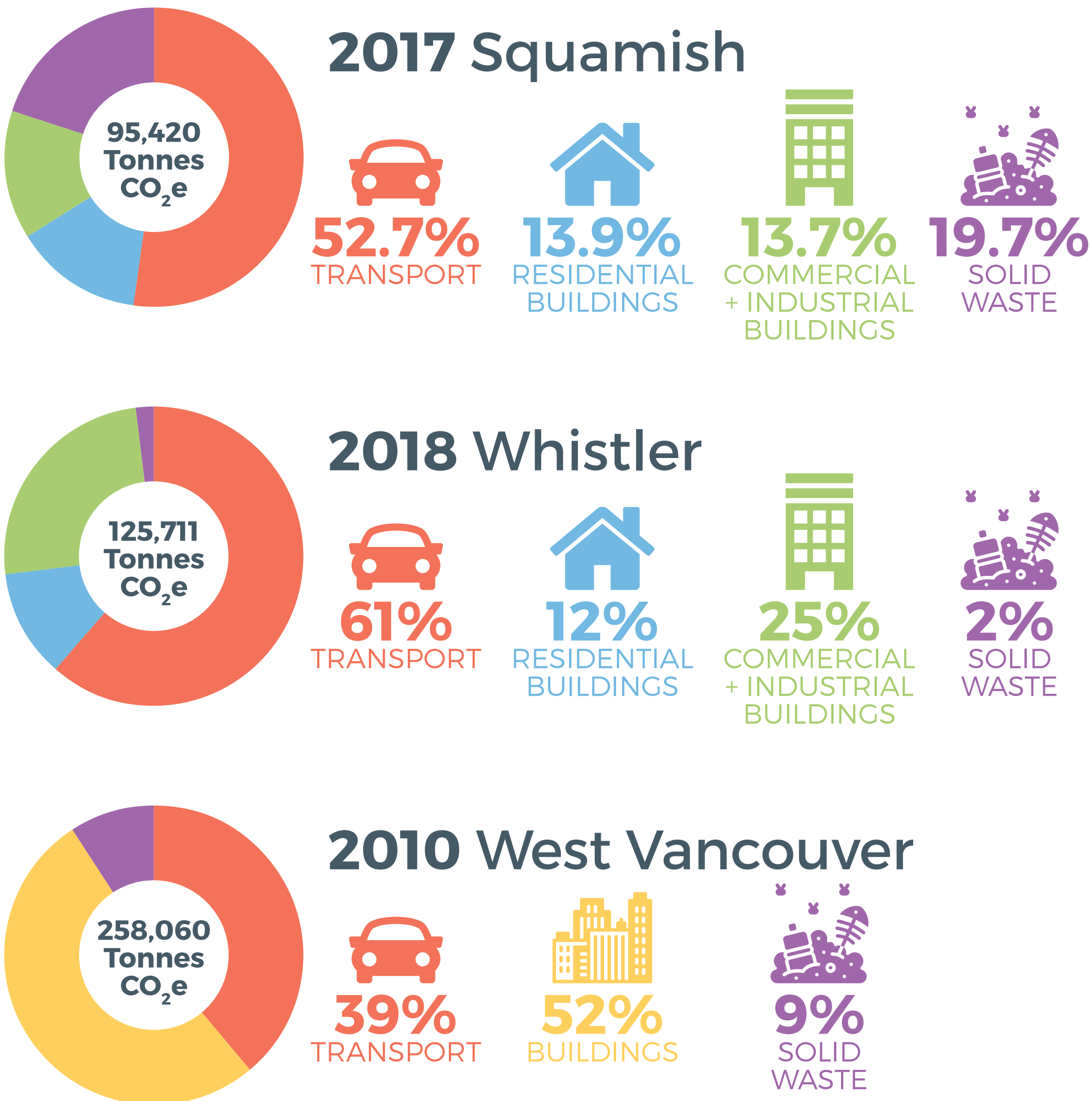


Figure 5. Community-wide greenhouse gas emissions for Sḵwx̱wú7mesh/Squamish (95,420 tonnes CO_2e in 2017),[45] Whistler (125,711 tonnes CO_2e in 2018),[54] and West Vancouver (258,060 tonnes CO_2e in 2010).[55] Note that emissions cannot be compared between municipalities because the methodology and years when these inventories were compiled are different e.g., West Vancouver assessed residential and commercial/industrial buildings under “buildings.”

What can you do?

These actions are aimed at government level because the focus of this article is on municipalities. Actions that individuals can take will be presented in a separate article, coming at a later date.

Government Actions and Policy:

Municipal Actions

- Declare a climate emergency to enable council and staff to dedicate the resources required to immediately reduce community-wide greenhouse gas emissions.
- Update greenhouse gas reduction targets to reflect (or surpass) IPCC recommendations (45% reduction below 2010 levels by 2030 and achieving net zero by 2050 at the latest).
- Conduct a baseline greenhouse gas emission inventory, with ongoing monitoring and reporting of community-wide emissions every year to track success.
- Establish interim targets and incorporate these targets into all relevant municipal planning documents (e.g., Official Community Plan, Community Energy and Emissions Plan).
- Establish community engagement and outreach to build widespread support for climate action.
- Create a climate action plan to prioritize policies and actions that will be the most effective at reducing community-wide greenhouse gas emissions. Identify challenges and opportunities, and establish key evaluation criteria to evaluate success.
- Implement the climate action plan, then monitor, evaluate, and report on successes and challenges. Adjust climate action strategies to ensure that emission reductions are successful.
- Build partnerships with local climate champions, businesses, industry, agriculture, community groups, and organizations.
- Build regional partnerships with other communities to share resources, implement programs, and secure greater levels of funding and investments.
- Support the Provincial and Federal governments to implement the policies and actions outlined below.

Provincial and Federal Actions

CARBON ACCOUNTING AND ACCOUNTABILITY

- Support evidence-based climate-action planning by local governments by conducting consistent, comprehensive, robust, and timely greenhouse gas inventories every year at the municipal level across B.C. and Canada. [50]
- Initiate discussions to determine how best to make greenhouse gas reduction targets binding for all provinces/municipalities. For example, make the B.C. Climate Action Charter binding.[72]
- Legislate a target of 45% reduction below 2010 levels by 2030 and achieve net-zero emissions by 2050 at the latest.[1,27] Ensure consistent targets for all levels of government, and update these targets regularly according to the latest science.[72]
- Support Local Government Act and/or Community Charter amendments which empower municipalities to achieve local climate targets.[72]
- Implement policies and legislation to provide funding and capacity building for municipalities as they transition to zero-carbon emissions.[22]
  - Develop a milestone-based incentive program to help municipalities achieve climate targets.[72]
  - Develop a climate action policy toolkit that municipalities can adapt and implement.[72]
- Convene experts (including municipalities) to identify what data needs to be collected to accurately track greenhouse gas emissions using both the CEEI and CBEI frameworks, then legislate development of and access to this data. For example, require ICBC to collect odometer readings when people renew their car insurance.
- Improve CEEI methodology to accurately track community-wide greenhouse gases and provide that data to the municipalities and the public online every year (contributing to Locally Determined Contributions).
- Transition to CEEI and CBEI at the municipal level to capture emissions that are not currently measured (e.g., embodied emissions from food, goods + services, flights).
- Standardize greenhouse gas inventory calculations between Local/Provincial/Federal governments (allow Locally Determined Contributions to inform Nationally Determined Contributions)

SOCIAL JUSTICE

- Ensure equity and anti-racism are key components of climate action.[51]
- Expand the Pan-Canadian Framework to support a just and fair transition for oil and gas workers and communities as we transition to a zero-carbon economy.[27]
- Support developing nations as they transition away from fossil fuels toward a zero-carbon economy.[5]
- Enact legislation to better enable municipalities and individuals to hold fossil fuel companies accountable for past greenhouse gas emissions and to pay their fair share of climate costs.[52]

FOOD

- Implement policies to reduce the consumption of animal products – the production of which releases significant amounts of methane – and increase consumption of plant-based foods.[5]
- Implement policies to support cropping practices such as minimum tillage to increase soil carbon.[5]
- Implement policies to promote local agriculture and eliminate food waste.[5]

Provincial and Federal Actions (continued)

ENERGY

- Implement energy efficiency and conservation practices.[5]
- Promote electrification of space-heating infrastructure (e.g. heat pumps).
- Promote installation of district heating systems.
- Replace fossil fuel energy with low-carbon renewable energy and phase out fossil fuel extraction.[5]
- Eliminate subsidies for fossil fuels.[5]
- Increase carbon emissions taxes systematically and progressively over defined long-term periods to further limit fossil fuel use.[5,36]
- Implement policies to promptly reduce emissions that have a high global warming potential over a short time frame such as methane, black carbon (soot), and hydrofluorocarbons (HFCs) to slow climate feedback loops and reduce short-term warming by more than 50%.[5]

TRANSPORTATION

- Adopt a Clean Fuel Standard and enhance measures for zero-emissions vehicles, including light and heavy-duty trucks.[27]
- Revise the Zero-Emission Vehicle Infrastructure Programme so that 100% of vehicle sales by 2030 are zero-emission.[27]
- Increase funding for investments in public transit with the goal to remove commuter traffic from the roads.[27]
- Subsidise electric vehicles while investing in fast-charging infrastructure along major roads.
- Transition BC Ferries to electric ferries where feasible.
- Increase carbon taxes on aviation emissions and provide incentives to transition to electric planes for short-haul flights; invest in alternatives such as high-speed rail along high-population-density routes.

BUILDINGS

- Implement policies and incentives for all new buildings to be net-zero.[27]
- Develop a strategy and provide incentives to undertake energy retrofits of existing buildings.[27]

ECONOMY

- Shift economic goals away from Gross Domestic Product (GDP) growth to the Happiness Index metric,[53] and recognize that humans depend on healthy ecosystems.[5]
- Redefine economic success to incorporate factors that measure human well-being and the health of ecosystems.

NATURE

- Create more protected areas with better interconnectedness.[5]
- Fund restoration of natural ecosystems.[5]
- Protect remaining primary and intact forests to curtail habitat and biodiversity loss.[5]
- Fund and incentivize reforestation and afforestation (i.e., planting trees) where appropriate.[5]
- Continue to fund research and monitoring of iconic and threatened species and habitats.

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Resources on Zero Carbon

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

My Sea to Sky has issued a #ZeroCarbonChallenge for individuals, businesses, and municipalities around Atl'ḵa7tsem/Howe Sound. Sign up as an individual or business and learn what tangible steps you can take now to start the transition to zero carbon: www.zerocarbonchallenge.ca

Climate Caucus is a non-partisan network of 250+ elected local leaders working collectively to create and implement policy which aligns with Canada's fair share of holding global temperature to 1.5°C, while respecting planetary limits: https://www.climatecaucus.ca/

Beyond Zero Emissions is one of Australia's most respected climate change think-tanks. They have created a step-by-step guide for communities working to achieve zero-carbon emissions: https://bze.org.au/zero-carbon-communities/zero-carbon-communities-guide/

BC Climate Action toolkit: https://www.toolkit.bc.ca/

Clean BC has resources on subsidies and savings for switching to an electric vehicle. https://goelectricbc.gov.bc.ca

Project Drawdown identifies the most effective solutions to reduce greenhouse gas emissions. https://www.drawdown.org/

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Climate Strike Squamish. (Credit: Tracey Saxby)

Ocean Warming: what’s heating up the Sound?

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What is happening?

According to the National Oceanic and Atmospheric Administration (NOAA), 2019 was the second warmest year on record since 1880 (Figure 1). Globally, the average temperature from combined land and ocean surface was 0.95°C above the twentieth-century average.

The globally averaged ocean-only temperature for 2019 was 0.77°C above average, also the second highest year on record. Many of the major oceans, including the Pacific Ocean, had record high sea-surface temperatures recorded in 2019.[1] This pattern continues a trend that is being seen year after year. On average, Canada is warming at twice the speed of the rest of the world, with warming in Northern Canada occurring even faster.[2]

Diver on the Annapolis. (Credit: Eli Wolpin)

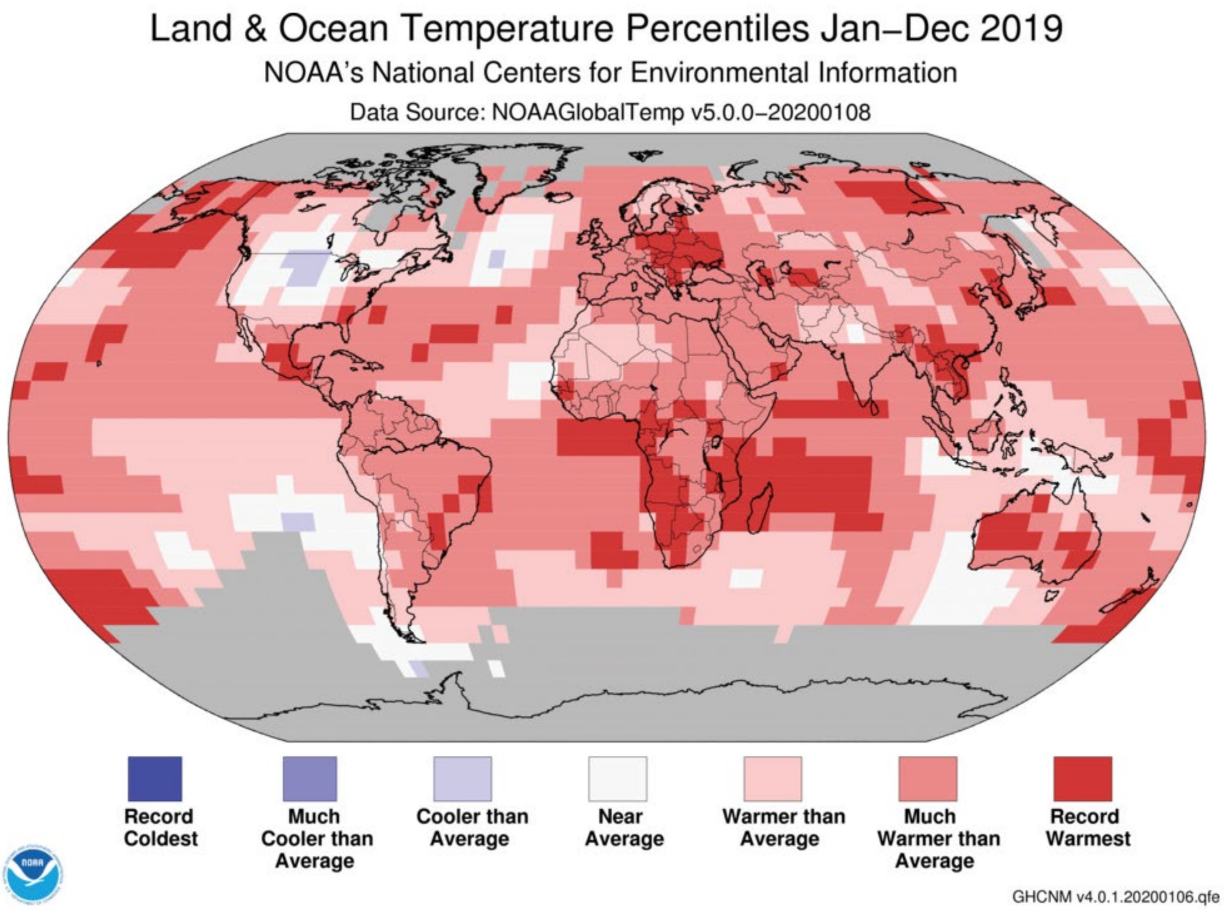


Figure 1. Land and ocean temperature percentiles from January to December 2019, compared to averages for the twentieth century. Source: NOAA National Centers for Environmental Information.

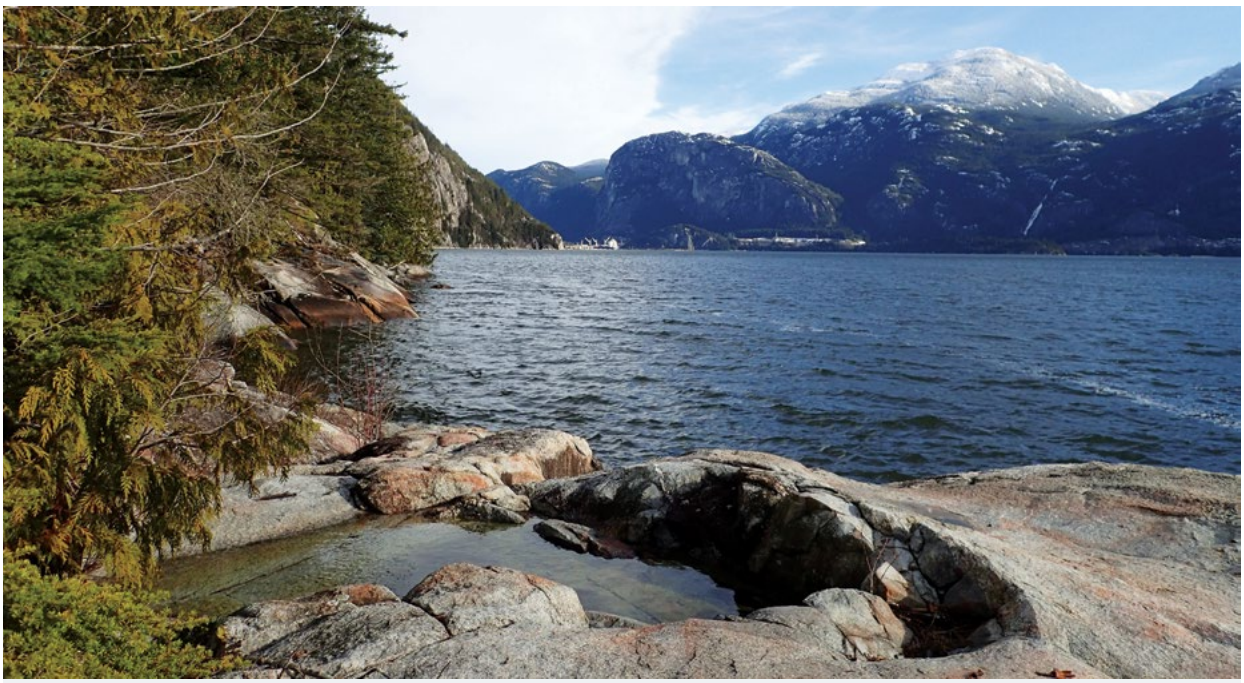
What is the current status?

Locally, there are two data sources relevant to identifying changes associated with ocean warming: 1) a weather buoy located in the Strait of Georgia; and 2) Squamish River flow data.[3] The weather buoy is maintained by Environment and Climate Change Canada, located on Halibut Bank in the Strait of Georgia. This buoy provides data on ocean warming relevant to the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region. Since 1990, this buoy has provided, with some gaps, hourly sea surface temperature (SST) data, among other meteorological observations, e.g., air temperature. These 30 years of data have been analyzed to provide a yearly cycle of SSTs (upper panel, Figure 2) to examine how conditions at the boundaries of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound can influence the marine environment within the Sound.

Rarely do temperatures exceed the 90th percentile; in fact, on any given day, we would expect three exceedances to occur in 30 years. When the temperature of the 90th percentile is exceeded for five straight days, this is considered a marine heat wave and is an extreme condition, like a heat wave on land.[4]

Most marine heat waves over the last four years occurred in 2016 (lower panel, Figure 2), which can be attributed to the lingering influence of the 2013–2015 marine heat wave in the northeast Pacific, known as “The Blob” (see Resources). In 2017 and for the first few months of 2018, cooler ocean conditions prevailed. However, in the spring of 2018, another warm period occurred, with record high SSTs observed in the summer. These observations provide evidence of marine heat wave activity in the summer and fall of 2018, comparable to that seen in 2016 (lower panel, Figure 2). Warm periods also occurred throughout the spring and summer of 2019.

Marine heat waves affect the ecosystem structure because the associated changes to the environment may support some species and suppress others. Discussion of why ocean warming is important can be found in Ocean Warming, Ocean Watch Howe Sound Edition [OWHS] 2017.



Warming water temperatures have many impacts both below water and above water. (Credit: Tracey Saxby)

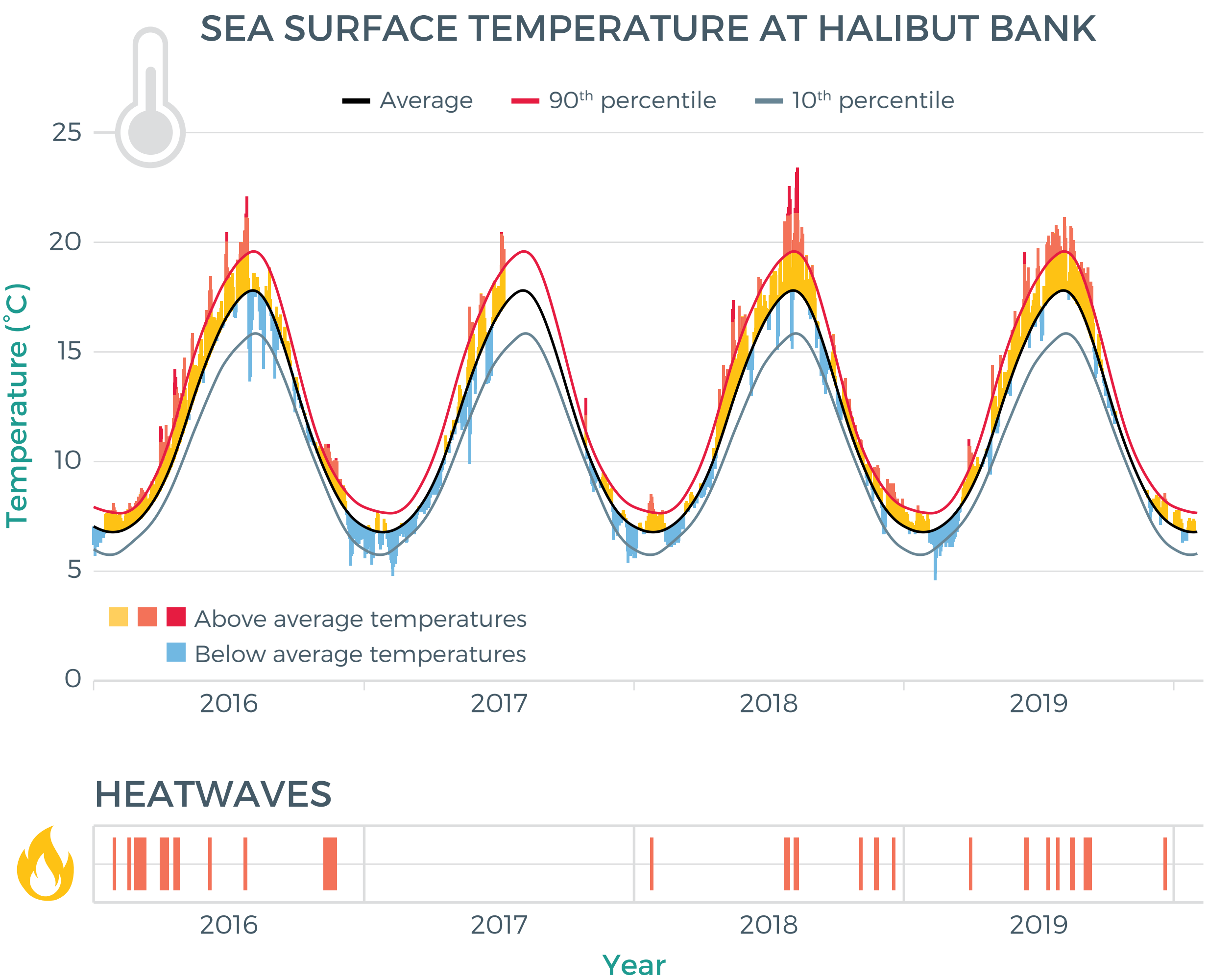


Figure 2. Upper panel: Daily sea surface temperatures (SSTs) recorded at Halibut Bank in the central Strait of Georgia since January 2016. Thirty years of data have been analyzed to provide a yearly cycle of SSTs, represented by the black line. The red line represents the 90^{th} percentile. The blue line represents the 10^{th} percentile. Thus, 80% of data falls in between the red and blue lines. Daily SST values that were higher than average from 2016 to 2019 are shown in yellow, orange and red. Daily SST values that were lower than average in this period are shown in blue. Note that there is some missing data in 2017 and 2019. Lower panel: Orange lines represent observed marine heat waves.

Additionally, the flow of fresh water into Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound can influence its temperature. The Water Survey of Canada measures the flow of the Squamish River near Siyích’m/Brackendale, about 10 km from the head of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. The Squamish River has the largest impact on this marine environment. It has a yearly discharge of 7.52 km^3, enough water to fill approximately three million Olympic sized swimming pools.

River discharge changes with the seasons, with the greatest flows seen in early summer as a result of snowmelt that occurs during the spring. The typical Squamish River discharge pattern (Figure 3) shows low flows in winter with a steep increase in April to July from the snowmelt, and a longer decline in summer through fall.

The freshwater discharge at the head of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound influences stratification of water in the Sound. Water discharged from the river is not salty, which allows it to float on top of the heavier, saltier ocean water. Factors that influence mixing of these two layers depend on both river and ocean conditions, which can change during storm events as well as seasonally and from year to year.

During periods of low river discharge, there is less fresh water entering the Sound, and thus there will be a thinner, less saline surface layer that is more easily mixed, especially in the winter when there is more storm activity. Under these circumstances, water temperature at the surface will be similar to that found at depth.

When mixing of these two layers due to winds or currents is weak, a surface layer develops that holds the heat from solar warming, creating conditions favourable for phytoplankton blooms. Changes in timing of phytoplankton blooms affect the base of the food chain, potentially impacting the whole ecosystem (see Plankton, OWHS 2017).

For 2016–2019, the water discharge hydrograph for the Squamish River near Siyích’m/Brackendale shows an early summer peak, consistent with the influences of snowmelt and spring runoff (Figure 3). Since 2016, the annual volume of water flowing into Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound from the Squamish River has decreased. All four years show a lower than average flow during the summer and early fall, with significant rainfall events occurring in late fall and early winter. However, there is considerable variation between years because the flow is driven by snowmelt, which peaks in early summer, and precipitation, which tends to increase in the last three months of the year.

While the oceanographic processes that influence mixing in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound are reasonably well understood, the factors that govern these processes are changing. The increasing water temperatures in the Strait of Georgia, and the early and rapid snowmelt that controls the Squamish River discharge, continue to challenge our ability to determine the environmental health of this region.

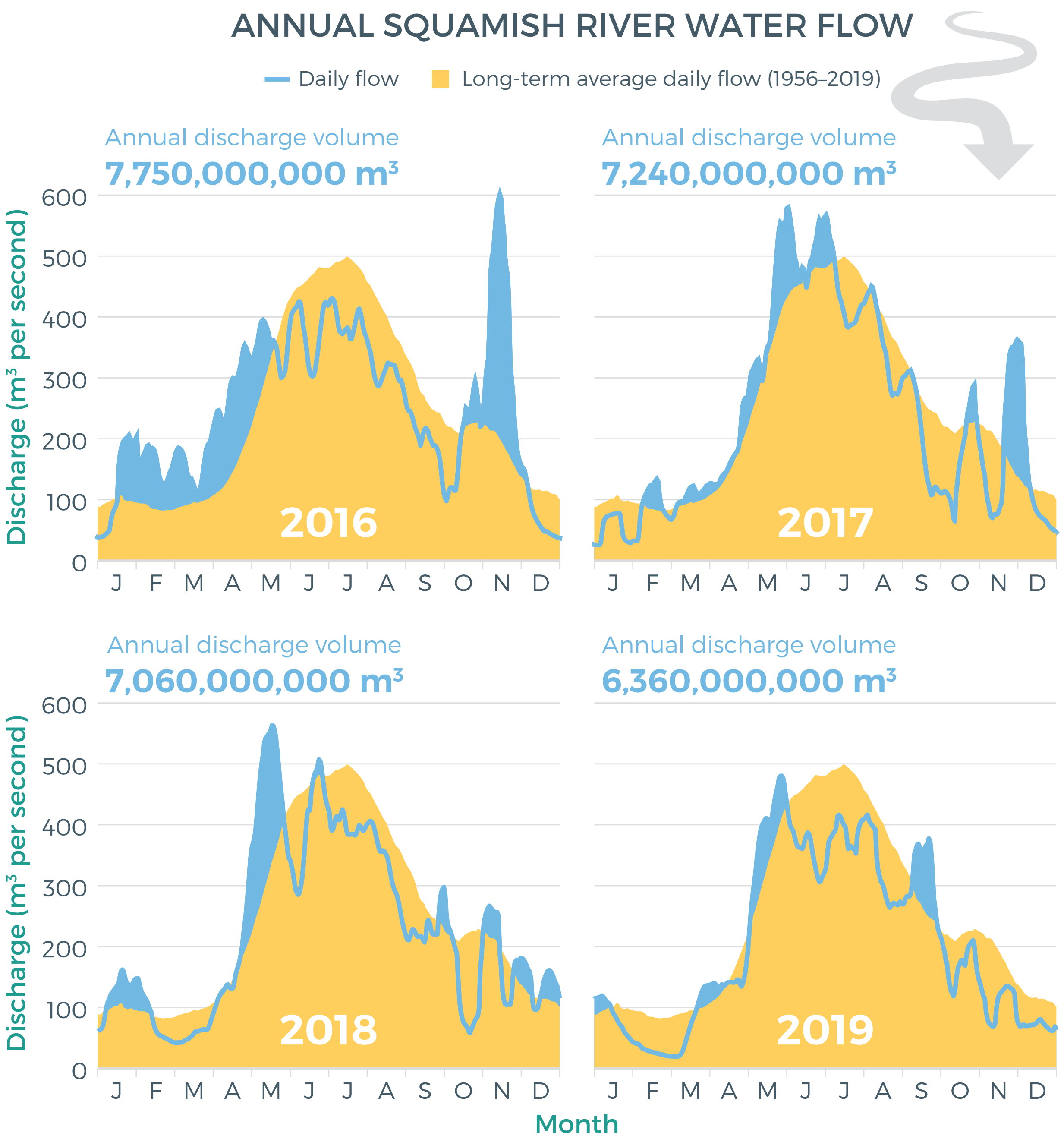


Figure 3. The water discharge hydrograph for the Squamish River near Siyích’m/Brackendale for the years 2016–2019 (blue); the orange area represents the long-term average daily discharge based on data since 1956[i].

i) The long-term average is based on data from 1956 up until the year prior to the year shown, i.e., for the 2016 graph, the long-term average was based on data from 1956 to 2015.

Thus, during periods of low freshwater discharge from the Squamish River (i.e., summer and early fall over 2016–2019), there would likely be a decrease in water mixing, potentially resulting in an increase in water temperature in the Sound. Conversely, the large rainfall events observed over these four years would have led to an increase in water mixing in the Sound. Simultaneously, marine heat wave activity has been seen in the summer and fall of 2016, 2018 and 2019 in the Strait of Georgia, which would influence the ocean temperature in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Together, these data indicate that the ocean temperature in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound has been warmer than average in recent years, which has implications for species and communities in the region.

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	
Help prevent climate change by producing fewer greenhouse gases. Adopt policies and practices within your organization.	There is little data available on an individual level. However, incentives to decrease the costs of electric vehicles are available in B.C. https://pluginbc.ca/incentives/vehicle-incentives/#izev
GOVERNMENT ACTIONS AND POLICY	
Protect any cold water “refugia” within rivers. Strengthen regulations that protect riparian areas along streams to keep warming to a minimum.	Squamish River Watershed Society, together with DFO and Sḵwx̱wú7mesh Úxwumixw/Squamish Nation, have carried out revegetation in the Squamish estuary area. West Vancouver Streamkeepers, Squamish Streamkeepers, and Bowen Island Fish and Wildlife Club all carry out habitat restoration on salmonid streams. Some funding for some of these groups comes from various government organizations.

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:

- Eat sustainable seafood to foster healthy and resilient fish populations.
- **NEW** Support political action to reduce fossil fuel impacts (use and technology).

Government Actions and Policy:

- Incorporate latest climate change hazard assessments into emergency response planning.
- Implement the Wild Salmon Policy as it recognizes that diversity among salmon populations will be critical in helping salmon populations adapt to future climate conditions.
- **NEW** Fund protection and revegetation of riparian areas to create shade along streams, helping to keep warming to a minimum.
- **NEW** Fund continual monitoring of ocean temperatures.

Methods

Global data were accessed from the NOAA website (see References). Sea surface temperature data specific to the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region were accessed via a weather buoy located on Halibut Bank in the Strait of Georgia, operated by Environment Climate Change Canada. Flow data for the Squamish River were accessed via the Water Survey of Canada website.

Resources

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

El Niño patterns contributed to a long-lived marine heat wave in the North Pacific. 2016. Available at: https://swfsc.noaa.gov/news.aspx?ParentMenuId=54&id=21991 Accessed August 9th 2019.

Ocean heat waves like the Pacific's deadly "Blob" could become the new normal. 2019. Available at: https://www.sciencemag.org/news/2019/01/ocean-heat-waves-pacific-s-deadly-blob-could-become-new-normal Accessed August 12th 2019.

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Ocean Acidification

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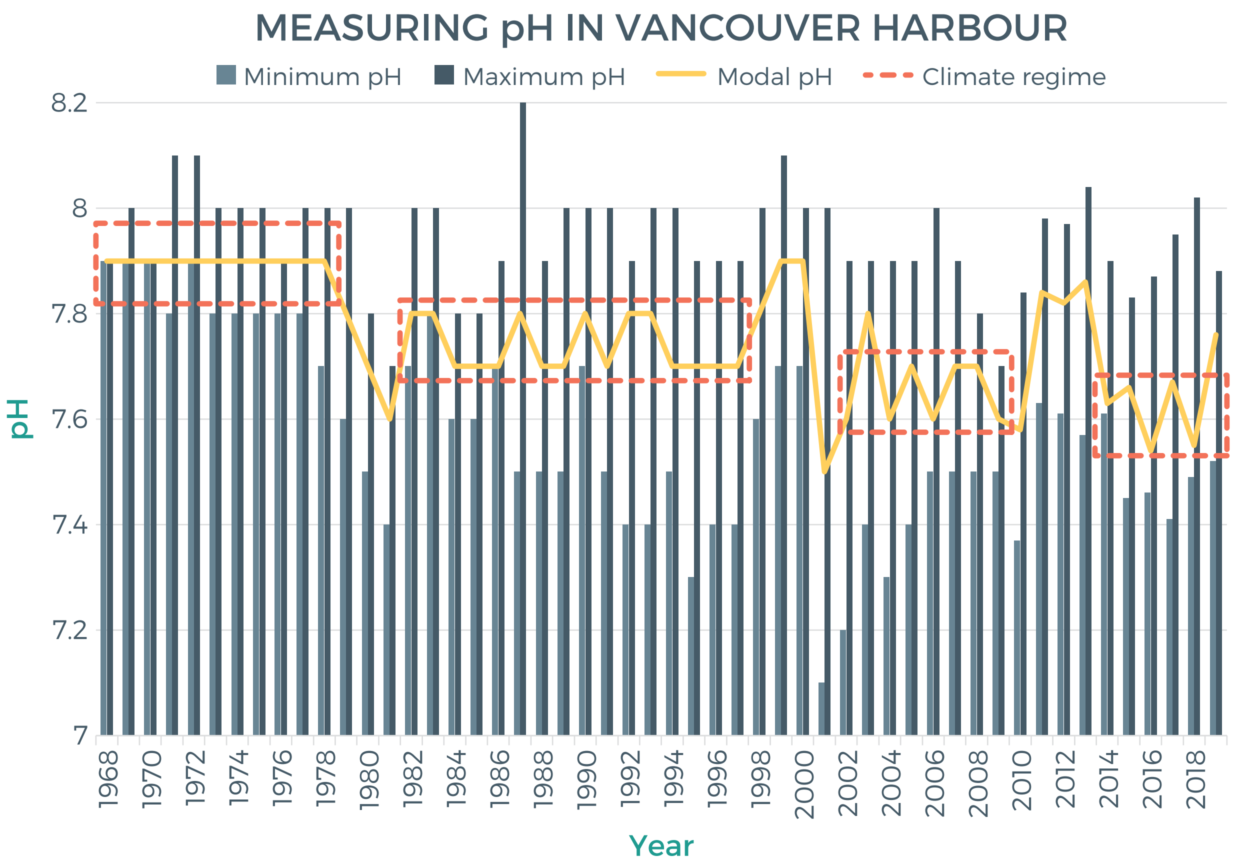
What is ocean acidification?

Ocean acidification refers to a decrease in pH of oceanic waters. Globally, ocean pH tends to be greater than 8.0. The northeast Pacific Ocean, with its large river inputs and upwelling of deep water, tends to have a lower pH, i.e., it is more acidic compared to the open ocean. Seawater intake records monitored since 1956 at the Vancouver Aquarium show that pH tends to remain at a relatively stable plateau until a climate regime shift occurs. A climate regime shift is an abrupt change from one climate state to another. Three major climate regime shifts have been discerned using pH measured in seawater intake records (Figure 1) in combination with broad seabed biodiversity data.[1,2] After a climate regime shift, ocean pH appears to go through a correction phase where pH rises, i.e., becomes less acidic, and then falls off, becoming more acidic. From there, it levels off at this new plateau, which may or may not be more acidic than what was occurring previously.[1]

Lower pH values can affect bivalves such as mussels by preventing shell formation at the larval stage, and preventing the formation of byssus threads in mussels, which are used to attach the mussel to the substrate. (Credit: Aroha Miller)



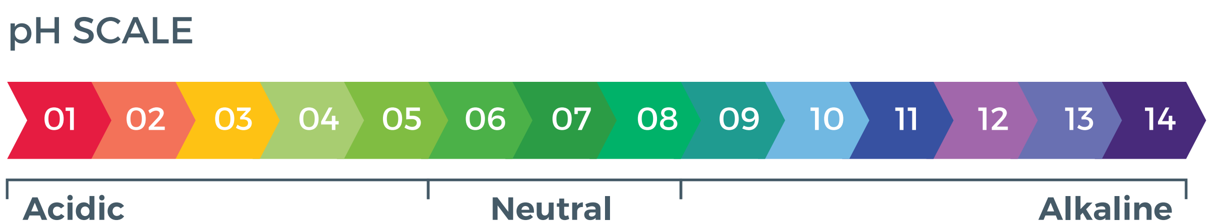


Figure 1. Modal pH and extreme range (minimum five measures for low or high values) for Vancouver Harbour from 1968 to July 2019. (Climate regime shift: an abrupt change from one climate state to another; the spaces between the dashed red boxes are where the regime shift takes place).

What is happening?

Since 2015, water quality measurements have been collected at two locations in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound – Ḵw'émḵw'em/Defence Island and Nínich Ḵw'émḵw'em sponge reef and Skwákwtsa7s/Popham Island – at depths of 10 to 25 m. Data collected include temperature, pH, salinity, dissolved oxygen and turbidity. Since 2015, across all locations and seasons that water quality data have been recorded, the average pH was 7.6–7.8. Seasonal relationships between temperature and pH have been documented (Figure 2, 3). During winter, when water temperatures are at their coldest, pH tends to be closer to 7.8 and inversely related to temperature, while during summer, pH tends to mirror patterns of temperature – as temperature increases, pH also increases. However, an uncharacteristically cold winter in 2017 may be responsible for anomalously high pH values (Figure 3).

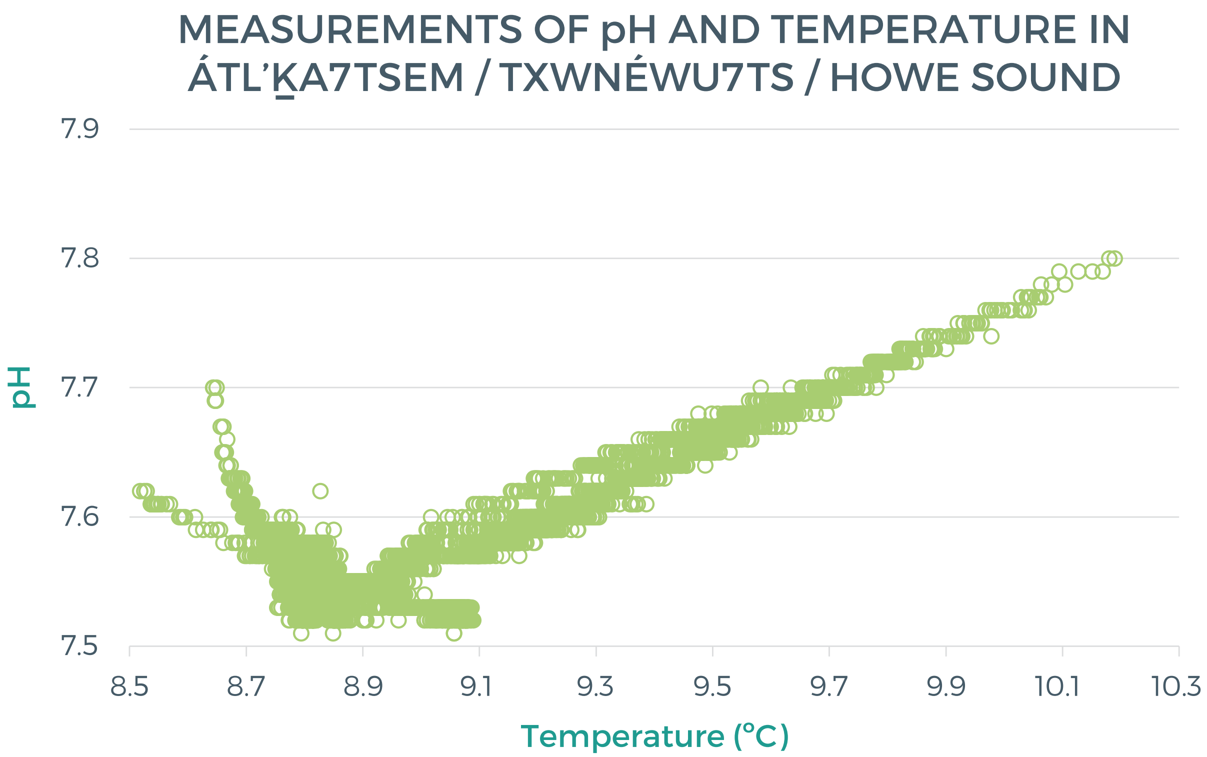


Figure 2. Measurements of pH and temperature taken during spring 2016 (Ḵw'émḵw'em/Defence Island and Nínich Ḵw'émḵw'em sponge reef, 22 m depth), indicating how changes in temperature affect pH. Data represent 10-minute interval points.

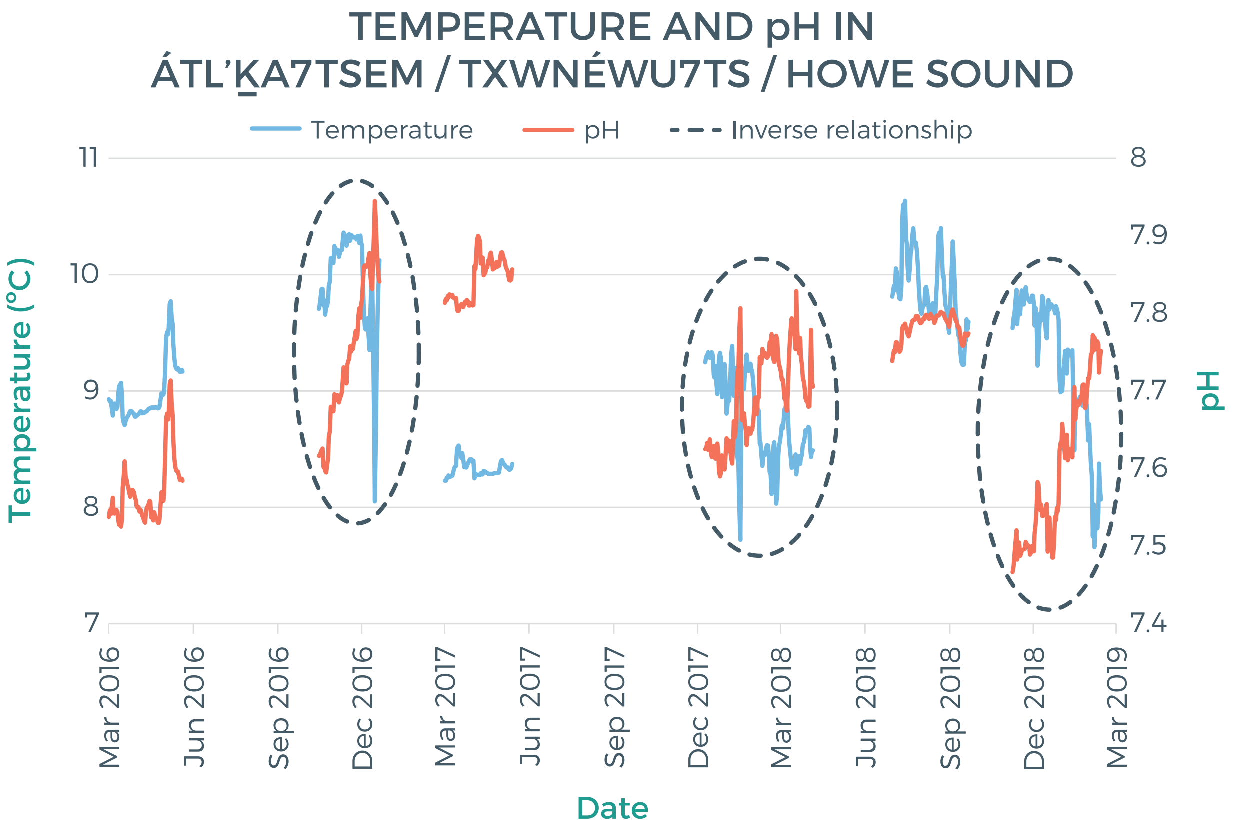


Figure 3. Temperature and pH at the Ḵw’émḵw’em/Defence Island and Nínich Ḵw’émḵw’em sponge reef (22 m depth) during six three-month deployments of equipment to measure physical parameters. Black ovals indicate inverse seasonal relationships between pH and temperature.

Although limited in time and space, these data provide a general sense of existing seabed conditions in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Examining these results alongside ocean water samples measured in Burrard Inlet at 20 m depth (Figure 1) shows the need for decadal length time series to identify real declines in pH and distinguish them from seasonal patterns and the effects of deep-water flushing events in the Salish Sea. Monitoring of water quality using these parameters continues and will eventually provide a more comprehensive picture of acidity in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound on a decadal or longer time scale.

Why is it important?

Many marine species may be negatively impacted by ocean acidification, either directly due to the need for calcium carbonate in shell formation, or indirectly, for example through the loss of prey. Lower pH values (i.e., more acidic) can impact marine animals that use calcium carbonate to form shells, such as oysters and mussels, preventing shell formation at the larval stage, and preventing the formation of byssus threads in mussels, which are used to attach the mussel to the substrate. These changes can result in death. Shellfish hatcheries in Puget Sound and the Strait of Georgia have been affected.[3] However, more research is needed regarding the cascade effects within the food web due to the relatively “recent” recognition of ocean acidification impacts (the term ocean acidification was only coined in 2003 after an abrupt climate regime shift was observed[4]).

What is the current status?

Current efforts at the Ocean Wise Research Institute suggests a relationship between climate regimes and ocean acidification in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[2] Acidification appears to change in a step-wise fashion. In contrast, seabed biodiversity records in the Strait of Georgia and from the west coast of Vancouver Island have not shown any changes in a particular direction in correlation with this step-wise decrease in pH (i.e., pH always decreases, whereas biodiversity both increases and decreases).[5]

What can you do?

A detailed overview of recommended actions is included in *The path to zero carbon municipalities* (OWHS 2020).

Methods

Data were collected by Ocean Wise researchers from the Howe Sound Conservation and Research Team using a YSI EXO2 Sonde buoy deployed at various locations across Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound in a depth range of 10 to 30 metres. Data collection began in July 2015, and has continued intermittently up until, and including, 2019. Water quality information pertaining to temperature, salinity, pH, dissolved oxygen and turbidity was collected at 10- to 15-minute intervals for up to three months at a time.

Ocean Wise staff have recorded pH for the Burrard Inlet intake during water quality sampling on an approximately bi-monthly basis since 1968. Current sampling utilizes an EXO Sonde.

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Shoreline Erosion and Sea Level Rise

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What is happening?

Globally, sea level continues to rise and pose risks to coastal communities.[1] Sea level rise (SLR) is caused by thermal expansion as ocean waters warm and increasing global temperatures melt ice caps and glaciers. Exactly how much sea level will rise is unpredictable due to various uncertainties, such as the amount of greenhouse gases produced, whether countries meet their carbon emission reduction goals, or even if a region is experiencing tectonic uplift.

The Government of B.C. recommends planning for a SLR of approximately 1 m by 2100, and 2 m by 2200[2]; however, SLR exceeding 1 m by 2100 could be possible.[1] Figure 1 shows the sensitivity of the shorelines in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to SLR. Sea Level Rise is causing concern for waterfront property owners and communities within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound due to higher waters encroaching on properties and carrying away shoreline materials such as sand and pebbles, a process known as shoreline erosion. Sea Level Rise is a relatively slow process and therefore the effects from storm surges (Figure 2) will be seen before the direct impacts of SLR are noticed.

During the winter of 2018/2019, several severe storms battered Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. This caused storm surges resulting in shoreline erosion, damage to infrastructure, loss of property, endangerment of lives that necessitated emergency services attendance, and high economic costs to clean up the damage and subsequent mitigation (see Comprehensive Planning, Ocean Watch Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020). Many of these issues were raised in Shorelines and Sea Level Rise, OWHS 2017.

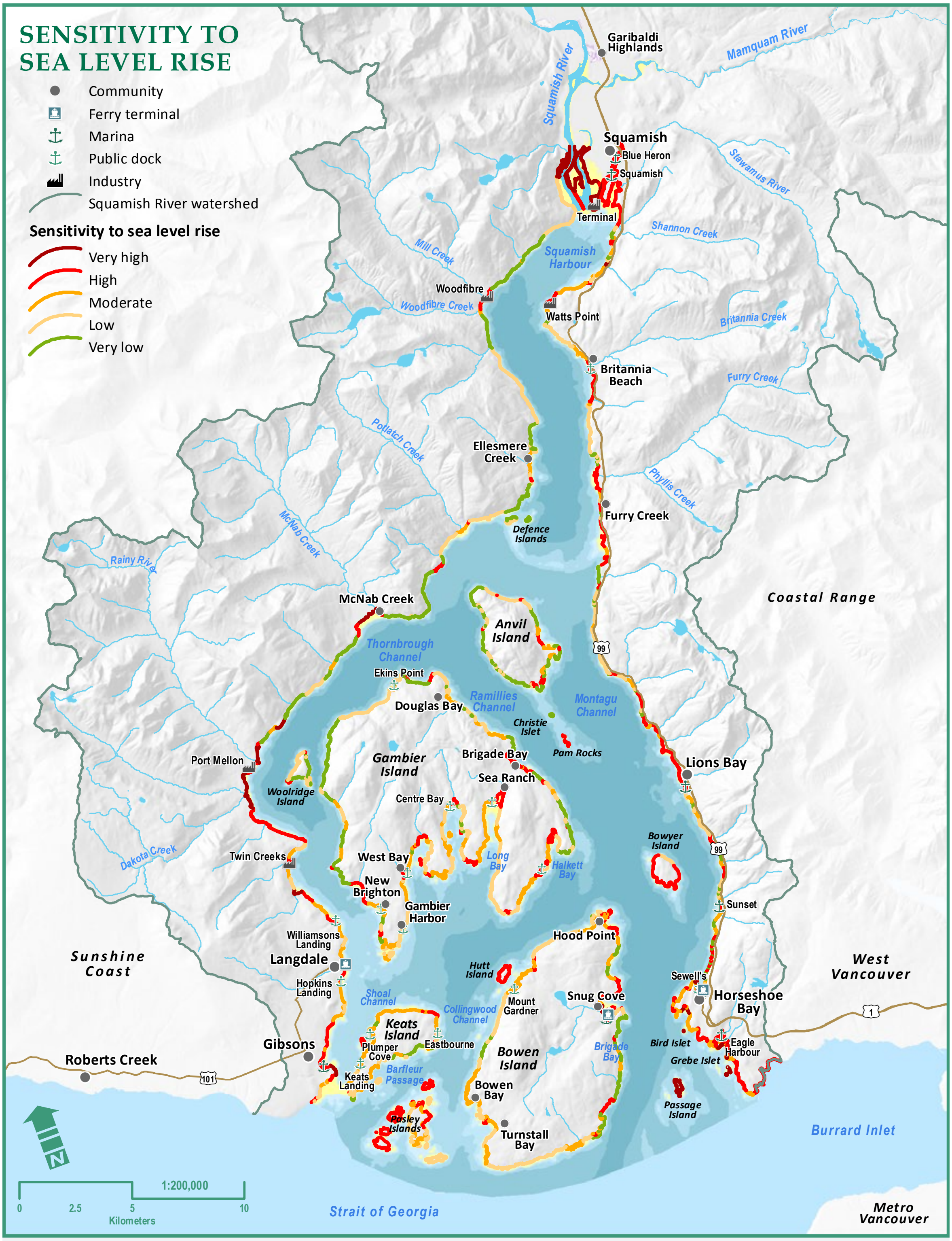

Figure 1. Sensitivity to sea level rise in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[3]

What is a storm surge?

