COASTAL OCEAN RESEARCH INSTITUTE

OCEANWATCH

B.C. Coast Edition | Executive Summary

OCTOBER 2018 | OCEANWATCH.CA/BCCOAST

ocean wise®

> "The region is arguably the site of extraordinary natural beauty that has animated what I call a reverential naturalism among many residents."
>
> **PAUL BRAMADAT,**
> **PRINCIPAL INVESTIGATOR,**
> **RELIGION, SPIRITUALITY, SECULARITY,**
> **AND SOCIETY IN THE PACIFIC NORTHWEST**

Acknowledgements

We would like to thank the many authors, reviewers, and contributors who generously shared their unique knowledge and photographs. Our collaborative work with the Marine Plan Partnership and with scientists behind the global Ocean Health Index inspired some of the topics explored in this edition.

PHOTO: TRACEY SAXBY

The British Columbia Coast

From the exposed west coasts of Vancouver Island and Haida Gwaii, to the deep fjords and channels cutting into the British Columbia mainland, to the sparkling Salish Sea, diversity along the B.C. Coast is unrivalled. A rich array of sea life has supported Indigenous peoples along this coast since time immemorial and settlers have contributed cultural diversity over the past few centuries.

Much of the B.C. coast is still relatively pristine, but the impacts of human activities extend far beyond population centers. Plastic and other trash is finding its way to remote beaches and into the food web, disease in sea stars remains a mystery, increasing underwater noise is making it harder for whales to find food, and the ecological consequences of ocean warming and sea level rise have no boundaries.

Pressures degrading the health of our marine ecosystems are mounting, but increasing awareness, a broadly based stewardship ethic, and more and more people taking action are changing our directions for the better.

The Coastal Ocean Research Institute and Ocean Watch

Keeping our coasts and oceans healthy starts with understanding what is happening. The Coastal Ocean Research Institute (CORI), an Ocean Wise initiative, was established to do just that. Ocean Watch delves into what's happening in our coastal ecosystems through a series of articles organized into seven themes. This B.C. Coast Edition is our second report, following the 2017 Howe Sound Edition.

In the full report, we present a collection of scientific articles on a wide array of topics, some contributed by guest authors. Article content has undergone technical review by experts in the appropriate field.

In order to provide a visual snapshot summary of all the status and trend information we compiled, we developed and applied a rating scheme to help people understand what is happening at a glance. From there you can dive in deeper.

This project was undertaken with financial support from

sitka foundation

NORTH GROWTH FOUNDATION

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full report at oceanwatch.ca/bccoast

Snapshot Assessment

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.

Species and Habitats

PHYTOPLANKTON

Monitoring spring 'blooms' of these essential species yields important information about the overall dynamics of the entire marine environment. Monitoring is insufficient along the B.C. coast, except in the Strait of Georgia.

SEA STAR WASTING

Despite anecdotal reports of recovery in some areas, a mysterious condition continues to ravage sea star species along North America's west coast.

ROCKFISH

Twenty-five years after several rockfish species were severely depleted, stock assessment models predict 90 years or more before meaningful recovery occurs for long-lived species such as quillback rockfish.

LINGCOD

After a decline in lingcod population triggered restrictions on commercial and recreational fisheries, indices show no clear trends in populations. Outside stocks are assessed as healthy but catches are decreasing.

HUMPBACK WHALES

Humpback whale populations have rebounded significantly, but their return comes with risks, such as boat strikes and entanglements, especially in the busy Strait of Georgia.

MARINE BIRDS

Declining populations of some marine birds on B.C.'s coast have come to the public's attention due to multiple die-off events. Citizen science audits are critical in monitoring bird populations and assessing potential threats.

Clean Water

PCBS IN SEDIMENTS AND MUSSELS

Starting in 2015, *PollutionTracker* began monitoring sediments and mussels along the B.C. coast for a wide range of contaminants. Legacy pollutants remain a concern in some areas.