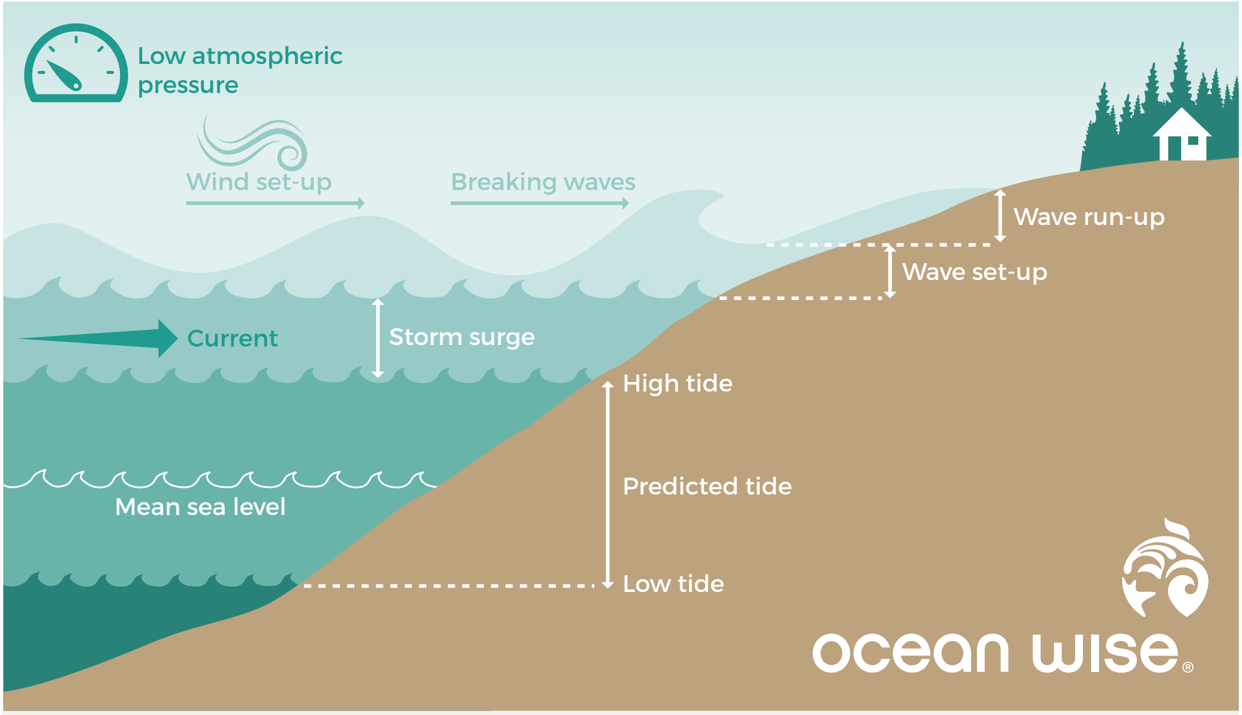

Figure 2. Factors that contribute to the creation of a storm surge.

To combat damage caused by SLR, communities often opt for hard armouring of shorelines, such as shoreline fortification made from rubble and rocks (also known as rip rap), seawalls, or dikes. However, an unintended consequence of such an approach is the erosion of the shoreline, including the sensitive habitats found in these areas (see Shorelines and Sea Level Rise, OWHS 2017). By contrast, use of soft armouring, such as placing sand and gravel along shorelines, building dunes, constructing wetlands, revegetating or preserving shoreline vegetation, and/or constructing offshore reefs, can help mitigate wave energy and allow the natural landward migration of the shoreline. Specialized habitat, such as eelgrass beds and fish spawning areas, are thus not lost to erosion but gradually migrate inland along with the shoreline.[4]

A storm surge refers to a temporary increase in the height of the sea due to extreme meteorological conditions such as low atmospheric pressure and/or strong winds. A storm surge is independent of a high tide, but its impact may be magnified during a high tide.

(FROM BC MoE 2013)

What is the current status?

Awareness of and interest in the Green Shores approach has continued to grow throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. The number of queries received by Green Shores has increased over the past few years, from both communities and private landowners throughout the Sound (approximately five to six queries per year).[5] Incentives to further increase the use of Green Shores are being considered, such as shoreline assessments, project design guidance from a professional on the application of Green Shores and fast-tracked permitting for projects that use a nature-based approach.

Green Shores delivers educational workshops in communities, with considerable ongoing education and outreach for communities and individuals to learn about shoreline erosion mitigation. In 2018, two one-day workshops were given in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound and the Strait of Georgia – one each on Neẖwlélex̱wem/Bowen and Thormanby Islands. Additionally, Green Shores is working with British Columbia Institute of Technology (BCIT) to develop a course for biologists, coastal engineers, planners, and landscape architects to gain an approved professional designation to ensure they have the necessary skills to design projects to effectively use Green Shores in their designs to mitigate shoreline erosion. This course should be available by the end of 2020.

For more than five years, the Gambier Island Local Trust Committee (GLTC) has made shoreline protection and stewardship a priority project. Over the last two years, the GLTC has been exploring updating policy and regulatory options to align with provincial guidelines, with a focus on Lehk’tines/Keats Island, using a two-phase approach.

A Green Shores project on an eroding shoreline in Qualicum Bay, Vancouver Island. Left – before restoration. The red line encircles a failing wooden bulkhead where erosion was beginning to undermine the structure. Plants were non-native species. Right – after restoration. The wooden bulkhead was removed, and the shore was regraded to a more natural slope. Large boulders were placed at ~1 m depth and infilled with smaller rock, sand and gravel, to provide a growing medium for native plants. Logs were buried along the upper portion of the shore to mimic the natural shoreline and provide shelter for plants to grow (Photo credit: Green Shores).

Phase 1 involved community engagement and the introduction of potential policy, regulation or voluntary stewardship options (e.g., increasing setback distances of buildings from the natural boundary of the sea). A survey to gauge the community's values in relation to the shoreline (e.g., protect, recreate) was circulated. This phase was completed in 2018.

Phase 2 began in 2019 with the establishment of a working group consisting of eight community members. The purpose of Phase 2 is to review and update the relevant Official Community Plan policies and land use bylaw regulations to:

- address sea level rise and flooding;
- protect archaeological sites/resources, which are predominantly found along shorelines;
- protect sensitive ecosystems, such as eelgrass beds;
- protect shoreline integrity and function;
- preserve public access to the foreshore; and
- ensure consistency with First Nations-led marine planning initiatives.[6]

Other municipalities throughout the Sound have been pursuing options to both protect their shorelines from erosion and SLR as well as to restore, enhance and protect ecosystem functions. For example, the West Vancouver Shoreline Preservation Society has been investigating options to protect shorelines for private landowners. In 2018, Bowen Island Municipality (BIM) released a parks plan, which acknowledges the importance of shoreline erosion by including a recommendation to protect shorelines and enhance marine habitat adjacent to land owned by BIM.[7]

What are the potential impacts of climate change on shoreline erosion?

Shoreline erosion is an indirect impact of climate change. The frequency and intensity of storms and storm surges is predicted to increase due to climate change.[8,9] Without appropriate planning, storms and storm surges will lead to greater shoreline erosion, increased infrastructure damage, loss of sensitive habitat, loss of property, economic losses and an increased risk of loss of life, not to mention impacts to species that use shorelines for habitat.

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
Adopt Green Shores approach as a policy. Use Green Shores approaches for protecting and enhancing public shorelines in communities. Join the Green Shores Local Government Working Group for Green Shores support and resources.	These actions are addressed by the following: The number of queries received by Green Shores has increased over the past few years, from both communities and private landowners throughout the Sound. These have not translated into enrolled projects.

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:

- Educate yourself on how to care for your shoreline using the resources provided below.

Government Actions and Policy:

- NEW Identify areas at high risk for shoreline erosion, flooding and landslides.
- NEW Limit and manage development in these areas, e.g., building restrictions, setback limits.
- NEW Incentivise or offset costs of shoreline stabilization of public assets, e.g., soft shore armouring.

Methods

Information on severe storms in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound during the 2018/19 winter season was presented at the Ocean Watch Howe Sound/Atl’ḵa7tsem Workshop held on June 7, 2019 (presenter: Ruth Simons). Information on Green Shores was sourced from DG Blair, Executive Director of the Stewardship Centre for BC. Information regarding GLTC was provided by Jaime Dubyna, Planner, Islands Trust, and relevant websites. Other information on various municipalities was sourced from relevant websites, as shown in the References and Resources. Information regarding climate change impacts on shoreline erosion was accessed on google using the search string “climate change AND Vancouver AND storm.” The most relevant resources were used.

Resources

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

DFO Guide for Property Owners:
Shoreline Care, https://www.csrd.bc.ca/sites/default/files/swmp/Shoreline%20Care.pdf

Islands Trust:
Marine Protection Tools for Local Governments, http://www.islandstrust.bc.ca/trust-council/advocacy/marine-environment/

A Landowner’s Guide to Protecting Shoreline Ecosystems, http://www.islandstrust.bc.ca/media/282417/Landowners-Guide-September-draft-revised.pdf

Islands Trust Conservancy:
Caring for our Shorelines, http://www.islandstrustconservancy.ca/initiatives/marineconservation/

Stewardship Centre for BC:
Green Shores resources, https://stewardshipcentrebc.ca/?cat=&s=shoreline

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Additional Resources

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Stream Flows: Daisy Lake Reservoir and the Cheakamus River

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What is happening?

Climate change predictions suggest that stream flow patterns will shift, meaning plants and animals that live alongside or in rivers will need to adapt to survive. Changing stream flow patterns will also influence the volume and timing of freshwater input to the marine environment, and consequently, the timing of plankton blooms (see Plankton, Ocean Watch Howe Sound Edition [OWHS] 2017), among other potential impacts. Therefore, it is important to monitor river flows to understand yearly differences and long-term trends.

Within the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound watershed, there are numerous river systems that are monitored for stream flows by the Water Survey of Canada (WSC), including most rivers and their major tributar-

The Squamish River, into which the Cheakamus River drains. (Credit: Aroha Miller) ies in the Squamish River watershed (the Mamquam, Squamish, Ashlu, Elaho, Cheakamus and Stawamus rivers). Daily river flow from Daisy Lake Reservoir was previously reported (see Stream Flows, OWHS 2017). The shift in flow seasonality reported for Daisy Lake Reservoir appeared similar to projected shifts due to climate change.

Daisy Lake Reservoir is located along the Cheakamus River. The upper Cheakamus River flows into the reservoir, where reservoir inflows and outflows have been monitored since the construction of the Cheakamus Generating Station in the late 1950s. The reservoir is connected to the Cheakamus Generating Station, which produces electricity.[1] The water used for power generation is discharged into the Squamish River.[1]

The amount of freshwater input into Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is an important variable impacting the marine environment. The Cheakamus River drainage basin is approximately 1070 km^2, while the drainage basin for the Squamish River is approximately 3600 km^2. Thus, the Squamish River contributes around two-thirds, or 66%, and the Cheakamus contributes almost one-fifth, or 20% of freshwater input into the Sound.[2] All drainage basins in the watershed, including the Cheakamus and Squamish Rivers, are largely glacier fed.

In 2019, the Government of Canada released *Canada’s Changing Climate Report*, in which it predicted changes in the seasonal availability of freshwater and an increased risk of water supply shortages in summer.[3] The Daisy Lake Reservoir/Cheakamus River system is the most studied watercourse in the Squamish River watershed and serves as an excellent indicator system for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. We are therefore updating data presented in the OWHS 2017 report, as well as taking a higher-level look further back in the historical record along the Cheakamus River (below the dam), to see if this predicted change could also be observed in Cheakamus River stream flow data.

What is the current status?

Daisy Lake Reservoir

Stream flow into Daisy Lake Reservoir has been monitored on an ongoing basis since construction in the 1950s. This long-term data was reported in OWHS 2017. Data presented here adds stream flow since 2017, up until early June 2019, although monitoring is ongoing.

The long-term range of flows (data from 1960 to 2016 inclusive, light-blue shading, Figure 1) shows freshet[i] typically peaks in mid-June, although there is considerable variation between years (Figure 1). Data for 2017 and 2018 fall within this long-term range. However, spring freshet appears to have occurred slight-

i) Freshet – increased water flow due to snow melt, typically resulting from spring thawing of the snowpack, and generally characterized by a steady rise in stream flow, to a peak, after which stream flows begin to decrease again.

ly earlier (mid-May to early June) compared to the long-term average, and summer flows are lower than average long-term summer flows. Flow peaks due to rainfall events were observed in fall and again in winter (December to February) although again, these are within the long-term range. The addition of two years of data is not enough to draw any conclusions about long-term trends.

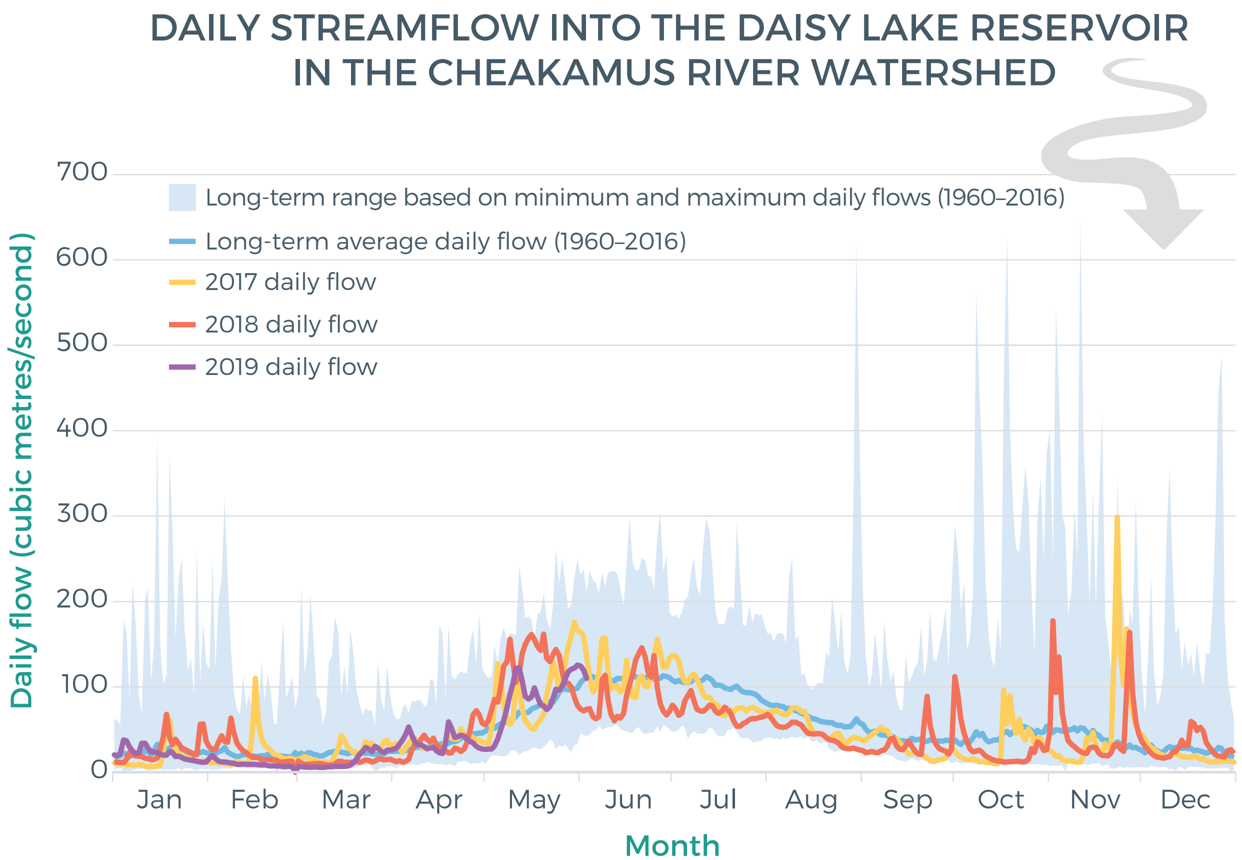

Figure 1. Daily stream flow into Daisy Lake Reservoir in the Cheakamus River watershed.[4] Light-blue shading shows the long-term range of flows (1960–2016). The light-blue line indicates the long-term average daily flow (1960–2016). The orange and red lines show the 2017 and 2018 daily stream flow, respectively, while the purple line shows daily stream flow for 2019, ending in early June 2019 due to data availability.

Cheakamus River

We looked at natural[ii] average daily discharge (flow) in the first and last 20 years of a 100-year data set. The early data set (1917–1937) was from a gauge that is no longer operational (*Cheakamus at Garibaldi*); the latter data set (1997–2017) is from the next closest gauge that is still operational (*Cheakamus at Brackendale*) (Figure 2). Data from the earlier period at the first gauge location has been normalized to the drainage area size of the second gauge location (representing the latter period). See Methods for further details.

We observed some differences between the two periods that appear to support predicted changes to the availability of freshwater (Figure 3).[3] The freshet peak is smaller, indicating less snowpack, and slightly earlier, peaking at the start of June (small blue oval), possibly because more precipitation fell as rain rather than snow in the winter, resulting in a smaller snowpack and therefore a smaller thaw. Average daily post-freshet summer flows are lower in the 1997–2017 period relative to the earlier period (large blue oval). Storm event peaks in the fall and winter are larger, again likely due to more of the annual precipitation volume falling as rain rather than snow.

Figure 2. Location of the two water gauges and the Daisy Lake Spillway, in relation to Sḵwx̱wú7mesh/Squamish town.

ii) Natural river flow – the volume of water under non-regulated flow conditions. The natural stream flow is calculated by BC Hydro as the sum of reservoir inflows plus inflows below Daisy dam.
Non-regulated – river flow is not controlled.
Actual river flow – the volume of water under regulated flow conditions.
Regulated – river flow is controlled during power-generating operations (typically this occurs year-round).

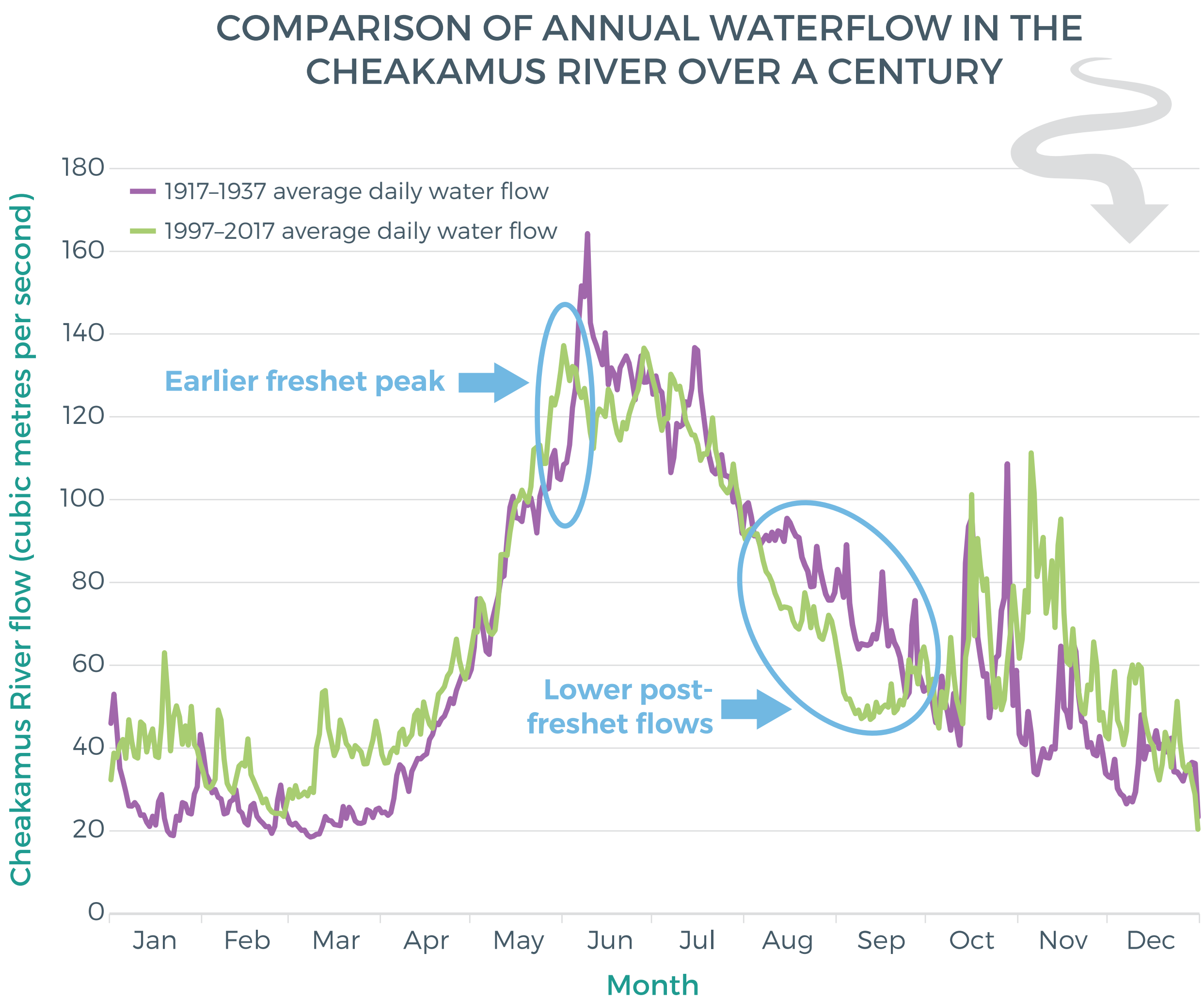

Figure 3. Natural annual water flow in the Cheakamus River. The purple line represents the average daily water flow for the period 1917–1937. The green line represents the average daily water flow for the period 1997–2017. The small blue oval indicates a smaller, earlier freshet peak; the large blue oval indicates lower post-freshet flows.

How will climate change impact stream flows in Átl’ḵa7tsem/ Txwnéwu7ts/Howe Sound?

Climate change will likely result in earlier peaks in stream flows (i.e., freshet), larger storm peak flows and lower late summer flows.[3] Such changes in stream flow may have implications for wildlife seasonal cycles both in the river and in the marine environment. For example, extreme precipitation events can lead to increased river flows, causing scouring of riverbeds and destroying spawning habitat for some fish species. Likewise, droughts can lead to low flows and increased water temperature, resulting in poor survival of eggs and early life stages.[5]

The rivers in the wider Átl’ḵa7tsem/Txwnéwu7ts/ Howe Sound watershed contribute to changes in volume and timing of freshwater input into Átl’ḵa7tsem/ Txwnéwu7ts/Howe Sound. The same changes we observed in freshwater availability for the Cheakamus may possibly be seen in other watercourses within the watershed. These changes impact ocean temperatures in the Sound (see Ocean Warming, OWHS 2017) and potentially the timing of plankton blooms, which form the basis of the food web in Átl’ḵa7tsem/Txwnéwu7ts/ Howe Sound (see Plankton, OWHS 2017).

Squamish River as it flows south towards the estuary and Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (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	
Become familiar with the current Integrated Flood Hazard Management Plan (IFHMP). Be aware of flood hazards in your area and be prepared for an emergency at your home and workplace.	Refer to the District of Squamish's IFHMP, adopted in 2017.
Help prevent climate change by producing fewer greenhouse gasses. Adopt policies and practices within your organization.	Incentives to decrease the costs of electric vehicles are available in B.C., link below. https://pluginbc.ca/incentives/vehicle-incentives/#izev
GOVERNMENT ACTIONS AND POLICY	
Continue to closely monitor streamflow data and trends.	BC Hydro continues to monitor river flows in areas where they have run-of-river hydroelectricity generators. This includes Daisy Lake Reservoir and Culliton Creek in the Squamish watershed.[5] Other hydroelectric projects monitor stream flows, e.g., Mamquam River. While BC Hydro is a provincial Crown corporation, other hydroelectric operators are not.
Increase capacity to respond to extreme weather events, including droughts.	Refer to the District of Squamish's IFHMP, adopted in 2017.
Continue to renew the Integrated Flood Hazard Management Plan (IFHMP) every five to 10 years.	See Resources on extreme weather events below. This is not a substitute for government-level actions. A number of the district municipalities have an emergency response program section on their websites.
Protect the coastline from storm surge and flooding using Green Shores techniques.	Greater awareness of and interest in Green Shores through Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound has been noted, although the increase in inquiries has not yet translated into enrolled projects (see Shorelines, OWHS 2020).
Withdraw, relocate or abandon public assets in high-risk areas of flooding.	Being discussed in some local Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound municipalities.
Increase public education on what to do in the event of extreme weather, flooding and drought.	A selection of resources outlining what to do in these events are provided below.

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:

- Record stream levels when enumerating salmon spawning.
- Withdraw, relocate or abandon private assets in high-risk areas of flooding.
- Implement and practise water conservation measures in your home and within your organization.
- **NEW** Plant trees and vegetation along waterways.
- **NEW** Join a citizen science group that restores wetlands.

Government Actions and Policy:

- Take action to minimize rainfall-related flooding and associated consequences.
- Develop an education plan for the Integrated Flood Hazard Management Plan to educate locals, especially those in high-risk areas.
- Identify and develop plans for slopes at high risk of landslide.
- Develop policies for back-up power in all eventualities.
- Increase flood construction levels, add covenants to reduce liability and retrofit existing buildings.
- Identify future no-build zones or use land acquisition or restriction tools such as land trusts.
- Work with BC Hydro to ensure sufficient water flow in “managed” rivers that support salmon spawning and migration.
- **NEW** Increase awareness and education around the importance of headwaters.
- **NEW** Data collected by BC Hydro and other independent run-of-river plants should be made available to independent researchers.
- **NEW** Hydroelectric power generation requires a substantial quantity of water. Operators of these facilities and government authorities that regulate power plants should consider water availability changes when setting future targets for water diversion.

Methods

Daisy Lake Reservoir

The previous graph from OWHS 2017 was updated with smoothed data from BC Hydro. Smoothed data is based on calculations of reservoir storage and discharge. The challenge of calculating reservoir volume is the main source of random error and therefore quality control procedures are applied to the data. A system of automated and manual data checks is applied to calculated daily averages from hourly averages. The developed application allows for estimations for poor quality or missing data.

Cheakamus River

Historical data for the Cheakamus River exists from the Water Survey of Canada (WSC) gauge *Cheakamus at Garibaldi* (08GA017). This gauge was located 1.6 km below the location of the current Daisy dam spillway and is no longer operational. The first 20 years of data available, 1917 to 1937, presented in Figure 2, comes from this gauge. The drainage area for the *Cheakamus at Garibaldi* gauge is 813 km^2.

Data for the latter 20 years, 1997–2017, were collected at WSC gauge *Cheakamus at Brackendale* (08GA043). This time period was selected because it is the most recent 20 years of data available, and natural streamflow data do not extend back beyond 1984. This gauge is located approximately 17 km downstream of the former *Cheakamus at Garibaldi* gauge, with a drainage area of 965 km^2; it is still in operation. Its location represents the flow compliance point for BC Hydro’s operations on the Cheakamus River (e.g., flows must be a minimum of ≥ 15 cubic metres per second at this location from November 1 to March 31; however, the required minimum flow varies throughout the year).

In order to compare data from the two gauge locations, the *Cheakamus at Garibaldi* data were normalized to the drainage area size of the *Cheakamus at Brackendale* drainage area (e.g., daily *Garibaldi* data were multiplied by 1.2), as per methods outlined in the Indicators of Hydrologic Alteration software package.[7] Natural flows for the 1997–2017 period were calculated with BC Hydro’s reservoir inflow and inflow below Daisy Lake spillway data (natural discharge at the *Cheakamus at Brackendale* gauge = Daisy reservoir inflows + inflows below Daisy dam spillway). The data presented are the average daily flows from the respective 20-year periods.

Resources

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

B.C. Centre for Disease Control:
Wildfire Smoke Response Planning
http://www.bccdc.ca/health-professionals/professional-resources/wildfire-smoke-response-planning

Wildfire Smoke:
health effects of wildfire smoke, how to prepare for wildfire smoke season, portable air cleaners, face masks for wildfire smoke
http://www.bccdc.ca/health-info/prevention-public-health/wildfire-smoke

Municipal Heat Response Planning in British Columbia, Canada (2017)
http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/Health-Environment/BC%20Municipal%20Heat%20Response%20Planning.pdf

Government of B.C.:
Get Prepared for Severe Weather in British Columbia
https://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/preparedbc/know-your-hazards/severe-weather?keyword=know&keyword=your&keyword=hazards&keyword=severe&keyword=weather

Government of Canada:
Get Prepared: Floods
https://www.getprepared.gc.ca/cnt/hzd/flds-en.aspx

Alberta Health Services:
Cleaning the House After a Flood
https://www.albertahealthservices.ca/Advisories/ne-pha-cleaning-house.pdf

Saskatchewan Ministry of Health:
Clean Up After the Flood. A Guide for Homeowners
https://www.yorkton.ca/livinghere/springrunoff/pdf/SK__cleaning__up__after__the__flood.pdf

Integrated Flood Hazard Management Plan
https://squamish.ca/yourgovernment/projects-and-initiatives/completed-projects/2018-completed-projects/floodhazard/ifhmp-2016/

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1 BC Hydro. Daisy Lake (DLY) [Internet]. [cited 2019 Sep 19]. Available from: https://www.bchydro.com/energy-in-bc/operations/transmission-reservoir-data/previous-reservoir-elevations/lower-mainland/daisy__lake__dsy.html

2 Fisheries and Oceans Canada (DFO). BC Inlets – Water Properties Trends – Howe Sound [Internet]. [cited 2020 Feb 14]. Available from: https://www.pac.dfo-mpo.gc.ca/science/oceans/BCinlets/howe-eng.htm

3 Bush E, Lemmen D. Canada’s Changing Climate Report [Internet]. Ottawa: Government of Canada; 2019. p. 444. Available from: www.ChangingClimate.ca/CCCR2019 ISBN: 978-0-660-30222-5

4 D. Rinvold, Generation & Hydrometric Specialist, BC Hydro, personal communications, 2019 Jun 17. Record of naturalized inflow to Daisy Lake Reservoir.

5 Selong JH, McMahon TE, Zale A V., Barrows FT. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. Trans Am Fish Soc. 2001;130:1026–1037.

6 BC Hydro. BC Hydro Clean Power Call [Internet]. [cited 2019 Sep 19]. Available from: https://www.bchydro.com/content/dam/hydro/medialib/internet/documents/planning__regulatory/acquiring__power/cpc__project__overviews.pdf

7 Nature Conservancy. Indicators of hydrologic alteration. Version 7.1. Software User’s manual. 2009.

Sḵwx̱wú7mesh/Squamish Flood Planning: adapting to climate change

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What is happening?

The District of Squamish is a vibrant, rapidly growing community located at the end of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, where five major river systems converge (Squamish, Mamquam, Cheakamus, Cheekye and Stawamus). The location of Sḵwx̱wú7mesh/Squamish at the head of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, surrounded by rivers, presents unique community challenges.

A view along the Squamish River dike upgrade, undertaken in 2019. (Credit: David Roulston)

What is the current status?

Due to its location and low-lying elevation, Sḵwx̱wú7mesh/Squamish faces a high risk of flooding from extreme weather events, such as heavy precipitation and storm surges. This risk is especially important for the significant portion of new development occurring within the floodplain. Due to the combination of ongoing floodplain development and the presence of natural flood hazards (e.g., rivers), the District of Squamish initiated an Integrated Flood Hazard Management Plan (IFHMP) in 2014 (see Resources). This plan provides a blueprint for safe and sustainable community growth that accounts for flood risks. The IFHMP was adopted in 2017 and has received provincial, national and international awards (Silver Award from the Planning Institute of British Columbia [PIBC]; Award of Excellence from the Canadian Consulting Engineering Awards; Award of Merit from the International Federation of Consulting Engineers [FIDIC, fidic.org]) for its ground-breaking and comprehensive work.

The IFHMP included a comprehensive mitigation program with over 100 recommendations, including new land use policy, flood regulations for new development and a prioritized capital plan to build and upgrade dikes. Since adoption of the IFHMP, Sḵwx̱wú7mesh/Squamish has been ambitiously implementing recommendations, as detailed in the “What can you do?” section, below.

Significant work remains; however, Sḵwx̱wú7mesh/Squamish is proceeding with confidence that the community is using the best planning tools available to manage flood risks.

What are the potential impacts of climate change on Squamish flood planning?

Climate change is anticipated to have significant impacts on flood risk in the District of Squamish. The IFHMP considers anticipated impacts and includes specific measures to mitigate additional flood risk posed by climate change. In accordance with provincial guidance, Sḵwx̱wú7mesh/Squamish is planning for 1 m of sea-level rise by 2100 and 2 m by 2200. In addition, an allowance of 10% has been added to peak river flows to account for increased precipitation and runoff. These climate change impacts are taken into consideration in the IFHMP’s dike upgrade plans and new development regulations, which require that buildings be elevated to consider anticipated flood levels.

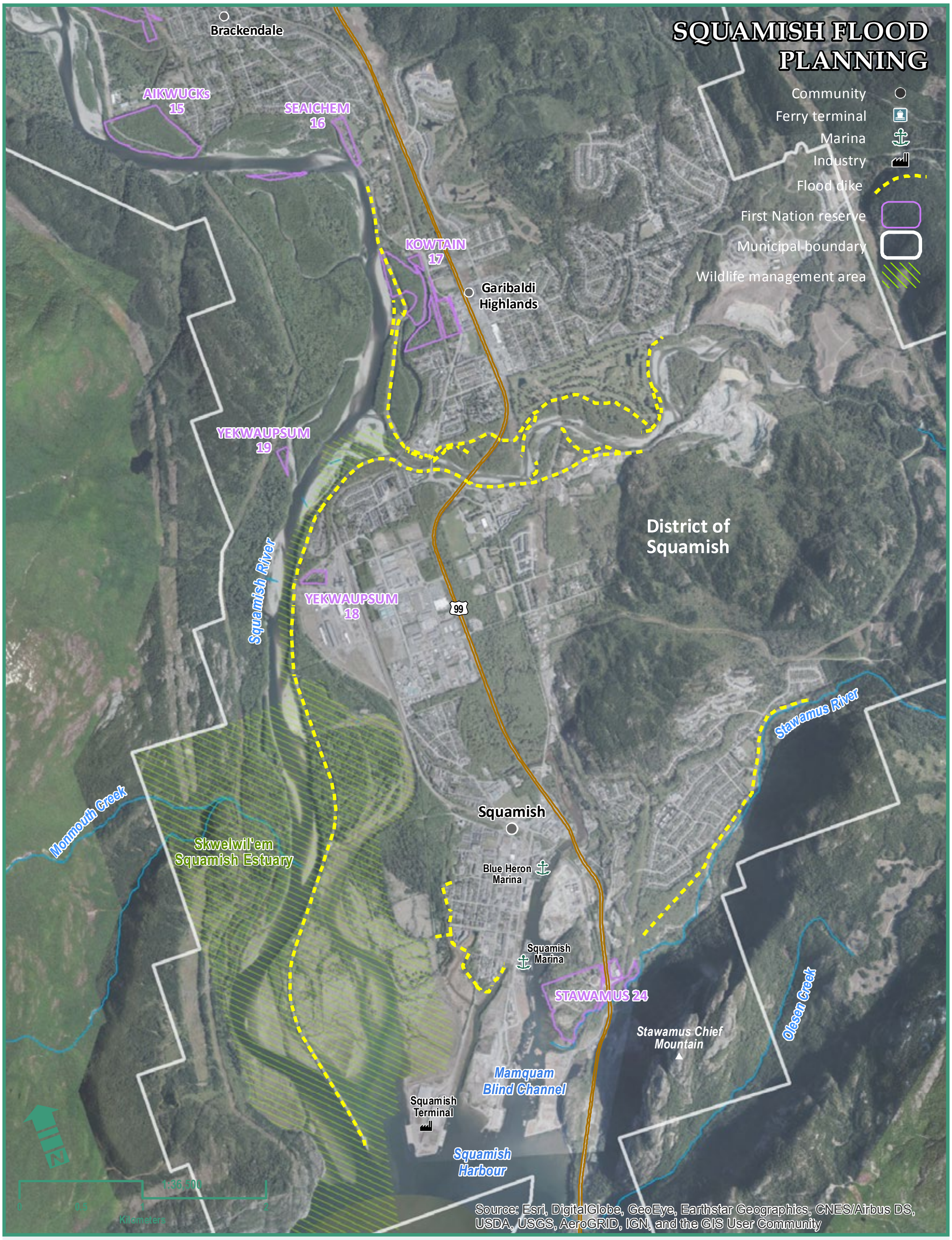

Figure 1. Flood dikes throughout the District of Squamish.[1]

A view from the Squamish River training berm to the Squamish estuary. (Credit: David Roulston)

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	
Improve strategic dike protection for the community using techniques that reflect an environmentally sensitive approach.	In 2019, a 1-km long, $4-million upgrade to the Squamish River dike in Brackendale to divert excess water was completed (Figure 1). A dike master planning process has also been initiated to prepare a dike upgrade plan for the eagle viewing area/Siyich'em Reserve in Brackendale (see Resources). In 2020, the building of 200 m of new sea dike is planned along the Mamquam Blind Channel (an inlet of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound) beside Xwu'nekw Park. Further dike upgrades are planned through redevelopment of private waterfront lands.
Manage development in flood hazard areas through updated Official Community Plan (OCP), DPA guidelines, bylaws, etc.	In 2017, the District adopted the community's first Floodplain Bylaw (see Resources), which establishes flood construction levels (the elevation that habitable areas must be lifted to) and building setbacks from watercourses and dikes.

2017 ACTION	ACTION TAKEN
Limit continued densification in the highest hazard areas.	In 2018, the District's OCP was updated (see Resources), which adds strong policy for community flood management and environmental protection; discourages new development in the highest flood risk areas; and directs new growth to lower risk areas. The OCP also includes a Development Permit Area that designates critical floodways through the town and establishes regulations for new development within those areas to avoid increasing flood risk over time.
Action and policy to reduce greenhouse gas emissions and meet or exceed current targets.	The Council of the District of Squamish recently declared a Climate Emergency. The District is focused on maintaining carbon neutrality within corporate operations as part of the commitment to the Climate Action Charter (CAC) (see Resources). This is an initiative developed by the Province of B.C. to encourage municipalities to work towards carbon neutrality within their corporate operations. The District is committed to the CAC initiative and has actioned updates within the OCP in support of this. Specific climate change mitigation measures that the District is undertaking include: • Developing a Community Carbon Marketplace, allowing the District to offset corporate emissions with local emission-reducing projects. • Establishing a citizen-led Climate Leadership Team that will work with the Mayor, Council and a Consultant to develop a Community Climate Action Plan that will provide insights into Squamish's greenhouse gas emission sources, establish bold actions to reduce emissions and capitalize on available economic opportunities to work towards carbon neutrality. • Preparing a Community Energy and Emissions Plan (CEEP). • Encouraging compact land use patterns that support complete communities, infill development, a diversity of transportation options and a greater mix of land uses. • Emphasizing active transportation and public transit as an essential part of the District transportation and land use network. • Ensuring that high-density employment areas are easily accessed by active transportation and transit networks, and that local employment opportunities provide alternatives to lengthy vehicle commutes. • Supporting and advocating for the implementation of effective regional transit services. • Facilitating the development and coordinated management of low impact alternative and renewable energy sources such as solar, bioenergy, geothermal, wind power, micro hydro, small-scale hydro, or run-of-the-river hydroelectric projects. • Reducing greenhouse gas emissions associated with landfill operations.

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:

- Become familiar with the current IFHMP. Be aware of flood hazards in your area and be prepared for an emergency at your home and workplace.

Government Actions and Policy:

- Conduct further studies on impacts of flood control on environmental processes and continued alternatives that work with nature.
- Continue to raise awareness of flood risks and responsible watershed stewardship.
- Incorporate latest climate change hazard assessments into emergency response planning.
- Complete complementary flood studies for unique hazards beyond the scope of the IFHMP as funding permits.
- Maintain a toolkit (e.g., models, guidelines, and best practices) to support staff analysis and recommendations to Council.
- Promote closer relationships with stakeholders from the river headwaters to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to facilitate working together.
- Continue to renew the IFHMP every five to 10 years.
- Begin planning for opportunistic retreat of key facilities and infrastructure from high flood hazard areas at the end of their service life.

Methods

The IFHMP was completed by a multi-disciplinary team of engineers (i.e., civil, hydrotechnical, geotechnical, coastal), planners and environmental professionals. The plan was prepared in four phases as follows:

- **BACKGROUND/GAP ANALYSIS.** This phase included an in-depth review of previous flood studies, data, and flood policy from around the world. The review was summarized in a Background Report (see Resources).
- **COASTAL FLOOD MITIGATION STRATEGY.** This phase evaluated coastal flood hazards and prepared a coastal flood mitigation strategy, including a conceptual design for a sea dike surrounding Sḵwx̱wú7mesh/Squamish’s coastal perimeter (see Resources).
- **RIVER FLOOD MITIGATION STRATEGY.** This phase evaluated river flood hazards, including utilization of a state-of-the-art two-dimensional floodplain model to determine how fast and deep floodwaters would move through the floodplain (see Resources).
- **INTEGRATED FLOOD HAZARD MANAGEMENT PLAN.** This phase brought together technical work completed in the first three phases into a comprehensive final plan (see Resources).

Public engagement was a central element of this plan and included three public open houses, numerous online surveys and workshops and several presentations to Sḵwx̱wú7mesh Úxwumixw/Squamish Nation and District of Squamish Councils.

Following completion of the IFHMP, the District completed a Quantitative Risk Assessment (not available online) for the Squamish River floodplain, which evaluated risk to loss of life and economic risk. The study indicated a high level of risk to both loss of life and economic loss in Sḵwx̱wú7mesh/Squamish and reinforced the importance of implementing the measures developed in the IFHMP.

Resources

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

District of Squamish Integrated Flood Hazard Management Plan Background Report. Available at: https://squamish.ca/assets/IFHMP/09252017/63a63fc5e6/FINAL-SquamishIFHMP-BackgroundReport_20170913.pdf

District of Squamish Coastal Flood Hazard Mitigation Strategy. Available at: https://squamish.ca/assets/IFHMP/09252017/e51255a3e4/FINAL_SquamishIFHMP-Coastal-Flood-Risk-Mitigation-Options_20170912.pdf

District of Squamish River Flood Hazard Mitigation Strategy. Available at: https://squamish.ca/assets/IFHMP/09252017/0d6609c9a4/FINAL_SquamishIFHMP-RiverFloodRiskMitigationOptions-20170915.pdf

District of Squamish Integrated Flood Hazard Management Plan. Available at: https://squamish.ca/yourgovernment/projects-and-initiatives/completed-projects/2018-completed-projects/floodhazard/ifhmp-2016/

Eagle Viewing Area/Siyich'em Reserve Dike Master Plan. Available at: https://squamish.ca/yourgovernment/projects-and-initiatives/eaglesiyichemdike/

District of Squamish Floodplain Management Bylaw No. 2676. Available at: https://squamish.civicweb.net/filepro/documents/19302?preview=162725

District of Squamish OCP and Zoning Bylaws. Available at: https://squamish.civicweb.net/filepro/documents/68132

B.C. Government Climate Action Charter. Available at: https://www2.gov.bc.ca/gov/content/governments/local-governments/climate-action/bc-climate-action-charter

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

Acknowledgements

The IFHMP was completed by:

Owner: District of Squamish

Prime Consultant: Kerr Wood Leidal Associates Ltd.

Sub-consultants: Arlington Group Planning Inc., Thurber Engineering Ltd. (geotechnical), SNC-Lavalin Inc. (coastal engineering), Cascade Environmental Resource Group Ltd.

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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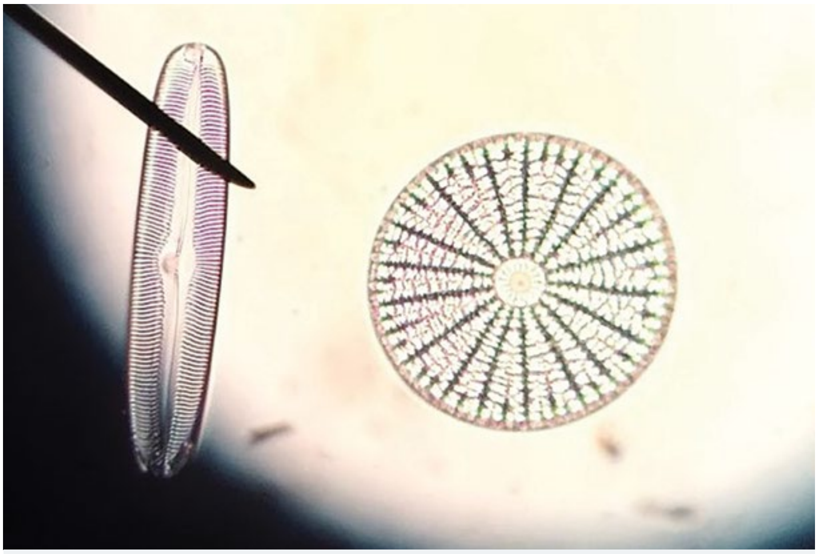
What is happening?

Plankton forms the basis of the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound food chain and is therefore vital for the ecosystem. However, plankton has not been studied in detail in Alt’ḵa7tsem/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’ḵa7tsem/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 Atl’ḵa7tsem/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’ḵa7tsem/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]

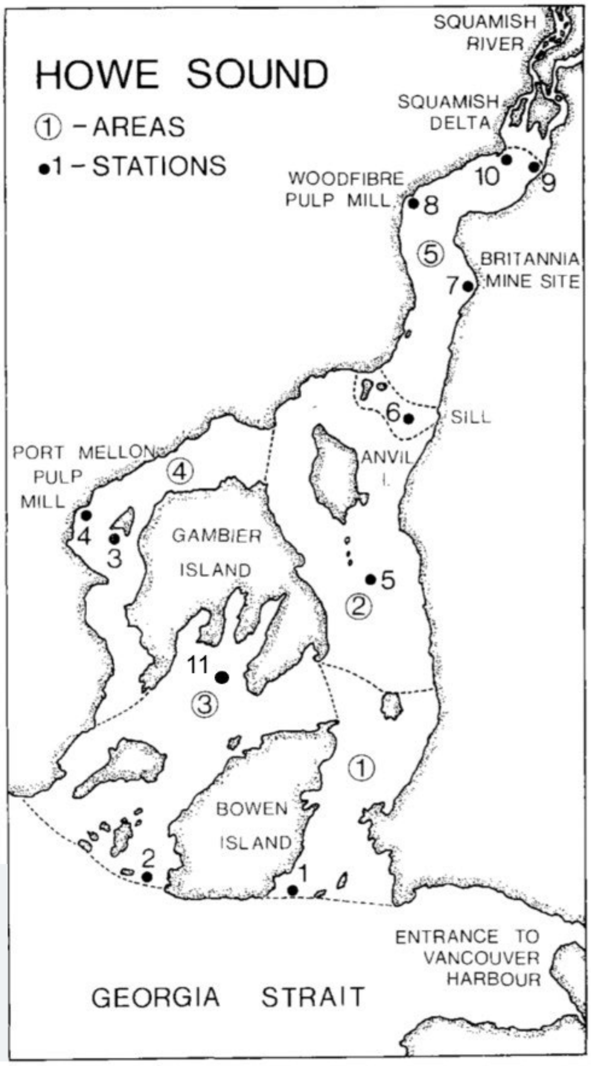


Figure 1. Map of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound showing original plankton sampling stations from the 1970s, to be re-sampled in the current pilot study. Small black circles indicate the location of sampling stations. Large open circles with numbers show the sampling zone, as defined by Stockner et 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’ḵa7tsem/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 Ḵw’émḵw’em/Defence Island and Nínich Ḵw’émḵw’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’ḵa7tsem/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’ḵa7tsem/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.

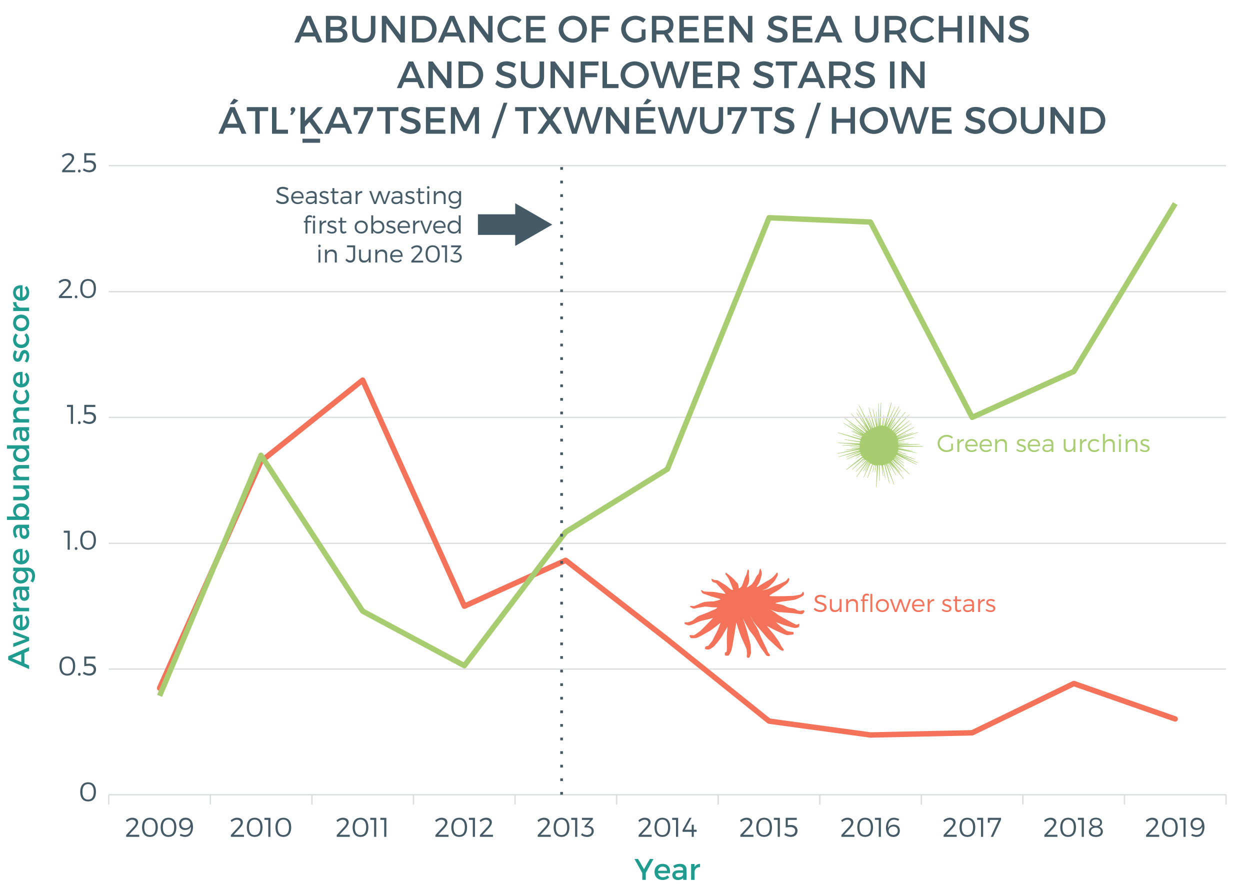
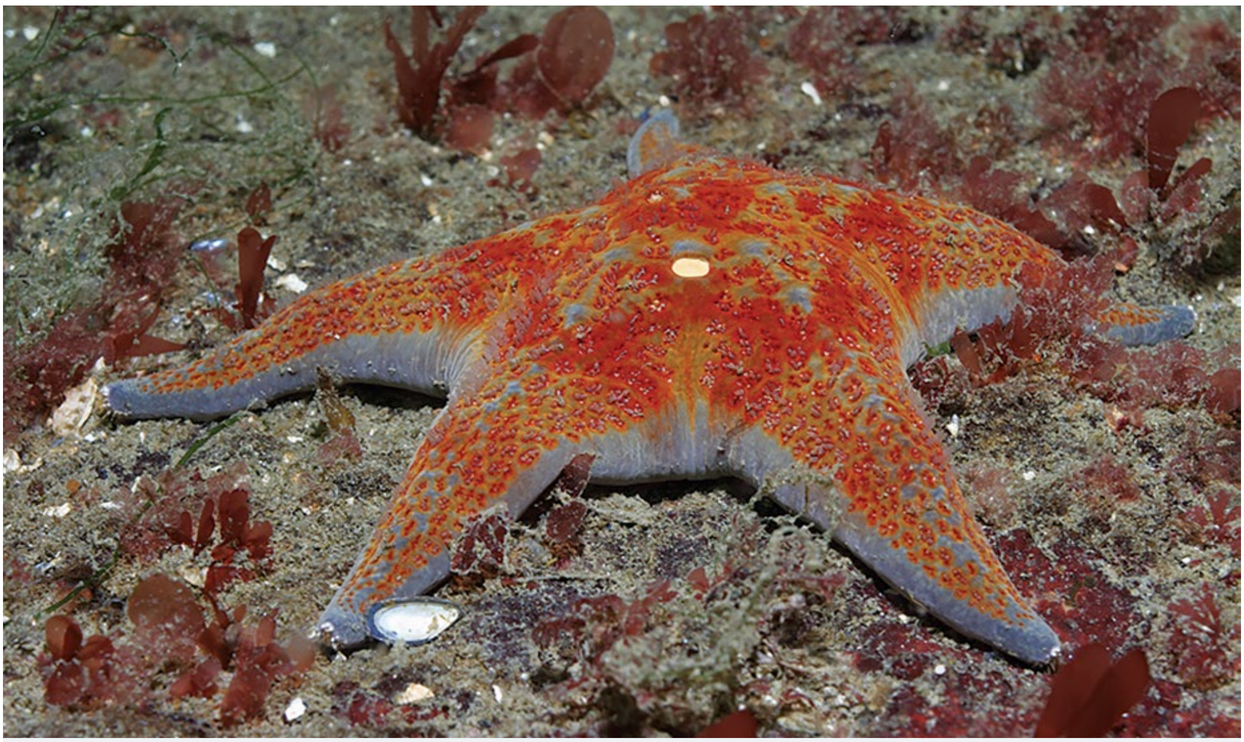


Figure 1. Following the outbreak of sea star wasting disease in 2013 (indicated by the red dashed line), the abundance of sunflower stars declined while the abundance of green sea urchins increased drastically. These data are from roving dive surveys at 116 sites in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound 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’ḵa7tsem/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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Ocean heat waves like the Pacific's deadly "Blob" could become the new normal. 2019. Available at: https://www.sciencemag.org/news/2019/01/ocean-heat-waves-pacific-s-deadly-blob-could-become-new-normal Accessed August 12th 2019.

UC Santa Cruz monitoring
https://marine.ucsc.edu/data-products/sea-star-wasting/index.html

Decreased biodiversity causes changes in keystone species.
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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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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

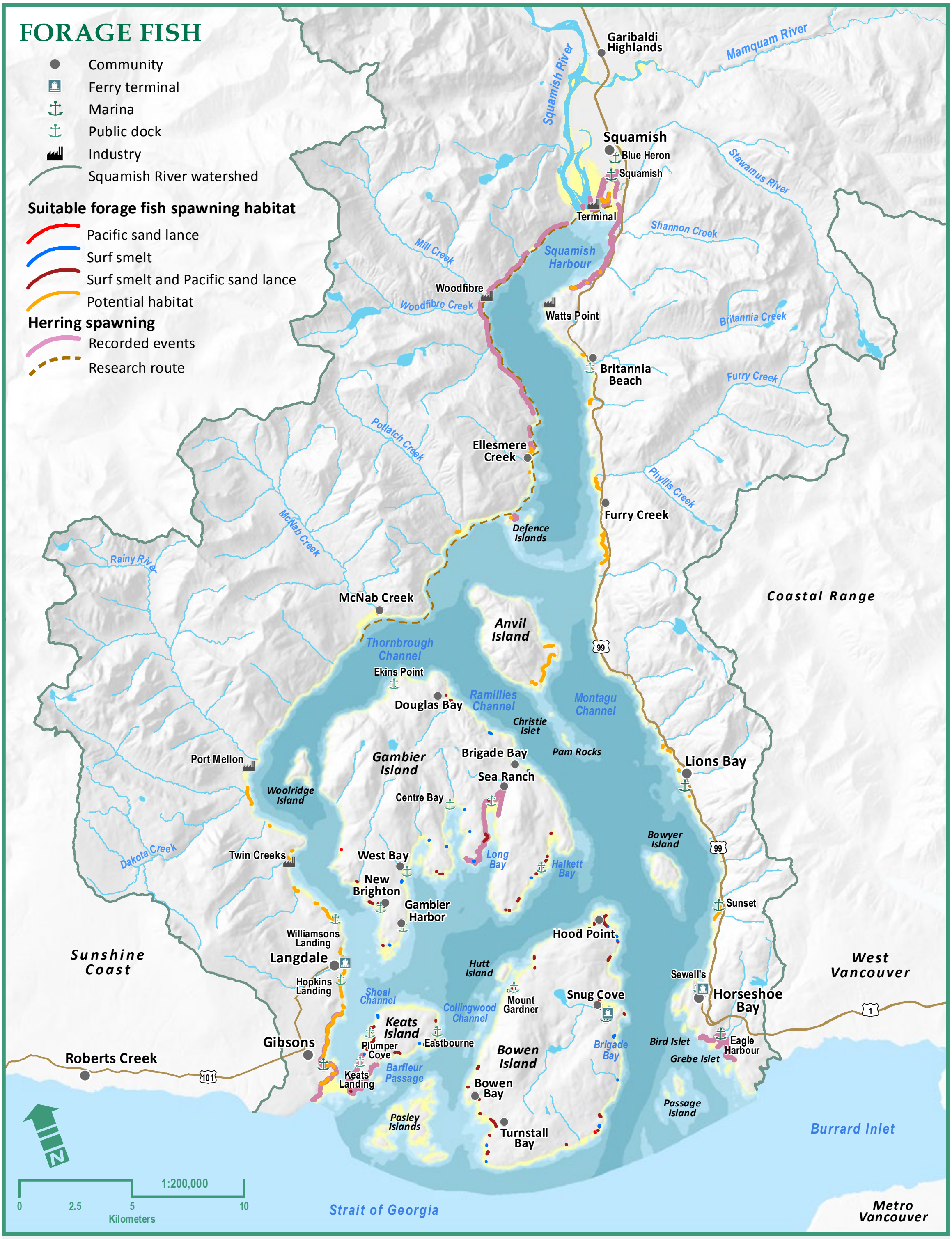

Figure 1. Forage fish spawning habitat and recorded herring spawning locations (data supplied by DFO, 1941–2002; citizen scientists on Bowen Island, 2015; Islands Trust, 2018; Friends of Forage Fish; and John Buchanan).[10]

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'ḵa7tsem/Txwnéwu7ts/Howe Sound. No data on herring spawn in Átl'ḵa7tsem/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'ḵa7tsem/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’ḵa7tsem/Txwnéwu7ts/Howe Sound. Anecdotal evidence of schooling anchovy in Átl’ḵa7tsem/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 Nex̱wlélex̱wem/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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/ 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’ḵa7tsem/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
www.youtube.com/watch?v=tABHmo0CDQk
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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3 Fisheries and Oceans Canada (DFO). Status of Pacific Herring (Clupea pallasii) in 2018 and forecast for 2019. *Can. Sci. Advis. Secr. Sci. Advis. Rep.* (2019).

4 Fisheries and Oceans Canada (DFO). *Stock status update with application of management procedures for Pacific Herring (Clupea pallasii) in British Columbia: Status in 2019 and forecast for 2020.* (2020).

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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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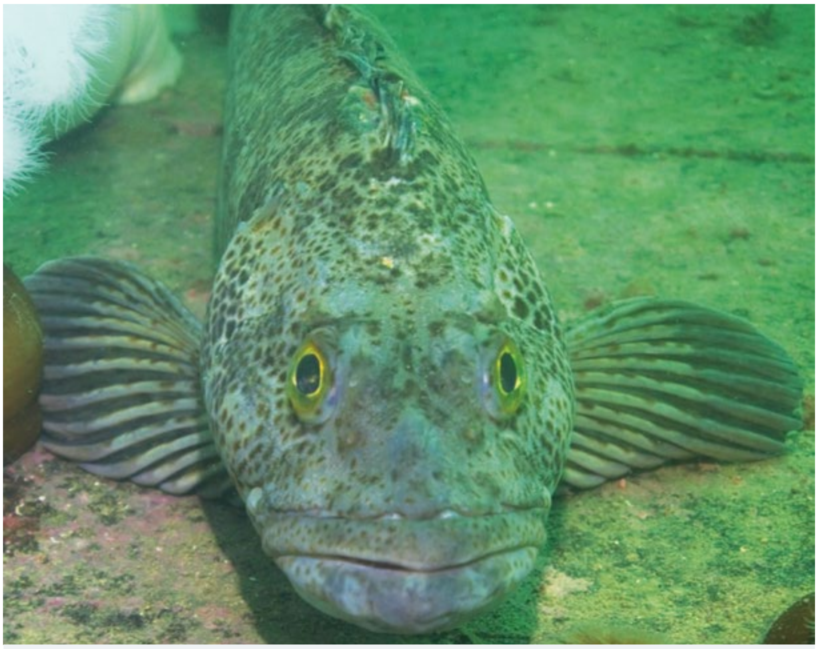
What is happening?

Despite various commercial and recreational fishing closures, lingcod and rockfish populations in Átl’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/Txwnéwu7ts/Howe Sound) lingcod since 2014.

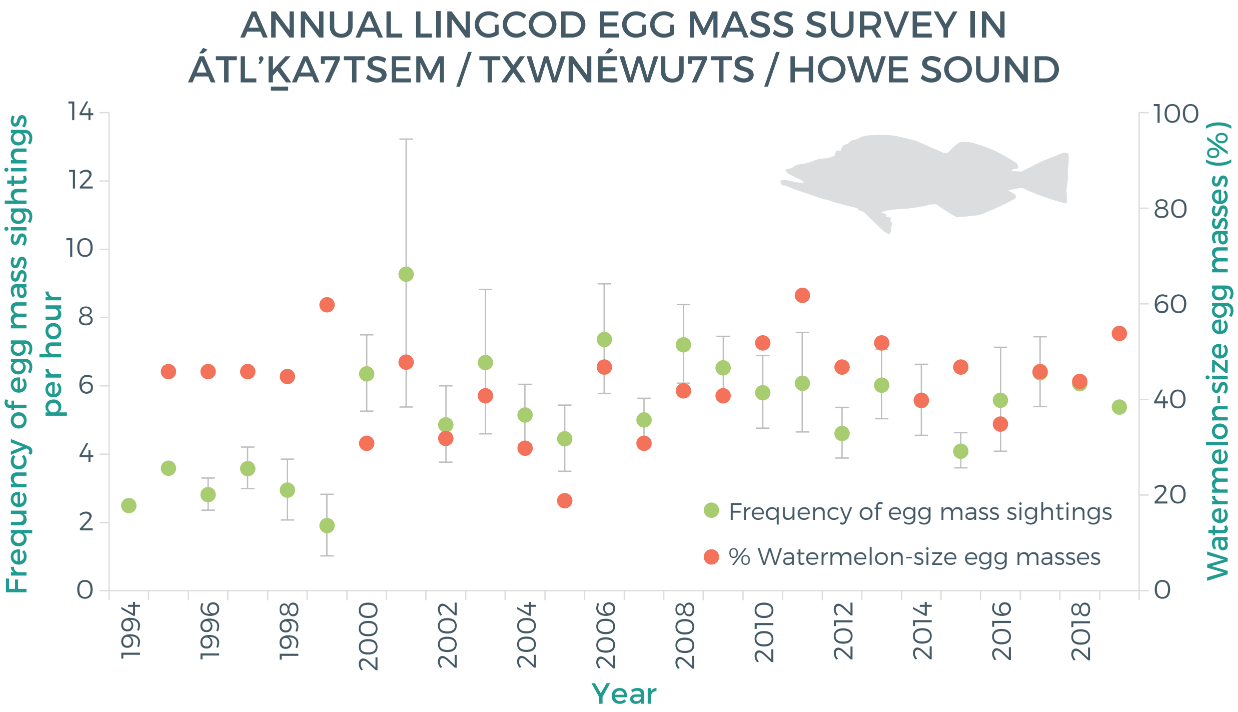


Figure 1. Frequency of egg mass sightings per hour and percentage of watermelon-size egg masses (produced by females at least five years old) in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound 1994–2019.

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’íẇitsut/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’íẇitsut/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’ḵa7tsem/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’ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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 Sḵwx̱wú7mesh/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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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’ḵa7tsem/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'ḵa7tsem/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]

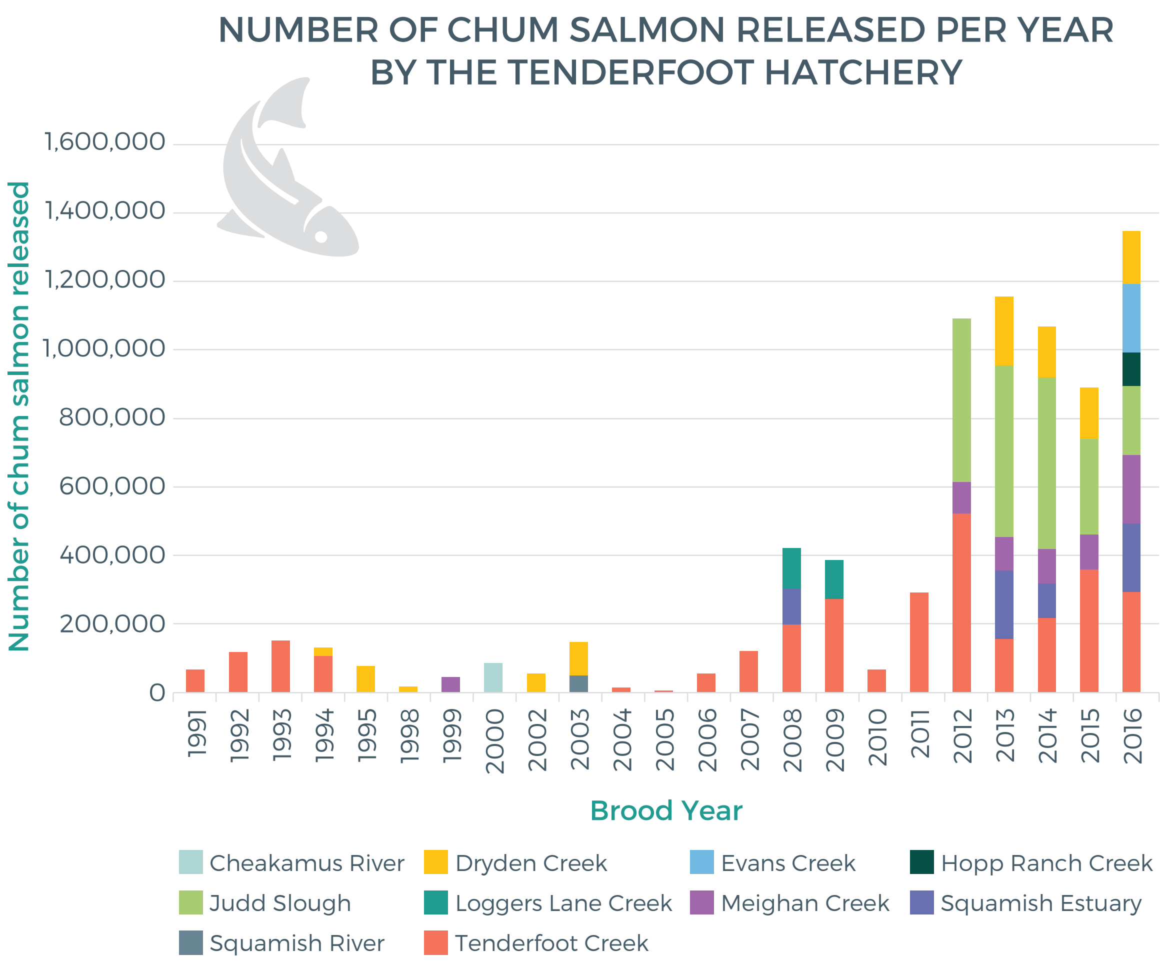

Figure 1: Number of chum salmon released per year at sites within Tenderfoot Hatchery's stocking program. Note increased efforts in 2012, aligned with the start of the chum stocking program.

Pink salmon *(O. gorbuscha)*

Pink salmon return to spawn every two years. The population occurring throughout Átl'ḵa7tsem/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'ḵa7tsem/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’ḵa7tsem/Txwnéwu7ts/Howe Sound (Subareas 28-1, 28-2 and 28-7), with a limit of four fish per day.[15]

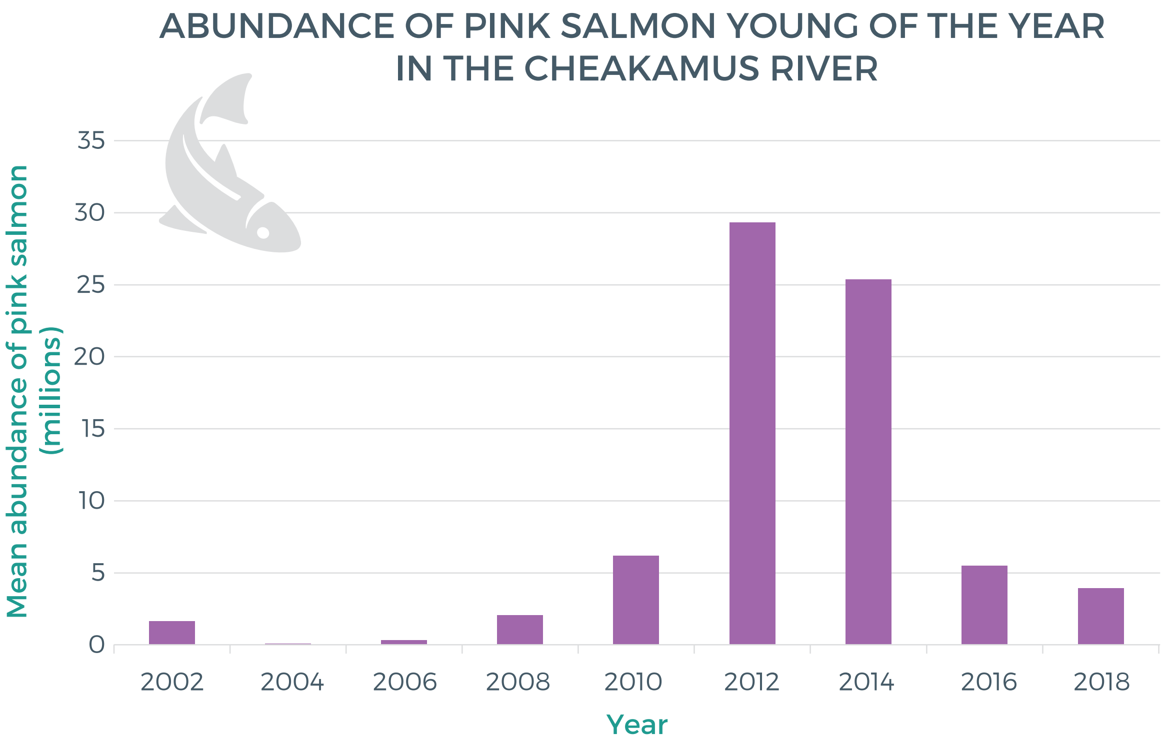

Figure 2. Mean annual abundance estimates of young of year (YOY) pink salmon collected bi-yearly in the Cheakamus River from 2002 to 2018, adapted from Lingard 2018.

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. Deadpitch 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.

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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'ḵa7tsem/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'ḵa7tsem/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’ḵa7tsem/Txwnéwu7ts/Howe Sound region (Figure 1). The English Bay – Burrard Inlet IBA was enlarged in January 2019 to include part of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, including Neẖwlélexwem/Bowen Island and areas in south-eastern Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound (see Marine Protected Areas, Ocean Watch Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020). The extension of the IBA was spearheaded by members of the Pacific WildLife 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’ḵa7tsem/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.

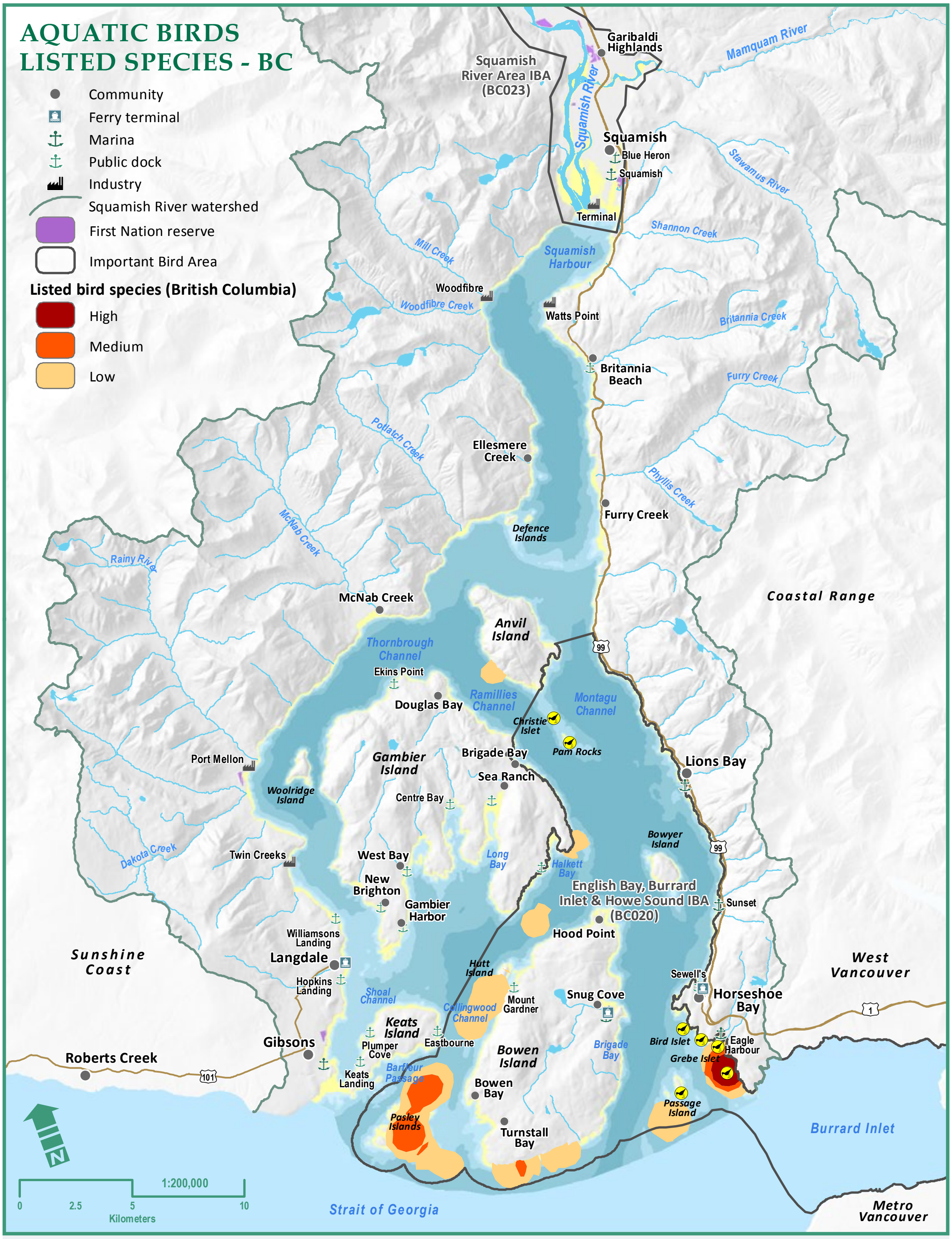


Figure 1. The English Bay – Burrard Inlet Important Bird Area, including its expansion into Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound that occurred in January 2019. Heat map shows recorded densities of listed bird species in the area. Yellow bird symbols represent the location of known bird colonies within the 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]

Barrow’s goldeneye

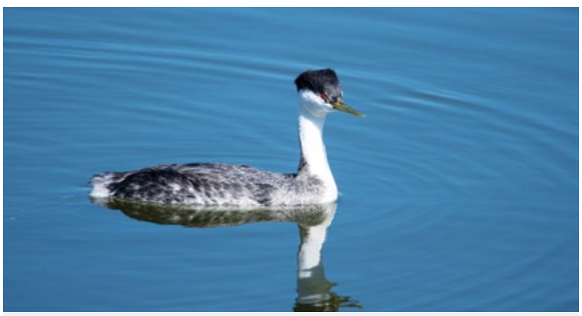
(Bucephala islandica)

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]

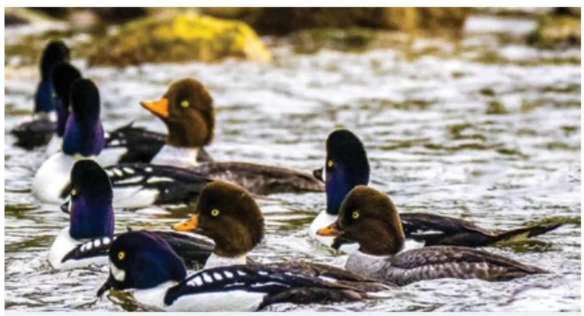
DISTRIBUTION AND HABITAT: These sea ducks have a confined distribution.[10] Two populations – an eastern and a western – are found in Canada. The western population is much larger.[10] The Salish Sea is an important habitat for these species during winter, providing nearshore coastal habitat, including within Átl’ḵa7tsem/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]



Western grebe. (Credit John Bakes)



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'ḵa7tsem/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'ḵa7tsem/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'ḵa7tsem/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.

Great blue heron. (Credit: John Bakes)

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’ḵa7tsem/Txwnéwu7ts/Howe Sound, there will be increases in suitable nesting habitat (see Eelgrass, OWHS 2020).[15]

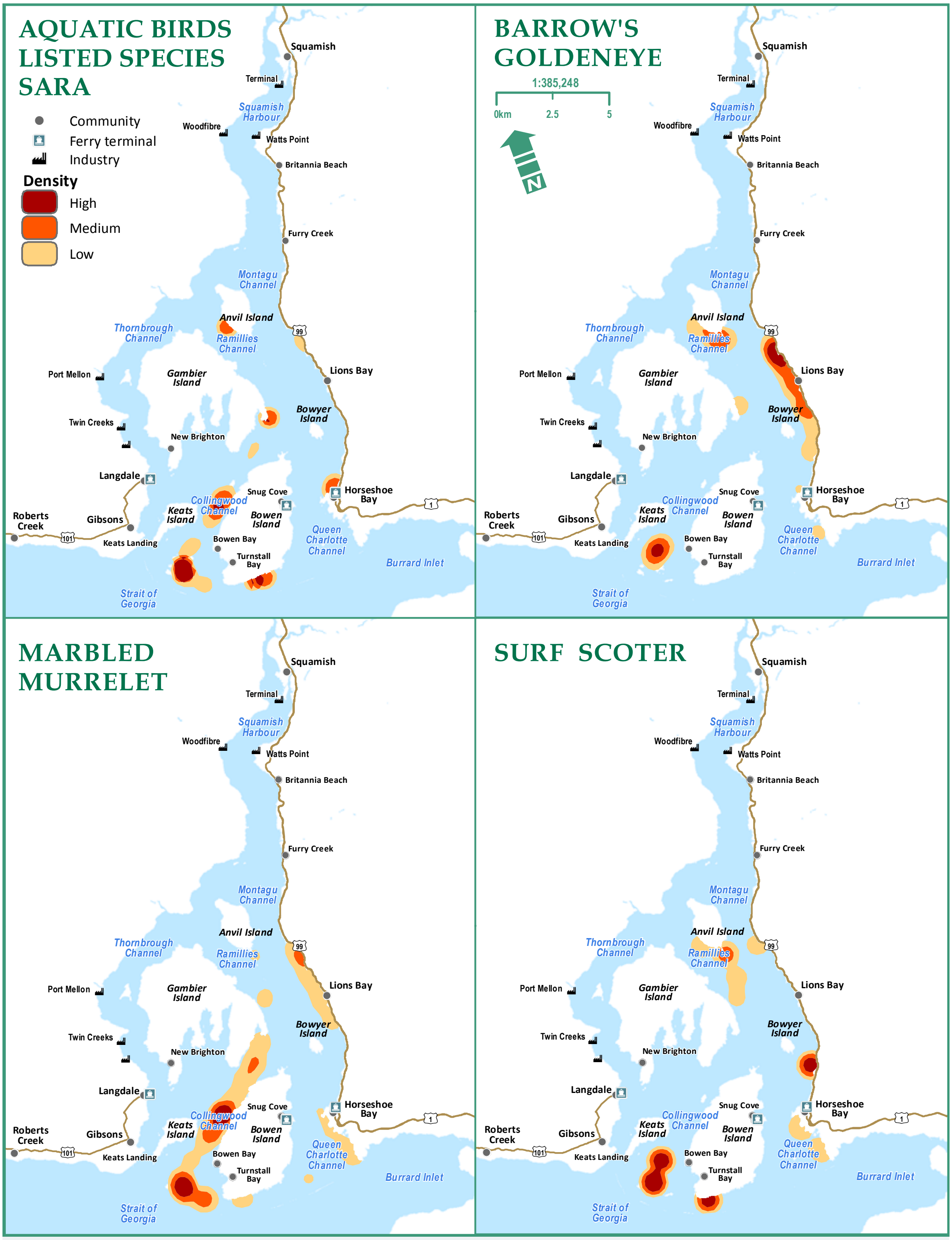


Figure 2. Densities of birds within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Top left: Density of SARA-listed marine birds. Top right: Density of Barrow’s goldeneye. Bottom left: Density of marbled murrelet. Bottom right: Density of surf scoter.

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’ḵa7tsem/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’ḵa7tsem/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=

https://stanleyparkecology.ca/2018/02/28/whats-an-iba/

INFORMATION ON “THE BLOB”

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Ocean heat waves like the Pacific’s deadly “Blob” could become the new normal. 2019. Available at: https://www.sciencemag.org/news/2019/01/ocean-heat-waves-pacific-s-deadly-blob-could-become-new-normal Accessed August 12th 2019.

xvi) www.pwrc.usgs.gov/BBS/about/

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

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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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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 Nex̱wlélex̱wem/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’ḵa7tsem/Txwnéwu7ts/Howe Sound.

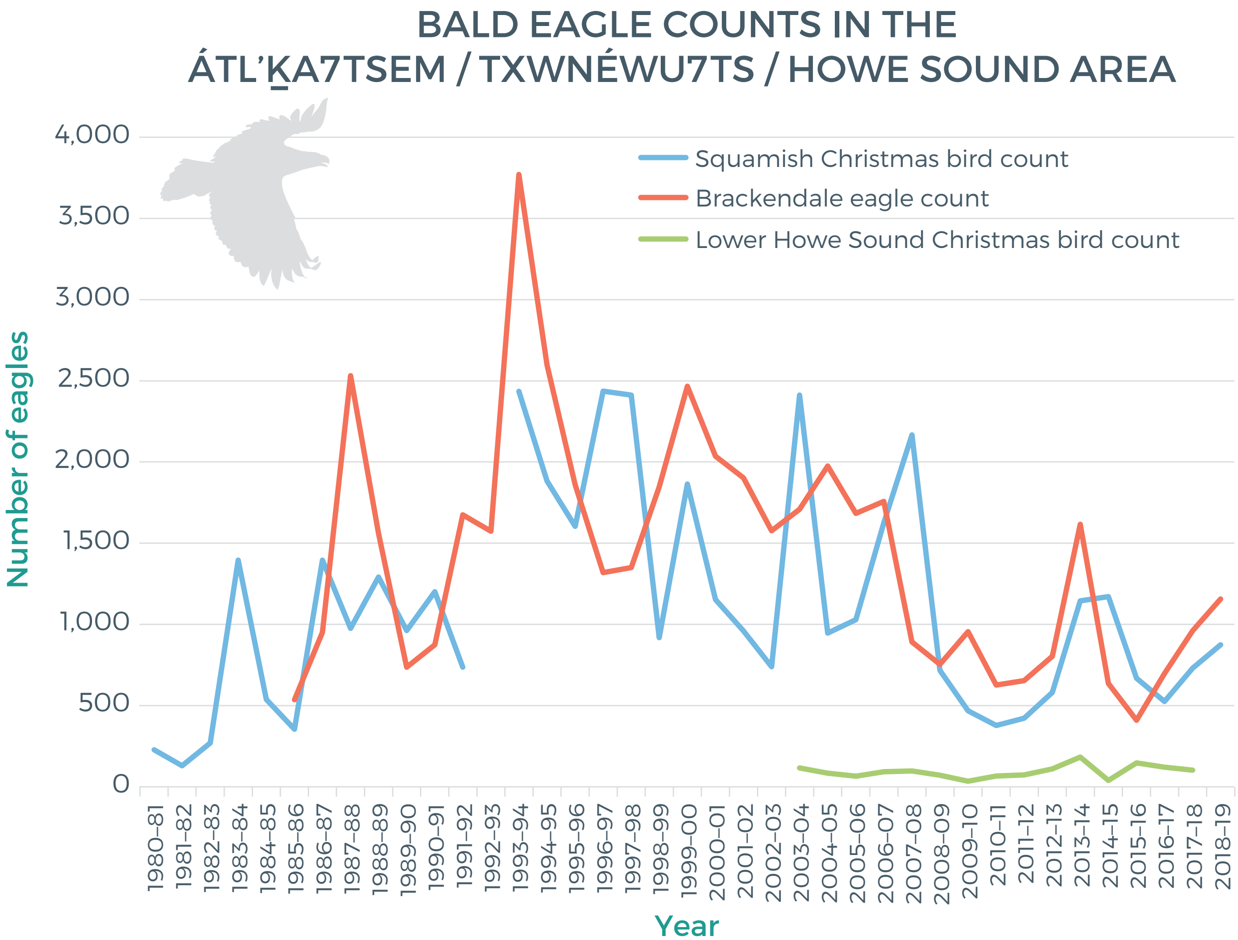

Figure 1. Bald eagle counts by each of three citizen science groups in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound from the early 1980s to 2019 for the Squamish Christmas and Brackendale eagle counts; and from 2002 to 2018 for the Lower Howe Sound group.

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’ḵa7tsem/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.

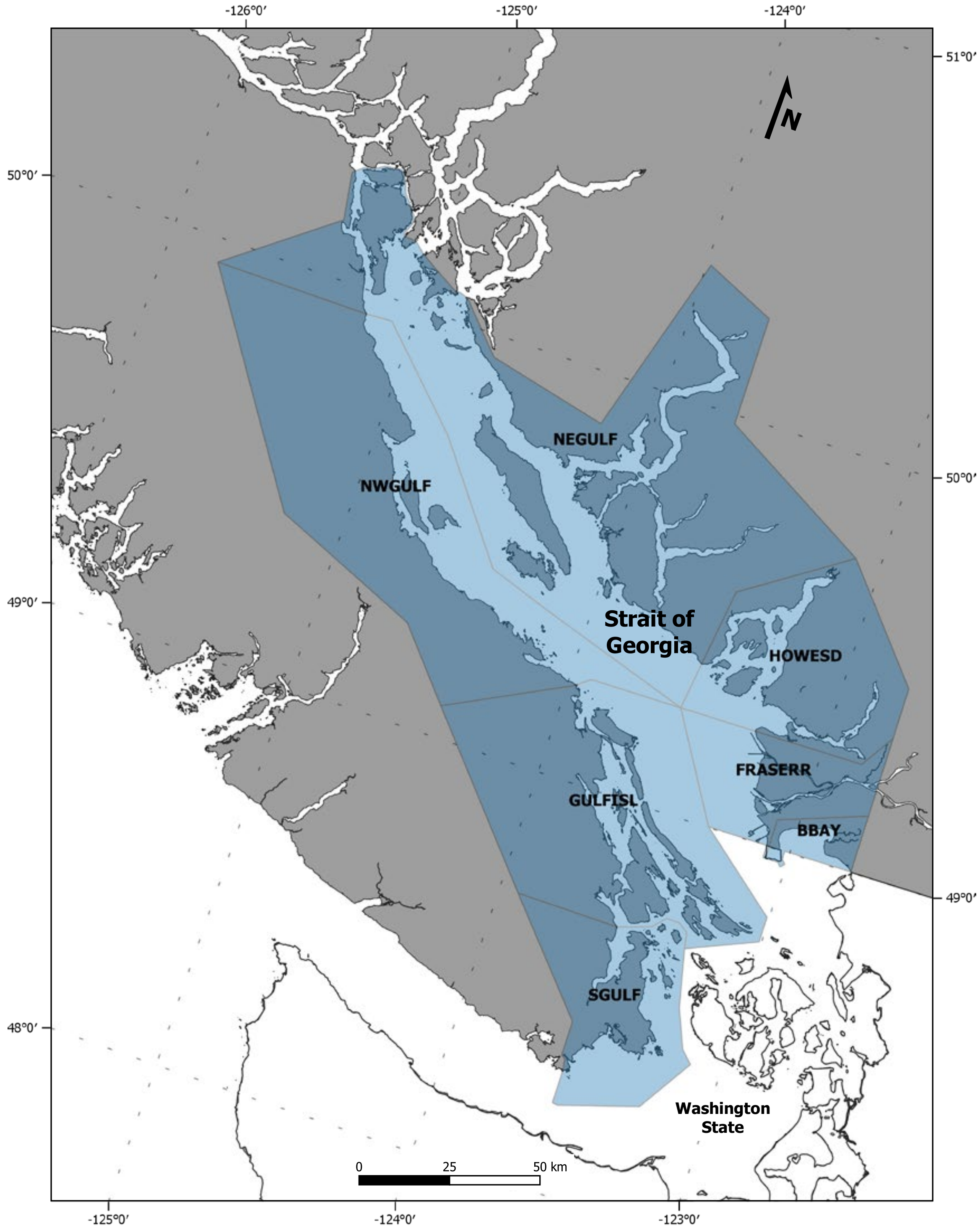


Figure 1. The Strait of Georgia harbour seal aerial survey occurs throughout the blue shaded area. Survey subareas are delineated by grey lines with Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound (HOWESD) located in the mid-eastern portion of the Strait.

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

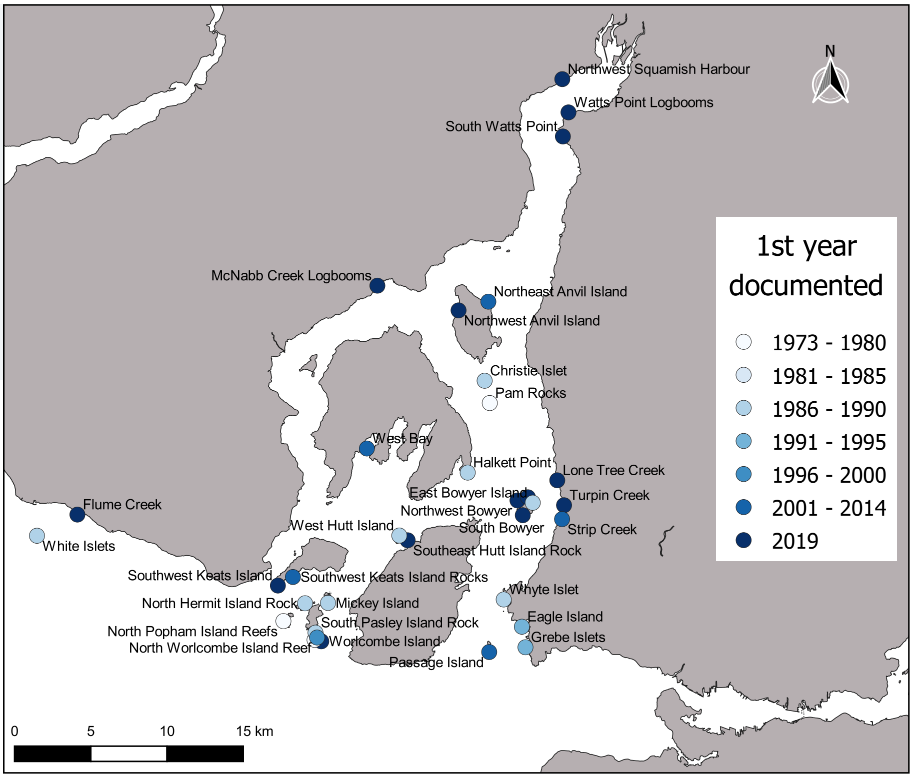
In the past, B.C. First Nations hunted harbour seals and sea lions for their pelts, meat and oil. Steller sea lion whiskers were used on traditional ceremonial garments.[4] Hunts took place either from the shore or on the water from canoes.[5]

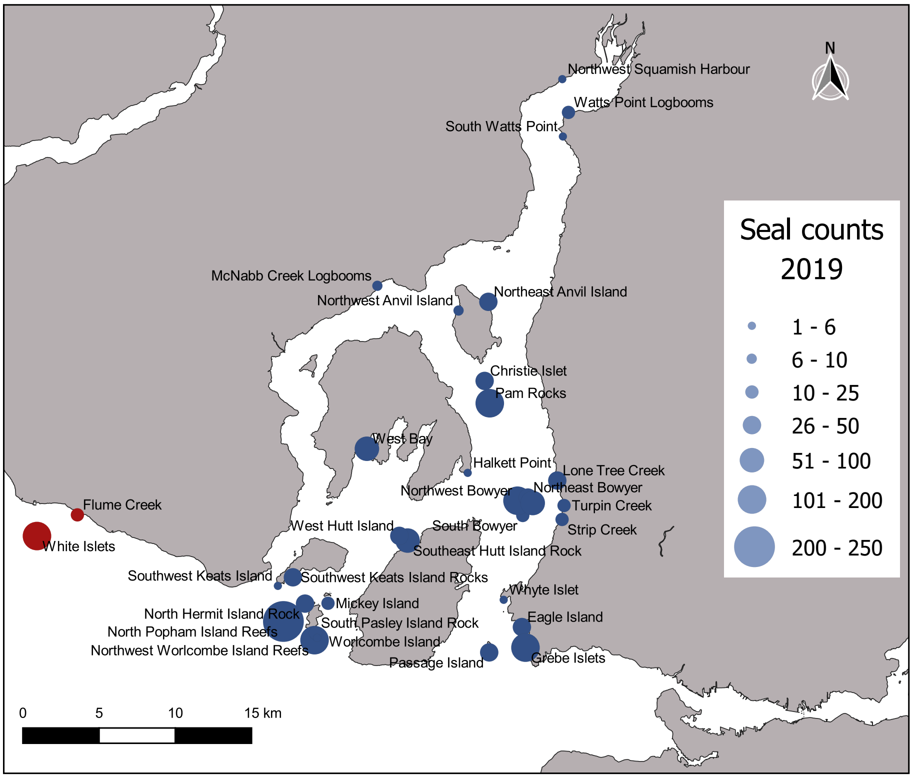
For the Sḵwx̱wú7mesh Úxwumixw/Squamish Nation, specially trained hunters harvested seals and sea lions from Sw̓esp̓ép̓s ta Kwenís, a rocky outcrop off Gibsons Landing on the Sunshine Coast. Ḵwiláḵm/Bowen Island was also known as an important sea lion hunting site.[6] These hunts typically took place 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,

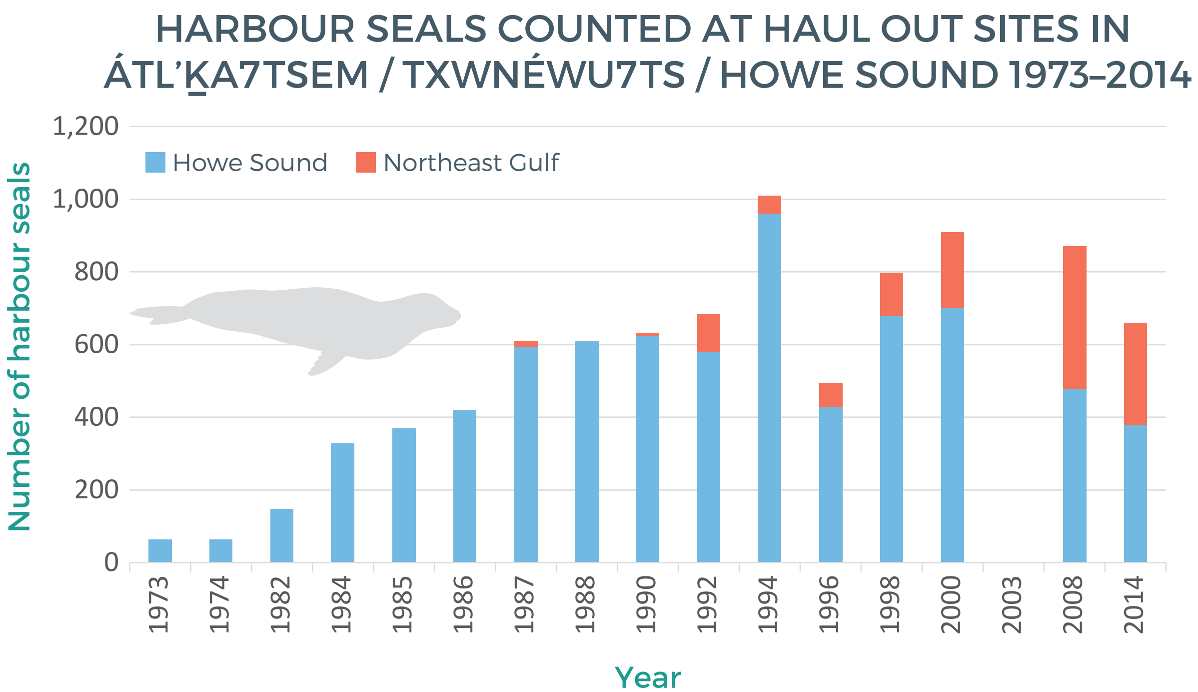


Figure 3. Number of individual harbour seals counted at haul-out sites in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound from 1973 to 2014. Seals were recorded at nearby Northeast Gulf sites beginning in 1978. The Northeast Gulf sites shown represent only two of the nearby sites, not the entire Northeast Gulf area. 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’ḵa7tsem/ 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’ḵa7tsem/ 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’ḵa7tsem/ Txwnéwu7ts/Howe Sound haul-outs interchangeably (Figure 4). When adding seals from those two haul-outs to counts within the Átl’ḵa7tsem/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’ḵa7tsem/ 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’ḵa7tsem/ 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.

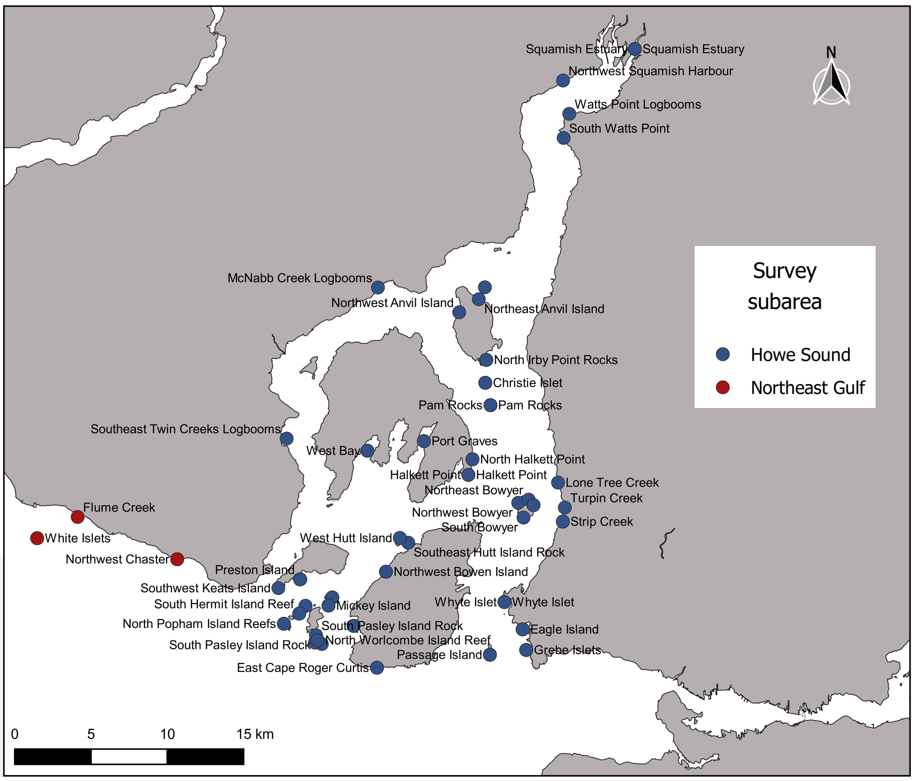


Figure 4. Harbour seal haul-outs documented in the Átl’ḵa7tsem/ Txwnéwu7ts/Howe Sound survey area (blue dots) and three nearby haul-outs to the west of the survey boundary in the Northeast Gulf area (red dots) from 1973 to 2019

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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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).

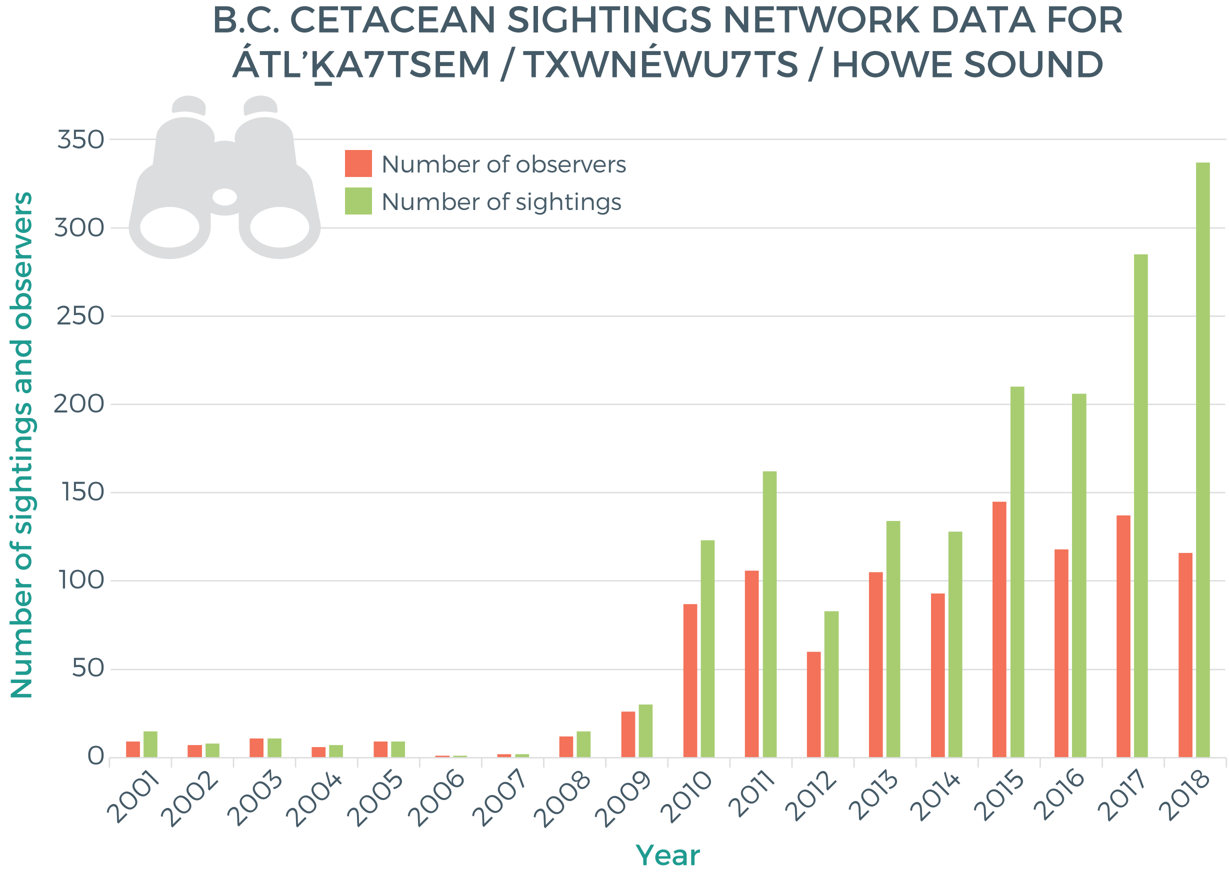

Figure 1. Total number of observers and number of cetacean sightings reported to the BCCSN in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound by year.

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'ḵa7tsem/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'ḵa7tsem/Txwnéwu7ts/Howe Sound in 2018. Chinook salmon runs

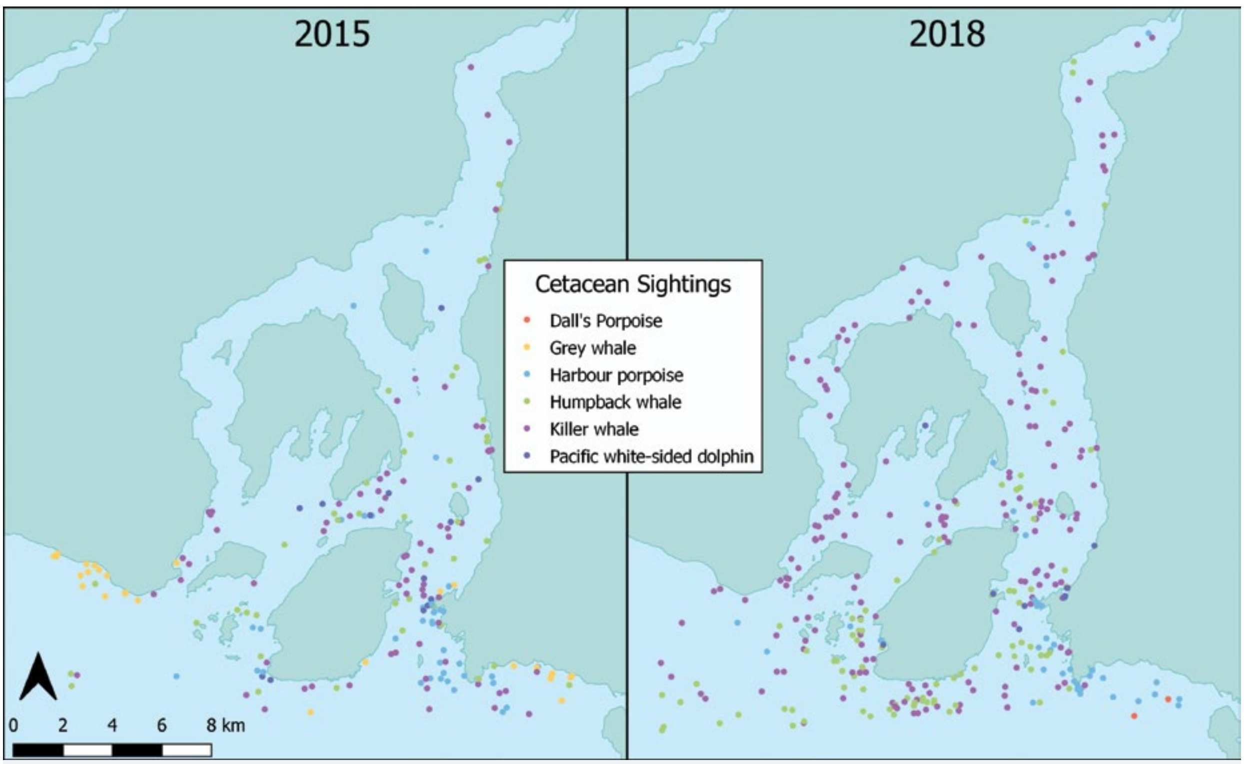

Figure 2. Cetacean sighting reports submitted to the BCCSN in 2015 (left panel) compared to 2018 (right panel), by species. One point on the map is equivalent to one cetacean sighting.