MICROPLASTICS

From microbeads to fibres from fleece and other textiles, microplastics are finding their way into marine ecosystems and entering the food chain.

RADIATION AFTER FUKUSHIMA

Testing following the Fukushima nuclear disaster in 2011 has detected radiation associated with the disaster, but levels determined to date are far below those considered harmful to human or marine health.

Clean Water

PERSISTENT ORGANIC POLLUTANTS IN SEALS
Despite the phasing out of many persistent organic pollutants (POPs) from industrial use in Canada, marine organisms are still testing positive for these harmful chemicals.

CONTAMINANT TRENDS IN SEABIRDS
Long-term studies show substances like mercury, brominated flame-retardants and PFAs are present at different levels in various seabird populations.

SHORELINE CLEANUP
Between 2014 and 2016, more than 10 metric tons of marine debris were removed annually from the west coast of Vancouver Island.

Sense of Place and Wellbeing

POPULATION PROFILE
Coastal regions account for nearly three-quarters of British Columbia's growing population and many coastal communities shoulder high rates of dependents — children and the elderly — in the population, compared to those of working age.

CITIZEN PARTICIPATION
Participation in volunteer conservation groups and citizen science initiatives is growing, benefitting those programs and creating strong community ties that boost overall wellbeing for participants.

PACIFIC MARINE LIFE SURVEYS
What started as underwater observations by a local marine naturalist has turned into a database of nearly 5,000 dives in 1,200 locations and has become a critical tool in monitoring the biodiversity of B.C.'s coast.

FISHING AND SENSE OF PLACE
Fishing, particularly in smaller communities, promotes strong cultural ties, intergenerational exchange and deeper community trust. However, recent changes in the industry may be threatening these intangible benefits.

INCOME DISPARITY AND WELLBEING
Income inequality has been on the rise throughout Canada for decades, a troubling trend linked to poorer health and wellbeing outcomes. Some coastal areas of B.C. are particularly affected.

Coastal Development and Livelihoods

POPULATION & MAJOR PROJECTS
B.C.'s growing population is increasing development pressure along B.C.'s coastline, particularly in the province's more densely populated south, highlighting the need for tracking the cumulative effects of development.

INCOME & EMPLOYMENT
With few exceptions, incomes in coastal B.C. are lower than the provincial average, while the percentage of low-income residents and unemployment is higher.

UNDERWATER NOISE
Underwater noise from shipping, construction, recreation and shoreline development has been doubling in intensity every decade since the 1950s. This impedes whales' ability to hunt, communicate, rest and breed.

Coastal Development and Livelihoods

SEAFOOD INDUSTRY JOBS

Jobs in the seafood industry have declined since 1984, as have the number of commercially active fishing vessels and licences. Emerging trends include diversity in catch, improved sustainability, and stable employment.

Stewardship and Governance

MARINE PROTECTED AREAS

Several new marine refuges and marine protected areas have been established or proposed recently. However, comprehensive oversight is still needed to ensure various marine protection areas function as a cohesive network.

EVOLUTION IN GOVERNANCE

Once strictly top-down, a more collaborative approach to conservation is emerging. Indigenous peoples are increasingly recognized for their role in stewardship and governance of conservation efforts on land and sea.

Oceanography and Climate Change

OCEAN WARMING

B.C.'s ocean surface temperatures in recent years have been consistently warmer than the 30-year baseline. We must track ocean warming to understand its effect on aquatic ecosystems and human settlements.

SEA LEVEL RISE

New science suggests sea levels may be rising faster, and by a greater amount, than initially predicted, rendering many planning guidelines and adaptation tools in B.C. insufficient.

Seafood

SUSTAINABLE SEAFOOD

Interest in sustainable seafood has grown exponentially since 2005. The Ocean Wise Seafood Program includes more than 700 partners and has recently launched its own monitoring program for small-scale Canadian fisheries.

INDUSTRY PRODUCTIVITY

The seafood industry contributed over $400 million to B.C.'s economy in 2016 and the value of exports continues to grow.