Humpback whale in Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound. (Credit: Rhys Sharry)

in Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound have been depleted since the 1970s and 1980s[3] and could explain the near absence of resident killer whales from Átl’k̲a7tsem/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’k̲a7tsem/Txwnéwu7ts/Howe Sound until 2008 when they began reappearing in large numbers. Humpbacks are now recovering to near historical levels in Átl’k̲a7tsem/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’k̲a7tsem/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]

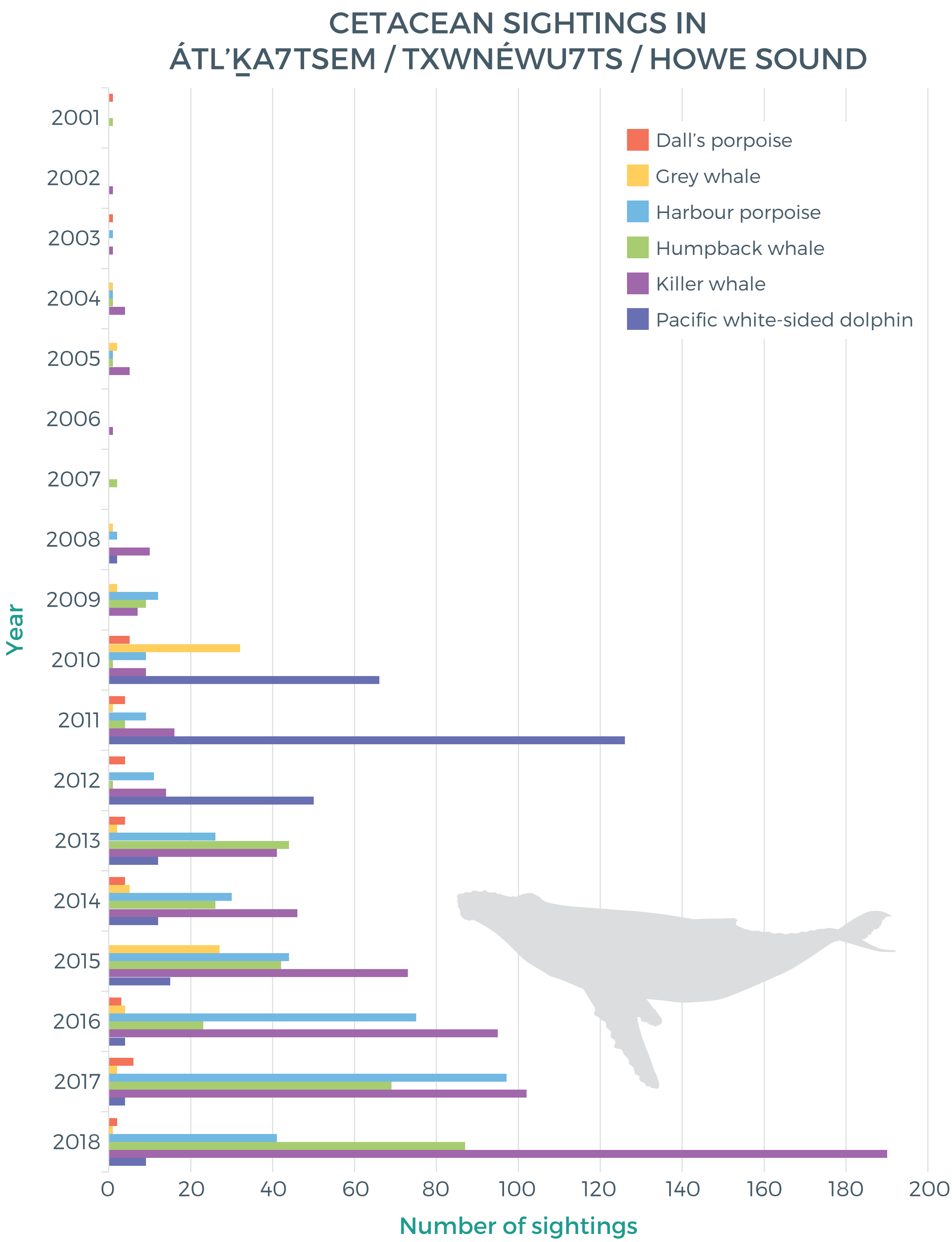

Figure 3. Cetacean sightings in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound from 2001–2018, by species.

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’ḵa7tsem/Txwnéwu7ts/Howe Sound, an issue potentially exacerbated by sea level rise, storm surges, and extreme weather due to climate change.

Residents of Átl’ḵa7tsem/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’ḵa7tsem/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’ax̱áy/Horseshoe Bay and the surrounding area (Figure 4), one of the areas of highest human population density in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Although the number of Átl’ḵa7tsem/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.

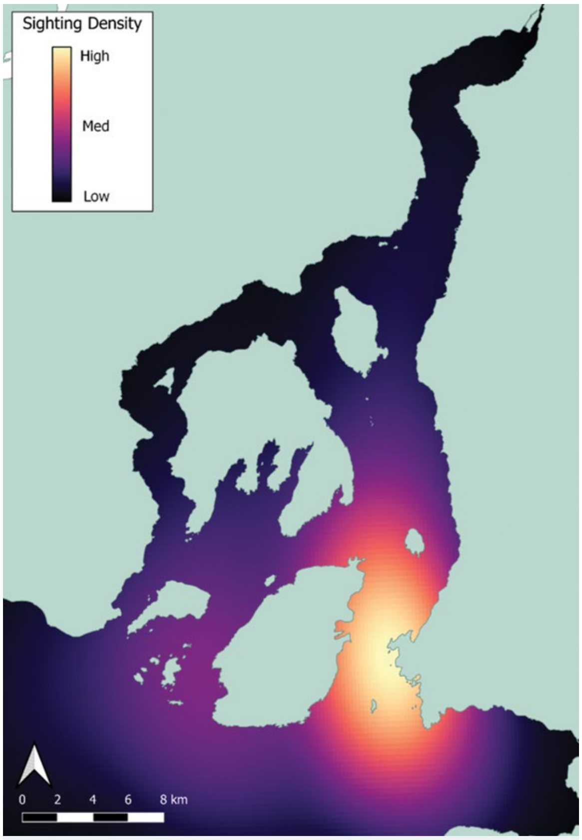

Figure 4. Density of cetacean sightings reported to the BCCSN from 2016 to 2019.

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’ḵa7tsem/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’ḵa7tsem/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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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)

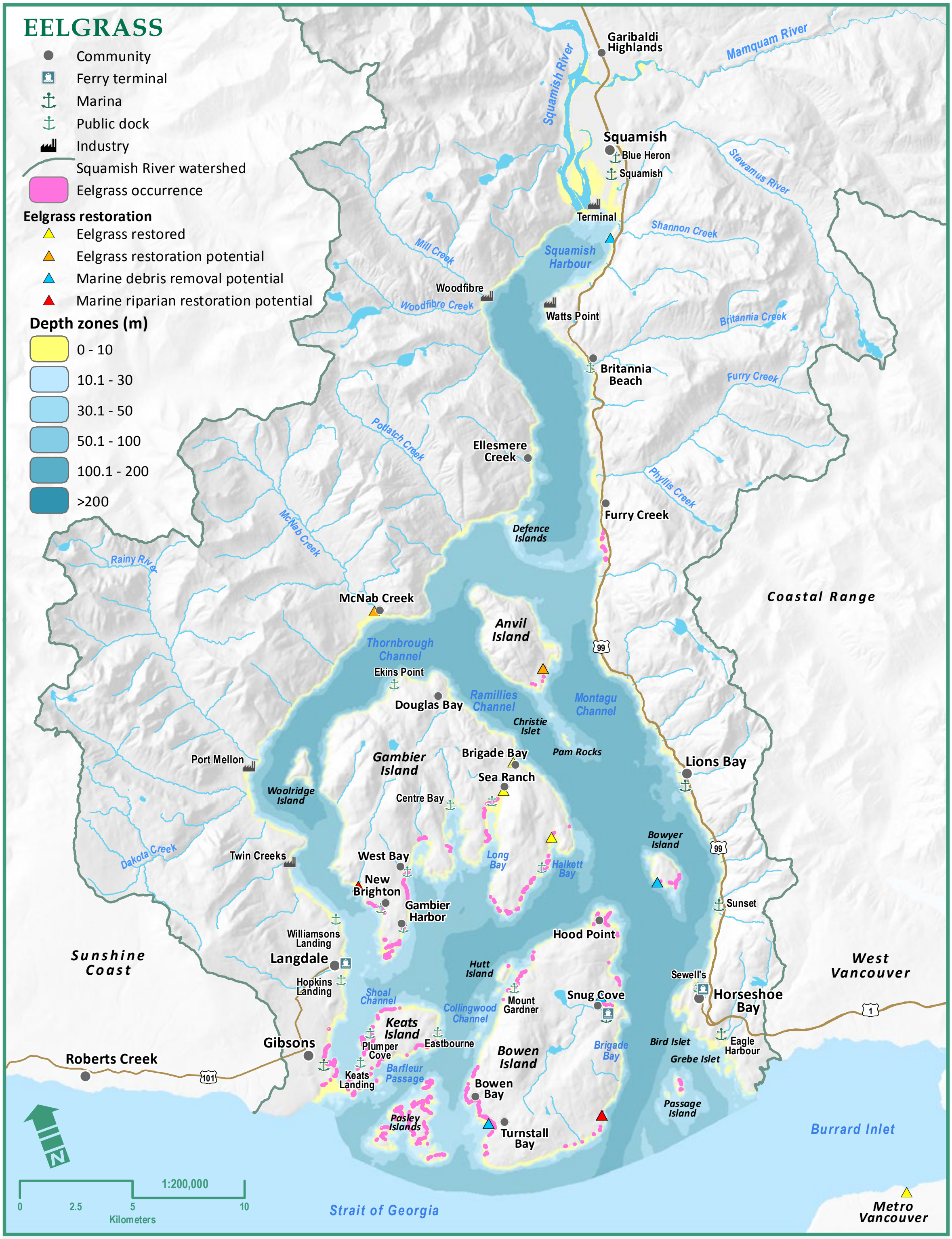
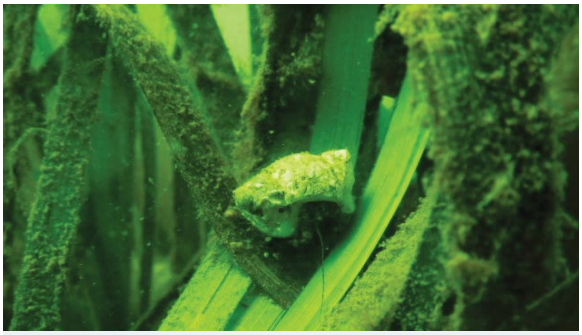


Figure 1. Eelgrass occurrence throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[1]

What is the current status?

Since 2017, there have been seven eelgrass transplants in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound: five on Chá7elkwnech/Gambier Island, one on Keats Island and one on Neẖwlélex̱wem/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, səl̓ilw̓ət/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’ḵa7tsem/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, səl̓ilw̓ət/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

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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’ḵa7tsem/Txwnéwu7ts/Howe Sound.	In March 2019, DFO announced the closure of the nine documented glass sponge reef complexes in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to bottom-contact fishing. Furthermore, 21 additional possible reef sites in eight distinct areas in Átl’ḵa7tsem/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 Ḵw’émḵw’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’ḵa7tsem/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’ḵa7tsem/ 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’ḵa7tsem/Txwnéwu7ts/Howe Sound.

Methods

The study by Marliave et al.[1] drew on more than a decade of scuba diving at the Nínich Ḵw’émḵw’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.

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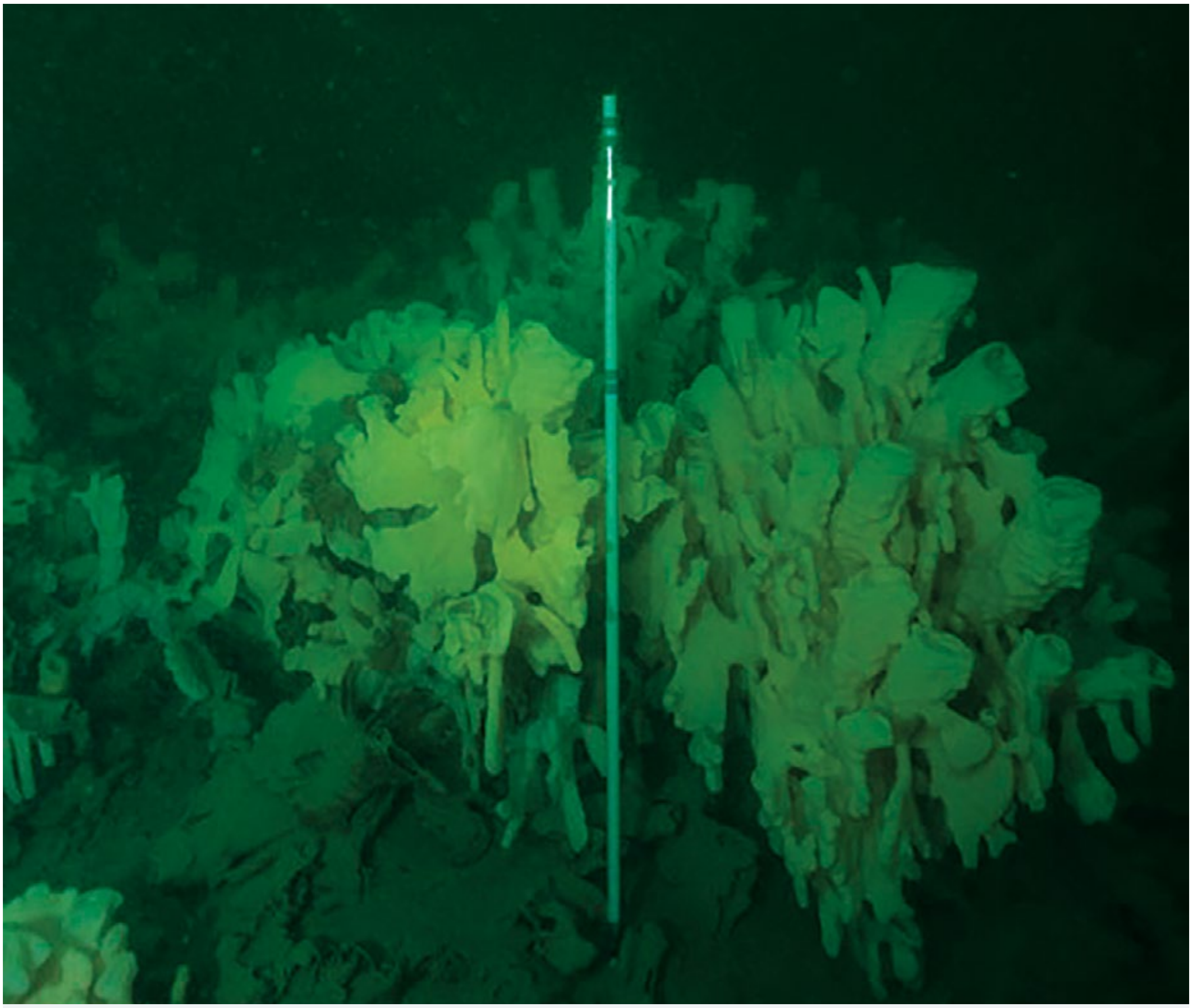

Glass sponge reef marked by a bar-coded stake. (Credit: Adam Taylor)

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’ḵa7tsem/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.

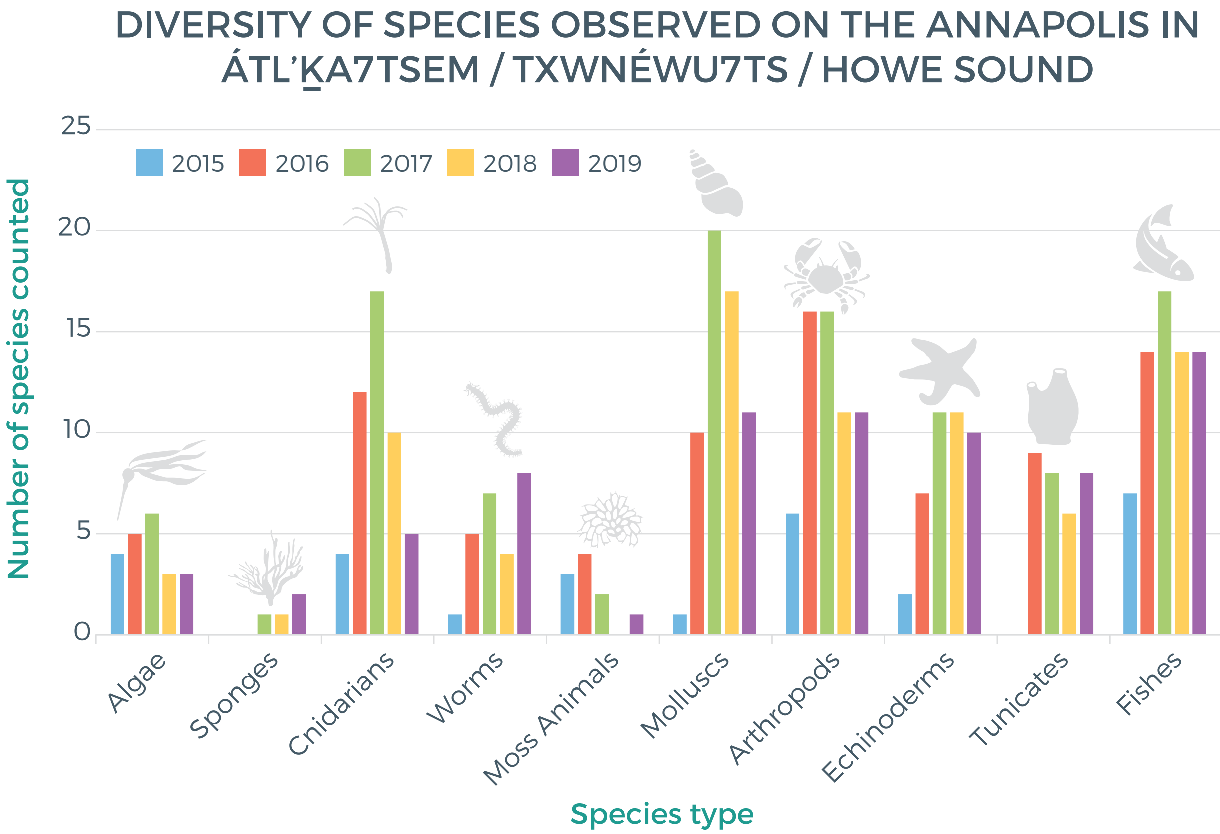

Figure 1. Number of species in different categories observed on the Annapolis since it was sunk in April 2015. Data for 2015 is from May 21. Data for 2019 includes dives conducted up to early March (the project completion date). All other years are full calendar years.

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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REVIEWER

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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’ḵa7tsem/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’ḵa7tsem/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’ḵa7tsem/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); Sḵwx̱wú7mesh 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/

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

Seafood

Shrimp fishing.
(Credit: Maxwell Hohn)

Summary

Unsustainable resource extraction is one of the great threats to our oceans, and this includes unsustainable harvesting of seafood by both recreational and commercial fishers. Recently, an increasing number of sports anglers have been attracted to the Sound by recovering fish stock, such as Chinook salmon. However, other species such as pink salmon have variable population estimates, and therefore their sustainability is uncertain. Monitoring population size is important to maintain healthy fish stocks; however, critical funding for monitoring salmon return in the Cheakamus River – the only consistent indicator of salmon population dynamics in the watershed – has been cut.

By contrast, the shrimp and prawn fisheries in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound benefit from strong monitoring programs, which result in fishery closures when stocks drop too low. Due to the indiscriminate nature of fishing methods, the shrimp trawl fishery has been closed throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound since 2017 due to low stock numbers. Further actions to protect sensitive habitat and species, such as glass sponge reefs, include using improved fishing technology and gear, closing certain areas to bottom trawling and promoting fishing methods to decrease bycatch.

Both sport fishing and the shrimp/prawn fisheries are likely to be negatively impacted by climate change because many of these species prefer cooler water temperatures. Warmer waters, droughts and floods will impact the survival of all life stages of these species. Taking action to address climate change, implementing long-term fish monitoring programs where they are lacking, and protecting fragile habitats will be key moving forward.

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
SPORT FISHING Pressure on fish stocks continues to increase from the rising popularity of sport fishing. There is a lack of monitoring to support stock management and enforcement of regulations.		
SHRIMP/PRAWN FISHERY Stocks have been declining since 2015, resulting in fishery closures. Industry is trying to decrease bycatch mortality.		

Sport Fishing: more anglers increase pressure on fish stocks

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REVIEWER
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What is happening?

Visitor numbers to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound have continued to grow since 2017. Consequently, more anglers have increased pressure on local sport fishing areas and fish species. Anglers and conservationists have repeatedly asked for additional enforcement efforts in the Squamish River and Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound; however, both federal and provincial agencies have been slow to respond.

Sport fishing in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Dave Brown)

What is the current status?

Sport fishing in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is benefiting from increases in some salmon stock. However, it is also experiencing challenges, such as threats to fish survival under certain river conditions and a reduction of data collection to support effective management.

An increase in Chinook salmon has been observed throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound by hatcheries and anglers. At the Tenderfoot Creek Hatchery, returning Chinook adults were seen in all river systems during summer 2018. This was the first time a return had been observed in the hatchery’s four years of operation. Then, in summer 2019, large numbers of four and five-year-old hatchery adult Chinook were caught and reported at Tenderfoot Creek.[1] Anglers have benefited from this increase in Chinook in the Sound.[2]

Pink salmon (*Oncorhynchus gorbuscha*) return to spawn every two years. In odd years between 2011 and 2017, large returns of pink salmon adults to the Squamish River watershed drew anglers to the area. Because of the large returns, a commercial fishery was opened in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound for pink salmon in 2013. However, because there was no stock assessment of this species in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to use for setting quotas, the commercial fishery was shut down in August 2015[3] and has not been re-opened. Nonetheless, data from the Cheakamus River indicates a declining trend in estimated juvenile pink salmon abundance since 2015, although there is clearly high variability in numbers.[4] Anglers, however, continue to enjoy sport fishing for pink salmon, one of the only sport fish species allowed to be retained.

Ramping[i] events are a concern for fish populations using rivers with hydroelectric facilities. In 2018, a fish

Happy young angler. (Credit: Dave Brown)

i) Ramping – increasing or decreasing the water flow on a run-of-river hydroelectric project, which can result in fish being stranded and dying if the water levels drop too quickly.

fry[ii] stranding occurred in the Cheakamus River due to a ramping event that aimed to control the release of water from BC Hydro’s hydroelectric facility at Daisy Lake Dam.[5] In September 2019, another large ramping event on the Cheakamus River resulted in considerable numbers of dead pink salmon, many of which had not yet spawned. Additionally, this event destroyed salmon redds[iii].[6] The number of fish being stranded and dying after ramping events and the frequency of these events is highly concerning for the local community.[2]

Unfortunately, the long-term monitoring programs in the Cheakamus River that were a part of a Water Use Plan for BC Hydro, ended in 2019. The monitoring provided the only consistent indicator of salmon population dynamics in the Squamish River watershed. The loss of this program will result in government agencies no longer having long-term monitoring data to guide resource management decisions such as fisheries quotas and closures.

What are the potential impacts of climate change on sport fishing?

Climate change is likely to have significant effects on the sport fishery in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Increasing water temperature, summer droughts and high discharge volumes due to extreme precipitation events are forecasted to increase under current climate change projections.[7,8] All these conditions have negative impacts to anadromous[iv] salmon and trout that make up a large component of the sport fish in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. However, positive impacts from climate change are also being observed for particular species. In recent years, elevated ocean temperatures have been linked to the higher abundance of Northern anchovy (*Engraulis mordax)* in the Salish Sea.[9] This positive correlation is likely to exist only up to a certain temperature threshold. Anchovy are an important forage fish in the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound food web.

Warmer water temperatures and droughts are likely to negatively impact the survival of all life stages of salmon from egg to adult. Energy use in fish is higher in warmer temperatures, and fish in warm water become stressed, which can lead to an increase in disease.[10] Storm events can wash fish out of rivers before they are ready to migrate or damage the eggs laid in redds. High river discharges also affect the ability of migrating adult salmon to enter spawning habitats, reducing the success of spawning events.[10,11]

ii) Fish fry – small young fish that are just emerging from their gravel nest.

iii) Redd – a depression in the riverbed where female salmon deposit eggs during spawning.

iv) Anadromous – moving into rivers from the sea to spawn.

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	
Ensure you are familiar with the current regulations before you fish.	Three educational signs were installed in the Squamish River watershed in summer 2017. Signs display species information including identification, where to look for fishing regulations and locations of Sḵwx̱wú7mesh Úxwumixw/Squamish Nation lands. These signs were placed at high traffic areas of the Squamish River (i.e., the Squamish Spit, Fisherman’s Park and at the confluence[v] of the Mamquam and Squamish rivers).
GOVERNMENT ACTIONS AND POLICY	
Support grassroots stewardship programs.	Some groups are supported by government funding. For example, the Tenderfoot Creek Hatchery (run by Fisheries and Oceans Canada [DFO]) provides fish to the Bowen Island Terminal Creek Hatchery, run by the Bowen Island Fish and Wildlife Club (BIFWC), a citizen science group.
Undertake baseline data studies to better determine fish populations, behaviours and returns so that conservation projects can be implemented, and retention, commercial harvests and industrial projects allowed only when supported by sufficient data.	The long-term monitoring programs in the Cheakamus River that were a part of a Water Use Plan for BC Hydro, ended in 2019. The monitoring provided the only consistent indicator of salmon population dynamics in the Squamish River watershed. This is a contrary move to the recommended action.

v) Confluence – the joining of two rivers.

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:

- Take fishing lessons to learn proper fish handling techniques.
- Take your garbage and used fishing line with you when you leave your fishing spot.
- Avoid unwanted and illegal rockfish by fishing away from rocky reef areas, key habitat for these fish.
- Sport fishing organisations and guides/outfitters can collect data on participants and catch and share the data to aid in quantifying the value of the activity to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.
- Participate in shoreline cleanups.

Government Actions and Policy:

- Require angler education through the licensing process.
- Make angler awareness programs available in multiple languages.
- Allocate more resources toward monitoring and enforcement of recreational fishing regulations. Ensure saltwater “guides” are licensed.
- Increase levels of protection for forage fish species such as herring, eulachon and anchovy as they are main food sources for Pacific salmon and some marine mammals in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.
- Require saltwater guides to be licensed and test their knowledge regularly.
- Unlink the allocation of DFO Conservation Officer enforcement funds with volume of reported infractions and increase enforcement capacity especially in heavily fished areas.
- **NEW** Implementation of ongoing long-term fish monitoring projects in this area.
- **NEW** Support surveys of angler activity and catch statistics.
- **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

Literature was scanned for potential impacts of climate change on sport fish species.

Resources

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

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Educational signage placed along the Squamish River. (Credit: Stephanie Lingard)

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Shrimp and Prawn Fisheries: managing declining stocks

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What is happening?

Within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, commercial and recreational fisheries have traditionally targeted spot prawn (*Pandalus platyceros*) via trap, and pink (smooth [*Pandalus jordani*] and spiny [*Pandalus borealis*]) and sidestripe shrimp (*Pandalopsis dispar*) via bottom trawl methods. Wild spot prawns in coastal B.C. harvested via trap are considered sustainable as per the Ocean Wise Seafood Program.[1] However, the sustainability of pink and sidestripe shrimp harvested by trawl is still under review due to potential interactions between fishing activity and sensitive marine species and habitats, such as glass sponge reefs and corals.

Pacific Prawn Fishermen's Association survey photos, October 2019. (Credit: Maxwell Hohn)

What is the current status?

Although annual stock sizes can vary, regional declines in pink and sidestripe shrimp stocks have been observed since 2014. Declining stock size has led to the closure of the Fraser River Shrimp Management Area (SMA), which includes Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound waters.[2–4] Prawn stock status (based on using commercial catch as a proxy of abundance) in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound has been more variable, with a record low catch in 2017, followed by a slight increase in 2018 (Figure 1).

Stock status of pink and sidestripe shrimp is estimated using data collected during annual fishery independent trawl surveys conducted by the Fisheries and Oceans Canada (DFO). In 2017/18, stock size of pink shrimp in the Fraser River SMA was estimated to be below the Limit Reference Point (LRP)[i] and in the critical zone[i].

i) Limit Reference Point (LRP) = ~30% of estimated sustainable yield; Critical zone – stock status falls below the Limit Reference Point (LRP).

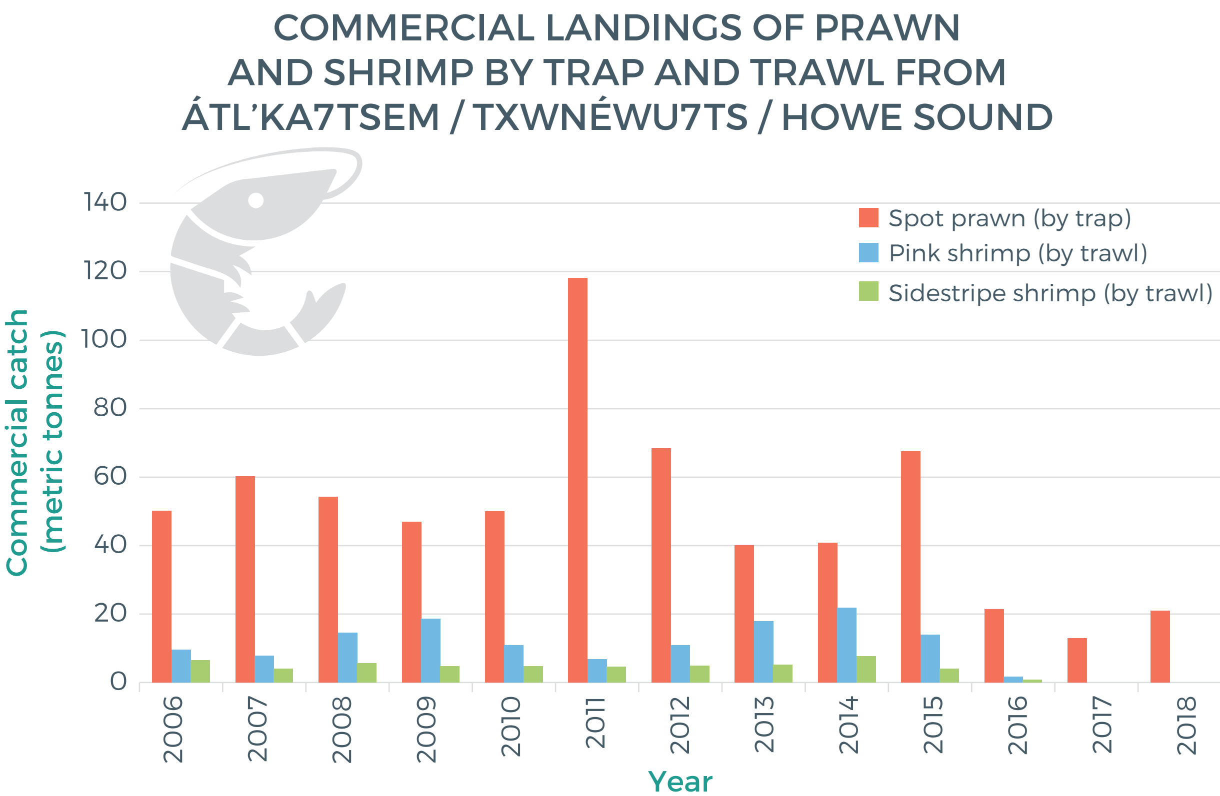

Figure 1. 2006–2018 Commercial catch (tonnes) of prawn and shrimp by trap and trawl methods from Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

Spot prawn (*Pandalus platyceros*). (Credit: Maxwell Hohn)

Sidestripe shrimp stock size was estimated to be above the Upper Stock Reference (USR)[ii] and in the healthy zone[ii].[5,6] When either pink or sidestripe shrimp stocks fall into the critical zone, no harvesting is allowed for either species due to the difficulty of species-specific targeting using trawl gear.

In 2017, as a result of pink shrimp being in the critical zone, the shrimp fishery using bottom trawl methods was closed and has remained closed (Figure 1).[5,6] As of 2019, pink shrimp stocks for the Fraser River SMA are still in the critical zone.[2] The estimated sidestripe stock biomass has decreased from ~153.5 t in 2018 to ~123.1 t in 2019, now falling below the USR and into the cautious zone[iii].[2] For stocks in the healthy zone, a 35% catch rate of total estimated biomass is set; for the cautious zone, a declining catch rate is set based on proximity to the LRP[iv]. For the critical zone, a 0% catch rate is set.[7]

The status of prawn stock size is monitored during the commercial trap fishery that occurs during May and June. When numbers of breeding females approach or reach the management target, the trap fishery closes for the season.[3] The management target is akin to a USR; therefore prawn stocks are considered to be in the healthy zone. DFO conducts a post-season prawn stock survey in November each year. The recreation-

ii) Healthy zone – stock status is above the Upper Stock Reference (USR); USR = ~80% of estimated sustainable yield.

iii) Cautious zone – stock status falls between LRP and USR.

iv) Limit Reference Point – the LRP is the stock size delineating the cautious and the critical zones.

al prawn trap fishery is open all year; however, if the number of breeding females drops below target based on the November survey, portions of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound are closed to fishing for the remainder of the recreational fishing season.

In addition to fisheries closures, other government efforts to increase the sustainability of shrimp trawl and prawn trap fisheries include:

- Improved technology, gear and bait. Increased recreational participation in recent years has led to discussions with DFO and the Sport Fishing Advisory Board on decreasing the daily recreational catch limit for prawns.[3] As of April 2020, the recreational prawn daily catch limit reduced to 125[v].
- The semi-annual DFO survey of prawn stocks in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound continued in February and November 2016, 2017 and 2018.[3] This study commenced in 1985 and contributes to a long-term data set of valuable information on the fluctuating prawn stock status in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Current reports do not mention 2019, and no data are available.
- Any interactions between commercial fishers and marine mammals is now required to be reported, including accidental drowning, bycatch, entanglements, collisions and fatalities.[2,4] This can be done via the Marine Mammal Incident Hotline (1-800-465-4336).

Bycatch is inevitable with trap and trawl fisheries and is a significant issue throughout the world's oceans. Programs to minimize bycatch include increased bycatch monitoring by observers, area closures and seasonal closures. There were 18 fishery-independent at-sea observers deployed for the 2018 prawn trap fishing season along the B.C. coast.[3] These observers undertake sampling, which helps with decision-making related to in-season closures, as well as assisting with enforcement. As was reported in Ocean Watch Howe Sound Edition (OWHS) 2017, 80% of the total commercial fleet was checked for compliance during the fishing season throughout the B.C. coast.[3] Bycatch reduction devices[vi] for trawl nets are also mandatory throughout the Pacific Northwest.

Extra concern surrounds Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed species within the B.C. shrimp trawl and prawn trap fisheries. Eulachon bycatch in the shrimp trawl fishery and some species of rockfish in the prawn trap fishery are a concern.[4,8] As mentioned previously (see [Prawn and Shrimp Fisheries](), OWHS 2017), Rockfish Conservation Areas are closed to trawl fishing but open to commercial and recreational prawn trap fishing (see

Checking for eggs. (Credit: Maxwell Hohn)

v) Recreational catch limits listed here: www.pac.dfo-mpo.gc.ca/fm-gp/rec/tidal-maree/a-s28-eng.html.

vi) Bycatch reduction devices are used to reduce the amount of non-target species caught.

Marine Protected Areas, OWHS 2017). The number of juvenile rockfish caught as bycatch varies annually. Although rockfish mortality by the prawn trap fishery is considered low relative to all other sources of mortality, the commercial prawn industry is proactively working to reduce bycatch mortality.

One way to reduce mortality of bycatch is by using devices called rockfish descenders. They have been shown to be very effective at reducing barotrauma[vii] by allowing the rockfish to quickly be lowered back down and released at the depth they were caught. From April 1, 2019, recreational fishers are now required to use these devices.[9] The commercial prawn industry will be encouraged to start using descenders, particularly for the COSEWIC-listed Quillback (*Sebastes maliger*) and Yelloweye (*S. reuberrimus*) species in the 2020 season.

Overall, Rockfish Conservation Areas and the activities permitted in them are under review. Rockfish Conservation Areas, sponge reef closures and no take zones are distributed throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound (Figure 2).

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

Shrimp and other crustaceans are at medium risk from climate change largely due to their low mobility, meaning they are less able to move to more suitable areas, and their high dependency on environmental conditions for their life cycle.[10,11] However, predicting the specific impact of climate change to prawn and shrimp stocks within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound and the Strait of Georgia is difficult.

Shrimp populations off the west coast of B.C. have been seen to decrease in number with increasing sea surface temperatures,[12] suggesting they prefer cooler water. Growth rates of similar shrimp species to those mentioned here have been closely linked with water temperature, with faster growth rates observed in cooler temperatures.[13] As water temperature increases, possible negative impacts on a variety of functions may be seen, including a reduction in the number of reproducing females, growth rates, developmental rates, egg production and larval survival of spot prawns.[11,13] Thus, any increase in water temperature may be detrimental to shrimp and prawn size and stocks. Pink shrimp species are also experiencing a northward range expansion in the Canadian Pacific because of ocean warming.[14] Additionally, more acidic conditions have been shown to result in delayed development of juvenile spiny pink shrimp.[15]

vii) Barotrauma – injury related to changes in pressure, caused by ascending too quickly to the water’s surface.

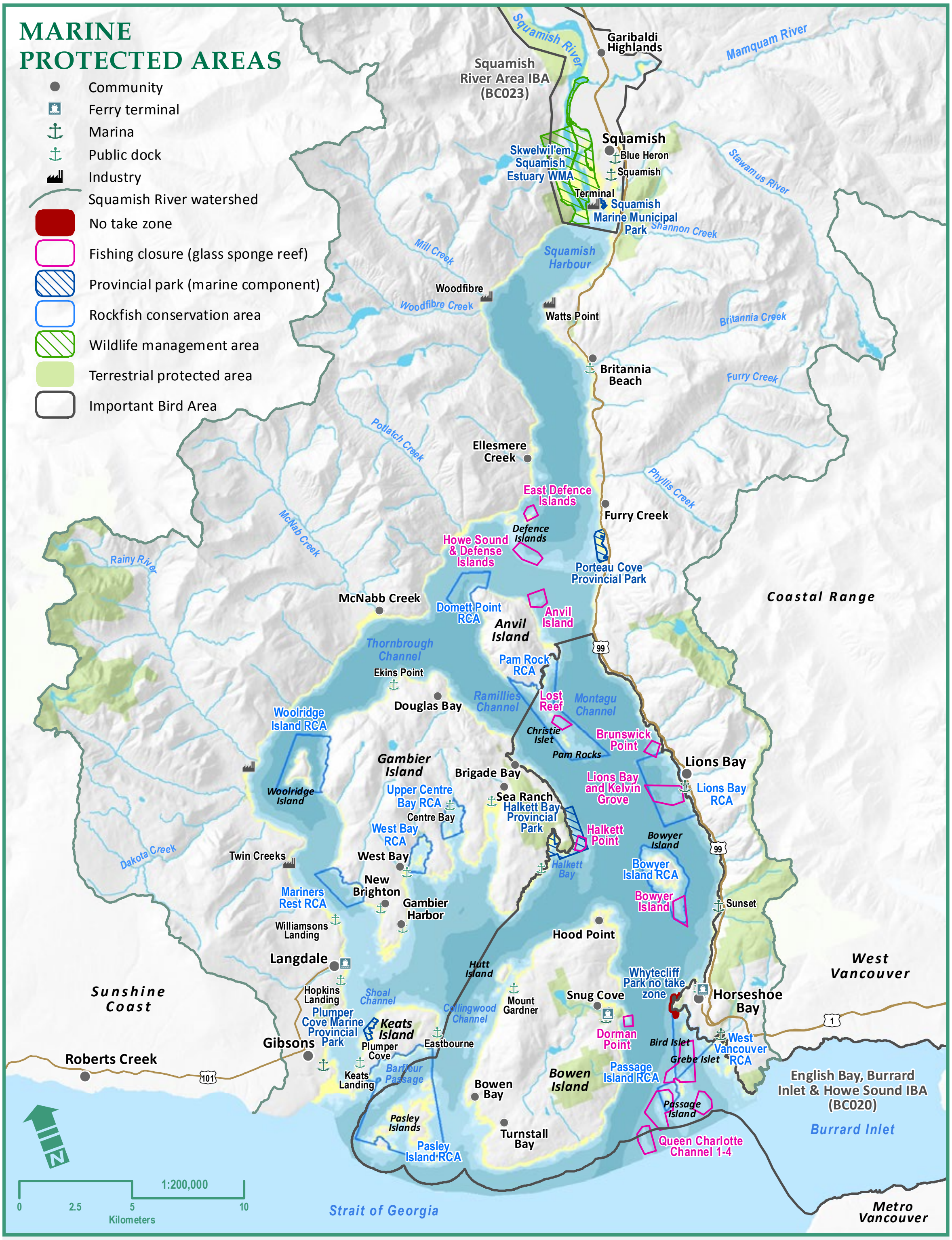

Figure 2. Rockfish conservation areas, glass sponge reefs and sponge reef fishing closures within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[16]

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 “rot cords” (a biodegradable escape mechanism) on your traps to allow bycatch to escape in the event traps are lost.	An amendment to the B.C. Sport Fishing Regulations will likely soon require a biodegradable escape mechanism, or “rot cord,” on all recreational prawn and crab traps, allowing bycatch to escape.
Make sure your buoys are clearly identified with your name.	This is now mandatory, along with a phone number or unique Fisher Identification Number (FIN). DFO is working towards adopting standardized buoys. Talks continue in 2019, in consultation with the Sports Fishing Advisory Board. When adopted, this will eliminate the use of Styrofoam and other plastic containers that break down and contribute to ocean plastic pollution.
Release prawns and shrimp that are carrying eggs under their tails (known as berried prawn and shrimp) as soon as possible at the fishing location.	As of April 2018, prawns with eggs are no longer allowed to be kept. This is in addition to seasonal closures in some areas during critical spawning and larval hatching times (January 1 to March 31).[3]

2017 ACTION	ACTION TAKEN
GOVERNMENT ACTIONS AND POLICY	
Expand sponge reef closures to include all sponge reefs and bioherms identified in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, in accordance with the Sensitive Benthic Areas Policy.	The previous report detailed nine glass sponge reef areas where bottom contact fishing was prohibited (as of 2015) (see Prawn and Shrimp Fisheries, OWHS 2017). In March 2019, DFO formed eight marine refuge areas to encompass the nine additional glass sponge reefs placed under voluntary protection in 2017.[3] DFO Fishery closures were implemented, which included all fishing activities likely to damage the reefs, including fishing activities for shrimp and prawn. Nine additional glass sponge reef areas in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound still require verification in order to determine their ecological importance.
Allocate more resources to enforcement of fishing regulations, including protected area closures.	The Pacific Prawn Fishermen’s Association (PPFA) provides funding annually to DFO for enhanced enforcement; in 2018, $29,000 was provided. At-sea observers in the prawn trap fishery conducted gear inspections and licence compliance checks (i.e., trap tagging, trap mesh size, buoy identification and logbook completion) on 80% of active vessels during the 2018 season along the B.C. coast.[2] Currently, DFO lists the investigation of illegal prawn sales as a top enforcement priority.[3] The PPFA received funding support to purchase and supply every commercial prawn vessel with a rockfish descender for the 2020 season.

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:

- Make sure your licence is up to date and comply with catch limits when you are sport fishing.
- Keep your traps away from sensitive areas including sponge reefs, bioherms, and RCAs.
- Release live catch (i.e. bycatch) in waters where caught.
- Report any gear theft and the theft of catch from traps to the police.
- Report accurate fishing activity and catch to DFO when requested to do so.
- NEW Carry a rockfish descender when fishing within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, and if accidental bycatch of rockfish occurs, make sure to release it back to the depth caught within two minutes.
- NEW Choose to buy Ocean Wise recommended shrimp and prawn.

Government Actions and Policy:

- NEW Verify the remaining glass sponge reefs and set up marine refugia and associated fisheries closures.
- 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

Information and data were obtained from the DFO website (i.e., fishery notices, Integrated Fisheries Management Plans,[3-6] Sport Fishing Guides); from personal communication with DFO staff who provided Shrimp Survey Bulletins[2] and unpublished data; and from members of the Pacific Prawn Fishermen's Association.

PRE-SEASON FORECASTS

A five-year running average model is used to forecast shrimp stock size within SMAs with ongoing surveys. This is used to set an initial catch ceiling, which can then be modified with data collected from in-season surveys. SMAs with no survey history have catch ceilings calculated from 10th or 25th percentile[viii] of the pre-1997 catch history.[3]

IN-SEASON SURVEYS

DFO monitors prawn trap fishing vessels in real time and uses this information to deploy at-sea-observers. In the 2018 season, 186 of the 205 active fishing vessels were sampled coast wide. This equated to a total of 2,177 strings, 54.4 strings/fishery day, and a total of 468 person-days of direct monitoring. Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound has been identified as one of the priority areas of interest, and therefore sampling commences early. The commercial fishery for prawns in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound in 2018 lasted 36 days, with portions of the area closed earlier based on sampling. In 2018, Pacific Fishery Management Area subarea 28-2 in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound closed after 12 days, 28-3 after 26 days, 28-1 after 29 days and 28-4,5 after 36 days.[17] Coastwide, the longest an area was open for was 40 days in 2018. In-season closures of subareas are implemented on three days' notice.[3,4]

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Clean Water

Shoreline on Ḵw’émḵw’em/
Defence Island.
(Credit: Tracey Saxby)

Summary

After years of industrial pollution and heavy usage of the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound waterways, large efforts have been made by government, industry and communities to clean up its waters. Today, the positive impacts of these actions are finally being seen, with some metals and dioxin and furan concentrations decreasing to near or within safe levels, and the passage in 2019 of Bill C-64 that assists in addressing wrecked, abandoned or hazardous vessels.

Unfortunately, new threats are emerging. The presence of plastics in our oceans is pervasive and was prominently seen after the 2018/2019 winter storms damaged infrastructure throughout the Sound. There is concern about the impact of microplastics (i.e., <5 mm) entering the food web, and further research is needed. Vessel traffic continues to grow and a number of large developments are proposed or underway along the shorelines, all of which can impact water quality in the Sound. An important piece of this puzzle – contaminant monitoring – is ongoing at three sites in the Sound via *PollutionTracker*.

Overshadowing everything are the myriad effects from climate change, most of which still require further research. Rising ocean temperatures are likely to stress marine organisms, potentially leaving them more vulnerable to the toxic effects of contaminants. Additionally, some of these contaminants have settled in sediments that could be stirred up by the predicted increasing frequency and intensity of storms, potentially releasing them back into the waters of the Sound.

Further actions are needed to continue the improving trends being observed. Some metals continue to exceed provincial water quality guidelines. Dioxins and furans continue to be detected in water, sediment and crab samples, albeit at lower concentrations than seen in previous years, and abandoned and wrecked vessels continue to be a problem.

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
BRITANNIA MINE Some improvements have been seen following wastewater treatment; however, exceedances of water quality guidelines are still occurring.	!	!
PULP MILL: MARINE EFFLUENT Dioxin and furan contamination in sediment and benthic life is decreasing following regulations but is still detected.	!	! ↑
WRECKED, ABANDONED, AND PROBLEM VESSELS The passage of Bill C-64 has increased resources available for removal of vessels; however, this is a complex issue and further refining of legislation is necessary.	!	! ↑
POLLUTIONTRACKER NEW Dioxin and furan concentrations are high, especially in mussels, when compared with other areas along the B.C. Coast. Metals continue to be detected in sediments, sometimes above sediment quality guidelines.		!

Britannia Mine: contamination, remediation and monitoring

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What is happening?

In the early 1900s, the former Britannia Mine was considered to be amongst the biggest sources of metal contamination into waterways in North America.[1] The Ocean Watch Howe Sound Edition (OWHS) 2017 article on Britannia Mine Contamination summarized evidence of environmental impacts. Specifically, Sḵwx̱wú7mesh Úxwumixw/Squamish Nation people were heavily impacted because they typically consumed greater quantities of traditional seafood sources, such as bivalves, crustaceans and fish (e.g., Pacific salmon),

Britannia Mine Museum. (Credit: Bob Turner) which can be exposed to and retain these contaminants. Further, Sḵwx̱wú7mesh Úxwumixw/Squamish Nation have high value and spiritual/human connection for the integrity of the ecosystem (i.e., spiritual ecology). Salmon were, and still are, of particular importance as seafood and as a spiritual connection for the Sḵwx̱wú7mesh Úxwumixw/Squamish Nation (see Britannia Mine, OWHS 2017); metals can be lethal or impair important sensory function[i] in salmon (see Britannia Mine, OWHS 2017; additionally, see Salmon, OWHS 2020 for current population trends in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound).

In 2001, a remediation project was started by the provincial government that combined a number of mitigation actions; for example, a water treatment plant was built with a deep-water outfall (see Britannia Mine, OWHS 2017). An overall closure plan was developed, which stipulated remedial efforts and risk assessments were required to attain acceptable environmental conditions (e.g., acceptable human health risk), at which point site closure would be achieved.[2] For some measures, e.g., the groundwater management system, operation and maintenance will continue indefinitely.[2]

What is the current status?

Monitoring and reporting has continued around the Britannia Mine site.[3,4] Metal contaminants continue to be measured in porewater,[ii] including at three sites close to the groundwater management system (i.e., BB-2, BB-13 and BB-3), and two sites located further from the point of release of groundwater (i.e., BB-1 and BB-6, considered near-field reference sites) (Figure 1).

In 2017 and 2018, exceedances of B.C. water quality guidelines (WQG)[iii], a level set to protect marine species, were observed for boron, cadmium, chromium, copper, lead, manganese, nickel and zinc.[3,4] Additionally, an exceedance of the chronic[iv] and national safety levels[v] for mercury was observed, but only during a single sampling event in 2017. Other sampling events did not detect mercury.[3,4]

The main contaminants of concern at the Britannia Beach shoreline have been identified as copper and zinc.[4] Zinc concentrations at all sampling areas have decreased from 2017 to 2018. However, four of the five locations exceeded zinc WQG. Copper concentrations at all sampled areas appear to be generally the same as in previous years with a few locations showing slight decreases (i.e., BB-2, BB-3 and BB-13). However, all

i) Specifically, olfactory sensing, which is akin to smelling under water.

ii) Porewater – water contained in pores in soil or rock.

iii) B.C. water quality guidelines: boron (1.2 mg/L); cadmium (0.00012 mg/L); chromium (0.0015 mg/L); copper (maximum 0.003 mg/L; chronic 0.0002 mg/L); lead (maximum 0.14 mg/L; chronic 0.002 mg/L); manganese (chronic 0.1 mg/L); mercury (chronic 0.00002 mg/L); nickel (chronic 0.0083 mg/L); zinc (maximum 0.01 mg/L; chronic 0.055 mg/L).

iv) Chronic – long-term exposure.

v) B.C. water quality guidelines and Canadian Water Quality Interim recommendation for mercury (0.000016 mg/L) are to be revised as protection of predatory fish is not certain.[9]

Figure 1. Satellite map of the Britannia Mine area showing sampling areas (blue boxes), including near the groundwater management system (BB-2, BB-13 and BB-3) and near-field reference areas (BB-1 and BB-6). Blue arrows show the direction of groundwater flow; red and white dots indicate extraction wells that are part of the groundwater management system. Replicated from Golder report.[4]

locations remain in exceedance of WQG (Figure 2). Because the measured concentrations are higher than the guidelines, marine life may be negatively affected.

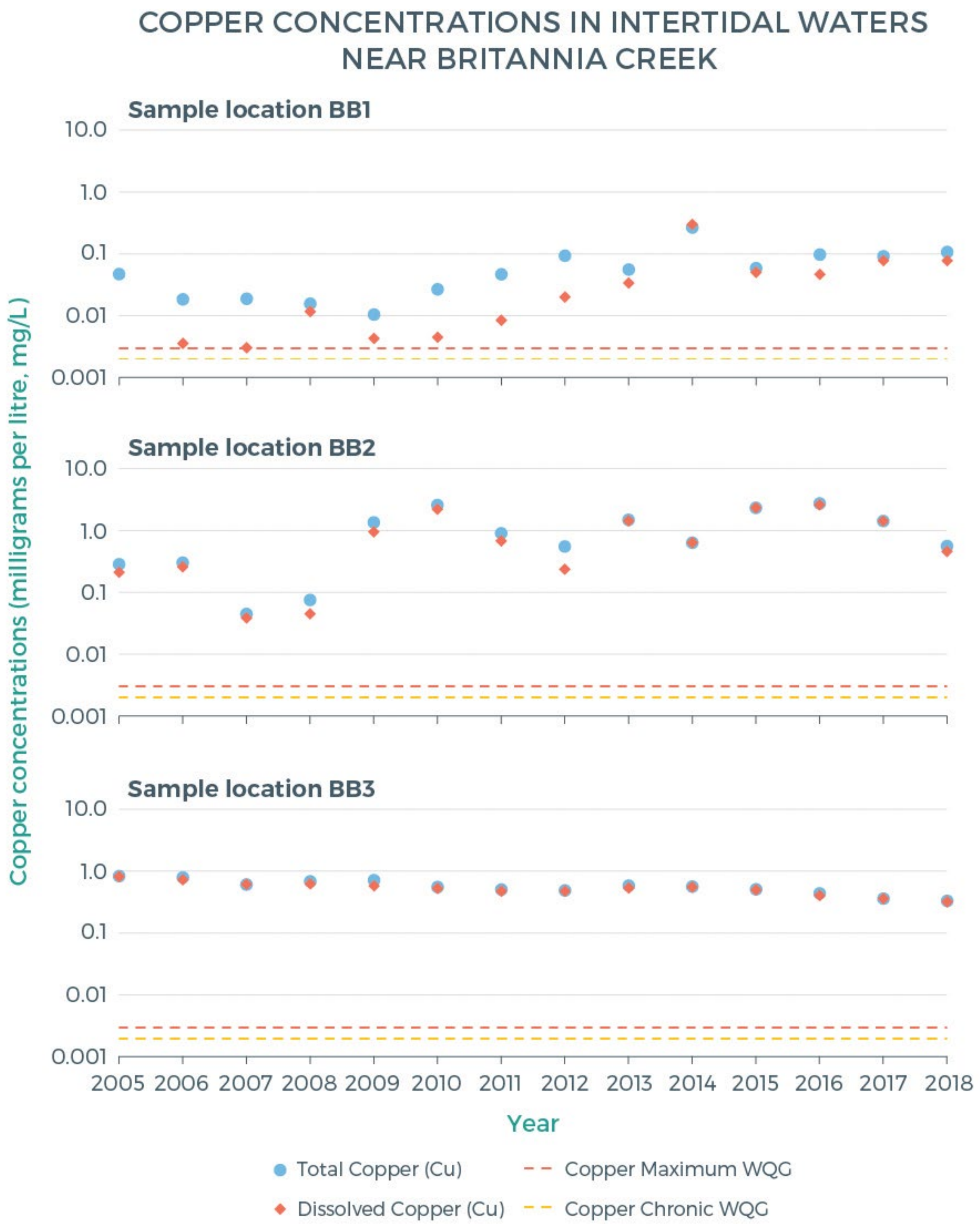
Surveys of intertidal animals[vi] were also conducted at the three sites located near the groundwater management system to monitor for effects from the above metals (Figure 1). Based on data from 2003 to 2018, the sampling location with the highest metal concentrations (i.e., BB-13) generally had the lowest number of motile[vii] invertebrates (e.g., crustaceans), a smaller coverage of aquatic plants and fewer indicator invertebrates (e.g., crab species [*Hemigrapsus* sp.]).

Additionally, the most common species at this location was green algae (*Cladophora* sp.), whereas the other locations were dominated by a brown algae seaweed species (i.e., *Fucus gardneri*). Another notable difference was the lower coverage of barnacles (*Balanus glandula*) at locations near the groundwater management system, excluding BB-13, compared to the near-field reference locations. In the case of site BB-13, the location with the highest metal concentrations, the coverage of barnacles and green algae had increased compared to recent years (i.e., since approximately 2012/2013).[4]

Trends observed in motile invertebrates suggest a natural variability in the presence of these species, as well as some evidence of recovery. For example, since 2013, an increase in decapods (e.g., crab species) has been observed at reference sites and locations near the

vi) Intertidal animals – animals living in the zone that is periodically covered/uncovered by water due to tidal movement.

vii) Motile – capable of movement.


COPPER CONCENTRATIONS IN INTERTIDAL WATERS NEAR BRITANNIA CREEK
Sample location BB1
Sample location BB2
Sample location BB3
10.0
1.0
0.1
0.01
0.001
Copper concentrations (milligrams per litre, mg/L)
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year
Total Copper (Cu)
Dissolved Copper (Cu)
Copper Maximum WQG
Copper Chronic WQG

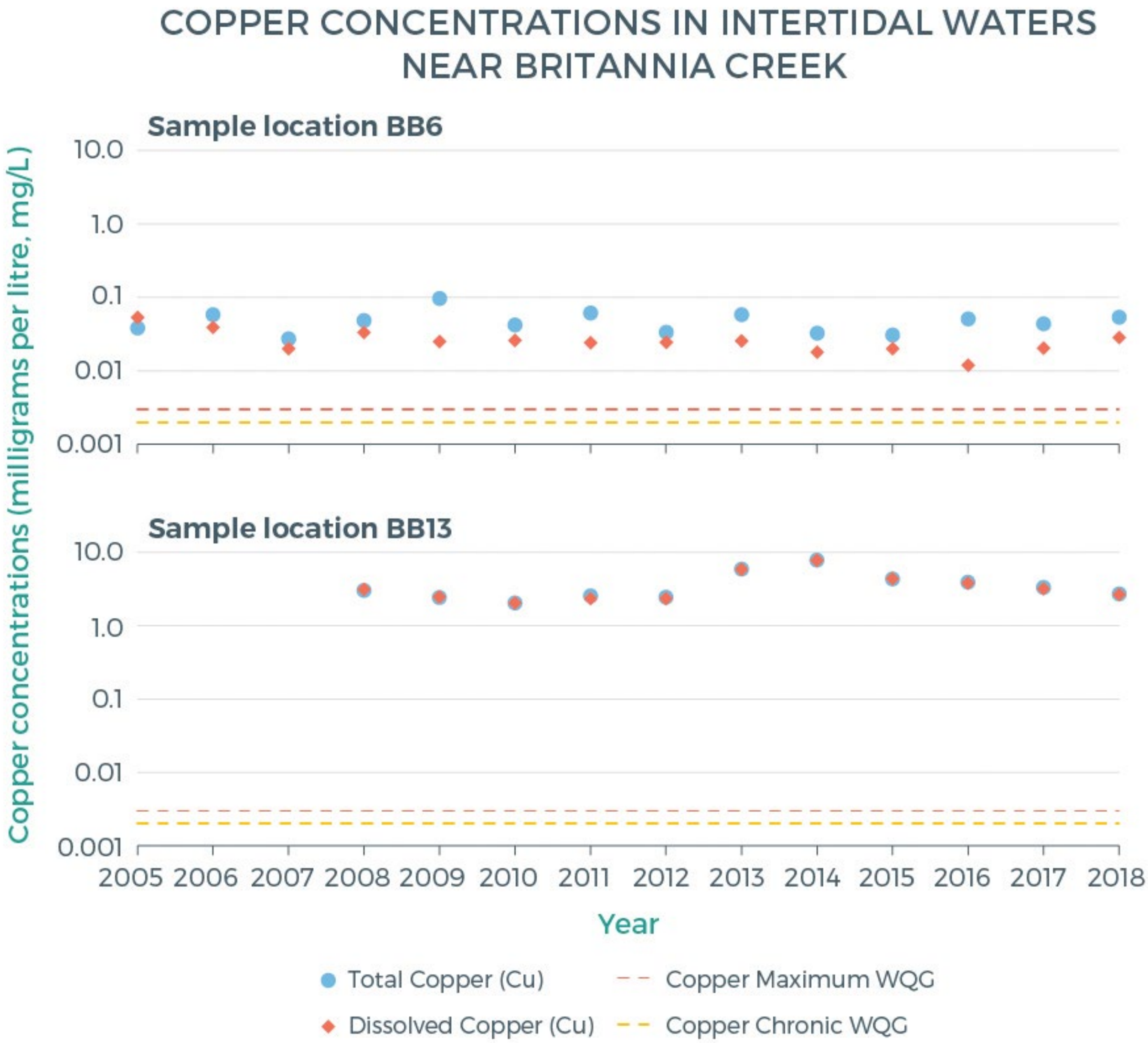
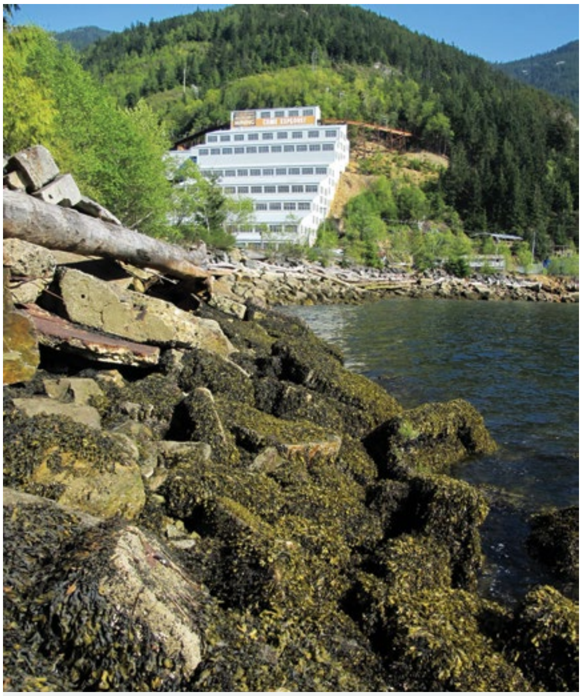


Figure 2. Porewater concentrations of total and dissolved copper in milligrams per liter (mg/L) for sampling locations BB-1, BB-2, BB-3, BB-6 and BB-13, top to bottom, respectively. WQG – water quality guideline. mg/L = milligrams per litre. There are 1000 milligrams per litre.

groundwater management system, except the location with the highest metals concentrations (BB-13).[4]

Overall, metal concentrations measured in 2017 and 2018 were comparable to previous years. Results from the location with the highest metal concentrations provide evidence of marine effects, but there were also signs of recovery. To support the understanding and recovery of the site, monitoring and remediation are ongoing.



The foreshore near Britannia Mine. (Credit: Bob Turner)

What are the potential impacts of climate change on contamination from Britannia Mine?

Pollutants from Britannia Mine have resulted in contaminated sediment.[5] These sediments now act as a sink and storage for contaminants and can potentially be released back into the environment (e.g., bioturbation by benthic macroinvertebrates, sediment resuspension by human activities, and due to disturbance during storm events). Additionally, there is evidence that the routes of exposure, accumulation and toxic effects from metals (e.g., mercury) can increase with warmer sea temperatures and under more acidic conditions (i.e., climate change-induced pollutant sensitivity in marine species).[6–8] The metal concentrations at Britannia Mine sites are already higher than the B.C. WQG for the protection of aquatic life. Increased temperatures coupled with exposure to metals stored in sediments has the potential to slow or even reverse ecosystem recovery.

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	
Reach out to the community with updates on remediation in the Britannia Mine area. The community needs information about observed metal concentrations and any risk of harm they pose to human and marine life.	Publication of a previous Ocean Watch report supports this action. All finalized reports for the Britannia Mine Remediation Project are submitted to the Ministry of Environment and Climate Change Strategies for review and approval. These reports are publicly available through the B.C. Ministry of Environment’s Land Remediation Website: www2.gov.bc.ca/gov/content/environment/air-land-water/site-remediation/contaminated-sites/information-about-sites
Recycle all batteries.	The B.C.-wide provincial program supports this action, with drop-off areas in Squamish/Sḵwx̱wú7mesh, West Vancouver and Gibsons. Link below. www.call2recycle.ca/british-columbia/
GOVERNMENT ACTIONS AND POLICY	
Track the state of the ecosystem health using a consistent ocean pollution indicator. Identify a consistently occurring, abundant biological indicator or bioindicator (i.e., an organism that can be used to monitor the state of pollution levels in the long term) to track metal contamination.	The Golder reports include surveys of intertidal animals.
Increase public education campaigns designed to educate citizens about the impact of phosphates, chlorine and pesticides, and how to minimize their impact.	Federal government sites support individual actions and access to additional resources. Links below. www.canada.ca/en/environment-climate-change/services/pollution-prevention/home.html https://pollution-waste.canada.ca/pollution-prevention-resources/Home/SearchIndividuals?lang=en
Support local recycling and zero waste initiatives.	The District of Squamish has developed a zero-waste strategy. Additionally, guidance for recycling items in B.C. is available from the Recycling Council of B.C. Links below. https://squamish.ca/our-services/garbage-and-waste-diversion/zerowaste/ www.rcbc.ca/recyclepedia/search

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:

- Sources of metals in wastewater are not all industrial. Be aware that what goes down your household drain or into the street gutter almost always ends up the ocean. Water treatment facilities can remove many contaminants, but plenty of dangerous chemicals that go down your drain will still end up in rivers, lakes, and oceans. Phosphates from detergents, chlorine from bleach, and the toxins in pesticides will all wreak havoc on fragile ecosystems once they leave your local sewage treatment plant.
- Do not put paint, solvents, pesticides or other chemicals down your drain.
- Help reduce the environmental impacts of mining by:
- Reducing your consumption of minerals; reducing consumption of consumer goods in general.
- Taking transit rather than buying a new car.
- Using recycled materials instead of mined materials and recycling all your metals (e.g., tin cans).

Government Actions and Policy:

- Increase support of research focuses to assess levels of metal contamination in waterways.
- Protect salmon stocks against the negative health effects of copper to the salmon's olfactory system similar to that established in Washington State (http://www.seadocsociety.org/scientists-who-showed-how-copper-damages-salmons-sense-of-smell-receive-prestigious-award/), which will benefit salmon recovery by reducing the amount of toxic metals entering the Salish Sea by hundreds of thousands of pounds each year.
- Legislate against the use of phosphates in household products.
- **NEW** Fund studies examining relationships between contaminant concentrations and temperature.
- **NEW** Potential for increased sensitivity of species to contaminants at higher temperatures will need to be considered in water quality guidelines.

Methods

Data was summarized from the Golder reports.[3,4] Briefly, data from these reports were collected from the intertidal zone using sampling and survey methods. Porewater samples to measure metal concentrations were collected and submitted to an accredited laboratory for analysis. Data for intertidal species surveys were collected using visual observations during low tide at water sampling locations. Species were identified and coverage recorded, or presence noted.

Metal data from Golder[4] along with data from previous reports, dating back as far as 2005, were compiled to determine trends. As the most recent reports have reported on metal concentrations from porewater samples, only these data were analyzed. Comparisons with graphs from the previous Britannia Mine article are not possible because surface and bottom water concentrations were reported.

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Pulp Mill: marine effluent

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What is happening?

The Howe Sound Pulp and Paper Corporation (HSPP) was established in 1908. Located near Port Mellon, directly opposite the Woolridge Island Rockfish Conservation Area, today it is the only operational pulp mill in the Sound. Currently, the mill only produces kraft pulp[i]. The bleaching process used to create pulp produces harmful by-products called dioxins and furans. These contaminants enter Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound’s marine environment via the mill’s effluent[ii] (see Pulp Mill Effluent, Ocean Watch Howe Sound Edition [OWHS] 2017). The focus of this article is marine effluent; no examination of air pollution is included.

Howe Sound Pulp and Paper Mill. (Credit: HSPP)

i) Kraft pulp – an intermediate product in the production of paper.

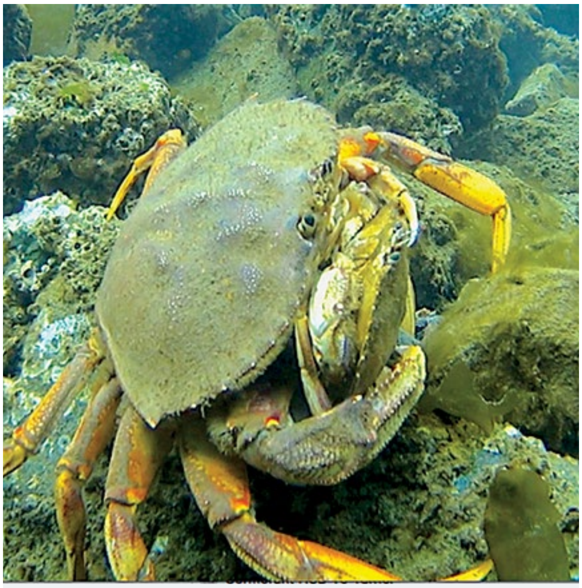
ii) Effluent – liquid waste released back into natural water bodies.

Over the years, HSPP has undergone various production changes to reduce the amount of dioxins and furans produced. In 1991, primary and secondary effluent treatment systems were installed. A significant reduction in effluent emissions followed. Further reductions in the generation of dioxin and furans was achieved by the conversion from elemental chlorine to chlorine dioxide in the pulp bleaching process.[1] Chlorine dioxide helps to prevent the formation of dioxins and furans.[1] Additionally, a project running from 2016–2017 improved the bleaching process and further reduced the amount of chlorine dioxide used.

HSPP also administers an environmental monitoring program, which seeks to identify the impact of the mill's emissions on the receiving environment (Figure 1). The Environmental Effects Monitoring program runs in three-year cycles, ever since the first cycle of testing started (1993–1996).[1] Monitoring is carried out in accordance with the evolving federal *Pulp and Paper Effluent Regulation*.[2]

What is the current status?

The most recent HSPP monitoring program (Cycle 8) ran from April 2016 to April 2019. Cycle 8 reported on the toxicity of the effluent discharged from HSPP and monitored the marine area around the effluent release point.



Dungeness crab. (Credit: Bob Turner)

Toxicity of mill effluent

Daily continuous monitoring of mill effluent involves measuring standard effluent characteristics (e.g., pH[iii]) as well as dioxin and furan[iv] concentrations once a year. During the 2007–2018 period, dioxins and furans were not detected. However, adsorbable[v] organic halides, a parameter that measures certain atoms (specifically chlorine atoms, which are associated with dioxins and furans) have been.

iii) pH – measure of acidity and alkalinity.

iv) Dioxins and furans – contaminants released as unintentional by-products of the pulp and paper bleaching process.

v) Adsorb – the adhesion of a molecule on the outside surface of a material, such as sediment.

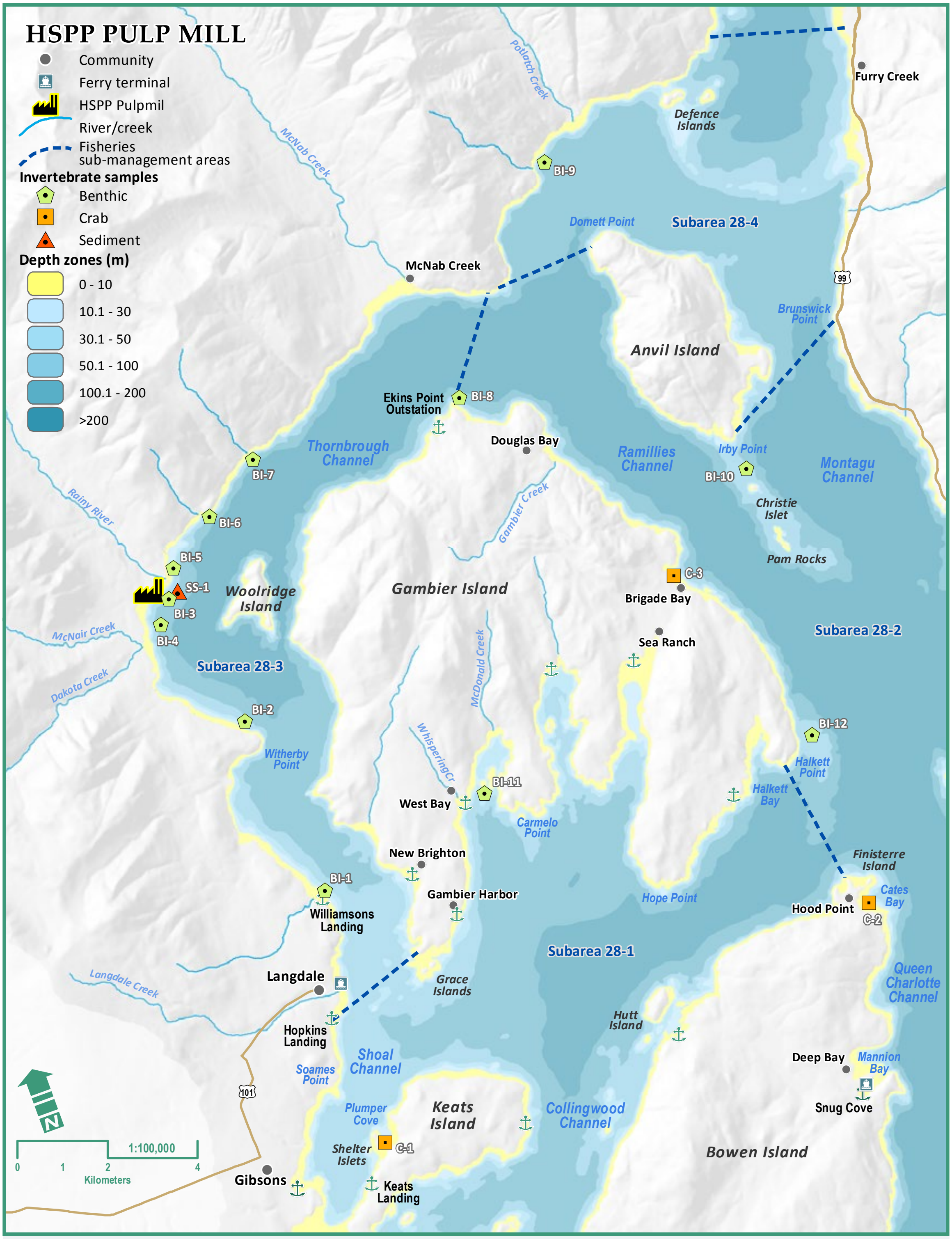


Figure 1. The location of Howe Sound Pulp and Paper Corporation and 2016–2019 environmental sampling points within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[3]

The survival of rainbow trout (*Oncorhynchus mykiss*) and *Daphnia magna*[vi] in effluent is measured on a monthly and weekly basis, respectively. Since 2016, federal *Pulp and Paper Effluent Regulations* have been met 100% of the time for rainbow trout, and between 98–100% of the time for *Daphnia*. This is an improvement on previous years.

The effect of effluent on purple sea urchins (*Strongylocentrouts purpuratus*) and giant kelp (*Macrocystis pyrifera*) reproduction and/or growth was measured. The effects zones (i.e., the estimated distance from the effluent release point where negative effects on 25% of the population are predicted) were 109 m for sea urchin reproduction, 29 m for giant kelp reproduction and 31 m for giant kelp growth. Urchin results from earlier testing cycles show that the effects zone has been decreasing over time (244 m, 162 m and now 109 m), indicating an improvement (i.e., the size of the area where detrimental effects are seen is decreasing).

Field monitoring for contaminants

Monitoring of dioxins and furans in Dungeness crabs (*Cancer magister*), sediment and benthic invertebrates was undertaken in Cycle 8. Contaminant concentrations were reported as toxic equivalencies (TEQ)[vii]. Similar to recent previous cycles, samples were collected once in the three-year cycle.[1]

Crab hepatopancreas[viii] (also known as tomalley or crab "fat") was analyzed for dioxins and furans, and compared with Health Canada guidelines for human consumption (24.4 pg/g)[ix].[1] The TEQ values in hepatopancreas were below this threshold (Figure 2, top). Recreational fishing for crabs is now open in Átl'ka7tsem/Txwnéwu7ts/Howe Sound.[4] However, restrictions apply around the mill area and the mouth of the Sound because dioxins and furans are still present at measurable concentrations. The current recommendation is to avoid consuming more than 55 g/week (crabs caught in area 28-3 and in portions of area 28-1) or 130 g/week (crabs caught in area 28-2 and in 28-1) of crab hepatopancreas.[5] These restrictions can change without warning; thus, it is important to always confirm the status of any species before fishing. See Resources for further information on sub-area restrictions for crab fishing.

Concentrations of dioxins and furans were measured from four replicate sediment samples, which were combined to make one sample for analysis, taken from a single sampling site very near to the effluent discharge point. The resulting TEQ value was the lowest observed throughout the entire monitoring program (Figure 2, bottom).

Benthic invertebrates[x] and the quality of the sediment they live in was examined in this cycle (benthic studies are not conducted in every cycle). Samples were collected at locations along a gradient, from near the

vi) *Daphnia magna* – an aquatic invertebrate.

vii) TEQ – there are several different dioxins and furans but not all are equally toxic. Each is multiplied by a toxic equivalency factor (TEF) to make it comparable to the most toxic dioxin contaminant. These values are then presented as toxic equivalents (TEQs).

viii) Hepatopancreas – the digestive tissue in crabs that combines the digestive function of the vertebrate liver and pancreas.

ix) 24.4 pg/g – this measurement is relative to the specific contaminant 2,3,7,8-TCDD; pg/g is picograms per gram, equivalent to parts per trillion.

x) Benthic invertebrates – species that lack a backbone (e.g., molluscs, insects, worms) living at or in the sediment surface.

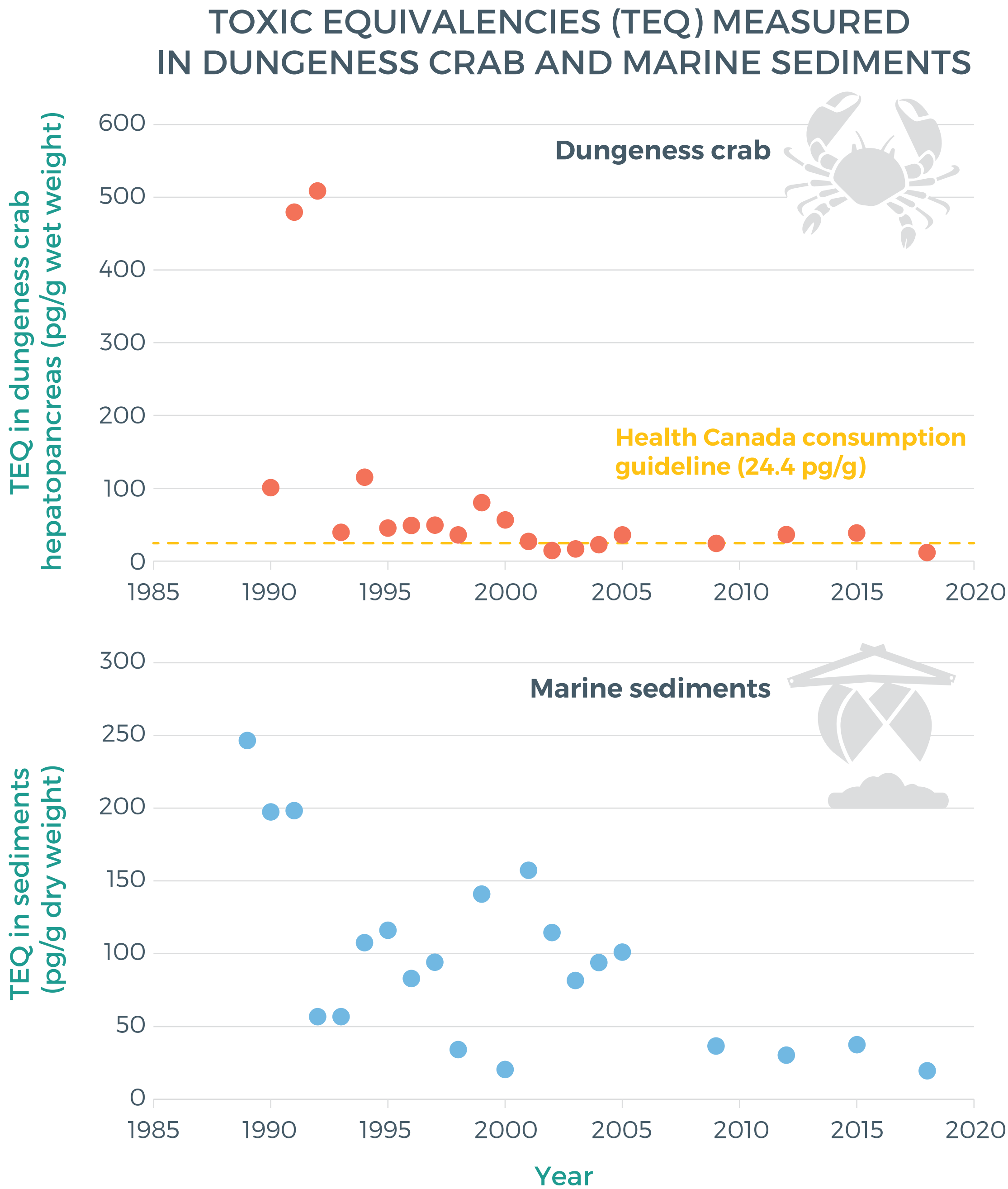


Figure 2. (Top) Dioxin and furan concentrations, presented as TEQ values wet weight[i], in crab hepatopancreas (orange circles) sampled in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, compared to the Health Canada TEQ consumption guideline of 24.4 pg/g (dashed yellow line). (Bottom) Dioxin and furan concentrations, presented as TEQ values dry weight, in sediment samples(blue circles) in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Note, for both crab and sediment, the number of sampling sites declined over time because of the decreasing contaminant concentrations observed. Concentrations measure in wet weight (crab hepatopancreas) are not comparable to those measured in dry weight (sediment).

i) Wet weight – weight measured including the water content.

effluent release point, progressively moving further away, to a distance of 20 km. Generally, there was no significant evidence of differences in benthic invertebrate community structure (i.e., the diversity or abundance of species present) with increasing distance from the effluent outfall.

The properties of the sediment samples differed. Locations within 4.4 km of the effluent outfall contained more organic content and less dissolved oxygen. However, concentrations of chlorinated phenolic contaminants, directly resulting from the mill process, are no longer detected at most sites. Of 12 monitoring sites, only one site near the effluent outfall had a concentration high enough to be detected.

Compared to previous monitoring cycles, improvements are evident; however, ongoing monitoring is necessary to continue to track changes in the environment as a result of contamination from mill effluent release.

What are the potential impacts of climate change on dioxins and furans?

Key impacts of climate change include warmer waters and an increase in frequency and intensity of storm events. Warmer waters will result in increased stress on some marine organisms as they try to adapt to changing conditions, which may increase their sensitivity to contaminants.[6,7] Increases in the frequency and intensity of storm events could resuspend dioxins and furans that have adsorbed in sediments, making them available to be taken up by organisms again. Potential implications, besides negative health impacts, include fishery closures to protect human health.

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 with the implementation of source controls and regulations to hamper dioxin and furan pollution from pulp mills in the coastal marine environment of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.	Environmental Effects Monitoring program is currently running Cycle 9.

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:

- Avoid the incineration of organic matter and plastics to prevent the release of dioxins into the air and coastal environment.
- Use and apply “green” or homemade pesticides and organic fertilizers in gardens and agricultural fields to avoid toxic run off (e.g., salmon friendly lawn and/or orca friendly lawn: non-toxic pesticides, non-toxic herbicides, non-toxic fertilizers).

Government Actions and Policy:

- Help to guide and design creative solution-oriented practices to reduce the levels of dioxins and furans in Dungeness crabs which still exhibit concentrations of dioxin/furans of concern for public health.
- Promote and sponsor national programs and solutions for marine pollution to protect ocean life from human made chemicals with research, continued education and engagement, and advocacy to succeed with actions.
- Regulate and control the usage of pesticides containing potential traces of dioxins and furans as impurities to avoid the accidental release of these by-products into the coastal marine environment.
- Address the appropriate disposal of old tanks and bins and any material containing dioxin-contaminated fluids and/or oil from former military facilities, old refineries, junk yards and harbours.
- NEW Educate fishers and/or fish consumers about the potential health implications of consuming crab or other foods contaminated with PCDD/Fs so they can make informed choices.

Methods

Detailed methods for the summarized studies can be found in Hatfield (2019).[1]

Resources

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

Sub-area restrictions for recreational fishing:
http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/tidal-maree/a-s28-eng.html

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Wrecked, Abandoned and Problem Vessels

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What is happening?

Wrecked, abandoned and problem vessels (for definitions see Glossary) continue to be an issue in the waters and shorelines of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. Every winter, storms leave wrecked boats on shorelines and submerged in the waters around Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. In addition, debris from boats and other structures (e.g., docks) create environmental issues due to pollution and habitat destruction, and/or navigational hazards.

Wrecked vessel off the north west side of Chá7elkwnech/Gambier Island, 2019. (Credit: Ian Winn)

What is the current status?

Since 2016, considerable efforts have been made to address problem vessels. Of particular note was the passage on February 28, 2019, of the Government of Canada’s Bill C-64, the *Wrecked, Abandoned or Hazardous Vessels Act*, which came into effect on July 31, 2019.[1] Bill C-64 increases owner responsibility and liability for vessels, addresses irresponsible vessel management, and enables the Government of Canada to remove problem vessels. Not complying with the *Act* can result in penalties of up to $50,000 for individuals and $250,000 for companies or corporations, while regulatory offence prosecution could result in a maximum fine of $1 million for individuals and $6 million for companies or corporations. This Bill puts the responsibility and liability for abandoned vessels back on vessel owners.

The Bill has been long awaited and is enthusiastically received by Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound communities, who now have at least some options to address vessels of concern as they arise. Along with improvements to vessel owner identification and creating an inventory of problem vessels and assessing their risks, communities are now able to establish a polluter pays approach for vessel cleanup.

However, existing problems may not fall under the new regulations (for example, prohibitive up-front costs for dealing with a vessel; a 25% funding requirement from local governments or community organizations that may be prohibitive for small communities; abandoned or derelict vessels on land not being included). In many cases, all identification markings have been removed from the vessel and ownership is unable to be determined.

Quite often the problem can quickly evolve from an abandoned, wrecked or problem vessel issue, where

Sailboat washed ashore at Schenk/Grantham’s Landing, Fall 2015. This vessel threatened the waterfront properties and involved huge community effort and expense to correctly dispose of. (Credit: Ian Winn) authorization for removal may lie with Transport Canada’s Receiver of Wrecks (responsibility for actual removal may lie elsewhere – see Problem Vessels, Ocean Watch Howe Sound Edition [OWHS] 2017), to a waste management issue, with responsibility lying with local and provincial governments. This is an example of how complex the situation is when First Nations, federal, provincial, and/or municipal laws are applied depending on where in the coastal environment a vessel or debris is located.[2]

In the spring of 2019, Sheila Malcolmson, MLA for Nanaimo, was appointed as special advisor on marine debris protection to the Minister of Environment and Climate Change.[3] MLA Malcolmson’s engagement mandate over the summer of 2019 took her to coastal communities to discuss provincial support mechanisms around marine debris and the consideration of end-use infrastructure ideas (i.e., fibre-glass reprocessing, plastics reprocessing).[4] Increased collaboration between all levels of government, along with non-profit groups and individual vessel owners, needs to continue, to solve the issues around problem vessels. Her report and recommendations will be presented at the end of 2019.

Thus, the Government of Canada also moved forward with other programs within the Oceans Protection Plan to provide funding for assessment and removal of existing problem vessels where the owner cannot be identified. Within the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region, Caulfeild in West Vancouver received $10,000 in May 2018 for the removal of one vessel, and in February 2019, Nex̱wlélex̱wem/Bowen Island Municipality received $11,330 for the removal of two vessels. The local government of Sḵwx̱wú7mesh/Squamish applied for funding under these new programs for the assessment and removal of wrecked vessels; however, at the date of writing (mid-October 2019), Sḵwx̱wú7mesh/Squamish had not received any funds.

Since April 2019, Marine Reference Guide (MRG) staff have been working to identify and inventory abandoned vessels and debris along the coastline of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[5] Because problem vessels and debris are ever-changing, it is difficult to quantify precisely the number of abandoned or wrecked vessels in the Sound. However, as of mid November 2019, approximately 25 vessels (ranging from a steel barge to a boat house) and a much greater number of large debris (more than 300), such as creosote pilings, rope and Styrofoam, etc., had been identified.

Removal of abandoned or wrecked vessels must be undertaken in an environmentally conscious manner to deal with the often-hazardous materials on board (e.g., fuel, diesel, sewage), making it extremely costly. The Dead Boat Disposal Society is a non-profit organization working to clean up problem vessels from B.C. waters, including Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[6] The process to inventory and assess the severity of each wreck is only the first step required. Subsequent disposal is the most time-consuming and costly step, and is dependent on various factors, for example, size and type of vessel; the presence and type of hazardous materials; whether the vessel is submerged and at what depth.

Derelict vessel washed ashore near Ḵ’iḵ’élx̱n/Port Mellon, Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, 2019. (Credit: Ian Winn)

What are the potential impacts of climate change on problem vessels?

Over the last few years, climate change has resulted in increased intensity and frequency of storms. When combined with king tides and sea level rise, the result is damage and destruction of dock structures, and an increase in the number of vessels sunk or washed ashore and abandoned. In the winter of 2019, many Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound communities, such as Schenḵ,/Grantham’s Landing and Lions Bay, experienced severe damage to community docks and shorelines.[7] In addition to various-sized vessels set adrift, other debris, such as pressure-treated lumber and polystyrene, presented hazards to navigation and washed up on the shores of Átl’ḵa7tsem/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	
A group of citizens and government representatives could assemble to collectively share data and develop integrated solutions to reduce ecological, social and economic impacts associated with wrecked, abandoned and problem vessels in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.	Since April 2019, the MRG has been working on identifying and inventorying problem vessels and debris throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. You can view the inventory at www.google.com/maps/d/viewer?hl=en&mid=10PK3Rz2FdceZm8dBDUtmIvCkFjG5U-wd&ll=49.563475717914244%2C-123.39813229876165&z=9.
GOVERNMENT ACTIONS AND POLICY	
Implement owner pay policies.	The introduction of Bill C-64 on July 31, 2019, increases owner responsibility and liability for vessels, and puts the responsibility and liability for abandoned vessels back on vessel owners.

Rusty, submerged vessel near Watts Point, Murrin Provincial Park, 2019. (Credit: Fiona Beaty)

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:

- Avoid the incineration of organic matter and plastics to prevent the release of dioxins into the air and coastal environment.
- **NEW** If you see a potentially abandoned, wrecked or problem vessel, photograph it and take note of as many of the following details as you can: the vessel name; boat registration; who the owner may be; contact details for the owner; the date you spotted the vessel/how long it has been there; information on what it contains and what it is made from; type of vessel (e.g., dinghy, sailboat). Report these findings to howesoundguide@gmail.com.
- **NEW** Send tips, solutions or success stories to marinespecialadvisor@gov.bc.ca.

Government Actions and Policy:

- Keep vessel inventories.
- Enforce local and municipal bylaws with respect to live-aboards.
- Develop educational material to increase awareness of environmental risks associated with problem vessels.
- Develop policies to close the gaps in jurisdiction over problem vessels.

Methods

Information provided through the Office of Pamela Goldsmith-Jones, MP, Sunshine Coast – Sea to Sky Country; via John Roe of the Dead Boats Disposal Society; and Fiona Beaty, Project Director of the Marine Reference Guide.

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ADDITIONAL INFORMATION

Telephone interview with John Roe, Dead Boats Disposal Society

PollutionTracker: monitoring contaminants in Átl’k̲a7tsem/ Txwnéwu7ts/Howe Sound

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What is happening?

PollutionTracker (pollutiontracker.org) is a monitoring program launched by Ocean Wise Conservation Association in 2015 to measure and document levels and trends of contaminants[i] in mussels (*Mytilus* species) and nearshore subtidal[ii] sediment collected along the coast of B.C., including in Átl’k̲a7tsem/ Txwnéwu7ts/Howe Sound.

Mussels, *Mytilus* species, in an intertidal shore. (Credit: Aroha Miller)

i) Contaminants – the presence of a substance where it should not be or at concentrations above background levels.

ii) Subtidal – the portion of a tidal flat environment that lies below the mean low water for spring tides. Typically always covered by water.

Mussels are useful for monitoring because they are immobile, exposed to all of the contaminants present in the surrounding water, and do not tend to metabolize contaminants. Bottom sediments are widely used to evaluate contaminants in aquatic environments because they can store and subsequently release contaminants to surrounding food webs.

The *PollutionTracker* team tests for over 500 contaminants (Figure 1) including metals, polychlorinated biphenyls (PCBs), flame retardants, pesticides and perfluorinated compounds (PFCs). Contaminants have the potential to adversely affect the health of marine organisms, and have been found in samples coast-wide, particularly in industrialized areas. Many of these contaminants were detected at three sampling sites in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound (Figure 2), reflecting both global and local inputs from historical and current industrial activities in the Sound.

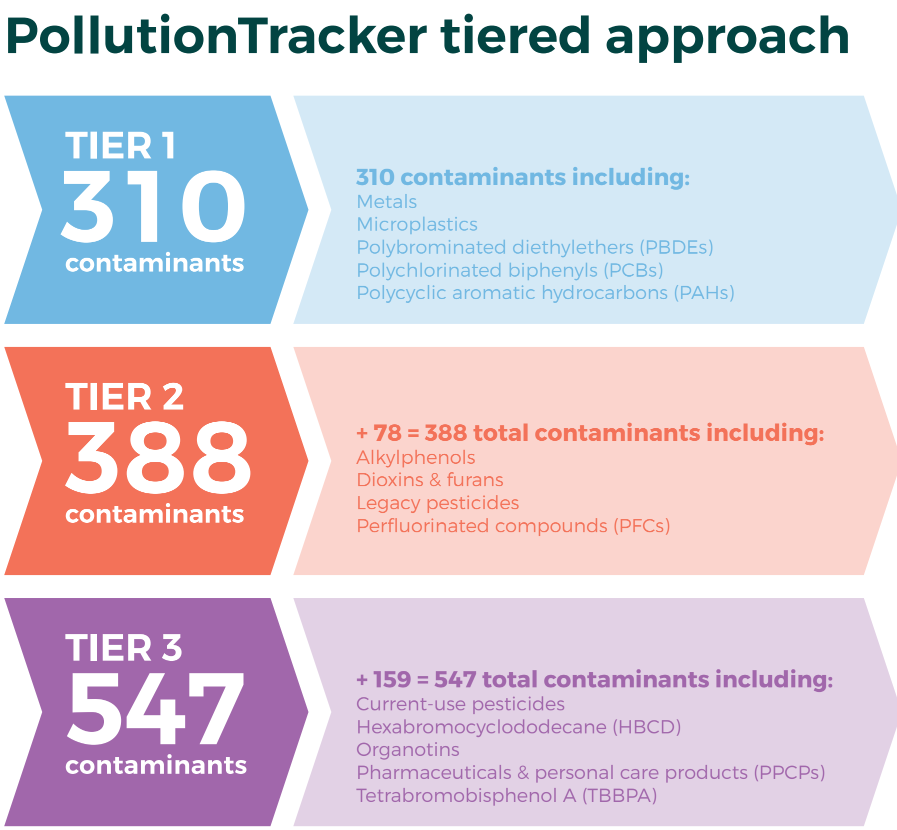

Figure 1. The *PollutionTracker* tiered approach to sample analysis. High-resolution contaminant analysis is costly; therefore, different options for analyses are available to reflect current and historical anthropogenic activities in the region.

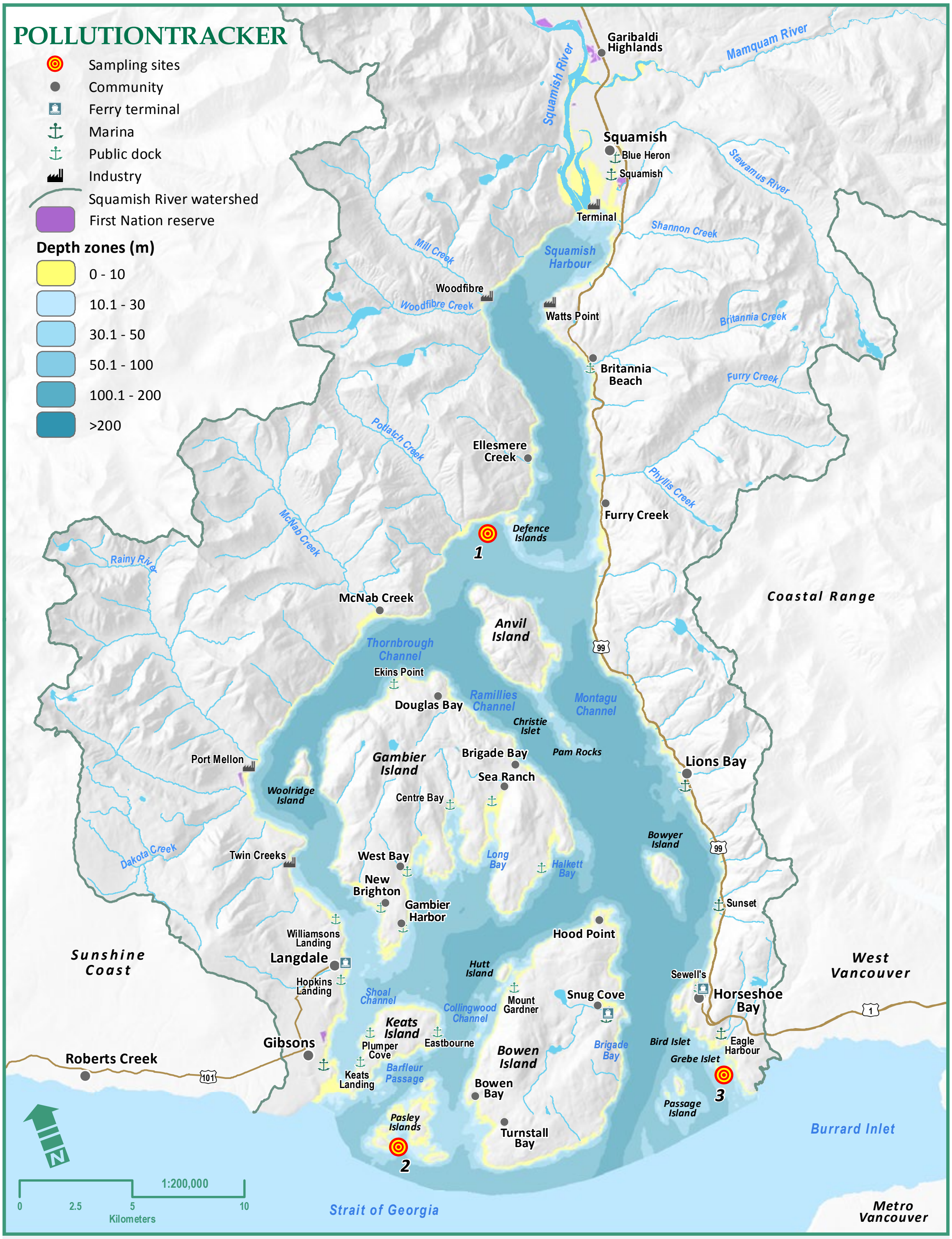

Figure 2. *PollutionTracker* sampling sites within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Top centre: Kw’émḵw’em/Defence Islands; bottom left: Skwákwtsa7s/Popham Island; bottom right: Ḵ’itl’álsm/Eagle Harbour.

Why is it important?

A multitude of contaminants are released or deposited into the marine environment from anthropogenic (human) activities. Contaminants may be of local or global origin because chemical contaminants can be transported long distances by oceanic and atmospheric currents. Monitoring helps to identify priority pollutants of concern and locate potential sources, thereby facilitating changes to regulations and best practices to protect ecosystems.

Pollution threatens the health of the marine environment and connected wildlife and human communities. Some chemicals, such as PCBs, accumulate in the food chain[1] and are known to cause developmental, immunological and reproductive impairment in animals.[2] The potential effects of many newer contaminants, such as pharmaceuticals and personal care products, are largely unknown.

Current sources of marine pollution continue to persist in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, such as vessel-related spills and releases from problem vessels, waste water effluent, storm water inputs, and others. Additionally, Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound has a history of marine pollution particularly associated with pulp and paper mills (Woodfibre and Port Mellon, (see Pulp Mill Effluent, Ocean Watch Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020) and mining (Britannia Beach copper mine, [see Britannia Mine, OWHS 2020]). While the mine and Woodfibre mill are now closed, the Port Mellon mill continues to operate.

Over the past hundred years, effluent from the two pulp mills has resulted in the discharge of chemical contaminants into Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound (see Pulp Mill Effluent, OWHS 2017). The most notable contaminants released were dioxins and furans, produced as unintentional by-products of the pulp and paper bleaching process. Dioxins and furans are persistent in the marine environment and are toxic to marine organisms and humans. High dioxin/furan levels led to the closure of fisheries in most of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound in the 1980s.[3] Effluent regulations in the late 1980s/early 1990s and changes to the mill process in the mid-1980s dramatically reduced dioxin/furan inputs to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, resulting in decreased contamination in fish and shellfish. However, advisories for crab consumption in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound are still in place.[4] Additionally, all of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is currently closed to shellfish harvesting due to marine biotoxins and/or sanitary closures.[5,6]

Between 1898 and 1974, over 40 million tonnes of tailings were generated by the Britannia Mine and deposited onto the marine subtidal slope near Britannia Beach. Four to 40 million litres of metal-laden waters (acid mine drainage) were discharged into Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound daily, depending on the time of year.[7,8] Acid mine drainage from the site included metal contaminants such as cadmium, copper, aluminum, iron, zinc and manganese. Many of these metals can result in negative impacts to marine life. Since closure, ongoing remediation efforts have significantly improved the creeks and nearshore environment in the area.

What is the current status?

Given the industrial history of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, dioxins, furans and metals are the primary contaminants of concern. Inputs of these contaminants have decreased in recent years due to pulp mill and mine closures, changes to mill operations and remediation; however, monitoring remains relevant today to confirm continued improvement in the health of the Sound. As part of *PollutionTracker,* other contaminants are also measured in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to monitor trends and identify potential new contaminants of concern.

Contaminant levels in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound are comparable to other sites along the B.C. coast (see pollutiontracker.org); however, concentrations of total dioxins/furans and some metals are elevated at some Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound sites relative to federal and provincial environmental quality guidelines.

Canadian and B.C. sediment quality guidelines are available for arsenic, cadmium, chromium, copper, lead, mercury, zinc and dioxin/furans[iii].[9,10] Metal concentrations in sediment collected for *PollutionTracker* were below these guidelines, with the exception of arsenic, copper and mercury at Ḵ’itl’álsm/Eagle Harbour, and copper at Kw’émḵw’em/Defence Islands (Figure 3). Guidelines for these metals are not available for mussel tissue; however, concentrations of metals were measured in mussel samples, providing evidence of bioaccumulation[iv] in this species and the potential for toxic effects in mussels and species that feed on mussels (Figure 4).

Dioxin/furan values are presented as toxicity equivalents (TEQs)[v]. In mussels, the dioxin/furan TEQ value at Ḵ’itl’álsm/Eagle Harbour (4.26 ng TEQ_{mamm}/kg wet weight; Figure 5, top) was above the tissue residue guideline protective of mammalian wildlife (0.71 ng TEQ_{mamm}/kg) and was second highest among mussels collected coast-wide. In sediment, the dioxin/furan TEQ value at Ḵw’émḵw’em/Defence Islands (1.244 ng TEQ_{fish}/kg dry weight; Figure 5, bottom) was above the federal interim sediment quality guideline (ISQG)[vi] protective of fish (0.85 ng TEQ_{fish}/kg). Continued monitoring is critical to understanding the potential effects of current and future industrial activities on the marine environment, as well as the potential emergence of new contaminants of concern. Historical contaminants buried in marine sediments may also be redistributed in the environment through physical disturbances (e.g., storms, boats, dredging activities).

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iii) Arsenic: 7.23 mg/kg dw, cadmium: 0.7 mg/kg, chromium: 52.3 mg/kg, copper: 18.7, lead: 30.2, mercury: 0.13, zinc: 124 mg/kg, dioxins/furans: 0.85 ng TEQ/kg dw for sediment, 0.71 ng TEQ/kg ww for mammalian wildlife consumers, 4.75 ng TEQ/kg ww for avian consumers.

iv) Bioaccumulation – the accumulation of chemicals in an organism at a rate faster than which the chemical can be excreted.

v) There are several different dioxins and furans but not all are equally toxic. Each is multiplied by a toxic equivalency factor (TEF) to make it comparable to the most toxic dioxin compound (2,3,7,8-TCDD). These values are then presented as toxic equivalents (TEQs). TEQ_{mamm} and TEQ_{fish} refer to the toxicity levels of mammals and fish respectively.

vi) ISQG – The concentration below which adverse biological effects are expected to occur rarely.

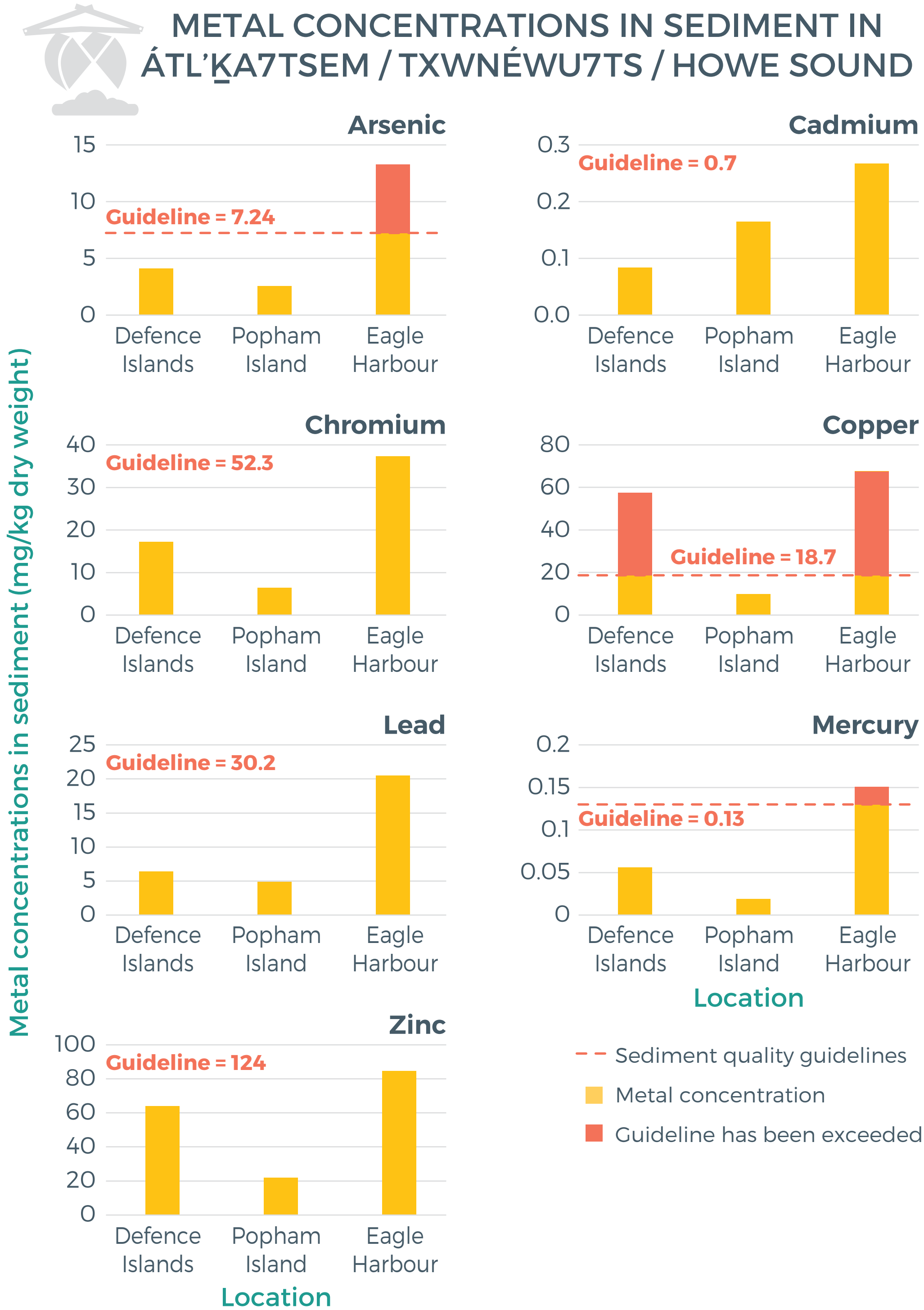

Figure 3. Metal concentrations in sediment in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Guidelines are not shown for cadmium. chromium, lead or zinc because the detected concentrations were well below the guideline concentrations.