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.

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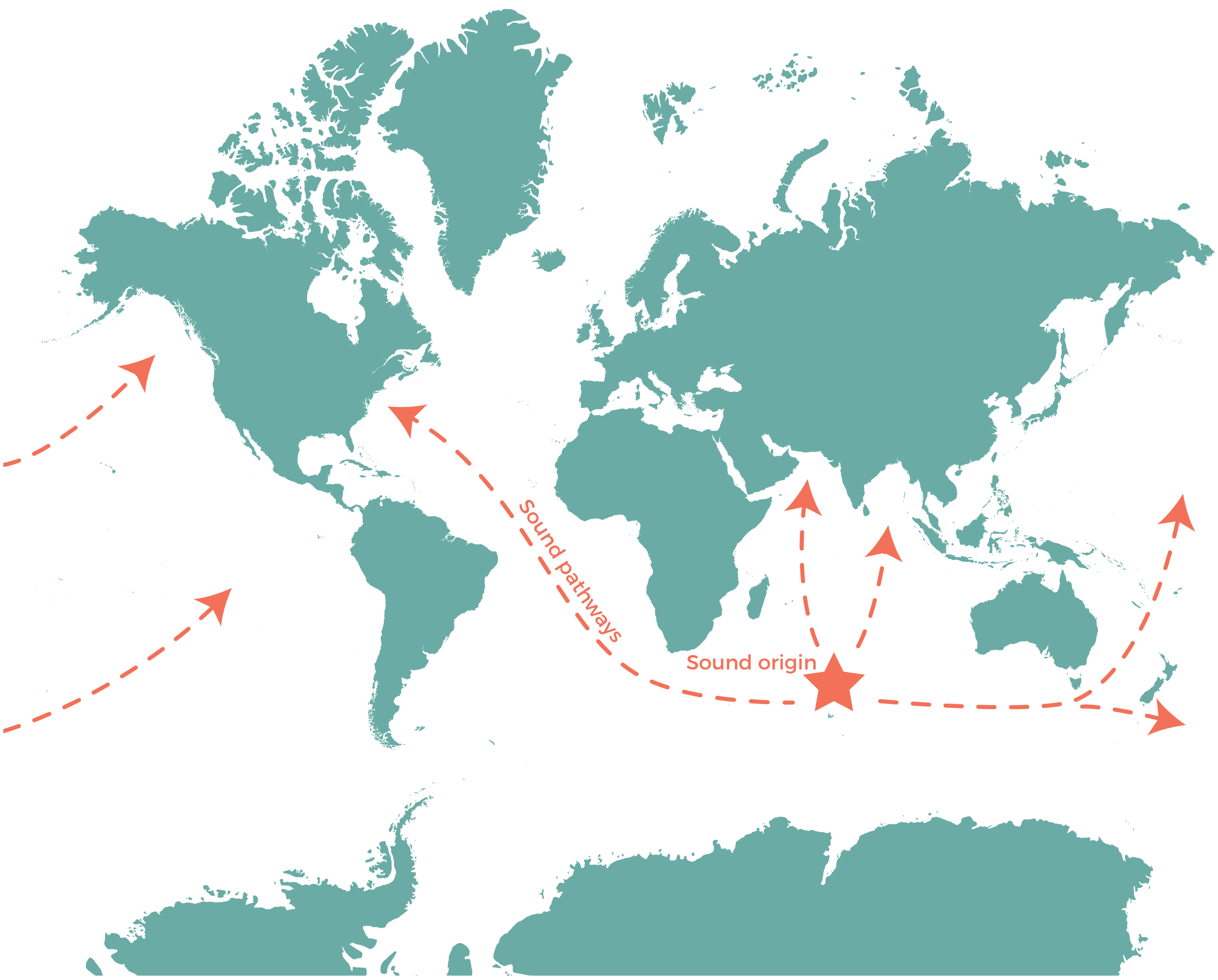