Figure 4. Metal concentrations in mussels in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Mussels were not collected from Ḵw’émḵw’em/Defence Islands. Guidelines for these metals are not available for mussel tissue.

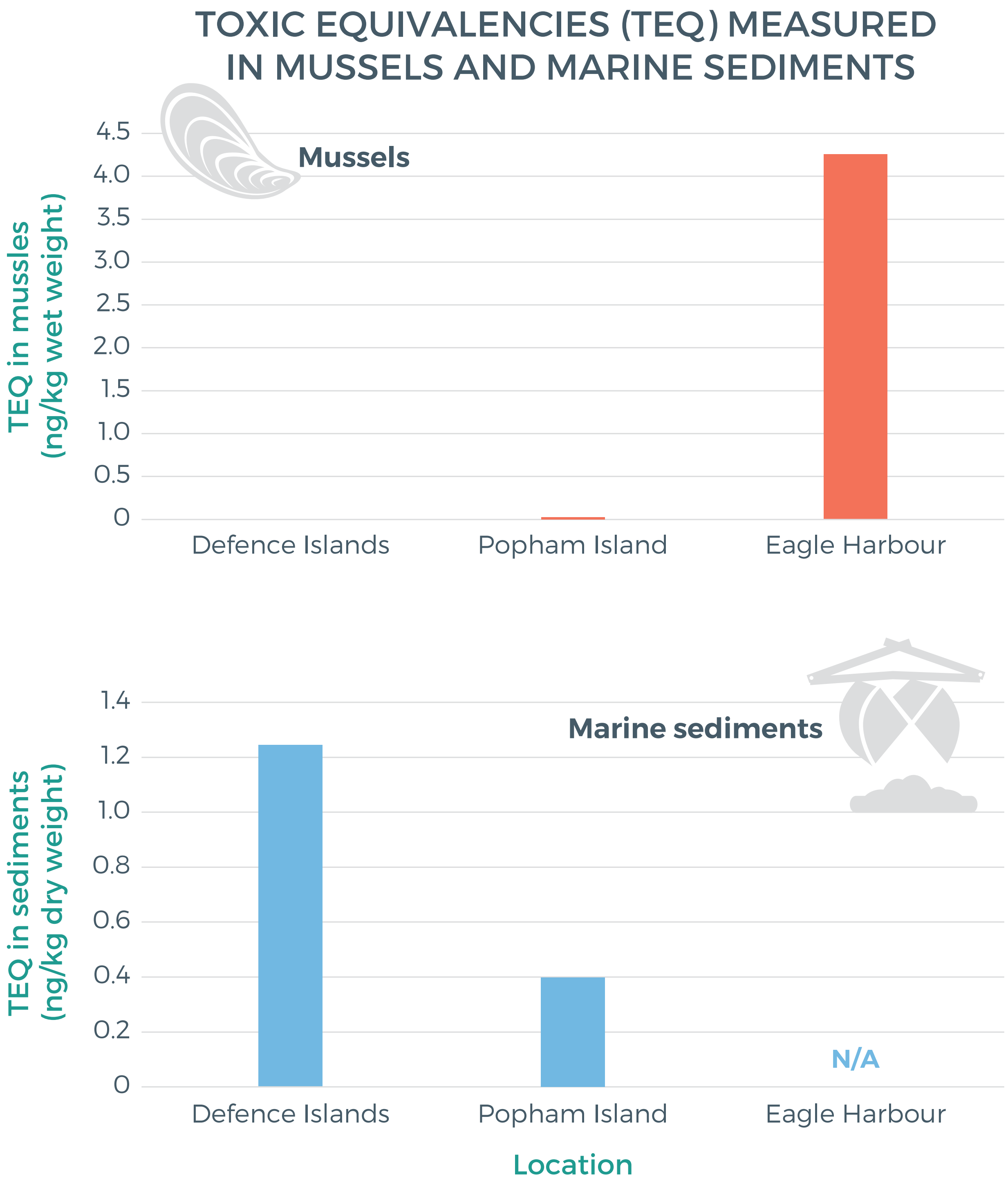

Figure 5. Dioxins/furans in mussel (top) and sediment (bottom) in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Dioxins/furans were not analyzed in sediment from Ḵ’itl’álsm/Eagle Harbour.

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

Ocean warming and ocean acidification may lead to increased sensitivity of marine organisms to contaminants in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Increased temperatures may modify the chemistry of contaminants and therefore alter their toxicity[11], and change their potential to remobilize from the ocean, freshwater, sediments and land. With these potential changes the transport, persistence, exposure and bioaccumulation rates in marine food webs may also be affected.[12]

Climate change-associated reductions in the size or condition/health of fish and marine mammals may increase concentrations of bioaccumulative chemicals in their remaining fatty tissues. As temperature increases, food consumption rates and respiration rates will also increase in fish, possibly leading to increased tissue contaminant concentration due to increased exposure. Primary production will also be affected by climate change, whereby the amount of persistent organic pollutants absorbed by phytoplankton and subsequently amplified through the food web may change.[12]

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). This is a new article for 2020. As such, there were no previous actions.

Individual and Organization Actions:

- Learn more about contaminants in the marine environment using the resources listed below.
- Reduce or eliminate toxic chemicals around the house and garden (for example, bleach, drain cleaner, ammonia, fertilizer containing nitrates, herbicides, pesticides, insecticides).
- Recycle and dispose of waste responsibly (City of Vancouver: https://vancouver.ca/home-property-development/recycling-and-disposal-facilities.aspx; District of Squamish https://squamish.ca/our-services/garbage-and-waste-diversion/).
- Follow fish consumption advisories from Health Canada (for example, mercury).
- Get involved! *PollutionTracker* is dependent on partner funding and involvement. If your community or organization is interested in becoming involved, please contact us at oceanpollution@ocean.org.

Government Actions and Policy:

- Invest in monitoring and research to better understand the risks posed by marine contaminants.
- Develop regulations for new contaminants of concern to prohibit and control their production, use, and disposal.
- Share data and publish science to inform consumer decisions and responsible business planning.

Methods

Phase one of the project has concluded (2015–2017). Data were compiled and analyzed, and results were uploaded for public access (pollutiontracker.org). During Phase 1, sediment and mussels were sampled at three sites in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound – one near Ḵw’émḵw’em/Defence Islands; and two sites near the mouth of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound – Skwákwtsa7s/Popham Island, and Ḵ’itl’álsm/Eagle Harbour (Figure 2). This article draws on data from Phase 1 only.

Mussels (*Mytilus* sp.) and nearshore, subtidal surface sediment were collected in collaboration with government agencies, port authorities, industry, community groups and First Nations. Samples were submitted to specialized laboratories for contaminant analyses.

Samples were analyzed for over 450 contaminants, including hydrocarbons, flame retardants, pesticides, pharmaceuticals and personal care products, and microplastics.

Web of Science and Research Gate were used to obtain literature on climate change – contaminant interactions using the key word search string: contaminant AND climate change.

Resources

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

Canadian Council of Ministers of the Environment
http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/

Health Canada
https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets.html

https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/chemical-contaminants/environmental-contaminants.html

Pacific Region Contaminant Atlas (including resources for children)
https://pacifictoxics.ca/

Green Science Policy Institute
www.greensciencepolicy.org/

Plastic Oceans
www.plasticoceans.org/the-facts/

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Plastics: an ubiquitous ocean threat

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What is happening?

Plastic pollution in the marine environment is a universal issue. Globally, more than 400 million tonnes of plastic are produced annually, and demand is still growing.[1–3] Global plastic production doubles every decade. Around one-third of the plastic produced is used for packaging – most of which is single-use. Although many plastics are used for just a few minutes and then thrown away,[3] this material does not readily biodegrade, persisting in the environment far beyond the length of time it was used.[4] Plastic is a valuable material because of its durability and characteristic of being lightweight. Unfortunately, these traits are what make it easily mobilized, widely distributed and persistent in the marine environment.[7,8]

Waste management infrastructure cannot cope with our current rate of plastic production and use, and it becomes more difficult still once this plastic enters our oceans. In Canada, an estimated 11% of plastic is recycled.[5] Globally, as little as 9% of plastic waste is collected for recycling.[1] Of the rest,

Collecting plastic pieces near the shoreline. (Credit: Ocean Wise) a small portion is incinerated (12%), while the remainder enters the landfills or the environment (79%).[1]

Even areas with low plastic consumption and excellent waste management can be plagued with plastics from other regions on their shorelines, because ocean currents can transport plastics long distances. For instance, plastic litter can find its way to remote Arctic ecosystems[3] and can enter the resident marine species, including birds[6] and fish.[7] Our research team has recently investigated microplastic ingestion in beluga whales from the Arctic, finding microplastics in every whale sampled.[8]

An estimated average of eight million tonnes of plastic enters the world's oceans every year, from land-based sources and waterways.[4] This does not include marine debris lost or discarded from fishing boats and other marine sources. These plastics contribute around 10% of the total marine plastic pollution and dominate the larger marine debris (macroplastics) category.[3,9,10]

Plastic does not degrade naturally. It only breaks down into smaller pieces that persist in the environment. When less than 5 mm in diameter, they are classified as microplastics, of which there are two types[i]:

1. Primary microplastics: these are deliberately produced to be less than 5 mm in size, such as microbeads from personal hygiene products;
2. Secondary microplastics: these are created from larger plastic items (macroplastics) that fragment over time.

Why is it important?

Plastics, both larger identifiable objects and microplastics, can be mistaken for food and eaten by marine organisms. Zooplankton, at the base of the food chain, have been documented ingesting microplastics, meaning plastics are permeating all tiers of the food chain.[11] Invertebrates, fish, seabirds and marine mammals are all at risk of ingesting plastics, potentially resulting in malnutrition, emaciation and death.[11–14]

In recent years, marine mammal species such as killer whales (*Orcinus orca*), humpback whales (*Megaptera novaeangliae*) and seals (*Phoca vitulina*) have begun returning to Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound waters. Entanglement of these animals in marine debris is a concern. Lost, discarded and abandoned fishing lines, nets or rope, also known as ghost fishing gear – most of which is made from plastic – tend to cause most marine entanglement.[10]

When fish and other organisms are caught in ghost fishing gear, scavenger species are attracted, which are then trapped themselves.[15] Ghost gear can also catch active gear, and like a snowball effect, the problem continues to increase.[10] Ghost gear is one of the "deadliest" of all marine debris, due to its proficiency at capturing marine life.[10] Ghost fishing gear can also result in habitat destruction, directly impacting the species using that environment.[10]

i) https://research.ocean.org/program/plastics-lab

What is the current status?

Large Marine Debris/Macroplastics

In 1994, the Great Canadian Shoreline Cleanup was launched by the Vancouver Aquarium. Since then it has evolved into one of the largest direct action conservation programs in Canada, a partnership by Ocean Wise and WWF-Canada, with community-led cleanups throughout the year.[16] Using data cards, volunteers collect data from these cleanups, which helps determine the most numerous and problematic litter within each area. In Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound in recent years, tiny pieces of plastic and foam[ii] have been the second most numerous litter item found, after cigarette butts, which top the list every year (Figure 1).

Extreme weather events are adding to the shoreline pollution problem. Communities throughout Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound were affected by a series of unusually strong storms in the winter of 2018/2019, resulting in large volumes of marine debris being washed ashore from damaged docks and boats.[17] Local residents undertook most of the cleanup. The most common debris found was Styrofoam from damaged docks and buoys, as well as various packaging.[17,18]

In 2016, the Ocean Wise Marine Mammal Rescue Centre responded to reports of a Steller sea lion (*Eumetopias jubatus*) in trouble around Whyte Islet, near Ch'ax̱áy/Horseshoe Bay. It had become entangled by a plastic packaging band. Other reports of marine mammals being entangled in plastic debris or ingesting plastics in nearby locations include:

- in 2015, a humpback whale died after becoming entangled in fish farm equipment near Klemtu, on the north coast of B.C.;[19]
- in 2016, another humpback was rescued after becoming entangled in fishing ropes north of Klemtu;[20]
- in 2018, five Fraser River seals were entangled in ghost fishing gear and drowned;[21]
- of 870 ghost nets recovered off the coast of Washington State, U.S., over 32,000 marine animals were found, most of which had died.[22]

Community cleanup and ocean literacy event on Hornby Island 2019. (Credit: Ocean Wise)

ii) Tiny pieces of plastic and foam in the Great Canadian Shoreline Cleanup survey are not considered macroplastics, as they are less than 2.5 cm but larger than microplastics (less than 5 mm).

Debris collected during the 2018 Great Canadian Shoreline Cleanup in Átl’ḵa7tsem / Txwnéwu7ts / Howe Sound

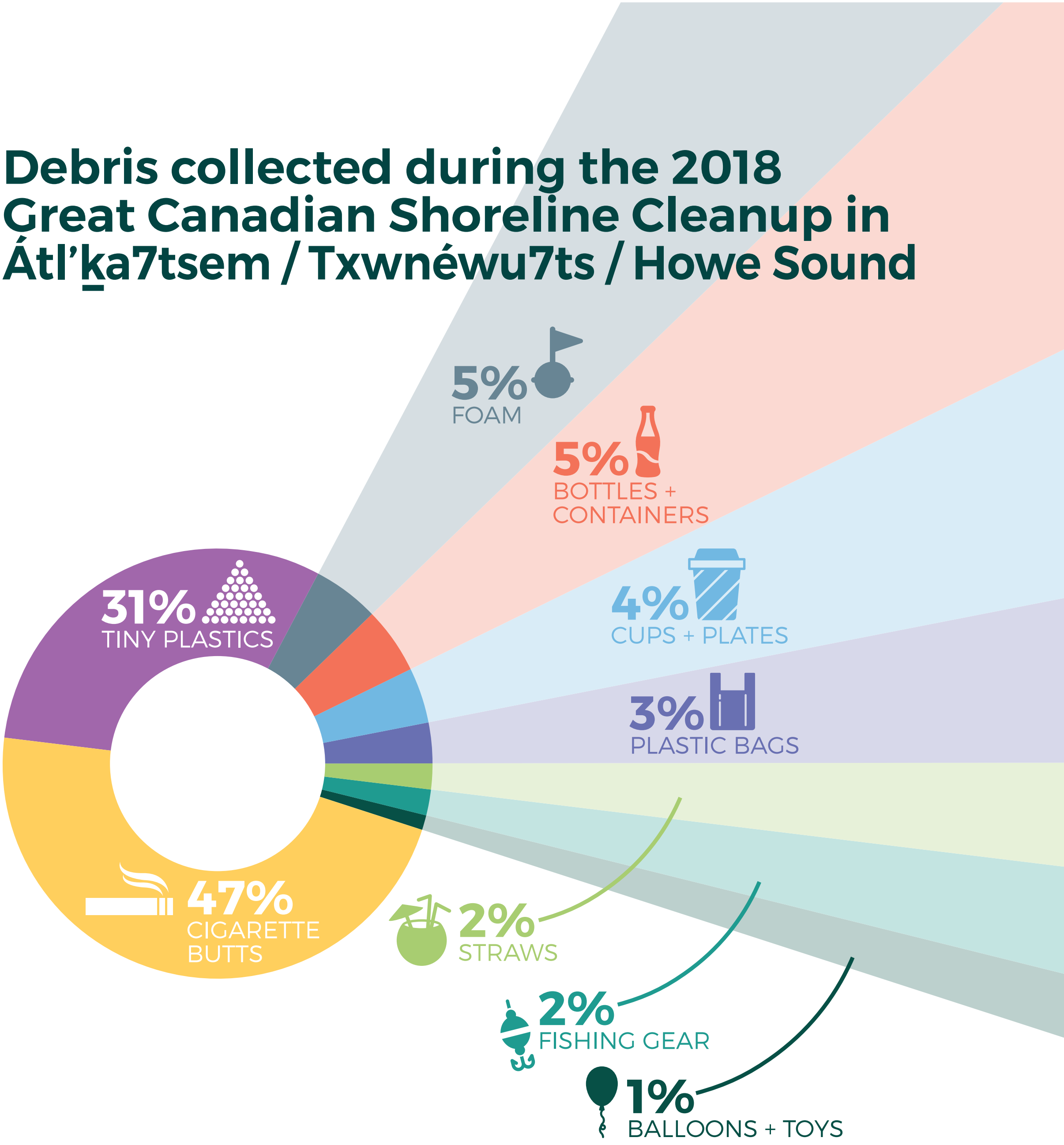

Figure 1. Itemized debris from the 2018 Great Canadian Shoreline Cleanup in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.

Microplastics

Microplastics are common contaminants in the coastal and offshore environment of B.C. Researchers at the Ocean Wise Plastics Lab found that microplastics are abundant in the surface seawater of coastal Strait of Georgia (up to 9,200 microplastics per cubic metre), decrease away from the shore, but are still prevalent in the remote Northeast Pacific.[23] This is of concern since these particles are mistaken for food by local zooplankton species[12] and may contaminate the marine food web. Microplastics have also been found in mussels and sediments along the B.C. coastline as part of the Ocean Wise *PollutionTracker* program. The causes of microplastic contamination are not yet fully understood and a subject of intense research at Ocean Wise. One important source of marine microplastics is the municipal wastewater, with an estimated 30 billion plastic particles escaping treatment of a secondary plant in Vancouver, B.C.[24] Microplastics in wastewater[24,25] and local seawater[23] are dominated by microfibers, the origins of which can be linked to home laundry as garments can release up to billions of microfibers in a single domestic wash.[22] Annually, households in Canada and the U.S. contribute 878 tonnes of microfibers to the aquatic environment (freshwater and ocean). That equates to the same weight as 10 blue whales entering our oceans, rivers and lakes, each year (Figure 2).[26]

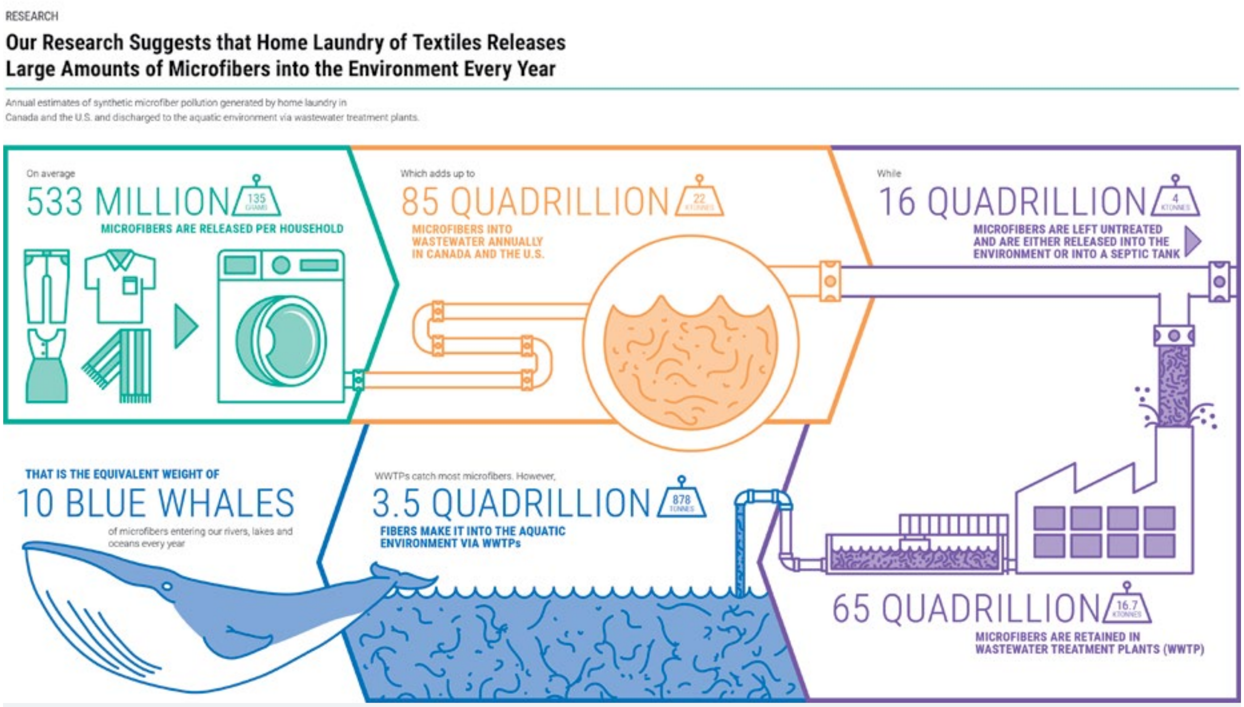

Figure 2. Home laundry releases large amounts of microplastics, as textile fibres, into the marine environment every year.[27]

What is being done?

Communities throughout Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound participate annually in the Great Canadian Shoreline Cleanup. Since 2010, shoreline cleanups in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound have removed over 6.8 metric tonnes of debris from some 162 kilometres of coastline.[16] However, the number of people participating in the Shoreline Cleanup program in this area has been declining. Consequently, the amount of debris removed (in kilograms) is declining too (Figure 3). This is likely an artefact of fewer people in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound taking part in the program and submitting data.

However, data from cleanups by organizations that do not submit to the Shoreline Cleanup are not recorded or included in the figure below. For example, community members made extensive efforts to clean up shorelines after the 2018/19 winter storms. Other cleanups are organized by the Future of Howe Sound Society, My Sea to Sky, Squamish Nation, B.C. Marine Trails and other conservation groups.[28]

PollutionTracker is a conservation tool launched by Ocean Wise. It monitors contaminant levels in sediment and mussels. An analysis of microplastics in sediment and mussels from the B.C. coast, including from within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, is underway. A report of these findings will be released in 2021.[29]

The *Plastics Lab*, an Ocean Wise Research Institute facility, is based in Vancouver, B.C., Canada, special-

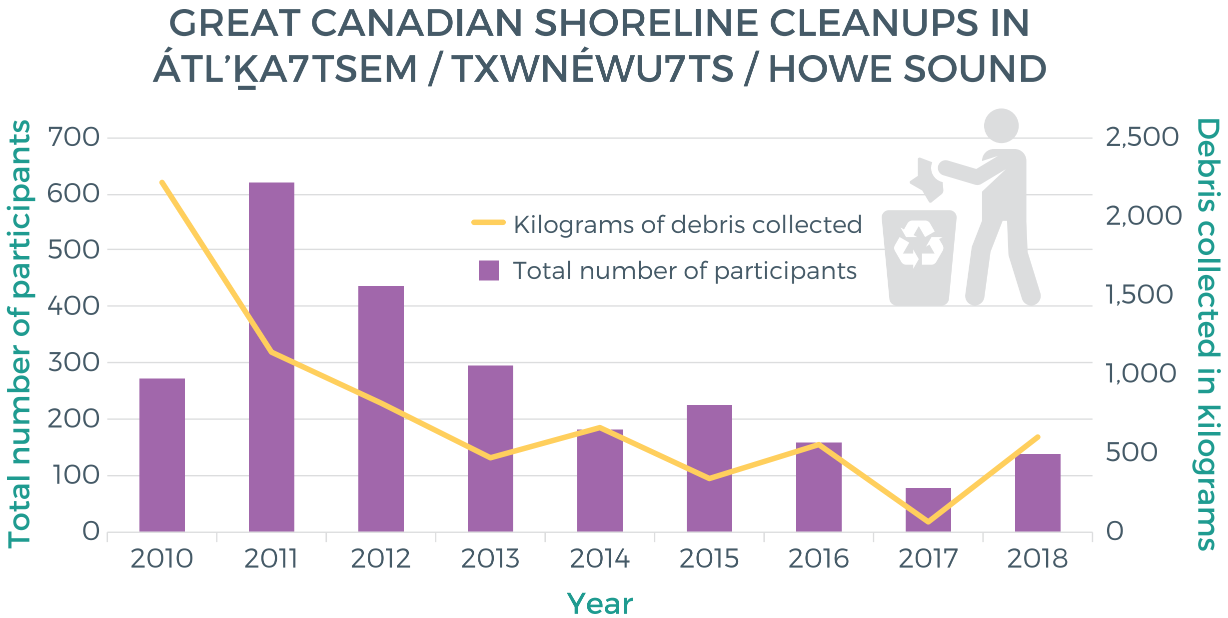

Figure 3. Great Canadian Shoreline Cleanup data from Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound (2010–2018).

izing in microplastic research. The *Plastics Lab* team partners with industry, government, academia and Indigenous groups to identify solutions to marine microplastics. The team investigates microplastics in home laundry, seawater, municipal wastewater systems, zooplankton, mussels, fish and marine mammals. This research will be available in 2020.

Ongoing research and funding, continued motivation for changes in the way we consume plastics, and innovative solutions in removal of plastic from our oceans and shorelines will be key in moving forward with a vision of plastic-free oceans.

Steller sea lion with plastic around its neck (right side of group), disentangled by the Ocean Wise Marine Mammal Rescue Centre from Whyte Islets in 2016. (Credit: Ocean Wise)

Success Story

In February 2019, a group of Squamish Elementary and Howe Sound Secondary students presented a case to ban plastic bags and straws. The Squamish Municipal Council voted in favour, agreeing to implement a ban effective from the end of 2019. The successful outcome means that single use plastic bags now come with a fee based on the greenhouse gas emissions associated with their production, and straws are only available upon asking[i]. Other nearby municipalities are now looking to follow suit (e.g., Lions Bay, District of Gibsons, Nex̱wlélex̱wem/Bowen Island, Chá7elkwnech/Gambier Island[ii]. However, there have been some issues, as the law states that municipalities are unable to adopt a bylaw if it relates to the environment, as that falls under the jurisdiction of the federal government. This has resulted in the district implementing a reduction strategy for single-use plastics instead[iii].

i) Chua, S. Squamish to keep plastic bags. Squamish Chief. https://www.squamishchief.com/news/local-news/squamish-to-keep-plastic-bags-1.23950285 (2019)

ii) Chua, S. Squamish bans plastic bags and straws by the end of 2019. Squamish Chief. https://www.squamishchief.com/news/local-news/squamish-bans-plastic-bags-straws-by-end-of-2019-1.23639967 (2019).

iii) Chua, S. Squamish will not ask provincial government for approval of its plastics reduction. Squamish Chief. https://www.squamishchief.com/news/local-news/squamish-will-not-ask-provincial-government-for-approval-of-its-plastics-reduction-1.23999677?utm_campaign=magnet&utm_source=article_page&utm_medium=related_articles (2019).

What are the potential impacts of climate change on plastics?

Climate change results in an increase of extreme weather events, which have the capacity to damage infrastructure, erode shorelines and mobilize large volumes of plastic debris. Four serious storm events occurred throughout the Sound in the winter of 2018/19. As extreme weather events become more frequent and intense, the input of plastic debris from land to ocean will likely increase. It is also expected that greater volumes of fishing gear will be lost during extreme weather events, resulting in an increase in harmful ghost gear.

Ocean warming driven by climate change will contribute to the breakdown of plastics in the ocean.[30] Some plastics can have harmful additives which, when ingested, can have toxic effects;[14,31] however, impacts are still being investigated. Additionally, plastic particles in seawater have been shown to accumulate other toxic contaminants.[14,31,32] Ongoing research is needed to determine the full extent of impacts from plastic ingestion on different marine creatures.

A pile of trash collected on the shoreline of Frye Island Nature Reserve, (Credit: Richelle Martin).

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). This is a new article for 2020. As such, there were no previous actions.

Individual and Organization Actions:

- Take the Ocean Wise plastic wise challenge https://ocean.org/plastic-wise/challenge/.
- Don’t flush anything other than toilet paper.
- Choose more sustainable toiletries and personal hygiene products, e.g., use silk dental floss, plastic free shampoo and conditioner bars, look for wooden handles on razors and toothbrushes and avoid disposables, choose menstrual cups or reusable period underwear instead of disposable feminine hygiene products.
- Always be plastic-prepared: keep an extra “plastic free” kit at work or in your vehicle, e.g., reusable cutlery, straw, water bottle, coffee cup, shopping bag, Tupperware/container for leftovers/takeout.
- Bring your own container for take-out leftovers. Refill containers at bulk food stores or bulk sections in your grocery store.
- Support initiatives to reduce single-use plastic items like bags, cutlery, cups and fast food containers.
- Reduce your microfiber footprint:
- Use fixtures for washing machines to trap microfibres, e.g., Fitrol – https://filtrol.net/filtrol-160/, Lint Luv-r –http://environmentalenhancements.com/index.html or
- Use a laundry ball or a washing bag to catch fibres, e.g., Cora Ball – https://coraball.com/, Guppyfriend – https://us.guppyfriend.com/
- Avoid fast fashion – purchase garments that last and repair
- Wash less often
- Do a full load of laundry, and wash on cold to reduce fibre shedding from clothing
- Pick up litter, lead or join a shoreline cleanup to prevent debris from re-entering the ocean, and submit your data to the Great Canadian Shoreline Cleanup – www.shorelinecleanup.ca.
- Call the Marine Mammal Rescue Centre if you see a marine mammal in distress/entangled – 604-258-SEAL (7325).
- Become a “Steward of the Strait” – https://georgiastrait.org/work/education-and-outreach/stewards-of-the-strait/.
- If you are a diver, help collect data. See what these groups are doing in your area:
    - Project Aware – www.projectaware.org/take-action
    - Global Ghost Gear Initiative – www.ghostgear.org/
    - Emerald Sea Protection Society – www.emeraldseasociety.ca/

Government Actions and Policy:

- Fund working towards a circular economy for plastics: design products that are recyclable, reusable and recoverable.
- Fund working towards solutions to single-use plastics such as sustainable alternatives to feminine hygiene products, plastic cotton buds, cutlery, plates, straws, drink stirrers and balloon sticks; in addition to incentives, consumption reduction targets, and waste management.
- Revise taxes on reusable feminine hygiene products.
- Enact legislation to put the responsibility of cleanup on the producers of plastics (extended producer responsibility) and incentivize the use of recycled plastics or natural materials.
- Fund actions towards ghost gear removal, and research toward solving the ghost gear problem.

Methods

The Great Canadian Shoreline Cleanup data were collected during cleanups, and collated/provided by the Shoreline Cleanup team at Ocean Wise.

Information on microplastics was sourced from the Ocean Wise Plastics Lab, as well as from literature searches. Searches on Google Scholar and Research Gate used the following key terms: microplastic, pollution, primary, secondary, ocean, marine.

A review of the current literature relating to climate change and plastic pollution was undertaken. Key search terms in Google Scholar and Research Gate included: plastic, climate change, ocean, marine, debris, pollution.

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Coastal Development and Livelihoods

Paddle boarder surrounded by dolphins in front of a local moorage. (Credit: Rich Duncan).

Summary

The beauty and accessibility of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound continues to draw increasing numbers of visitors and residents alike. While this gives a significant boost to the local economy, it also results in a need for increased housing and infrastructure, and often creates competition for access to recreational resources.

To keep up with demand, a number of construction projects (residential, commercial and industrial) are taking place within communities around the Sound, some directly on shorelines. Provincial and regional parks generally saw increases in visitation since the last report, as did some tourist attractions. However, other attractions, specifically the Sea to Sky Gondola, encountered serious challenges due to vandalism. There was growth in the number of passengers and vehicles transported by BC Ferries, as well as continued use of water taxis.

While ferries are a key transport infrastructure, there are also other large vessels (greater than 20 m in length) using the waters. While large vessel traffic to the Port Mellon pulp and paper mill and Squamish Terminals has not increased, if the industrial development projects proposed for the Sound come to fruition, then an increase in large vessel movement is unavoidable.

However, there is a downside to this growth that cannot be ignored. Maintaining a healthy, sustainable economy is intrinsically linked to a healthy marine environment and actions are needed to successfully manage and balance this growth. Supporting the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound UNESCO Biosphere Region Initiative, undertaking cumulative effect assessments, and integrating conservation tools, such as the Marine Reference Guide and the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound marine conservation assessment map, into decision making, are all steps in the right direction to balance sustainable growth and ecological health.

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
COASTAL DEVELOPMENT With rapid growth occurring in the region, and subsequent development, sustainable management is key.		
LARGE VESSEL TRAFFIC The volume of large vessel traffic has not changed significantly. However, not all shipping traffic is represented. Risks from vessel traffic continue. Future development may increase vessel numbers. Efforts are being taken to decrease impacts on cetaceans.		
TOURISM AND RECREATION Demands for activities and resources is high, creating pressure on ecosystems, and there is no sign of growth slowing. This growth requires sustainable management, and there is movement towards this, but more needs to be done.		

Coastal Development: balancing growth with ecosystem health

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What is happening?

It is important to balance environmental and socio-economic objectives for the overall health of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound’s communities and ecosystems and to address the United Nations Sustainable Development Goals (SDG). To recognize the importance of this popular area, work is underway to have Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound designated as a United Nations Educational, Scientific and Cultural Organization (UNESCO) biosphere region. This designation would allow for the protection of biodiversity so people and commerce can benefit from a sustainable economy.

Sewell’s landing development in Horseshoe Bay, February 2020. (Credit: Bob Turner)

Growth continues to be a trend in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, with more people moving to the area and more visitors seeking out attractions such as parks (see Tourism and Recreation, Ocean Watch Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020). To cope with this growing demand, new development (residential, commercial and industrial) is occurring to support people moving to the area while providing economic gains. Ideally, coastal development would be examined across the entire watershed. However, here we focus specifically on shoreline development.

Shoreline development requires unique consideration of environmental conditions, for example the interruption of the land-sea connection of habitats (see Coastal Development, OWHS 2017). Based on 2014 data, 12% of the Sound's shoreline was considered modified. In 2017, 13 new large[i] shoreline development proposals or projects were identified. Therefore, it is important to know what developments are occurring and to consider what environmental impacts they will have, both individually and cumulatively.

Sea to Sky highway. (Credit: Tracey Saxby)

i) Large – for lodging projects, large means more than 10 units.

What is the current status?

Pressure from development – driven primarily by population growth and associated demand for housing and resources – continues to increase within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. In the last few years, overall population growth has varied little across the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound region. Previously, combined (total aggregate) growth within census subdivisions in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound grew by 4% from 2006–2011; updated data shows that population growth remained steady at 4% for 2011–2016.[1] Although little variation is seen for the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound region, much larger changes are being seen on a municipal level (Table 1), with the largest five-year growth occurring in the Squamish-Lillooet Regional District (SLRD) Electoral Area D, Sḵwx̱wú7mesh/Squamish, and Nex̱wlélex̱wem/Bowen Island.

Table 1. Population change from 2006 to 2011 using the most recent census data available (2011–2016) throughout for various areas in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

	POPULATION			POPULATION CHANGE	
COMMUNITY	2006	2011	2016	2006–2011	2011–2016
Bowen Island	3362	3402	3680	1.19%	8.17%
Gibsons	4182	4437	4605	6.10%	3.79%
Lions Bay	1328	1318	1334	-0.75%	1.21%
Squamish-Lillooet D	839	836	1057	-0.36%	26.44%
Squamish (DM)	14949	17158	19512	14.78%	13.72%
Sunshine Coast E	3552	3482	3664	-1.97%	5.23%
Sunshine Coast F	2235	2015	2043	-9.84%	1.39%
West Vancouver	42131	42694	42473	1.34%	-0.52%
TOTAL	**72578**	**75342**	**78368**	**3.81%**	**4.02%**

Development projects and proposals

The status and scope of many large coastal development projects in the region were reported previously (see Coastal Development, OWHS 2017). Updates and additions to these projects are presented below (Table 2). Although the local planning authorities are named, multiple organizations are typically involved in the approval process (e.g., provincial government, Fisheries and Oceans Canada [DFO]). All project details are reported provisionally because development review and project approval processes are ongoing.

Current project status, as noted in Table 2, is summarized as:

- in progress (i.e., building is occurring);
- pending (i.e., the project is waiting for decisions on, e.g., environmental assessments, before building can start);
- dormant (i.e., work is not being carried out on applications or building);
- planning (i.e., the project is in the initial stages of planning);
- abandoned (i.e., all work on the project has ceased);
- complete.

Table 2. Major coastal development projects and proposals on the *shorelines only* of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound with an extension into Mamquam Blind Channel (situated to the east of downtown Sḵwx̱wú7mesh/Squamish) up to and including October 2019.[i] Where status has progressed (i.e., is moving forward through some aspect of the approval/building process) from the previously reported status or the project/proposal is new, it is coloured green. Projects that have remained similar in status are coloured yellow. One project that has been abandoned is coloured red. Blank cells indicate no information is available. Some previous statuses from OWHS 2017 were uncertain and therefore include a "?". (Abbreviations: SLRD – Squamish-Lillooet Regional District; SCRD – Sunshine Coast Regional District; OCP – Official Community Plan)

i) Excludes projects or proposals under 10 units. Table may not be complete or accurate and does not represent total development potential under current (and proposed zoning).

PROJECT NAME	LOCATION	TYPE OF DEVELOPMENT	LOCAL PLANNING AUTHORITY RESPONSIBLE	STATUS: JUNE 2016 – PREVIOUS OWHS 2017	STATUS SEPTEMBER 2019	NO. OF UNITS
Sewell's Landing	Horseshoe Bay, West Vancouver	Mixed use, with dock	District of West Vancouver	Application to be submitted?	In progress	158
Horseshoe Bay Ferry Terminal Redevelopment	Horseshoe Bay, West Vancouver	Transportation infrastructure	District of West Vancouver	Not previously reported.	Planning	N/A
The George Hotel and Residences	Gibsons	Commercial, residential	Town of Gibsons	Application under review?	Pending	39 residential units, 116 hotel rooms
Seaglass	Gibsons	Residential, commercial	Town of Gibsons	Application submitted? First reading given to zoning and OCP amendments.	Abandoned	12
Gibsons Foreshore Redevelopment	Gibsons	Community development	Town of Gibsons		Complete	N/A

PROJECT NAME	LOCATION	TYPE OF DEVELOPMENT	LOCAL PLANNING AUTHORITY RESPONSIBLE	STATUS: JUNE 2016 – PREVIOUS OWHS 2017	STATUS SEPTEMBER 2019	NO. OF UNITS
Gospel Rock	Gibsons	Residential, commercial, recreational	Town of Gibsons	Not previously reported.	In progress	360 residential
Porteau Cove Community	Porteau Cove	Residential, commercial, and community uses (e.g., amenities and recreation)	SLRD	Zoned; no development permits issued; application under review?	Dormant	1400
Furry Creek Community	Furry Creek	Resort, recreational, residential, marina	SLRD	Under Development Covenant (permit granted).	In progress	920 residential, 120 hotel, commercial and marina
Britannia Beach South	Minaty Bay Britannia Beach	Resort (surf park), recreational, residential, commercial	SLRD	Master planning, zoning required.	Pending	1,050 residential, 190 hotel, commercial (2,500 population)
Britannia Beach North	Britannia Beach	Commercial, residential	SLRD	Application to be submitted?	In progress	84 residential + commercial
Watts Point	North of Britannia Beach	Industrial	District of Squamish	Not previously reported.	Pending[ii]	N/A
Klahanie Resort Redevelopment	Shannon Falls / Squamish South	Resort, residential, seasonal camping	District of Squamish	Requires rezoning and Development Permit.	Planning	80+ hotel units, 60 residential
Squamish Oceanfront Development / Newport Beach	Squamish – Downtown Peninsula	Mixed-use employment, residential, commercial, oceanfront park and marina use	District of Squamish	Rezoning Application approved; Development Permits in progress.	In progress	1,500+ residential, employment, commercial space and future marinas
Waterfront Landing (Sea to Sky)	Squamish – Mamquam Blind Channel	Mixed use: residential, commercial village and marina, waterfront park	District of Squamish	Not previously reported. Rezoning Application approved.	In progress	900–1,000 residential units

ii) Crown tenure application submitted for expansion in 2018. Table is not an exhaustive list of crown tenure applications and others likely exist in the area.

PROJECT NAME	LOCATION	TYPE OF DEVELOPMENT	LOCAL PLANNING AUTHORITY RESPONSIBLE	STATUS: JUNE 2016 – PREVIOUS OWHS 2017	STATUS SEPTEMBER 2019	NO. OF UNITS
Mistral + Sirocco Developments	Squamish – Mamquam Blind Channel	Mixed use residential; commercial and marina. Sirocco project includes float home residential use.	District of Squamish	Not previously reported.	In Progress	Upland residential 217 units (combined). Float home residential, up to 31 units.
Waste to Energy Facility	West Howe Sound	Industrial	SCRD	No longer a potential project? Metro Vancouver has discontinued its current waste-to-energy procurement process.	Dormant	N/A
Burnco Gravel Mine	McNab Creek	Industrial	Environmental Assessment – British Columbia. Land use zoning – SCRD	Pre-application started 2010. In late 2018, SCRD passed a resolution to abandon this project. Land use planning is the jurisdiction of local government (SCRD); mining falls within provincial jurisdiction. Provincial authorization remains valid to extract raw aggregate, ship off site, and then process.	Pending	N/A
Woodfibre LNG	Squamish	Industrial	Environmental Assessment – British Columbia for federal and provincial governments. District of Squamish permits	Provincial EA Certificate Issued Oct 2015; Federal environmental approval rec’d March 2016; Squamish Nation Council issued an Environmental Assessment Certificate with legally binding conditions in Oct 2015.	In progress	100+ temporary housing for during construction; > 3 years

Since 2017, the status of five projects has advanced, including the Gibsons Foreshore Redevelopment, which is now complete. Four other projects moved to an “in progress” status. Gospel Rock in Gibsons, noted above as “in progress,” was not reported previously.

In Sḵwx̱wú7mesh/Squamish, two additional coastal redevelopment projects were identified along the shore of the Mamquam Blind Channel (i.e., Waterfront Landing, and the Mistral and Sirocco projects). These waterfront redevelopments include major sea diking infrastructure that is part of the District of Squamish coastal flood protection system for Downtown.

Seven projects are pending or dormant. The Gibsons’ Seaglass development has been abandoned. The Ch’ax̱áy/Horseshoe Bay Ferry Terminal redevelopment project is in the planning stage.[2] Information gathered from the public consultation will be used in the planning process, which is ongoing.

Two of the industrial projects listed previously (Waste to Energy, Burnco gravel mine) remain similar in status to three years ago (dormant, pending, respectively). At the time of writing[iii], the most recent update on the Burnco website was from June 2018, wherein it states that Fisheries and Oceans Canada (DFO) has allowed the project to progress to regulatory permitting.[3] However, the project cannot process mined material on site due to a decision by the SCRD to abandon a rezoning application.[4]

The Woodfibre LNG project’s status is now “in progress.” In March 2019, the Sḵwx̱wú7mesh Úxwumixw/ Squamish Nation signed an agreement with Woodfibre LNG to share benefits from the project, such as financial gains. The agreement includes the transfer of certain parcels of land from the Province back to the Sḵwx̱wú7mesh Úxwumixw/Squamish Nation and confirms Sḵwx̱wú7mesh Úxwumixw/Squamish Nation support of the LNG project.[5] In 2018, an application was submitted for crown tenure to expand the mining project at Xwelxwalitn/Watts Point , which includes plans for marine shipping infrastructure.[6]

However, development in the region goes beyond coastal properties, extending into the broader Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[7] There are plans for the development of a multi-billion dollar four-season resort, Garibaldi at Squamish, at Brohm Ridge (north of Sḵwx̱wú7mesh/Squamish, within the Squamish-Lillooet Regional District). The project received approval from the Environmental Assessment Office in 2016, with 40 conditions; planning continues. Further investment in support of ski tourism occurred with the Renaissance project upgrades to Blackcomb Whistler. Inland developments have an obvious impact, which is to increase traffic in the region and pressure on infrastructure.

iii) March 2020.

Regional Traffic Impacts

Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is full of attractions, e.g., hiking, biking, breweries, eagle viewing, skiing at Whistler. It is also very close to Vancouver, making it a prime destination for locals and tourists alike. While these visits provide economic gain for the region, they also drastically increase traffic and pressure on infrastructure in an area already struggling to cope with increasing commuter traffic.

In the past decade, traffic volume has increased for Brackendale and along Highway 99 north of Ch’axá̱y/Horseshoe Bay (see Coastal Development, OWHS 2017). However, traffic volume increases have been somewhat slower in the past few years (Figure 1). Insufficient public transit options contribute to higher private vehicle use, resulting in traffic congestion, increased transport-related emissions and potentially a decrease in air quality and an increase in contaminated run-off.

Calls for regional transit solutions for the Sea to Sky region have been ongoing for years; however, the issue remains unaddressed. To initiate action, stakeholders from around the region, including First Nations, tourism operators and local government officials, presented a case to the provincial government detailing recommendations for interregional transit and infrastructure.[8]

Since then, in order to assist with planning and implementation of transit strategies, a Regional Transit Study was undertaken in 2016 to assess requirements and demand. The area between Metro Vancouver and Pemberton has an estimated daily weekday transit demand of approximately 575 people.[9] These numbers are based off a survey of residents from around Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound and Metro Vancouver, and do not account for additional tourism or other Greater Vancouver area residents.

The biggest obstacle appears to be resolving the viable long-term service funding model. Despite suggestions of financial support from a motor-fuel tax, the provincial government has yet to agree.[10] Stakeholders and residents alike hope a resolution can be achieved shortly.

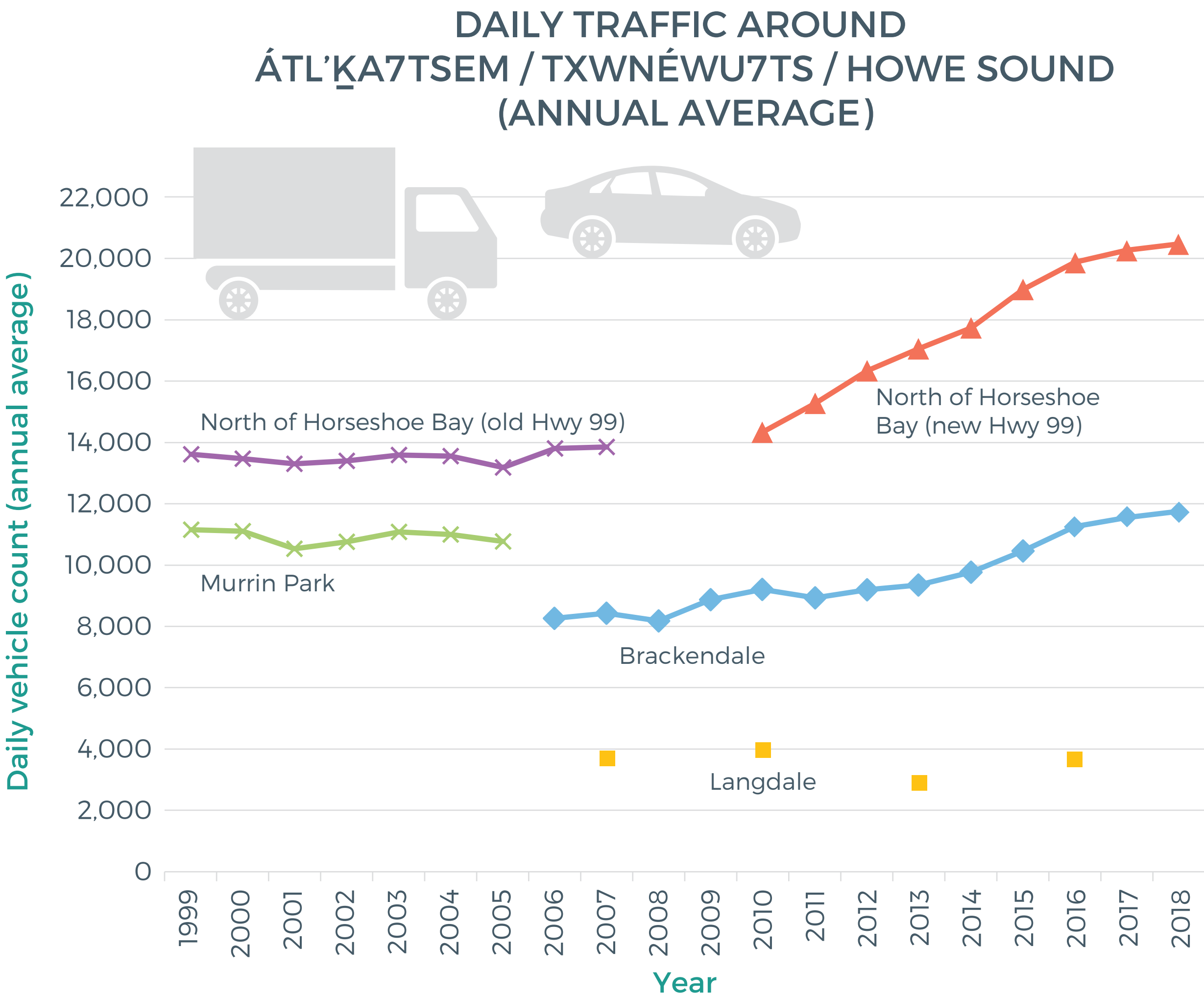

Figure 1. Updated graph of average annual daily traffic from locations within the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

Balancing the cumulative impacts

The ecosystems in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound face multiple stressors at the same time. For example, habitat loss and soil/erosion run-off from construction; toxic effects from contaminants; climate change. Addressing multiple stressors requires consideration of the cumulative impacts. A Cumulative Effects Monitoring pilot project investigated a framework to assist the Sḵwx̱wú7mesh Úxwumixw/Squamish Nation with understanding and addressing past, present and future changes to the environment in the Sound caused by human activity.[11] The province of B.C. has also conducted a cumulative environmental assessment (see Resources).

How will climate change impact coastal development?

Sea level rise and extreme rainfall events will increase the risk of flooding from rivers and will exacerbate shoreline erosion; therefore, the planned retreat of public assets and infrastructure will be necessary. New developments will require restrictions, for example mandated set-back distances from the water’s edge, to protect buildings. Set-backs would also help protect buildings and infrastructure from storm surges created during storms, which can damage property and further erode coastline. Water supply issues are also likely to be exacerbated due to drier summers coupled with higher demand from larger populations. Additionally, issues could potentially arise due to the seepage of sea water into groundwater drinking supplies.

Squamish. (Credit: Tracey Saxby)

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	
Develop and promote an inventory of best practices for developers and update it regularly.	Ocean Watch: Howe Sound Strategic Plan lists local government protection tools in Appendix A.
Apply new and proven methods to assess development projects. For example, innovative tools to provide decision support for complex planning problems are becoming more widely available and accepted. Taking ecosystem service values into account when evaluating the trade-offs of proposed development is one way to proceed. Howe Sound is the study area for a comprehensive assessment that estimates the total annual value of intact ecosystems at between $793 million and $4.7 billion.[12]	The Town of Gibsons has integrated natural capital into their management program. The District of West Vancouver has completed a natural capital inventory and in summer 2019 recommended that this be considered in financial planning, asset management, financial reporting and capital budgeting processes and decisions.[13] Up-to-date information for other local governments was unavailable at the time of publication.
Collate and make available pre-proposal data from environmental and social research.	The Atl’ḵa7tsem/Howe Sound Marine Reference Guide (https://howesoundguide.ca/) will provide a map with many layers of detail, including human use, ecological, and physical, that is being developed to visualize information and support decision making and marine social planning. The anticipated completion date for the guide is late 2021.
Support jurisdictions that want to work together to develop comprehensive land and marine use plans.	The Atl’ḵa7tsem/Howe Sound Marine Reference Guide project receives some funds from local government and municipalities (https://howesoundguide.ca/).

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:

- Individuals, developers and industry can follow, promote, develop, discuss and share best practices (e.g., Green Marine certification, GreenShores approaches for shoreline development).

Government Actions and Policy:

- Add marine values to the B.C. cumulative effects assessment that is underway for Átl'ḵa7tsem/Txwnéwu7ts/ Howe Sound.
- Implement a trust fund from development proceeds to fund environmental mitigation and remediation.
- Plan for construction of key facilities and infrastructure to occupy previously developed shoreline, if feasible.
- Make sharing of pre-proposal data from environmental and social research mandatory.
- Develop targets for ecosystem health, goals for sustainability indicators, and limits for environmental impacts.
- NEW Strengthen regulations and guidelines (i.e., best practices) that can be applied to development/project assessment.