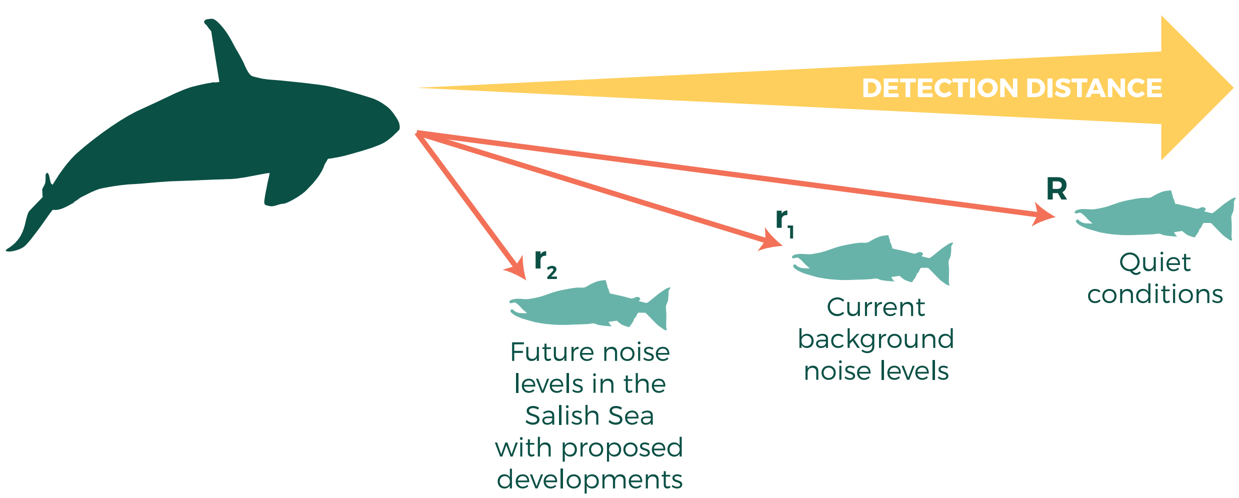
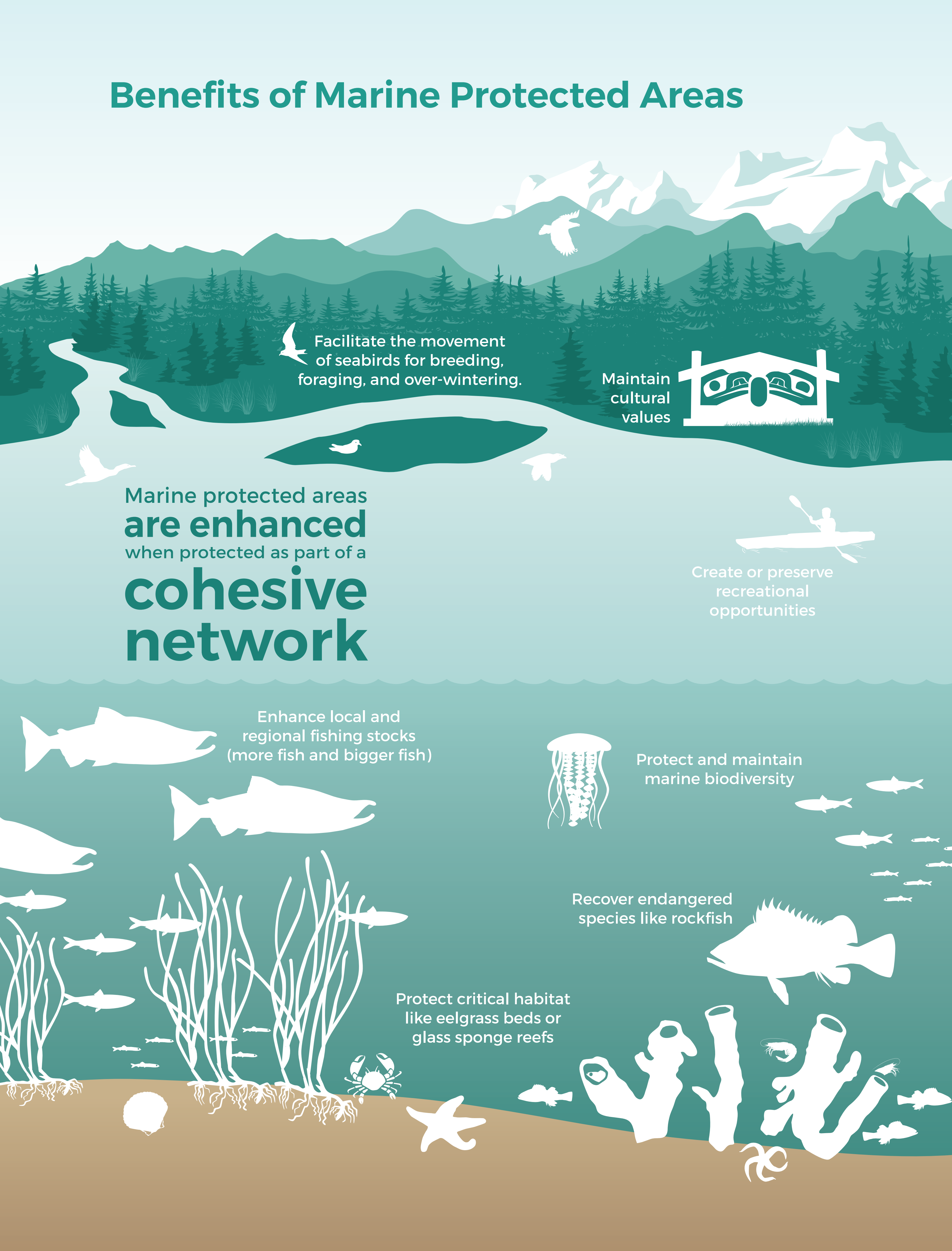
Low Frequency Sound Can Travel Thousands of Kilometres in the Ocean



Detection of Prey Decreases as Underwater Noise Increases




Benefits of Marine Protected Areas
Facilitate the movement of seabirds for breeding, foraging, and over-wintering.
Maintain cultural values
Marine protected areas are enhanced when protected as part of a cohesive network
Create or preserve recreational opportunities
Enhance local and regional fishing stocks (more fish and bigger fish)
Protect and maintain marine biodiversity
Recover endangered species like rockfish
Protect critical habitat like eelgrass beds or glass sponge reefs

Key Trends and Actions

The British Columbia coast hosts a diverse human population and several distinct ecological regions, each with unique characteristics. Socio-economic conditions along much of the coast have changed significantly over the last few decades, and ecological systems are now facing emerging issues, such as climate change. This report touches on emerging threats, highlights a few unhealthy trends, and acknowledges areas of positive action and change. Here, we summarize reported-on trends, positive and negative, that are influencing the state of B.C.'s coastal ecosystems. Further, we share ideas for actions that we can all take to reverse the negative and bolster the positive. The bottom line is — we are all connected to the ocean.

Unhealthy Status and Trends

1. Recovery from depletion is prolonged due to continued harvest of some fish species.
2. The increasing volume of underwater noise is a clear threat to endangered marine mammals.
3. Some contamination introduced in past decades still lingers and new pollutants pose emerging concerns.
4. Economic indicators suggest that coastal areas of B.C. are less prosperous and have fewer employment opportunities than the provincial average. Household income in coastal areas is below the provincial median and unemployment is higher, except in the more populated south coast.
5. Income disparity is increasing throughout the province, emphasizing that not all citizens benefit from growth in GDP, or traditional economic prosperity.
6. Commercial fishing quota prices and quota lease prices are increasing rapidly.
7. Employment is falling in the seafood production sector.

Patterns that Generate Concern or Uncertainty

1. Changing weather patterns, warming seas, and rising seas mean changing conditions. Sea star recovery is spotty and uncertain. Coastal waterbird declines may be a warning sign that favourable conditions for these species are shifting.