Methods

Census data was downloaded for 2016 (the most recent census data available from B.C. Statistics at the time of writing). Specific geographical locations were used to correspond with the previous report and represent areas around Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.[1] The specific subdivisions included were: Bowen Island, Gibsons, Lions Bay, Squamish-Lillooet Regional District Area D, Squamish (District Municipality), Sunshine Coast Area E, Sunshine Coast Area F, and West Vancouver.

Updated data on coastal development provided in Table 2 was gathered using mixed methods, including inputs from community planners and leaders who provided personal knowledge, results from google searches and first-hand witness. Additional information was added from consultation with community representatives, additional google searches, exploration of Sḵwx̱wú7mesh/Squamish's Development Showcase Map, development websites and planning documents.

Traffic data were adapted from the B.C. Government’s Traffic Data Program, run by the Ministry of Transportation (http://www.th.gov.bc.ca/trafficdata/). Sufficient multi-year data was available only for Cheekeye (Site ID: P-15-3NS), Eagle Ridge (Site ID: P-99-01NS), and Langdale (Site ID: P-15-085NS). Data points refer to annual average daily vehicle counts.

Resources

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

Sea to Sky Transit Corridor Study
https://www.bctransit.com/sea-to-sky/home

Howe Sound Cumulative Effects Project
https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/cumulative-effects-framework/regional-assessments/south-coast/howe-sound-cumulative-effects-project

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3 BURNCO. DFO Determines Project Not Likely to Cause Significant Adverse Environmental Effects. (2018). Available at: http://www.burncohowesound.com/announcements/dfo-determines-project-not-likely-to-cause-significant-adverse-environmental-effects. (Accessed: 27th March 2020)

4 Sunshine Coast Regional District. Minutes of the meeting of the Board of the Sunshine Coast Regional District held in the boardroom at 1975 Field Road, Sechelt, B.C. (2018). Available at: https://www.scrd.ca/files/File/Administration/Minutes/2018/2018-OCT-25 BRD Minutes.pdf. (Accessed: 27th March 2020)

5 BC government. *Squamish liquefied natural gas (LNG) benefits agreement*. (2019).

6 The Future of Howe Sound Society. What’s with Watts Point. (2020). Available at: https://www.futureofhowesound.org/latest-news-blog/whats-with-watts-point. (Accessed: 26th March 2020)

7 District of Squamish. Development showcase map. doi:November 21, 2019

8 BC Transit. Sea to Sky Transit Future Plan. Available at: https://www.bctransit.com/documents/1507213430453.

9 BC Transit. Sea to Sky Corridor Regional Transit Study. Transit Future Action Plan. (2017).

10 District of Squamish. Sea-to-Sky governments urge province to consider creative funding solutions for regional transit system. Available at: https://squamish.ca/yourgovernment/news/creative-funding-solutions-for-regional-transit-system-needed/. (Accessed: 25th November 2019)

11 Squamish River Watershed Society. Cumulative effects monitoring program pilot project. (2019).

12 Molnar, M. *Sound Investment: Measuring the Return on Howe Sound’s Ecosystem Assets*. (2015).

13 District of West Vancouver. Natural Capital in the District of West Vancouver. *Council Report* (2019). Available at: https://www.westvancouver.ca/sites/default/files/dwv/council-agendas/2019/jul/15/19jul15-6.pdf. (Accessed: 26th March 2020)

Acknowledgements

Ruth Simons compiled much of the data for Table 2.

Large Vessel Traffic: making waves and noise

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What is happening?

Large vessels[i] within Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound tend to be comprised mostly of ferries, tugs and cargo ships (see Large Vessel Traffic, Ocean Watch Howe Sound Edition [OWHS] 2017). The volume of large vessels in the Sound presents certain challenges. For example, vessel wake can exacerbate shoreline erosion and impact salmon spawning habitat; species that use echolocation[ii] such as whales and dolphins may experience acoustic masking, whereby vessel noise reduces their ability to find prey, mates and pod members (see Underwater Noise, Ocean Watch B.C. Edition [OWBC] 2018).

Ship docked at Squamish Terminals. (Credit: Bob Turner)

i) Large vessels – vessels over 20 m length.

ii) Echolocation – location of objects using reflected sound.

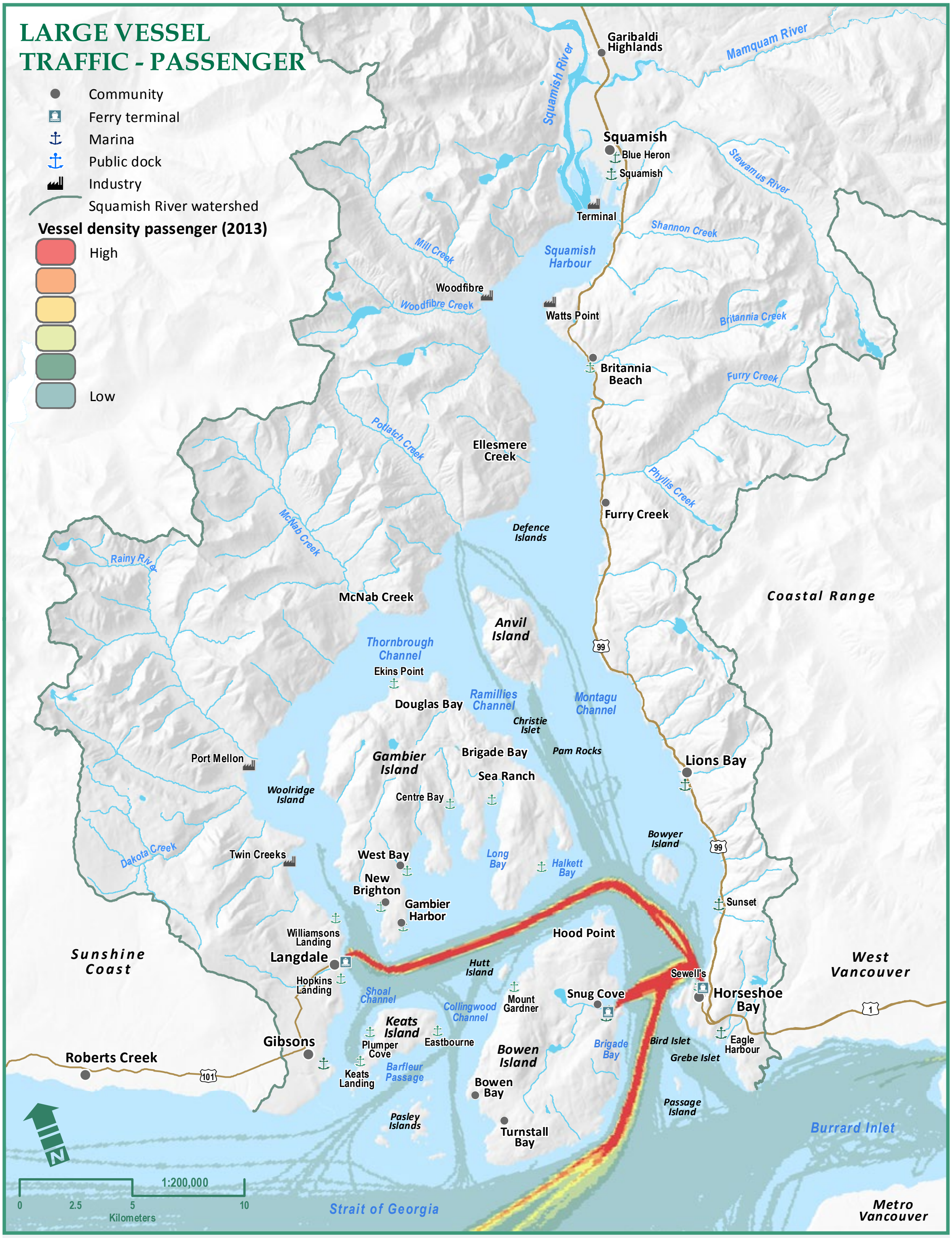

Figure 1. Density map of 2013 passenger traffic in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound (see Methods).

What is the current status?

BC Ferries, under contract by the Province of B.C., provides coastal ferry service on 25 routes along the B.C. coast, supported by 35 vessels and 47 terminals. Within Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, the three most heavily serviced ferry routes connect Ch'ax̱áy/Horseshoe Bay with Gibsons, Nex̱wlélex̱wem/Bowen Island and Snenáymexw/Nanaimo[iii] (Figure 1). Routes that connect Ch'ax̱áy/Horseshoe Bay to Langdale and Nex̱wlélex̱wem/Bowen Island are commuter routes with many daily foot passengers. These routes have between 3,000 and 5, 5000 round trips per fiscal year[iv] (Figure 2).

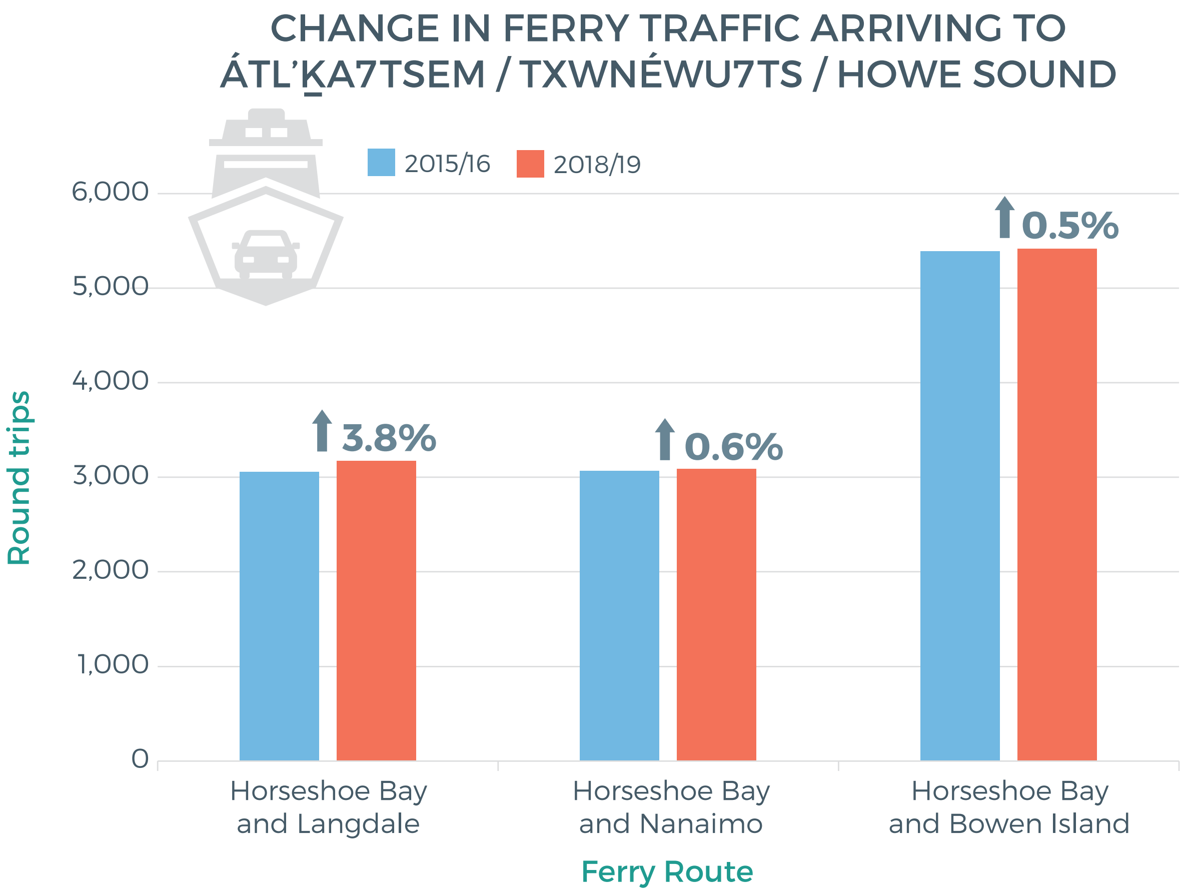

Figure 2. Number of round trips at terminals from Ch'ax̱áy/Horseshoe Bay to Langdale, to Snenáymexw/Nanaimo, and to Nex̱wlélex̱wem/Bowen Island in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound (2015/16 compared to 2018/19). Percentages above bars indicate percentage change.

iii) Snenáymexw/Nanaimo – On Vancouver Island outside of the Sound.

iv) Fiscal year – April 1 to March 31.

Since the previous report, the volume of ferry traffic has varied. The 2015 fiscal year saw sailings reduced on some routes that were considered not viable. In the 2016 fiscal year, some sailing routes were reinstated as per consultation with local advisory committees. A small increase in round trips is therefore seen from 2015/2016 to 2018/2019 (Figure 2). For the 2020 fiscal year, the Province of B.C. provided funding to re-establish sailings impacted by the 2015 reductions.

Cargo ships and tugs call at Howe Sound Pulp and Paper in Port Mellon, and Squamish Terminals in Sḵwx̱wú7mesh/Squamish. These were the only two ports for which data were available for the 2017 report and this update[v]. Both locations have received between 35 and 78 calls per year[vi] (Figure 3). Squamish Terminals has generally received more calls than Howe Sound Pulp and Paper; however, this number of calls to Squamish Terminals has declined by almost half since 2015. Calls received at Port Mellon show only very slight changes over time.

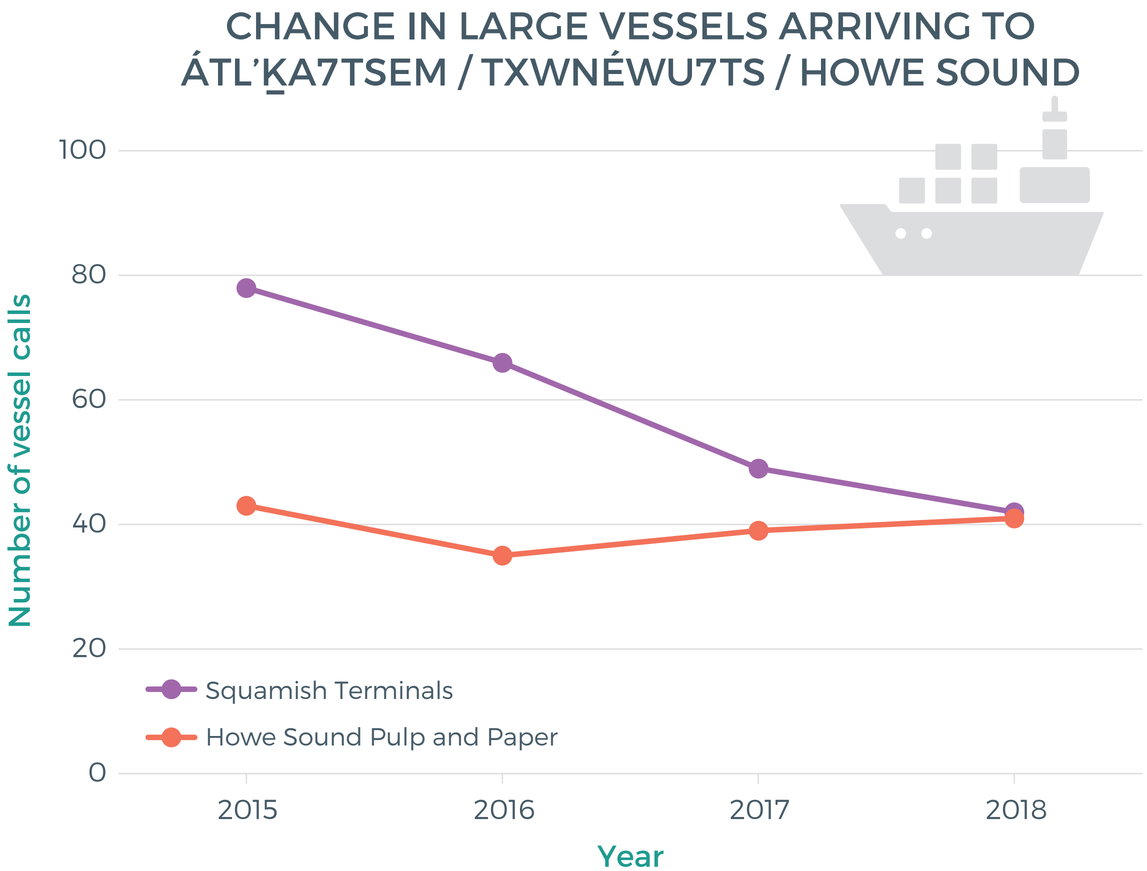

Figure 3. Annual number of vessel calls reported for Squamish Terminals and Howe Sound Pulp and Paper from 2015 to 2018.

v) Does not represent all cargo and tug movement within the Sound.

vi) Calendar year.

Three proposed developments could increase the volume of traffic in the near future. The BURNCO Aggregate Mine at McNab Estuary would ship out gravel; the Woodfibre LNG at Woodfibre Creek would ship liquefied natural gas (i.e., LNG); and the Watts Point expansion would increase the shipping of mined aggregate by barge. Currently, development on the BURNCO Aggregate Mine and Watts Point are pending and the Woodfibre LNG is progressing (see Coastal Development, OWHS 2020).

Ferries constitute a high volume of large vessel traffic in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. BC Ferry upgrades are thus aiming to produce less noise and greenhouse gases.[1]

A B.C. ferry travelling within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Bob Turner)

Ongoing Efforts to Reduce Impacts by Industry

BC FERRIES

BC Ferries is investing in low carbon energy as a fuel source for its vessels. There is a total of five vessels in the fleet, which are on dual fuel (i.e., ultra low sulfur diesel and LNG). There is also a plan for an electric-ready ferry fleet.[a] It is expected that these electric-ready ferries will be quieter than the current ferries operating on these routes.

In an effort to better understand its contribution to underwater radiated noise in the Salish Sea, BC Ferries examined the baseline radiated noise levels (“RNL”) for all of its vessels operating in southern resident killer whale critical habitat and those vessels that may be deployed in southern resident killer whale critical habitat.

Finally, through anti-idling campaigns at terminals and on board vessels, BC Ferries has been able to decrease emissions from the public travelling on board ferries in private vehicles.[i]

i) BC Ferries Clean Futures Plan [Internet]. 2019 [cited 2019 Dec 3]. Available from: www.bcferries.com/files/AboutBCF/2019-bc-ferries-clean-futures-plan.pdf

How will climate change impact large vessel traffic?

Sea level rise, flooding and an increase in storm frequency and intensity are likely to cause costly damages to port and terminal infrastructure. In fact, these changes are already occurring within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[2] Already, more frequent and severe storms are causing an increase in the number of cancelled ferry trips. As weather patterns continue to shift, other consequences could cause disruptions to the supply chain. Storms can result in lost or damaged cargo, damage to terminal infrastructure and damage to the vessels themselves.

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
ORGANIZATION ACTIONS / GOVERNMENT ACTIONS AND POLICY*	
(from Individual and Organization actions) If on a large vessel or transiting near large vessels, ensure you are familiar with best practices for transiting by wildlife, response to pollution, and emergency response. *(from Government actions/policy)* Provide large vessel operators/pilots with on-board cetacean resources that include the distribution of species in the area, and how to safely transit when cetaceans are observed (e.g., The Mariner’s Guide to Whales, Dolphins and Porpoises of B.C.). Create an alert system to notify large vessel operators via AIS when cetaceans are observed in the area (e.g., using real-time verified reports from the BC Cetacean Sightings Network, or a similar data source).	The following applies to the three actions listed on the left. New regulations as of 2019 outline safe transit distances from cetaceans (see Resources): • 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) in B.C. waters. • Whales in our Waters Tutorial (see Resources). • Whale Report Alert System (WRAS) is a mobile and desktop-based program which alerts commercial mariners to the presence of whales, enabling them to take adaptive management measures (slowing down, diverting course, etc.) to reduce the risk of disturbance and collision.

2017 ACTION	ACTION TAKEN
Continue to support and grow the Marine Mammal Response Network to offer guidance on what to do in the event that a cetacean is struck by a vessel, or observed in distress.	Failing to report striking a cetacean is a chargeable offense. Reports of marine mammal incident or sighting can be made to Fisheries and Oceans Canada (DFO). https://dfo-mpo.gc.ca/species-especes/mammals-mammiferes/report-rapport/page01-eng.html
Empower local communities by ensuring they are educated on the proper action in the event of an oil spill. Provide the required resources (e.g., equipment and training) for these communities to safely respond and assist in the event of a spill.	Members of the public should not respond to a spill unless they have received appropriate training. There is now a pollution response vessel available to help stationed at the Kitsilano Coast Guard Station.[3] Additionally, the marine spill response organization, Western Canada Marine Response Corporation, has a Vancouver response base and an equipment cache on the Sunshine Coast. http://wcmrc.com/ Further caches can be created by communities contacting info@wcmrc.com.
Increase monitoring of marine pollution produced from large vessels, and enforce penalties for preventable pollution.	The National Aerial Surveillance Program has a Marine Aerial Reconnaissance Team that conducts flyovers searching for oil spills/dumping. https://www.tc.gc.ca/eng/mediaroom/video-nasp-6599.htm The number of flights being conducted has increased, and in 2018-2019 the hours flown set a record.[4]
Incentivize slower transits within Howe Sound and the Vancouver area to aid environmental protection (by decreasing emissions, whale-ship-strike risk, and noise pollution).	Voluntary slowdowns have been implemented in areas of the Haro Strait and Boundary Pass beyond Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound’s waters. The summer 2019 trial of this voluntary slowdown had an 82% participation rate. The noise reduction results from this trial will be released in spring 2020. https://www.portvancouver.com/wp-content/uploads/2019/12/2019-11-28-ECHO-Program-participant-update-11.pdf https://www.portvancouver.com/wp-content/uploads/2019/02/EcoAction-Program-Brochure-Online-v%C6%92-2019_FINALlrg.pdf Underwater noise in Burrard Inlet is currently being monitored. https://www.portvancouver.com/environment/water-land-wildlife/echo-program/projects/ EcoAction, a long-running program coordinated by the Port of Vancouver, offers reduced harbour fees for ships that meet non-required environmental best practices. Recently, criteria for underwater noise has been included. https://www.portvancouver.com/environment/air-energy-climate-action/marine/

*Actions were previously suggested for government action and policy; however, in some cases these actions have been taken by organizations.

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:

- Reduce your consumption of goods or consider shifting to locally produced products to reduce your footprint and the need for shipping.
- Educate yourself on the pattern, trend and function of large vessel traffic in Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound, and any potential threats.
- As a vessel operator (commercial, recreational including human powered) ensure you are familiar with best practices for transiting by wildlife, response to pollution, and emergency response.
- If you operate a terminal, port, marina or shipyard, develop an oil spill contingency plan for your site and have easily accessible spill response material available.
- **NEW** Shipping operators consider implementing sustainable procurement policies.

Government Actions and Policy:

- Ensure proposed developments have a thorough public consultation period, and ensure Citizen Science data and citizen scientists are consulted extensively for all development decisions.
- Monitor and enforce the safe condition of vessels transiting the coast in addition to vessels coming from elsewhere.
- Explore the possibility of implementing a Traffic Separation Scheme in Átl’k̲a7tsem/Txwnéwu7ts/Howe Sound.
- Explore the need for a policy related to shipping activities in the vicinity of sensitive marine habitats (e.g., productive estuaries).
- **NEW** Increase outreach and education opportunities to the public, industry and stakeholders.
- **NEW** Engage First Nations and incorporate traditional use and Traditional Knowledge into area-use planning.

Methods

The density map of passenger data (Figure 1) was supplied from the MapApp project (https://howesoundconservation.ca/mapapp/#).[5] Data used to create the map was based on Automatic Identification System (AIS) information collected from ship transmitters.[6] Transmitters may not be used in smaller vessels. Formatted data appropriate for mapping was only available up until 2013.

The data for Figure 2 is based on BC Ferry round-trip data.[7,8] The fiscal year (i.e., April 1 to March 31) was used, as this was the reporting format for this data.

Data for the number of calls at Squamish Terminals and Howe Sound Pulp and Paper were obtained through a data request.[9,10]

Resources

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

Watching marine wildlife.
https://www.dfo-mpo.gc.ca/species-especes/mammals-mammiferes/watching-observation/index-eng.html

Be Whale Wise
http://bewhalewise.org/

The Mariner’s Guide to Whales, Dolphins and Porpoises of B.C.
https://wildwhales.org/learn/mariners-guide/

Whales in Our Waters Tutorial
https://echolearn.portvancouver.com/

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2 Simons R. Winter storms 2018/2019. Vancouver BC; 2019.

3 Vancouver Sun. “We’re Back”: Kits Coast Guard Base officially reopens. Available from: https://vancouversun.com/news/local-news/were-back-kits-coast-guard-base-officially-reopens

4 Transport Canada. Government of Canada is increasing its eyes in the sky with a new aircraft for its marine surveillance program [Internet]. 2020 [cited 2020 Apr 7]. Available from: https://www.canada.ca/en/transport-canada/news/2020/01/government-of-canada-is-increasing-its-eyes-in-the-sky-with-a-new-aircraft-for-its-marine-surveillance-program.html

5 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

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9 Annonymous, Howe Sound Pulp & Paper, personal communications, September 10th, 2019.

10 E. Jarrett, Manager, Management Systems & Training, Squamish Terminals, personal communications, September 24th, 2019.

Tourism and Recreation: opportunities and challenges

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Bob Turner, Geoscientist and citizen scientist, Nex̱wlélex̱wem/Bowen Island, Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound

What is happening?

The Lonely Planet travel guide refers to Sḵwx̱wú7mesh/Squamish, at the tip of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, as “the perfect perennial playground.”[1] In fact the whole Sea to Sky corridor supports year-round adventures. As the area offers a diverse range of activities from hiking and mountain biking, kayaking, craft beer tasting, eagle viewing and sports fishing (see Sports Fishing, Ocean Watch Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Edition [OWHS] 2020), plus other seasonal attractions, the number of visitors to the area increases year after year.

Kayaker, Nex̱wlélex̱wem/Bowen Island. (Credit: Bob Turner)

What is the current status?

Between 2012 and 2014[i], the number of overnight visitors to the Vancouver and Coastal Mountain region, which includes Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, increased by 12.5%, from 8.2 million (see Tourism and Recreation, OWHS 2017) to over 9.2 million.[2] Accordingly, related spending also increased by 2.3%, from $4.7 billion in 2012 to $4.81 billion in 2014.[2] Similar growth trends have also been seen in transportation and park use and for some visitor attractions.

Within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, movement of the many visitors and residents alike is supported by BC Ferries. The departure point at Ch’axáy/Horseshoe Bay connects to the islands throughout the Sound, and to the Sunshine Coast (Figure 1). Growth has also been seen in the number of ferry passengers in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, with an increase of 4% from the 2015/16 fiscal year, to close to 7.5 million for the 2018/2019 fiscal year.[3,4] Additionally, the number of vehicles transported on Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound ferry routes increased by 6.5% from 2.8 million to almost to 3 million.[3,4]

Additional access to the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound islands and waters is supported by marinas, which offer services such as moorage, boat rentals and water taxis (see Table 2, Tourism and Recreation, OWHS 2017). New marinas are proposed, one for Furry Creek, between Porteau Cove and Shishaỷu7aỷ/Britannia Beach, and another two for Sḵwx̱wú7mesh/Squamish, in the Mamquam Blind Channel (See Coastal Development, OWHS 2020).

Recreational activities are supported by a number of provincial and regional parks within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. From the 2015/16 fiscal year, to the 2017/18 fiscal year, recorded daily attendance to parks within and around the Sound[ii] has varied; however, the overall trend indicates an increase in visitor numbers (Figure 2).

Paddleboarders taking advantage of calm waters in the Sound. (Credit: Aroha Miller)

i) 2012 to 2014 – most recent data available at the time of writing.

ii) Visitor data was only available for the nine parks in Figure 2.

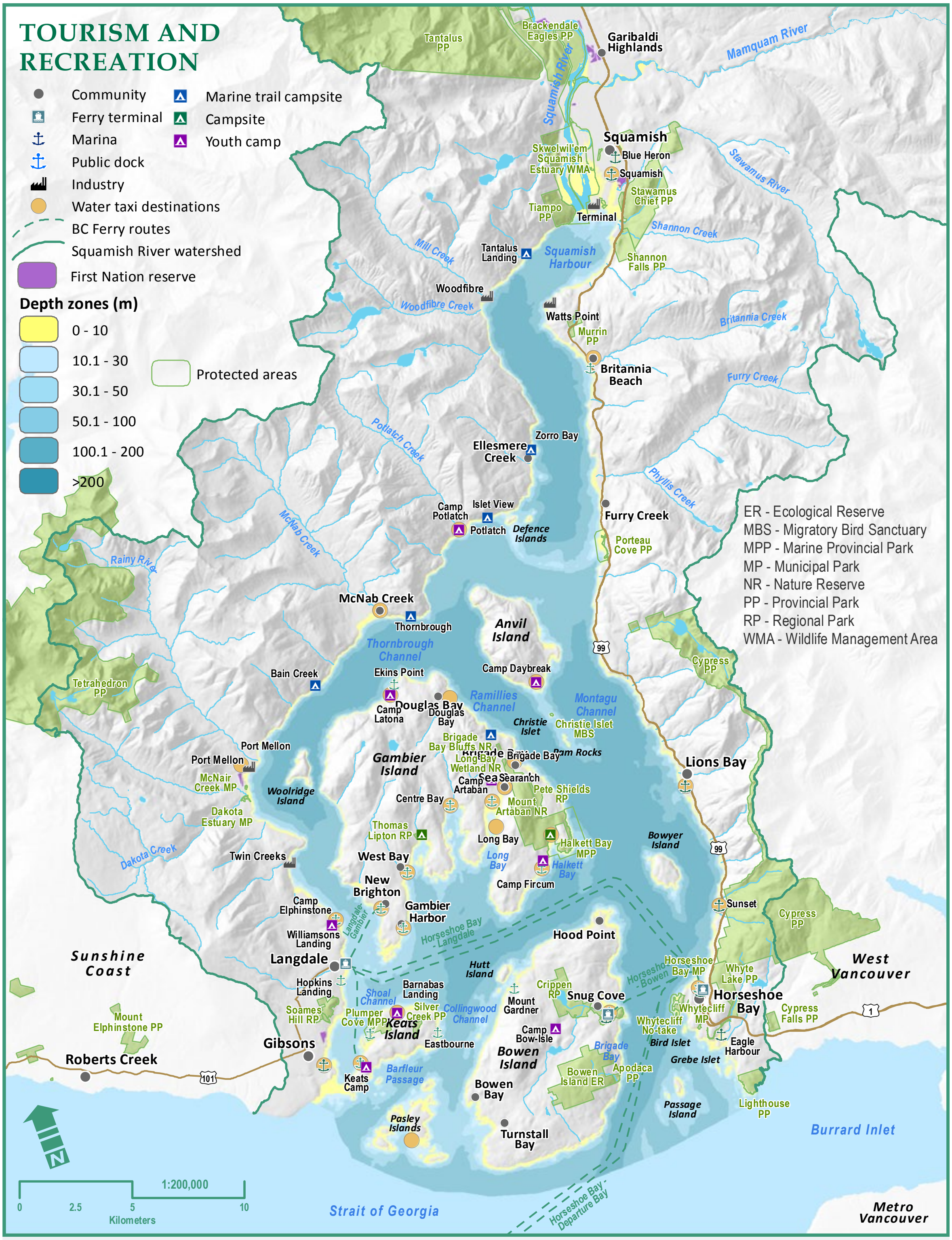


Figure 1. Map of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound parks, camps, BC Ferries routes and terminals, and water taxi destinations.[5]

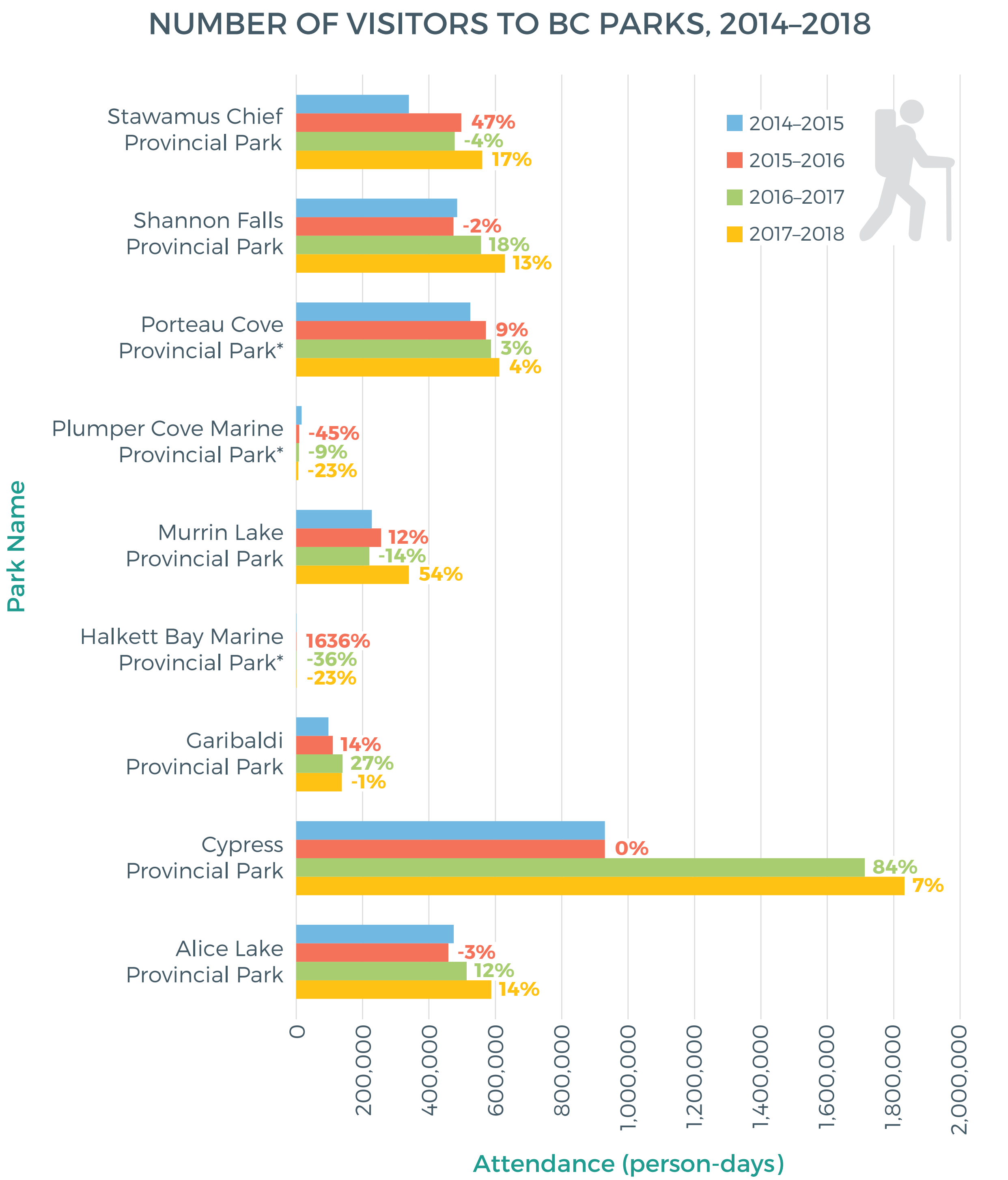


Figure 2. Both total attendance, and change in attendance, year over year, between the 2014-2015 and 2017-2018 year as a percentage (%) at parks throughout Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. *Has a marine component.

A wide range of recreational activities, ranging from scuba diving to snowshoeing, are available (Table 1, Figure 1). Six additional parks not included in OWHS 2017 were included. Parks with marine aspects support water activities (e.g., canoeing, scuba diving). Additionally, the network of landings and campsites jointly called the Sea to Sky Marine Trail allows kayak and canoe trips through the length of the fjord.[6]

Table 1. BC parks and protected areas arranged in geographical order, from the mouth of the Sound moving north.

NAME	LOCATION	MARINE COMPONENT?	FACILITIES AND ACTIVITIES	SIZE (HA)
Lighthouse Park, West Vancouver	Shoreline, West Vancouver	Yes		75
Horseshoe Bay Park	Shoreline, West Vancouver	Yes		1
Whytecliffe Park, West Vancouver	Shoreline, West Vancouver	Yes		16
Cypress Provincial Park[iii]	Northeast of Horseshoe Bay	No		3,012 (includes Howe Sound Crest Trail)
Apodaca Provincial Park[iii]	Bowen Island	Yes	The park is largely undeveloped and primarily serves to preserve unique plant communities. Recreational use not encouraged.	12 (8 hectares terrestrial and 4 hectares marine)
Bowen Island Ecological Reserve[iii]	Bowen Island	No	Bowen Island Ecological Reserve was established to preserve the dry subzone forest ecosystems in the Coastal Western Hemlock Zone at a location convenient for research. Recreational use not encouraged.	397
Crippen Regional Park	Bowen Island	Yes		221
Plumper Cove Marine Provincial Park	Keats Island	Yes		66
Halkett Bay Marine Provincial Park	Gambier Island	Yes		309
Tetrahedron Park[iii]	Mainland, northwest of Gambier Island	No		6,000

iii) Parks not previously included in OWHS 2017, with descriptions verbatim from BC Parks website (see Methods).

NAME	LOCATION	MARINE COMPONENT?	FACILITIES AND ACTIVITIES	SIZE (HA)
Porteau Cove Provincial Park	Shoreline, Highway 99	Yes		56
Murrin Lake Provincial Park	Highway 99 near Britannia	No		24
Shannon Falls Provincial Park	Highway 99 near Squamish	No		87
Stawamus Chief Provincial Park	Highway 99 near Squamish	No		530
Brackendale Eagles Provincial Park	Squamish	No		755
Garibaldi Provincial Park[iv]	Squamish	No		194,676
Skwelwil’em Squamish Estuary Wildlife Management Area	Squamish	Yes		673
Alice Lake Provincial Park[iv]	Highway 99 near Squamish	No		411
Baynes Island Ecological Reserve[iii]	Squamish River, 10 km north of Squamish	Yes	Established to preserve floodplain cottonwood stands for purposes of hybridization and stock improvement. Recreational use not encouraged.	71
Brohm Lake Interpretive Forest[iv]	Highway 99 near Squamish	No		400
Esté-tiwilh/Sigurd Creek Conservancy[iii,iv]	North of Squamish	No	Esté-tiwilh/Sigurd Creek Conservancy, and the adjacent areas within Tantalus Park, offer opportunities for	1,112
Tantalus Provincial Park	North of Squamish	No		11,351

iv) Parks are out of range of the map (Figure 1).

ACTIVITIES LEGEND

BACK COUNTRY SKIIING	BEACH COMBING	BIKING	BOAT LAUNCHING
CAMPING	CANOEING	FERRY WATCHING	FISHING
HIKING	HORSE RIDING	HUNTING	ICE CLIMBING
ICE SKATING	KITESURFING	MOUNTAINEERING	PARAGLIDING
PICNICKING	RIVER RAFTING	ROCK CLIMBING	SCUBA DIVING
SEA KAYAKING	SNOWSHOEING	STAND-UP PADDLE BOARDING	SWIMMING
TENNIS	WILDLIFE VIEWING	WINDSURFING	

Other attractions along the Sea to Sky corridor are also very popular. For example, in 2017 the total number of visitors to the Britannia Mine Museum was slightly more than 75,000; admission revenues[v] were over $1.3 million.[7] Both of these counts are slightly higher than previously reported numbers (74,000 visitors; $1 million in admissions revenue; Tourism and Recreation, OWHS 2017).

The Sea to Sky Gondola, which opened in 2014 (see Tourism and Recreation, OWHS 2017), transports visitors to the 885 m summit restaurant and viewpoint from which they can explore the surrounding network of trails or enjoy events that were being hosted.[8] In 2017, the estimated number of people taking the gondola was 425,000.[a] However, in early August of 2019, the attraction suffered a devastating blow to operations when it became the target of an act of vandalism, which saw the cable that carried the gondolas cut.[8] The closure impacted around 200 employees and the damages alone[vi] cost around $1 million dollars.[8] However, the gondola was able to reopen only months later on February 14, 2020.[9]

Indigenous tourism featuring First Nations continues to draw visitors to Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, and throughout wider B.C. Many national and international visitors are interested and curious to learn more about First Nations; cultural tourism offers a means to experience some of the long-held traditions. Increasing understanding and acknowledging the history are both small steps towards reconciliation. Experiences offered range from outdoor adventures, such as fishing and paddling, to experiencing traditional foods and visiting heritage sites of historical and cultural significance.[10] Information about Indigenous tourism offered in B.C. can be found at www.indigenousbc.com.

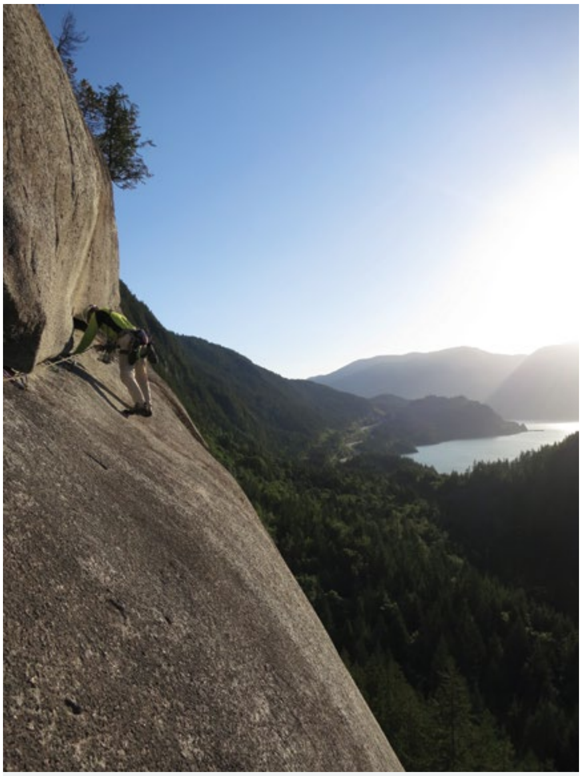
As noted previously (see Tourism and Recreation, OWHS 2017), conflicts, issues and challenges arise throughout this very popular area, most of which are

v) Admission revenues – general visits, booked and school tours.

vi) Damages – not including lost revenue.

related to the increased demand on limited resources. Additionally, new challenges have arisen, the most recent being the six-month closure of the Sea to Sky Gondola and its associated repercussions throughout the community.

The current state of these challenges, based on emails received by the author from knowledgeable community members and leaders, shows that: 1) there are still conflicts because the demand for facilities exceeds capacity; 2) the difficulty for seasonal/tourism and recreation industry workers to find affordable housing persists; 3) marine emergency response is considered adequate; and 4) a disconnect exists between provincial plans to continue to draw visitors to the area, and local government bodies responsible for managing this tourism demand.



Climber, Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Tracey Saxby)

Challenge 1: How much tourism is too much?

OWHS 2017 stated that the very activities that bring visitors closer to the environment and introduce a stewardship ethic to many, can also have negative impacts on the marine and terrestrial ecosystems, and local residents especially when participation exceeds carrying capacity. In this case, there is potential for misuse and overuse of public areas, which can put the tourism and recreation industry at odds with residents and environmental health.

- Anecdotal observation: “With the growth of the conservation initiatives by the Skwxwú7mesh Uxwumixw (Squamish Nation), DSF (David Suzuki Foundation), the Biosphere Region Initiative, Make Way and Ocean Wise, communities around Atl’ka7tsem (Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound) are becoming more aware about how special this region is and how tourism can negatively impact the environment and lifestyle. Recreational tourism plays an important part in local economies, but we should have a clear understanding of how much is too much.”[11]
- Public access to the ocean in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound is limited due to steep rocky shores and extensive private ownership of shorelines, which results in overcrowding of available public access points, and illegal use of private property for access.
- Since 2017, the number of people accessing the waterfront continues to grow; however, demand is higher than the capacity of the facilities (for example, parking availability and public washrooms).

Demand exceeding capacity has led to misuse, including trespassing, illegal camping, littering and open defecation in many places along the corridor. Outdated infrastructure is not keeping up with the volume of tourists, and investment is needed to ensure a positive visitor experience. Currently, local community members are left with the clean-up.[12]

- A collaborative project is underway to create a Shannon Basin recreation management strategy. The project aims to support sustainable recreation and give importance to environmental and cultural aspects of the area[vii]. At the date of writing (November 2019), the project had collected public input through an online survey, and estimates that the plan will be implemented and monitored in summer 2020.[13]
- Management strategies from Destination BC consider in their vision the development of amenities for areas in the Sound. Destination BC has a vision statement for the Sea to Sky and Sunshine Coast, which highlights improving amenities to support visitor experience.[14,15]

Sailing race around Nex̱wlélex̱wem/Bowen Island. (credit: Bob Turner)

vii) Area includes Shannon Falls, Stawamus Chief and the Shannon Creek Watershed.

Challenge 2: Making it affordable for tourism workers

People working in the tourism and recreation industries increasingly struggle to find affordable housing in the area.

- The shortage of affordable accommodation for seasonal and/or temporary workers continues to be an issue. Some businesses subsidize accommodation so they can ensure full staffing, e.g., the Sea to Sky Gondola.[16]
- Attention to this issue and the need for action are supported in Destination BC’s vision for development.[14,15]

Challenge 3: Marine emergency response

In OWHS 2017, it was expressed that marine emergency response capacity is limited within the Sound. However, the input for 2020 suggests it is adequate.

- A boat owner who frequents the Sound thought marine rescue was adequate, specifically supported by the re-opening of the Kitsilano Coast Guard base in 2016, after its closure in 2013;[17] the placement of a hovercraft at the Fraser River; the Royal Canadian Marine Search and Rescue (RCMSAR) stations in Ch’ax̱áy/Horseshoe Bay, Gibsons and Sḵwx̱wú7mesh/Squamish;[18] and response support from frequent commercial (e.g., ferries, water taxis, tugs) and recreational traffic. [19]

Challenge 4: Alignment between Destination BC and local authorities

There is no comprehensive recreation and tourism policy regarding the Sound. Each jurisdiction makes its own rules that may differ from the neighbouring jurisdiction.

- There are concerns that there is a disconnect between Destination BC’s marketing plan to increase tourist visits, and local government planning for increased visitor volume.[12]
- Destination BC has also indicated that their vision includes improvements to collaboration and networks between their organization and local businesses.[14,15]

Climbing in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Tracey Saxby)

Elfin Lakes (credit: Amber Dearden)

What are the potential impacts of climate change on tourism and recreation?

Climate and weather are of particular importance to outdoor recreation. With a predicted increase in frequency and intensity of severe weather and heat waves, the enjoyment and safety of outdoor activities will be jeopardized.[20] Changing weather conditions and shifting seasons may result in changes in tourism peaks; for example, high season may shift to spring or fall if summers become too hot or too smoky.[20] Further warmer average temperatures could threaten snow- and ice-based recreational activities (e.g., snowshoeing).

Due to the large coastline and the proximity of communities and tourist attractions to the water, Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound is vulnerable to climate-related damage. For example, flooding and storms have caused costly damage to boats, marinas and infrastructure.[21] Beach areas are expected to be lost or recede due to sea level rise and erosion.[22] Marinas are particularly vulnerable, being situated right on the shoreline. Consequences of climate-induced damage include increasing moorage fees and insurance costs. There is recognition of the need to build capacity to respond to climate change in the development of the tourism industry in and around the area.[14,15]

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	
Encourage your marina to provide sanitary waste pump-out facilities. If you operate a marina, make these facilities available.	Online information and an app are available to identify pump-out stations in the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, see below (this list is not exhaustive). https://georgiastrait.org/work/cleanmarinebc/pumpouts/ https://www.howesoundmarine.com/sound-advice/75-locations-marine-pumpout-stations.html http://www.bucksuzuki.org/current-projects/green-boating/
Report whale and dolphin sightings to Wild Whales. You can report by phone, your Wild Whales app on your smartphone, or at the online website. This database of sightings assists researchers in understanding whale and dolphin habitat in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound and the Salish Sea, and can provide advice to management of vessel traffic or other human activities.	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 the WhaleReport Alert System.

Howe Sound marine trail, Zorro Bay. (Credit: Tracey Saxby)

2017 ACTION	ACTION TAKEN
GOVERNMENT ACTIONS AND POLICY	
Develop and publish a map of sensitive habitat where boat anchoring is prohibited.	The David Suzuki Foundation, in collaboration with Ocean Wise, and together with scientists, individuals and government agencies, developed the Atl’ka7tsem/Howe Sound Marine Conservation Assessment online map (https://howesoundconservation.ca/mapapp/#). This map features more than 140 layers of data, ranging from the biophysical (e.g., hydrology, oceanography) to cultural, ecological and human use (e.g., recreation, economic, proposed use) In addition, the Marine Reference Guide (MRG) is currently under construction. The MRG is an online interactive map that displays spatial data associated with the Sound’s marine environment and watersheds (https://howesoundguide.ca/). This will support decision making, marine social planning and community education by allowing the visualization of how ecological and human values interact and overlap.
Develop thresholds or limits for certain activities or areas, along with associated management and regulatory tools.	Shannon Basin is in the process of creating a recreation management plan.
Develop and promote regulations and guidelines for safe distances between boaters and other recreationists, wildlife, and sensitive habitats such as the small islets in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.	New regulations as of 2019 outline safe transit distances from cetaceans (see Resources): 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) in B.C. waters.

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:

- Encourage your local marina to achieve a Blue Flag designation. Blue Flag is a certification by the Foundation for Environmental Education that sets standards for marinas using criteria for water quality, safety, environmental education and general environmental management (see Resources).
- Boaters can also fly the Blue Flag on their vessels by taking the Blue Flag Pledge of Conduct, available at the Gibsons Marina.
- Encourage your local municipality, regional district, or BC Park to achieve a Blue Flag designation for its beaches.[32] A Blue Flag beach meets criteria for water quality, environmental management, environmental education and safety and services. At present, no Howe Sound beaches have been designated.
- Protect marine mammals by adhering to guidelines.[33] Report violations of the Be Whale Wise Guidelines in Canada to Fisheries and Oceans Canada, 1-800-465-4336.
- If you fish, obtain a fishing license. Be informed of fishing regulations and the location of no-fish Rockfish Conservation Areas. Report poaching at: Department of Fisheries and Oceans: Observe, Record, Report (ORR) Line, 1-800-465-4336; Province of B.C.: Report All Poachers and Polluters (RAPP), 1-877-952-7277
- Organizations and societies can keep track of club membership and use of recreational infrastructure or resources to ensure the growth in demand is documented.
- Educate yourself on safe boating practices. If you operate a boat, be sure you obtain your B.C. Boat License.

Government Actions and Policy:

- Survey existing docks and foreshore structures and enforce related tenure restrictions.
- Identify and develop additional marine recreation sites and controlled/managed access points to help address increasing demand.
- Develop and promote regulations and guidelines for safe distances between boaters and other recreationists, wildlife and sensitive habitats, such as the small islets in Howe Sound.
- Maintain recreation infrastructure.
- Require sanitary waste pump-out facilities at more marinas and outstations.
- Rename “Crown land” to “public land” to acknowledge ownership and invite stewardship.
- Ministry of Forests, when planning forested areas to cut, account for the viewscapes of boaters on the water in the Sound, and hikers on mountain trails or at the gondola, in addition to viewpoints along Highway 99.
- Increase monitoring and enforcement on the water in Howe Sound.
- Support and encourage volunteer enforcement options including marine and river steward programs.
- Develop coastal management policy, legislation and regulations to manage recreational use of Crown lands and the foreshore, and keep the benefits of recreation and tourism sustainable.
- NEW Demarcate boundaries where boat/vessel users can anchor to avoid sensitive habitat.

Methods

All reported values were taken from referenced materials. Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound park visitation data was collected from BC Park reports.[23–26] Additional parks in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound were identified through BC Parks online map (Table 2).[27] Descriptions were accessed by selecting specific parks from the map. For previously identified challenges, community member input was requested by email and correspondence summarized. Permission was obtained for *personal communication* references.

Resources

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

Watching Marine Wildlife
https://www.dfo-mpo.gc.ca/species-especes/mammals-mammiferes/watching-observation/index-eng.html

Be Whale Wise
http://bewhalewise.org/

Blue Flag
https://www.blueflag.global/

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Sense of Place and Well-being

Sḵwx̱wú7mesh Úxwumixw/ Squamish Nation opening the Orca Celebration 2019. (Credit: Silke Labson)

Summary

Spending time in the outdoors not only boosts mental and physical health, but also gives people a sense of connectedness to nature. With that comes a sense of responsibility and motivation to act as guardians for the environment. In Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, both interest and participation in outdoor learning and citizen science have been increasing in the last decades.

Many schools, universities and organizations using the Sound as an outdoor classroom incorporate Traditional Indigenous Knowledge (TIK) into their programs. TIK enhances participants' understanding and appreciation of traditional teachings and cultural practices. However, more can be done and continued efforts to incorporate TIK should be prioritized moving forward.

Citizen scientists are some of the greatest educators in the Sound. They foster a passion and love for the environment, and readily share that enthusiasm with others during outdoor learning experiences. Citizen science groups are also pivotal in gathering information about species and habitats to address knowledge gaps that government agencies are unable to resource. The dedication of the many passionate community volunteers continues to support actions that improve ecosystems throughout Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound.

Outdoor learning and citizen science initiatives in the Sound will continue to be very important in protecting the environment, especially in the face of climate change. Put simply, increasing outdoor learning and citizen science opportunities fosters the next generation of environmental guardians.

(NB: An update for Cultural Continuity was not available at the time of release. If an update becomes available, it will be added to our website).

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
CITIZEN SCIENCE There are a large number of citizen science activities in the Sound.	Healthy	Healthy
OUTDOOR LEARNING There are a large number of outdoor educational organizations and opportunities in the Sound, with an increasing emphasis on traditional knowledge.	Healthy	Healthy

Citizen Science: protecting and restoring the Sound

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What is happening?