2. Humpbacks, no longer hunted, are returning to the Salish Sea to face new threats, such as ship-strike or entanglement.

3. Biodiversity needs room to thrive without anthropogenic threat.

4. Coastal developments, whether it be expansion of human population centres or commercial, industrial, and residential construction, are not equally dispersed along the coast. Neither are areas set aside to mitigate threats and to protect natural ecosystems. Costs — such as threats to the environment —, economic benefits, and clusters of marine protected areas are concentrated in some areas more than in others. Without integrated planning, can we know this is the healthiest arrangement?

5. Limiting the study area for socio-economic indicators to truly *coastal* communities — those in close proximity to the marine environment — is not supported by publicly available census data.

Positive Trends to Encourage and Foster

1. Increasing focus on designating areas to protect species and habitats from threats resulting in more Marine Protected Areas.

2. Increasing co-management and collaboration among governments.

3. Increasing awareness and recognition of First Nations' rights and title and the importance of reconciliation.

4. Increasing participation in citizen science, monitoring, stewardship, and conservation initiatives, as these activities increase individuals' ecological knowledge, boost wellbeing, and foster a positive sense of place.

5. Increasing seafood production — kept within ecologically sustainable limits.

6. Increasing sustainable seafood choices and increasing access to those choices.

7. Monitoring of plankton blooms, and other sea life, all along the coast.

8. Ongoing monitoring of seabirds, marine mammals, sediments and mussels for contaminant levels and emerging threats.

What We Can All Do

1. Share monitoring data publically, as the default.

2. Support local fishermen and support initiatives to revitalize the fishing industry in smaller coastal centres.

3. Follow posted fishing regulations and stay well away from rockfish conservation areas with fishing gear.

4. When boating, slow down to reduce noise and modify your route to avoid whales.

5. Choose sustainable and local seafood; eat lower on the food chain.

6. Get involved in coastal monitoring through a citizen science program or conservation initiative.

7. Avoid purchasing things with plastic packaging, recycle responsibly, and properly dispose of garbage to prevent debris from entering the marine environment.

8. Eliminate the use of toxic chemicals and single-use plastics around the house and garden.

9. Follow, promote, develop, discuss, and share best development practices.

10. Acknowledge and respect Indigenous peoples' territories where you live and work.

11. Reduce personal energy use to produce fewer greenhouse gases.

12. Continue to learn, share, and adapt.

"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."

ALDO LEOPOLD (1968)

PHOTO: JENN BURT

Please visit oceanwatch.ca/bccoast to learn more.

You can browse and download the full report online.

COVER PHOTO: KAREN BODTKER

Our aim is to produce independent, credible, and well-presented information so that you are inspired to make better decisions for nature and people.

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COASTAL OCEAN RESEARCH INSTITUTE

OCEANWATCH

B.C. Coast Edition

OCTOBER 2018 | OCEANWATCH.CA

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Credits

This Ocean Watch report was prepared by the Coastal Ocean Research Institute, an Ocean Wise initiative. Established to measure and monitor the health of coastal ecosystems, the Coastal Ocean Research Institute produces and communicates scientific knowledge and understanding about Canada's West Coast. Please visit our website oceanwatch.ca for Ocean Watch editions focused on other geographies.

Editor

KARIN BODTKER, MRM, Manager, Coastal Ocean Health Initiative,
Coastal Ocean Research Institute, an Ocean Wise initiative

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We would like to thank all of the many authors, reviewers, and contributors who have generously shared their unique knowledge and photographs. Some of the topics explored in this edition were inspired by our collaborative work with the Marine Plan Partnership and with scientists behind the global Ocean Health Index.