Community members continue to play an important role in monitoring the coastal and marine environment in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, as well as engaging with the public to share their knowledge and encourage participation in activities. This is reflected by the continuation of many previously identified citizen science initiatives, some of which have been running since before 2000, plus the formation of new initiatives. Volunteers in these groups generously spend considerable time taking part in these activities.

Pink salmon spawn in the Stawamus River. (Credit: Bob Turner)

What is the current status?

Since the release of the Ocean Watch Howe Sound Edition (OWHS) 2017 report, an additional five citizen science groups have been identified. Two began activities in 2019. These included nearshore habitat recovery activities and a marine species identification course for divers. The other three initiatives are not new but are additions to this list since 2017. These included the recording of biodiversity in Sḵwx̱wú7mesh/Squamish, from the ocean to the alpine region; restoration and monitoring of streams in West Vancouver; and the Great Canadian Shoreline Cleanup focused within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Additionally, the activities of some groups were separated out to provide a clearer view of the multiple programs they undertake (Table 1).

For many of these groups, education is a key activity within their programs. One example is the Bowen Island Fish and Wildlife Club (BIFWC), which focuses on habitat restoration and monitoring of streams to enhance salmonid populations, as well as operating the Terminal Creek Salmon Hatchery. In addition, the

An example of rubbish collected during shoreline cleanups. (Credit: Ocean Wise)

BIFWC work to educate Neẖwlélex̱wem/Bowen Island children on the importance of protecting wild salmon and their habitats. Working together with local schools, they offer tours of the hatchery and nearby creeks, and additionally help run a "Salmonid in the Classroom" program at the hatchery.

Another example where education is a key component is the Great Canadian Shoreline Cleanup, run through Ocean Wise. Schools, workplaces or communities can get involved by either leading or taking part in a shoreline cleanup. Free curriculum-linked lesson plans are available online for elementary teachers (see Resources).

Citizen science activities are key in gathering large amounts of data, such as bird counts. The Squamish Environment Society (SES) organizes monthly bird counts in addition to facilitating larger-scale bird counts in the region, such as the Christmas Bird Count (CBC), Breeding Bird Surveys, and the Great Backyard Bird Count (GBBC). During the 2018 GBBC, a record 6,456 species of birds were counted by bird watchers from over 100 countries.[1] This accounts for over half of the known bird species in the world. This number was topped again in 2019, the 22nd year of the annual count, with 6,849 total species observed. The GBBC had 22 participants in the Sḵwx̱wú7mesh/Squamish region in 2019. The CBC is the longest-running citizen-science project in North America, with December 2019 marking its 120th year. It had 24 participants recorded for the Sḵwx̱wú7mesh/Squamish region in 2019. These counts all contribute important data to establish trends, spatially and temporally.

The knowledge held by citizen science groups and people living in the area is invaluable in supporting conservation actions that protect Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound, such as in the creation of the Atl'ḵa7tsem/Howe Sound Marine Reference Guide.[2]

Table 1. Known citizen science activities in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. New initiatives since 2017 are denoted by an asterisk. Initiatives that are new to this list are denoted by two asterisks.

ACTIVITY	ORGANIZATION	LOCATION	MARINE SPECIES	ROLES OF CITIZEN SCIENTISTS AND SCIENTISTS	YEAR PROGRAM STARTED
Christmas Bird Count Lower Howe Sound	Lighthouse Park Preservation Society in collaboration with local birding groups	West Vancouver to Anvil Island to Gibsons	all birds including marine species	Volunteers observe, record and report. Organizers coordinate count, compile and submit results to Audubon Society. Results available online. https://netapp.audubon.org/CBCObservation/CurrentYear/ResultsByCount.aspx	2003
Christmas Bird Count Squamish	Squamish Environmental Society	Squamish area	all birds including marine species	Volunteers observe, record and report. Organizers coordinate count, compile and submit results to Audubon Society available at: https://www.squamishenvironment.ca/programs/winter-eagle-count/eagle-counts-by-year-by-area/	1980

ACTIVITY	ORGANIZATION	LOCATION	MARINE SPECIES	ROLES OF CITIZEN SCIENTISTS AND SCIENTISTS	YEAR PROGRAM STARTED
Christmas Bird Count Sunshine Coast	Sunshine Coast Natural History Society	Includes west shore of Howe Sound from Port Mellon to Gibsons	all birds including marine species	Volunteers observe, record, and report. Organizers coordinate count, compile and submit results to Bird Studies Canada (previously, results were submitted to Audubon Society). https://www.birdscanada.org/volunteer/cbc/index.jsp?targetpg=mapviewer&lang=EN	1971
Eagle Count, Brackendale Winter Eagle Festival	Brackendale Art Gallery and Squamish Environmental Society	Lower Squamish River and tributaries	bald eagles	Volunteers observe, record and report. Organizers coordinate count and compile results. https://www.squamishenvironment.ca/programs/winter-eagle-count/eagle-counts-by-year-by-area/	1985
Monthly Bird Count Squamish Estuary	Squamish Environmental Society	Squamish estuary	all birds including marine species	Volunteers observe, record, and report to ebird. Results available online: https://ebird.org/hotspot/L292545?yr=all&m=&rank=mrec	1991
Monthly Bird Count Lighthouse Park	Lighthouse Park Preservation Society	Lighthouse Park, West Vancouver and adjacent marine waters	all birds including marine species	Volunteers observe, record, and report to ebird. Organizers coordinate count. https://ebird.org/hotspot/L292545	2004
BC Coastal Waterbird Survey	Birds Studies Canada	Bird count locations throughout Howe Sound, including Bowen Island, Squamish, Porteau Cove, Horseshoe Bay, Woodfibre, and Lighthouse Park	marine/aquatic bird species	Volunteers observe and record details about birds using the habitat, including species, maturity (e.g., juvenile, adult), position (onshore, offshore, nearshore). This data is uploaded to Bird Studies Canada.	1999 (but for specific areas this varies)
Nearshore Habitat Recovery *	Seachange Marine Conservation Society	Howe Sound (also Gulf Islands, Sechelt Inlet, Burrard Inlet)	eelgrass, salmon, forage fish, marine riparian vegetation	Volunteers restore nearshore habitat by participating in eelgrass transplants (harvest, prepare, and replant shoots); removing subtidal debris that covers benthic habitat and shades nearshore plants; and, restoring marine riparian zone by replanting native species along the waterfront.	2017
Annapolis Biodiversity Index Study	Ocean Wise Conservation Association and Artificial Reef Society of BC	Annapolis wreck dive site, Halkett Bay, Gambier Island	invertebrates and fish	Volunteer divers observe, record and report data from personal dives. Temperature logger installed.	2015

ACTIVITY	ORGANIZATION	LOCATION	MARINE SPECIES	ROLES OF CITIZEN SCIENTISTS AND SCIENTISTS	YEAR PROGRAM STARTED
Intertidal Diversity Studies	Coastal Scene Investigation by Dr. Shannon Bard	Tunstall Bay (Bowen Island), Port Mellon and Chaster Beach, Lions Bay, Porteau Cove, Darrel Bay, Britannia Beach, Furry Creek, Whytecliff	Intertidal life	Scientists train volunteers to identify species and conduct surveys. Scientists supervise work.	1990
Marine Species Identification Course *	Ocean Wise Conservation Association – Marine Life Identification for Divers	Taught at Vancouver Aquarium	fish and invertebrates for all B.C. coast	Identification course designed to teach divers about marine species in B.C. waters.	Starting mid-October 2019
Beach & Marine Debris Cleanups **	Ocean Wise Conservation Association Great Canadian Shoreline Cleanup	Various shorelines and marine areas throughout Howe Sound	n/a	Cleanup of marine debris.	1994
Beach Sampling for Forage Fish Spawn	Friends of Forage Fish / BC Shore Spawners Alliance	Gibsons to Langdale, Sunshine Coast	forage fish species	Volunteers collect samples and analyze for presence of forage fish eggs.	2008
Exploratory Dives and Seafloor Technical Assistance	Underwater Council of BC in collaboration with Ocean Wise Conservation Association and Marine Life Sanctuaries Society	Dive sites at Lions Bay, Pam Rocks, Anvil Island, Bowen Island and elsewhere	glass sponges, rockfish	Volunteer divers explore, record and install seafloor monitoring instruments such as temperature loggers.	2013
Howe Sound Sponge Reef Studies	Marine Life Sanctuaries Society of BC	Throughout Howe Sound from Defence Island in north to Passage Island in south	glass sponges, rockfish	Volunteers build deep sea survey equipment, design studies, gather data using bathymetric mapping, drop cameras, depth sounders and seafloor instruments including temperature loggers. Work in collaboration with scientists from Fisheries and Oceans Canada (DFO) and Ocean Wise Conservation Association.	1998

ACTIVITY	ORGANIZATION	LOCATION	MARINE SPECIES	ROLES OF CITIZEN SCIENTISTS AND SCIENTISTS	YEAR PROGRAM STARTED
Glass Sponge Surveys	Ocean Wise Conservation Association	Howe Sound	glass sponges	Volunteer divers photograph and video glass sponge reef/gardens and reference markers during personal dives and submit online. This provides repeated observations of one reef.	2013
Rockfish and Select Invertebrate Surveys	Ocean Wise Conservation Association; Reef Environmental Education Foundation	Howe Sound and worldwide	rockfish, select invertebrates	Volunteer divers take rockfish identification course run by Ocean Wise. Divers observe, record and report data from personal dives.	2015
Rockfish Monitoring	Ocean Wise Conservation Association	Howe Sound and coastal B.C.	rockfish	Volunteer divers observe, record and report rockfish abundance during personal dives. Supplemented by Ocean Wise staff surveys.	2006
Lingcod Egg Mass Survey	Ocean Wise Conservation Association	Howe Sound and B.C. coast wide	lingcod	Volunteer divers observe, record and report rockfish abundance during personal dives.	1994
Herring Spawn Surveys	Squamish Streamkeepers Society	Upper Howe Sound including Squamish Estuary and Woodfibre area	herring	Volunteers map extent and character of herring roe along intertidal zone during herring spawn. Principal surveyor John Buchanan posts results on YouTube https://www.youtube.com/user/sqecs2/videos	2016
Observing and Documenting Biodiversity **	Biodiversity Squamish	Howe Sound	marine species and birds	Observers take photos; record where and when sightings occurred; and upload to the Squamish Biodiversity iNaturalist App.	2012
Habitat Restoration & Monitoring of Streams **	West Vancouver Streamkeepers	Streams in West Vancouver	salmonids	Volunteers restore habitat and monitor streams for activity.	1990
Habitat Restoration & Monitoring of Streams	Squamish Streamkeepers	Streams in Squamish area	salmonids	Volunteers restore habitat and monitor streams for activity.	2006

ACTIVITY	ORGANIZATION	LOCATION	MARINE SPECIES	ROLES OF CITIZEN SCIENTISTS AND SCIENTISTS	YEAR PROGRAM STARTED
Habitat Restoration & Monitoring of Streams	Bowen Island Fish and Wildlife Club, partnered with Pacific Salmon Foundation, Pacific Streamkeepers Federation, Metro Vancouver Parks, Bowen Island Municipality	Streams on Bowen Island	salmonids	Volunteers restore habitat and monitor streams for activity.	1982
Bowen Island Terminal Creek Hatchery	Bowen Island Fish and Wildlife Club, partnered with DFO Salmon Enhancement Program	Bowen Island	salmonids (chum, coho, pink)	Volunteers prepare, operate, maintain facilities for incubation, rearing, and release of salmon fry. Assist with taking brood stock and eggs.	1982
Creek Temperature Monitoring *	DFO with various Streamkeepers	Various creeks in Howe Sound with salmonid bearing habitat	salmon	Volunteers install, maintain, and collect data.	2019
Salmon Spawning Counts	Squamish Streamkeepers Society	Streams and spawning channels from Furry Creek to Upper Squamish River Valley	salmon (chum, coho, pink)	Volunteers are responsible for specific streams. This includes stream maintenance and enhancement and counts of spawning salmon. Some enumeration by underwater video recording.	2000
Marine Mammal Counts	Pacific Wildlife Foundation with help from Sewell’s Marina Sea Safari	Outer Howe Sound	all marine mammals	Sewell’s Marina Sea Safari boat-tour guides and guests observe and report wildlife sightings to Pacific Wildlife Foundation	2014
Cetacean Sightings	BC Cetacean Sightings Network, Ocean Wise Conservation Association & DFO	Pacific Coast, including Howe Sound	whale, dolphin, porpoise, turtles	Volunteers observe, record and report via smartphone app (Whale Report), web form, log book or toll-free number.	2000

What are the potential impacts of climate change on citizen science?

Predicted climate change impacts in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound range from increased extreme precipitation events to warmer ocean waters. Such changes will undoubtedly impact the species and habitats monitored by citizen science groups. Data collected by these groups will support the scientific understanding of changes in habitats and species, and support decisions to protect and adapt to climate change within Átl’ḵa7tsem/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	
Encourage citizen science participation within your company or organization.	Ocean Wise’s Great Canadian Shoreline Cleanup frequently organizes local cleanup events for the organization. Information from other organizations is lacking.
GOVERNMENT ACTIONS AND POLICY	
Continue to support and raise awareness of the ongoing citizen science projects within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.	Some citizen science groups partner with government institutes such as DFO. Overall, however, the groups are non-profit organizations and rely on volunteer time and donors/sponsors or external funding to continue their work.
Provide resources needed to enhance and continue local citizen science projects as funding permits.	DFO’s Tenderfoot Creek Hatchery supplies the Bowen Island Terminal Creek Hatchery with salmon for their hatchery.

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:

- Get involved with an ongoing citizen science project in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound (Table 1).
- Share your photos and videos of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound nature on your favourite social media platform.
- Join NatureWatch (www.naturewatch.ca), a partnership of Nature Canada and the David Suzuki Foundation to engage Canadians in four ongoing citizen science projects: FrogWatch, PlantWatch, IceWatch and WormWatch.
- Donate. Almost all the groups engaged in citizen science projects in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound are non-profit groups and projects depend upon donations to continue.
- Learn more about citizen science and how to do it at Citizen Science Central sponsored by Cornell University's Lab of Ornithology: www.birds.cornell.edu/citscitoolkit/toolkit/steps
- **NEW** Collaborate across citizen science groups to strengthen advocacy for use of data within decision making.
- **NEW** Create a central hub where members of the community can find all of the ongoing citizen science projects in the region.

Government Actions and Policy:

- Provide and maintain a central portal of information including; citizen science project listings, data gathering, community training, and a tool-kit for best practices of designing and maintaining citizen science projects.
- Promote closer relationships with stakeholders to citizen science projects in order to facilitate further participation and awareness.
- Increase the use of citizen science data contributing to natural resource and environmental science, natural resource management, and environmental protection and policy making.
- Develop policy to recognize and weigh citizen science, in addition to other scientific evidence and traditional knowledge, submitted for review in the environmental assessment process.
- Invite citizen scientist representation at public engagement events for policies and management to add their voice to input throughout decision-making processes.
- Partner with non-government organizations and other groups to create more citizen science projects on diverse subjects.

Methods

These citizen science groups were located via personal interactions and communications throughout the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound community, and confirmed by cross-checking websites of groups, where available.

Resources

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

Lead a school cleanup!
https://www.shorelinecleanup.ca/school

References

1 The Great Backyard Bird Count. Great Backyard Bird Count Should Be “Finchy” and Fun [Internet]. 2019. Available from: https://gbbc.birdcount.org/news/2019release/

2 Make Way. Atl’ḵa7tsem/Howe Sound Marine Reference Guide [Internet]. [cited 2019 Aug 1]. Available from: https://tidescanada.org/project/howe-sound-atlkitsem-marine-reference-guide/

Outdoor Environmental Learning: increasing opportunities

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What is happening?

The Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region presents countless opportunities for formal and informal learning. From overnight school and camp programs to field trips and interpretive experiences, there continues to be a growing interest in providing children and youth a wide range of year-round outdoor learning opportunities. These opportunities provide meaningful outdoor experiences, which is a powerful way to foster understanding and care for our environment.

There are significant physical, social and cognitive benefits provided through learning in nature. Such benefits may include increased physical activity, reduced stress and anxiety, and enhanced enthusiasm and engagement in learning.[1]

Learning about garbage in the marine environment. (Credit: Ocean Wise)

What is the current status?

Park access and usage across B.C. has increased by approximately 23% since 2014.[2] A similar trend is evident in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound as public and independent secondary and elementary schools in Sḵwx̱wú7mesh/Squamish, Lions Bay, West Vancouver, North Vancouver, Nex̱wlélex̱wem/Bowen Island, Langdale and Gibsons use their school sites and nearby Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound forests and shores for outdoor learning.

Additionally, post-secondary institutions including Quest University (Sḵwx̱wú7mesh/Squamish), Capilano University (North Vancouver), University of British Columbia (Vancouver) and Simon Fraser University (Burnaby) have all conducted field-based courses in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound for undergraduate students, including student-teacher candidates. Many of the groups, schools and organizations using Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound as an outdoor learning classroom have begun to recognize and include Indigenous learnings and Traditional Indigenous Knowledge into their programs.

In addition to the numerous camps, programs and outdoor schools operating in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound (see tables 1 and 2, Outdoor Environmental Learning, Ocean Watch Howe Sound Edition [OWHS] 2017), three new programs have been identified since the last report. These include the Cheakamus Centre Environmental and Indigenous Learning Workshops, the Ocean Wise Mountains to Oceans Youth Leadership Camp, and the Nicholas Sonntag Marine Education Centre. The first two have been offered since 2018, and the latter since 2017.

Cheakamus Centre offers unique Sḵwx̱wú7mesh Úxwumixw/Squamish Nation cultural learning opportunities. For example, since 2018, Cheakamus Centre has been offering an Indigenous Youth Leadership Program. This is a four-week intensive learning course teaching traditional Sḵwx̱wú7mesh Úxwumixw/Squamish Nation cultural practices, with a focus on skills related to outdoor education and tourism, such as outdoor facilitation and food safety. The centre has also been offering a range of workshops for educators designed to enhance participants’ understanding and appreciation of traditional Sḵwx̱wú7mesh teachings and cultural practices. Sḵwx̱wú7mesh Úxwumixw/Squamish Nation offers courses for Nation members which include, among other skills, Sḵwx̱wú7mesh/Squamish language.

Ocean Wise offers numerous educational opportunities. Amongst these, as above, is the Mountains to Oceans Youth Leadership Camp, an outdoor education program that utilizes the Squamish River watershed. This is a multi-day program with a focus on environmental learning, outdoor adventure activities and stewardship. Participants visit the Cheakamus Centre and stay at the Longhouse, spending that time to learn about traditional knowledge, led by Sḵwx̱wú7mesh Úxwumixw/Squamish Nation employees of the centre. There is a focus on traditional storytelling and history, and environmental education such as ethnobotany.

The Nicholas Sonntag Marine Education Centre is an aquarium based in Gibsons. They offer experiential and classroom learning experiences for schools, as well as week-long camps focussed on learning at the land-sea interface. In addition, the centre carries out regular community release days, where aquarium specimens collected from the local marine environment are released upon conclusion of a display.

In addition, throughout 2019, two youth project leaders from Sḵwx̱wú7mesh Úxwumixw/Squamish Nation worked with the Marine Reference Guide (MRG) team to elevate Indigenous youth voices and participation in marine stewardship and spatial planning, while acknowledging and respecting Traditional Indigenous Knowledge and values. They led activities engaging youth in outdoor learning, such as a canoe journey to Ḵw’émḵw’em and Nínich Ḵw’émḵw’em/Defense Islands and a shoreline cleanup.

Various other environmental program service providers exist. Examples include the Sea to Sky Gondola, which offers interpretive environmental programs for school-aged children and youth; and the Britannia Mine Museum, which offers children’s programming during school months that includes conservation-based educational content.

An educator instructing a participant at Cheakamus Centre’s Youth Leadership Program, 2019. (Credit: Gadbois Photography)

What are the potential impacts of climate change on environmental learning?

The summer of 2017 and 2018 presented challenges for outdoor learning as smoke from wildfires across the province resulted in poor air quality. At certain times, air quality advisories recommended that time outdoors be restricted. Children and adults with respiratory issues were particularly at risk. These climate-related conditions present significant concerns for summer camps whose core activities are outdoor based.

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	
Prioritize protection of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound’s natural beauty so that it remains preserved for educational opportunities to thrive and expand in the future.	In January 2019, an Important Bird Area (IBA) in English Bay/Burrard Inlet was extended to include part of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. In March 2019, Fisheries and Oceans Canada formed eight marine refuges around known glass sponge reefs in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, closed to all bottom contact fishing activities. (See Marine Protected Areas, OWHS 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. Additional actions marked as **NEW** also follow.

Individual and Organization Actions:

- Familiarize yourself with educational opportunities available to all ages in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound, and get involved!
- Explore opportunities to incorporate outdoor learning and natural sciences into professional development.
- **NEW** Promote volunteer opportunities that support educational initiatives.

Government Actions and Policy:

- Increase awareness of and encourage participation in the many educational opportunities offered in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound for all ages.
- Support research on children and youth development outcomes from natural science educational opportunities, in order to better understand and document the benefits of these programs and justify further growth.
- Collect and maintain information on educational opportunities and participation in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to track trends to understand needs and desires for this type of learning.
- Identify additional local conservation groups, citizen science projects, and restoration efforts for potential collaborations with educational initiatives.
- Capitalize on the uniqueness of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound’s natural beauty and accessible location by expanding outdoor education programs throughout more schools in the Greater Vancouver Area.
- **NEW** Prioritize and support education at a range of sites in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound by providing appropriate campsites and facilities and access points.
- **NEW** Identify and support initiatives to enhance Indigenous knowledge and connections in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.

Methods

Information included in this article was obtained via scanning the websites below, specific to learning and education (see Resources Accessed). Additionally, much of the information came from conversations the author had with educators currently working in the public and independent K-12 systems in Átl’ḵa7tsem/

Txwnéwu7ts/Howe Sound. These were not formal interviews.

References

[1] Rugel E. Green space and mental health: pathways, impacts, and gaps [Internet]. National Collaborating Centre for Environmental Health; 2015. Available from: http://www.ncceh.ca/sites/default/files/Full_Review-Greenspace_Mental_Health_Mar_2015.pdf

[2] BC Parks. Facts and figures [Internet]. 2019. [cited 2019 Nov 12]. Available from: http://www.env.gov.bc.ca/bcparks/about/facts-figures.htm

RESOURCES ACCESSED

Bowen Island Community School
westvancouverschools.ca/bics-elementary/

Camp Artaban
campartaban.com

Camp Elphinstone
gv.ymca.ca

Camp Fircom
fircom.ca

Camp Sunrise
campsunrise.ca

Camp Suzuki
campsuzuki.org

Camp Potlach
bgcbc.ca

Capilano University
capilanou.ca

Cheakamus Centre
cheakamuscentre.ca

Children and Nature Network
childrenandnature.org/

Easter Seals Camp Squamish
eastersealscamps.ca

Evans Lake Forest Education Centre
evanslake.com

Island Pacific School, Bowen Island
islandpacific.org

Quest University Canada
questu.ca

Metro Vancouver School & Youth Leadership Programs
metrovancouver.org

Sea to Sky Outdoor School for Sustainability Education
seatosky.bc.ca

Sḵwx̱wú7mesh Úxwumixw/ Squamish Nation
squamish.net

Mountains to Oceans students in the Squamish Estuary, 2019. (Credit: Hailey Renaud)

Stewardship and Governance

A view over Átl’ḵa7tsem/ Txwnéwu7ts/Howe Sound. (Credit: Amanda Weltman)

Summary

In 2017, the OWHS report noted a distinct lack of comprehensive, region-wide planning to manage growth and development, while protecting the environment. Today, many steps have been taken to bring this vision closer to fruition.

Local governments have committed to support and develop the Atl’ḵa7tsem/Howe Sound Marine Reference Guide (MRG), as recommended in the OWHS 2017 Action Plan. The MRG team is creating an online interactive map that displays spatial data associated with the Sound’s marine environment and watersheds to support decision making, marine social planning and community education.

The Ocean Watch Task Force (OWTF), formed by the Howe Sound Community Forum (HSCF) and comprised of locally elected government representatives, planning staff, NGOs and First Nations, worked to advance relevant actions proposed in the OWHS 2017. The OWTF advanced the development of the MRG and, with support from Ocean Wise, created the Strategic Plan to guide local government protection of the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region over the next three years (2019–2021). In addition, efforts continue towards the goal of having Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound designated as a UNESCO biosphere region.

Within the Sound, there has been an expansion of protected areas. In 2019, eight new marine refuge areas were created to protect nine glass sponge reefs placed under voluntary protection in 2017, bringing the total number of protected glass sponge reefs in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to 11. The English Bay/Burrard Inlet Important Bird Area (IBA) was expanded into the southern part of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. However, IBAs do not offer any legal protection. Further support and collaboration are still needed to continue this momentum and support the communities in the Sound in the face of climate change.

(NB: An update for Sḵwx̱wú7mesh Úxwumixw/Squamish Nation Stewardship was not available at the time of release. If an update becomes available, it will be added to our website).

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
MARINE PROTECTED AREAS Positive actions have been taken, with the creation of new marine refugia to protect glass sponge reefs and the expansion of the important bird area (IBA). However, the IBA offers no legal protection.		
COMPREHENSIVE PLANNING Recent accomplishments suggest positive improvements, but a need for continued collaboration and communication is essential.		

Marine Protected Areas: expanding, but under protected

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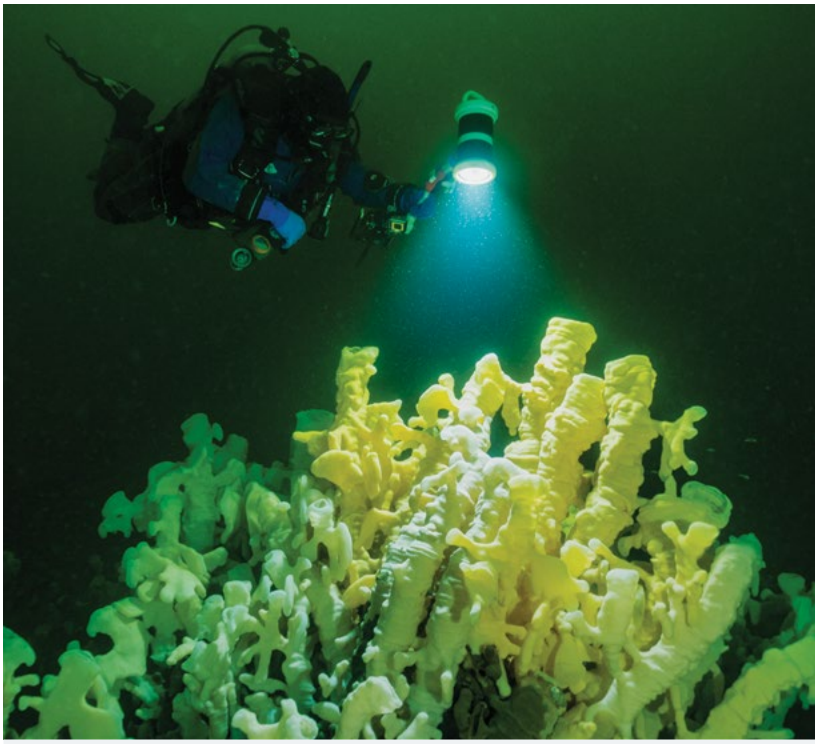
What is happening?

Although no new marine parks have been added to the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound area since the 2016 expansion of Ch'á7elsm/Halkett Bay Marine Park, several areas designated to protect specific species or groups of species have been added.



Glass sponge reefs. (Credit: Adam Taylor)

What is the current status?

Glass sponge reefs

In 2016, Fisheries and Oceans Canada (DFO) closed areas around nine known glass sponge reefs in the Strait of Georgia and Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to all bottom contact fishing activities.[1] Bottom contact fishing activities are those likely to damage the reefs, including fishing activities for prawn, shrimp, crab and groundfish, as well as fishing activities that use downrigger gear for recreational salmon trolling. During this process, DFO was informed of nine additional reefs in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. In 2017, DFO requested voluntary avoidance of bottom contact fishing activities within the additional sites identified in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.

In March 2019, DFO formed eight marine refuge areas to encompass the nine additional glass sponge reefs placed under voluntary protection in 2017, bringing the total number of protected glass sponge reefs in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to 11. These included closures in the Nínich Ḵw’émḵw’em/East Defence Islands; Lhaxwm/Anvil Island; Lost Reef; Brunswick Point; Ch’á7elsm/Halkett Point; Lha´kw’tich /Bowyer Island; Dorman Point; and Lions Bay and Ḵél̓etstn/Kelvin Grove, combined into one area. The refuges include a protection boundary extending to 150 metres from the reefs’ edges (Figure 1). Not only do these marine refuges protect the glass sponge reefs, they also protect numerous fish and invertebrate species that use the reefs as habitat.

The establishment of these marine refuges effectively bans all commercial, recreational and Food, Social and Ceremonial (FSC) bottom contact fishing activities, as detailed above, and adds an additional 3.5 km^2 to the marine refuge areas[2] in the Strait of Georgia bioregion (total approximate size: 36.2 km^2).[3]

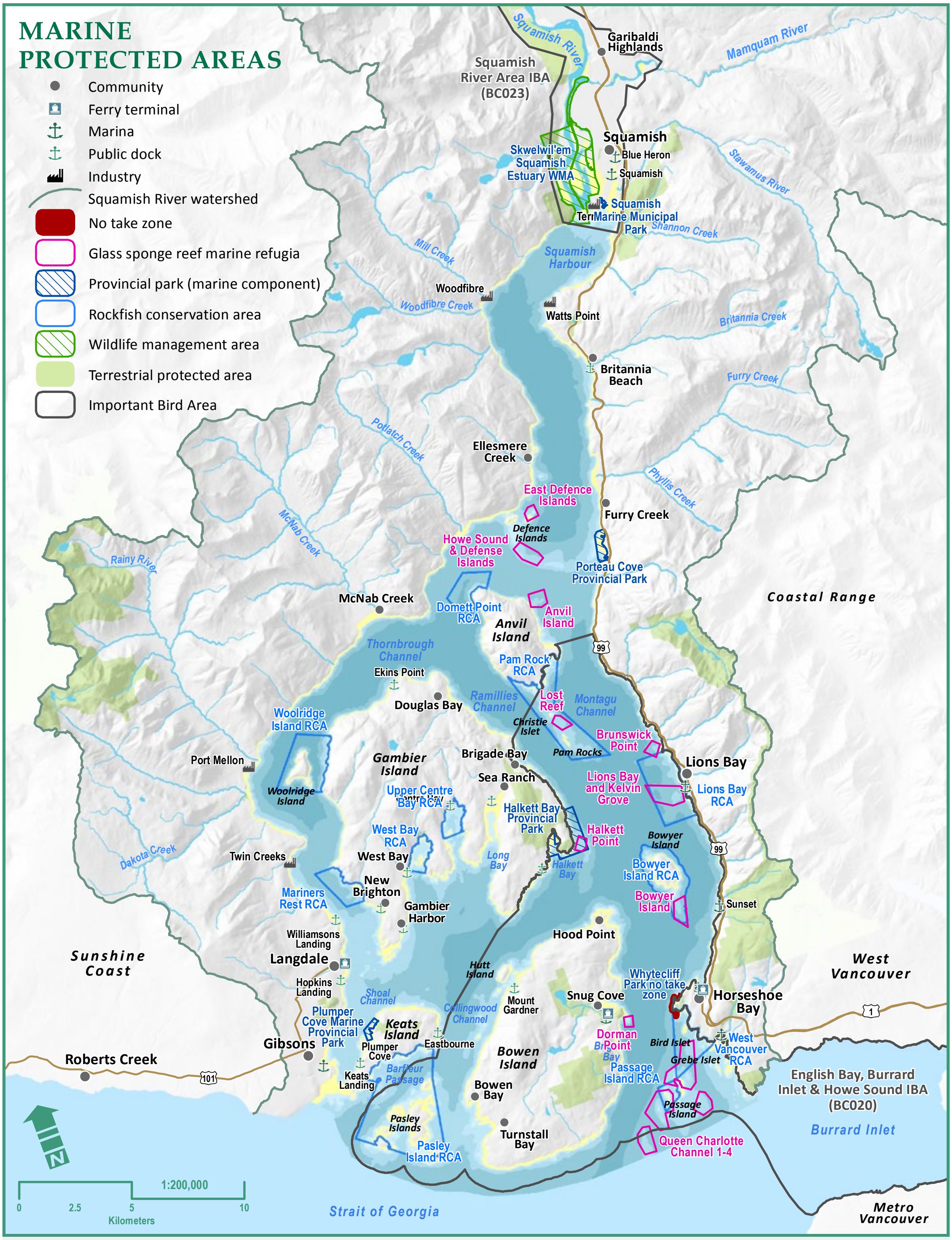


Figure 1. Marine Protected Areas and Important Bird Areas within Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.[4]

Important Bird Areas

Important Bird Areas (IBA) are sites that support threatened species, birds restricted by range or habitat, or large groups of birds that gather in one area. IBAs do not afford any legal protection. However, the sites are identified using internationally agreed upon, standardized, quantifiable, and scientifically defensible criteria. Because of this rigour, IBAs provide excellent opportunities for bird conservation.

In January 2019, an already existing IBA in English Bay/Burrard Inlet was extended to include part of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound (Figure 1). This particular IBA was designated specifically to protect three species deemed important at the global level and one species at the national level[i] that congregate in large numbers in the area – the western grebe (*Aechmophorus occidentalis*); Barrow's goldeneye (*Bucephala islandica*); surf scoter (*Melanitta perspicillata*); and the local subspecies, the Pacific great blue heron (*Ardea herodias fannini*).[5] This IBA supports numerous other Pacific Northwest marine and coastal bird species, including high numbers of marbled murrelets, (*Brachyramphus marmoratus*), recorded in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound during winter surveys conducted in 2014–2015.[6] Marbled murrelets are a blue-listed species (i.e., considered to be of special concern) with a SARA[ii] status of threatened.

What are the potential impacts of climate change on MPAs?

MPAs will not prevent climate change impacting the species they are designed to protect. However, creating MPAs, where certain human activities, such as commercial fishing or resource extraction, are limited or prohibited, will reduce stressors on the species using these areas, allowing a better chance for them to adapt to climate change. MPAs help to prevent further destruction or removal of coastal habitats, such as coral reefs, mangrove forests, or wetlands, thereby protecting the coastline and populations living there from effects such as more extreme storms. Many of these habitats are also natural carbon sinks, helping to reduce carbon emissions and potentially reduce the rate of warming.[7]

i) National level – If a species occurs in numbers significant at a global level then they are usually, but not always, important at a national level. Significant is 1% of a global or a national population.

ii) *Species at Risk Act*. More about the *Species at Risk Act* can be found here: https://www.canada.ca/en/environment-climate-change/services/environmental-enforcement/acts-regulations/about-species-at-risk-act.html.

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	
Meet commitment to protect five percent of the coastal and marine environment by 2017, and 10 percent by 2020.	On August 1, 2019, Prime Minister Justin Trudeau announced that Canada has surpassed its target of 10% protection of marine and coastal areas. Currently, Canada has preserved just over 13% of its marine and coastal areas (793, 906 km^2).[8] English Bay/Burrard Inlet Important Bird Area was extended into Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound in January 2019. Eight marine refuge areas were created around glass sponge reefs in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound in March 2019. The total number of protected glass sponge reefs in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound is now 11.

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:

- To report any prohibited activities within these areas, call DFO's 24-hour Observe, Record, Report (ORR) Hotline toll free at 1-800-465-4336, or in greater Vancouver at 604-607-4186. Include as much detail as possible, such as location, time, date and activity.

Government Actions and Policy:

- **NEW** Increase the area of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound covered under MPAs, with an immediate focus on glass sponge reefs, beach spawning habitat, water flow and Wildlife Management Areas.

Methods

Information for glass sponge reef marine refuges was sourced from DFO web pages. For the IBA, information was sourced from the IBA website, as well as from Butler et al.,[6] who conducted bird count surveys along transects between June 2014 and May 2015. A literature scan was conducted on Google, using key words: “climate change” and “marine protected areas.”

Resources

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

What is an Important Bird Area? https://www.ibacanada.com/iba_what.jsp?lang=en

IBA. English Bay, Burrard Inlet & Howe Sound, Vancouver, British Columbia https://www.ibacanada.com/site.jsp?siteID=BC020

References

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2 Fisheries and Oceans Canada (DFO). Fisheries Notice. FN0205-Glass Sponge Reefs – Pacific Region – Area 28 – Bottom Contact Fishery Closures – Effective April 1, 2019 [Internet]. 2018 [cited 2019 Jul 19]. Available from: https://www-ops2.pac.dfo-mpo.gc.ca/fns-sap/index-eng.cfm?pg=view_notice&DOC_ID=219517&ID=all

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4 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

5 Bird Studies Canada. Important Bird Area (IBA) English Bay, Burrard Inlet & Howe Sound Vancouver, British Columbia [Internet]. 2019 [cited 2019 Aug 13]. Available from: https://www.ibacanada.ca/site.jsp?siteID=BC020

6 Butler RW, Couturier AR, Richmond S, Dickson E, Middleton H, Beaty P. Status and Distribution of Marine Birds and Mammals in Southern Howe Sound, British Columbia. Pacific Wildlife Foundation & Bird Studies Canada. Unpublished. Port Moody BC, and Port Rowan Ontario; 2018.

7 International Union for Conservation of Nature (IUCN). Marine protected areas and climate change [Internet]. Issues Brief. [cited 2019 Jul 19]. Available from: https://www.iucn.org/resources/issues-briefs/marine-protected-areas-and-climate-change

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Comprehensive Planning: progress continues but collaboration remains key

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What is happening?

Since 2017, there has been encouraging progress towards a comprehensive plan that will direct stewardship and growth for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. Defining the boundary for the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region is an important step to allow further planning to occur.

Several important tools have either been developed or are in progress. These include the Provincial Cumulative Effects Assessment, the Ocean Watch Health Rating, the creation of the Atl’ḵa7tsem/Howe Sound Marine Conservation Assessment online map, and the commitment of local governments

Howe Sound Community Forum, April 26, 2019, at Camp Fircom, Gambier Island. (Credit: Kyla Hemmelgarn) through the Howe Sound Community Forum (HSCF) to develop an Atl’ḵa7tsem/Howe Sound Marine Reference Guide. These are all important tools designed to better inform decision makers about the region and support their decisions to enhance nature and the lives of the people who reside in the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region. In addition, work continues towards the goal of Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound to be designated as a United Nations Educational, Scientific, and Cultural Organization (UNESCO) biosphere region.

What is the current status?

At the May 2017 Howe Sound Community Forum, members agreed to form the Ocean Watch Task Force (OWTF). The OWTF is comprised of members of local governments, First Nations, government representatives, planning staff and NGOs. Members meet regularly to advance the recommendations presented in Ocean Watch Howe Sound Edition (OWHS) 2017. The OWTF has been focusing primarily on local governance tools and opportunities, with the goal of increasing the protection of the natural environment in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound and contributing towards more holistic comprehensive planning in the region. The OWTF reports back at the twice-yearly HSCF (see Resources).

The Ministry of Forests, Lands, and Natural Resource Operations and Rural Development (FLNRORD) South Coast produced the Provincial Cumulative Effects Assessment (CEA) project of the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Region.[1] The project assessed the current condition of five environmental and wildlife values. The CEA provides general information for all levels of government to consider within their authorizations, management and planning in the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound region. FLNRORD is incorporating the results from these assessments into new decision-support/integrated monitoring tools that will continue to improve integrated monitoring and assessment throughout the South Coast.

The David Suzuki Foundation, in collaboration with Ocean Wise, and together with scientists, individuals and government agencies, developed the Atl’ḵa7tsem/Howe Sound Marine Conservation Assessment online map (see Resources). This map features more than 140 layers of data, ranging from the biophysical (e.g.,

Ruth Simons, Drew Copeland, Bob Turner (Credit: Tracey Saxby) hydrology, oceanography) to cultural, ecological and human use (e.g., recreation, economic, proposed use, etc.). The project uses a computer modelling analysis called Marxan, which is a decision-support tool used in conservation planning to help identify priority conservation areas. It is compatible with both the province's CEA project as well as the Marine Reference Guide. This valuable resource highlights marine biodiversity hot spots throughout the region. Consequently, 34 high-priority conservation areas have been recommended for protection and management. The maps are publicly available via the above website and support further community dialogue.

The OWHS 2017 included an Action Plan (see Resources). At the top of the list was the development of a Marine Reference Guide (MRG). Under the leadership of the OWTF and the Sḵwx̱wú7mesh Úxwumixw/Squamish Nation, and together with Ocean Wise, the David Suzuki Foundation and Make Way, a project director was appointed to establish this project. A Steering Committee, consisting of nine representatives from various sectors in the region, oversees the development of the Guide. Building on the Marine Conservation map, the MRG is forming an online interactive map that displays spatial data associated with the Sound's marine environment and watersheds (see Resources). This will support decision making, marine social planning and community education by allowing the visualization of how ecological and human values interact and overlap. Narrative resources that describe best practices will enhance the value of the MRG for local residents, scientists, boaters, planners and policymakers, and help to protect significant ecological and human values associated with the aquatic environment in the Sound.

Local governments and many organisations are working together to protect beautiful Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Amanda Weltman)

Support and progress towards the Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound region being designated a UNESCO Biosphere Reserve continues to advance. The Howe Sound Biosphere Region Initiative Society (HSBRIS) (see Resources) is fostering support and commitment using a roundtable governance model that works towards objectives of comprehensive planning, sustainable development, and providing logistic support.

While the authority for decision making remains with the various legal entities governing the region, the roundtable governance committee could be considered the most inclusive and representative decision-making body to help steer the direction of the Biosphere

Region. The representatives appointed to the roundtable, co-chaired by First Nation and non-First Nation members, will represent various sectors in the Sound. The body will consist of elected or appointed representatives from local government, First Nations, industry, tourism, BC Government, and Fisheries and Oceans Canada, as well as conservancy organizations, academia and science. Qualifications for appointment to the roundtable will be based on commitment to the objectives of UNESCO and the framework of the Man and the Biosphere program, and the objectives of the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Biosphere Reserve.

In the meantime, the mandate of the current provincial government is to modernize land use planning. This modernization, combined with the ongoing work of reconciliation with First Nations, will also influence the overall future of the region. More than ever, good relationships and effective collaboration are essential in shaping the future of the Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound Region for generations to come.

Fostering cooperation between the “community of communities” has continued through ongoing Howe Sound Community Forums, and through the development of these various tools and groups, and many gatherings. Consequently, the network around the Sound has strengthened the awareness of this area as a unique and special region.

What are the potential impacts of climate change on comprehensive planning?

Winter storms of 2018/2019 were evidence of the unpredictable intensity of storms and resulting consequences. Extreme wind gusts combined with king tides caused unprecedented damage in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. The storms caused erosion to shorelines resulting in damaged and sinking boats; broken, sinking docks and wharves; and enormous amounts of debris landing on shorelines and floating around the Sound. The need for ongoing communication and collaboration between the various authorities and communities is critical to aid in the prevention of further widespread damage and mitigate the effects of future storm events. Comprehensive planning supports knowledge of best practices so all the communities within the watershed are working on the same basis of information and together implementing changes needed to adapt to a changing climate.

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	
Undertake/collaborate on comprehensive marine and land use planning for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound.	Progress has been made, as detailed above in the “What is the current status” section.
Participate in the Howe Sound Community Forum meetings.	Local municipality representatives attend the HSCF meetings.

Planning a vision for Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound. (Credit: Tracey Saxby)

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:

- Engage and contribute to your Regional Plans and Official Community Plans (OCPs); they always include public input!
- Encourage your OCP to consider how impacts of growth, development and zoning relate to the whole of Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound. (Transportation is a perfect example. Moving from Squamish to Vancouver on transit means passing between BC Transit authority and Translink's authority. Efficient services suffer because neither authority is focused on the Squamish to Vancouver commuter.)
- Work to make Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound live up to your own vision for the area. You can, for example, join and follow one of the many non-profit organizations focused on Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound conservation and protection. Volunteer for restoration programs, such as the wetland work on the Squamish foreshore, or work with local conservancies to improve trails. Give your time to marine groups who are looking to citizen vigilance to monitor illegal fishing or trapping. Attend events and learn about the diverse communities around the Sound, starting with First Nations and their history and culture.
- Experience the awesomeness that is Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound! Get on a boat and experience the sound from the water. Hike a ridge or kayak the new Sea to Sky Marine Trail.

Government Actions and Policy:

- Recognize the value of ecosystem services in Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound when considering the best allocation, use and regulation of Crown Land, foreshore and marine areas.
- **NEW** Consider new/revised governance options to strengthen local government regional coordination and representation on Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound-wide planning and development issues.
- **NEW** Maintain an inventory of reports, plans and strategies on Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound ecosystems and make them publicly available.
- **NEW** Fund increased regional marine planning capacity for Átl'ḵa7tsem/Txwnéwu7ts/Howe Sound as a bioregion.

Methods

Information for this article was sourced from websites specific to the projects and tools discussed above.

Resources

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

OWHS 2017 Action Plan
Please see the Executive Summary from 2017, which includes the action plan.

Atl’ḵa7tsem/Howe Sound Marine Conservation Assessment online map
https://howesoundconservation.ca/mapapp/#

https://davidsuzuki.org/project/howe-sound/

Howe Sound/Atl’ḵa7tsem Marine Reference Guide
https://howesoundguide.ca/

https://makeway.org/project/howe-sound-atlkitsem-marine-reference-guide/

Howe Sound Biosphere Region Initiative Society
www.howesoundbri.org

The Future of Howe Sound Society
http://futureofhowesound.org

Howe Sound Community Forums (2019)
https://www.howesoundbri.org/howe-sound-community-forum

References

[1] BC Government. Howe Sound Cumulative Effects Projects [Internet]. Available from: https://catalogue.data.gov.bc.ca/dataset/howe-sound-cumulative-effects-project-area-data-howe-sound-cumulative-effects/resource/4cc98644-f6eb-410b-9df0-f9b2beac9717

Abbreviations & Glossary

Abbreviations

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzodioxin (the most toxic dioxin compound)
ABIS	Annapolis Biodiversity Index Study
ARSBC	Artificial Reef Society of BC
B.C.	British Columbia
BCCSN	British Columbia Cetacean Sightings Network
BCIT	British Columbia Institute of Technology
BIFWC	Bowen Island Fish and Wildlife Club
BIM	Bowen Island Municipality
CBC	Christmas Bird Count
CEA	Cumulative Effects Assessment
CERP	Central Estuary Restoration Project
CN	Canadian National Railway
CO_2	carbon dioxide
DFO	Fisheries and Oceans Canada (a federal agency)
dw	dry weight
e.g.	for example
ECCC	Environment Climate Change Canada (a federal agency)
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
FIDIC	International Federation of Consulting Engineers
FLNRORD	Ministry of Forests, Lands, and Natural Resource Operations and Rural Development
FSC	Food, Social and Ceremonial
GBBC	Great Backyard Bird Count
GCM	global climate models
GHG	greenhouse gases

GLTC	Gambier Island Local Trust Committee
HSBRIS	Howe Sound Biosphere Region Initiative Society
HSCF	Howe Sound Community Forum
HSSP	Howe Sound Pulp and Paper Cooperation
i.e.	that is
IBA	Important Bird Area
IFHMP	Integrated Flood Hazard Management Plan
IPCC	Intergovernmental Panel on Climate Change
ISQG	interim sediment quality guidelines
IUCN	International Union for Conservation of Nature
LMFM	Lower Mainland Facilities Management
MLA	Member of the Legislative Assembly
MPA	Marine Protected Area
MRG	Marine Reference Guide (https://howesoundguide.ca/)
NASA	National Aeronautics and Space Administration
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
OWBC	Ocean Watch British Columbia Edition
OWHS	Ocean Watch Howe Sound Edition
OWTF	Ocean Watch Task Force
PCBs	polychlorinated biphenyls (a group of chemical contaminants)
PCIC	Pacific Climate Impacts Consortium
PDO	Pacific Decadal Oscillation
PFCs	perfluorinated compounds (a group of chemical contaminants)
PIBC	Planning Institute of British Columbia
PICS	Pacific Institute for Climate Solutions
RCA	Rockfish Conservation Area
RCP	Representative Concentration Pathway
ROV	remotely operated vehicle

SARA	*Species at Risk Act*
SES	Squamish Environment Society
SLR	sea level rise
SRWS	Squamish River Watershed Society
SSWD	sea star wasting disease
TEF	toxic equivalency factor
TEQ	Toxic equivalents (used when examining dioxins and furans, a group of chemical contaminants)
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WQG	Water Quality Guidelines
ww	wet weight
YOY	young of year

Glossary

10th percentile	a percentile is a statistical measure below which a given percentage (here, 10%) of data points fall
90th percentile	a percentile is a statistical measure below which a given percentage (here, 90%) of data points fall
Abandoned Vessels	are legislated in the Navigation Protection Act (NPA) and the Canada Shipping Act (CSA). The NPA, Section 20, deems a vessel abandoned after 30 days when no owner can be located. Authorized removal of abandoned vessels in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound waters may be obtained through Transport Canada’s Receiver of Wrecks. Funding for the removal is limited. Often the person or agency performing the work is held financially accountable
Adsorb	the adhesion of a molecule on the outside surface of a material, such as sediment
Anadromous	moving into rivers from the sea to spawn
Anthropogenic	human-caused
Bathymetric mapping	mapping of the seafloor, or the floor of other bodies of water
BC water quality guidelines	water quality guidelines refer to the desired condition of a body of water. BCWQG are set to protect marine species
Benthic invertebrates	species that lack a backbone living at or in the sediment surface (e.g. molluscs, insects, worms)
Berm	a flat strip of raised land bordering a body of water
Bioaccumulation	the accumulation of chemicals in an organism at a rate faster than which the chemical can be excreted
Bioherm	ancient organic reef of mound-like form built by a variety of marine invertebrates and calcareous algae
Brownfield	a former industrial or commercial site

Chronic	occurring over a long period of time
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
Confluence	where two rivers join
Contaminants	the presence of a substance where it should not be or at concentrations above background levels
Daphnia magna	an aquatic invertebrate
Dead Pitch program	population assessment program where carcasses are recovered to get population numbers
Debris drifts	stable piles of fallen glass sponges
Dioxins and furans	contaminants released as unintentional byproducts, for example of the pulp and paper bleaching process
Effluent	liquid waste released back into natural water bodies
El Niño Southern Oscillation (ENSO)	irregular, periodic variations in wind and sea surface temperatures over much of the Pacific Ocean, which impact climate in surrounding areas
Escapement	the number of salmon that are not caught in fisheries (commercial, recreational, ceremonial) and return to their freshwater spawning areas
Fish fry	young fish that are recently hatched
Geoengineering	large-scale manipulation of Earth’s natural processes in an effort to counter climate change
Hepatopancreas	the digestive tissue in crabs that combines the digestive function of the vertebrate liver and pancreas
Interim sediment quality guideline	the concentration below which adverse biological effects are expected to occur rarely
Intertidal	the area which is uncovered at low tide and covered at high tide
Intertidal animals	animals living in the zone that is periodically covered/uncovered by water due to tidal movement
Kraft pulp	an intermediate product in the production of paper

Median	when data points are arranged in order, the median value is that which falls in the middle
Motile	capable of movement
Pacific Decadal Oscillation (PDO)	a recurring pattern of ocean-atmosphere climate variability centered over the Pacific basin
Paleoclimate data	information about the climate at any given time in the past e.g., data from tree rings, ice cores, sediment samples, or other sources of evidence
pH	measure of acidity and alkalinity
Porewater	water contained in pores in soil or rock
Positive feedback cycles	cycles that can feedback into the system, resulting in a positive outcome. For climate change, common feedbacks include water vapour (which is a GHG that increases in concentration as air temperatures increase); albedo feedbacks (i.e., less snow and ice makes the earth less reflective allowing more heat to be absorbed by the oceans); forest fires; permafrost melting; and loss of ocean life
Primary production	photosynthesis; how plants make energy from the Sun’s energy
Problem Vessels	include boats that are causing social unrest or ecological degradation as a result of, for example, raw sewage or grey water discharge, garbage disposal, or intentional beaching by liveaboard occupants or known owners. Problem vessels may be abandoned and become wrecks. Problem vessel owners may be found in contravention of local bylaws, e.g. land use or zoning bylaw provisions; provincial legislation, e.g. Land Act, Trespass Act Environmental Management Act, Public Health Act; or federal statutes, e.g. Fisheries Act
Ramping	increasing or decreasing the water flow on a run-of-river hydroelectric project, which can result in fish being stranded and dying if the water levels drop too quickly
Redd	a depression in the riverbed where female salmon deposit eggs during spawning
Reference sites	uncontaminated sites
Rip rap	large boulders and rocks

Riparian zone	the transitional zone between land and water
Spicule	a minute, slender, sharp-pointed body, typically present in large numbers
Subtidal	the portion of a tidal flat environment that lies below the mean low water for spring tides; typically always covered by water
The Blob	a large mass of warmer than usual water that occurred off the coast of the Pacific northwest, beginning in late 2013
Thermal expansion	water increases in volume as it warms
Water quality guidelines	guideline levels of water quality parameters set to protect marine species
Wrecked Vessels	are those boats that are no longer intact. They may reside on the sea floor or clutter the shoreline. Vessels in imminent danger of sinking may also be classified as wrecks. Without restoration they are no longer seaworthy. Transport Canada’s (TC) Receiver of Wrecks can authorize the removal of a wrecked vessel under provisions in the Canada Shipping Act (CSA) and the Navigation Protection Act (NPA)
Young of year (YOY)	salmon born within the past year


ocean wise