Graphic Design and Production

DESIGN AND LAYOUT

RYAN MURRAY, Ocean Wise

LAYOUT

LAUREL MILLER

ILLUSTRATIONS, CHARTS AND ICONS

TRACEY SAXBY, Visual Science

CARTOGRAPHY

RAISSA PHILIBERT, Coastal Ocean Research Institute

KARIN BODTKER, Coastal Ocean Research Institute

COVER PHOTO

KARIN BODTKER

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About the B.C. coast

"The region is arguably the site of extraordinary natural beauty that has animated what I call a reverential naturalism among many residents."

PAUL BRAMADAT, PRINCIPAL INVESTIGATOR, RELIGION, SPIRITUALITY, SECULARITY, AND SOCIETY IN THE PACIFIC NORTHWEST

AUTHOR
Karin Bodtker, MRM, Manager Coastal Ocean Health Initiative, Coastal Ocean Research Institute, an Ocean Wise initiative

The B.C. coast is wonderfully diverse in many ways. From the exposed west coasts of Vancouver Island and Haida Gwaii, to the deep fjords and channels cutting into the British Columbia mainland, to the sparkling Salish Sea, the range of marine habitats is huge. Diversity in habitats brings great diversity in sea life. This coast is home to thousands of species of marine invertebrates, over 400 species of fishes, about 30 different marine mammals, and over 150 species of seabirds, shorebirds, and coastal waterfowl. Marine plants too numerous to count including phytoplankton, kelps, and seagrasses provide habitat and food at the base of a complex and elegant food web.

The ecological riches of this coast have supported indigenous peoples since long before recorded time – for at least 13,000 years according to recently carbon dated footprints uncovered on the central coast.[1] Almost 200 different First Nations have their homes and traditional territories in British Columbia – many of them overlapping coastal regions. Over the last few

Tribal Canoe Journey 2014, Bella Bella, British Columbia. (Photo: Kris Krug, Flickr, CC BY-NC-ND 2.0)

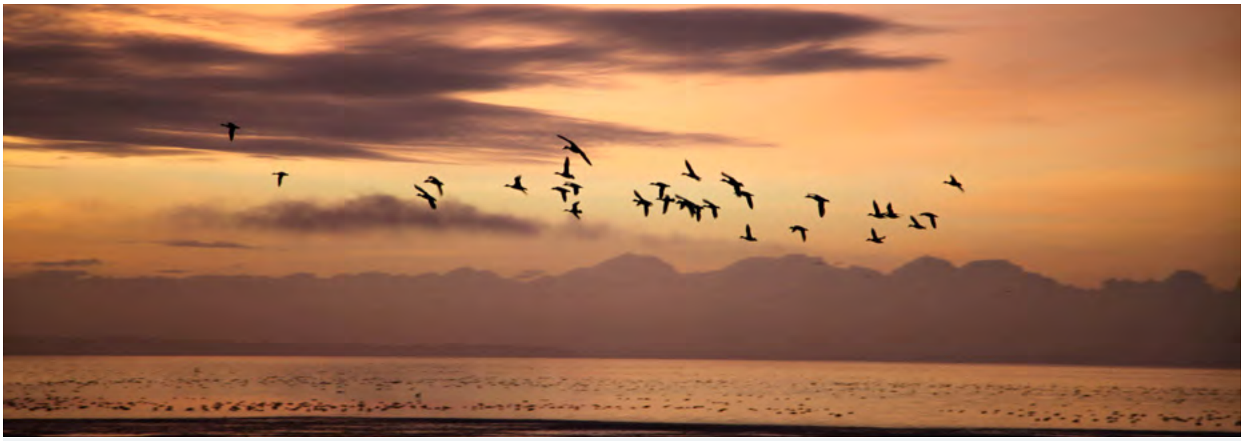


Photo: John Anderson (Flickr, CC BY-SA 2.0)

hundred years, settlers from all around the globe have added to the pre-existing cultural diversity.

Ours is a temperate system, with seasonally high productivity driven by diverse ocean currents. Thousands of islands disperse tidal flows, creating strong currents that stir up the nutrients brought down from coastal mountains by rivers and streams. Farther out to sea, on the western edge of the continental shelf, summer currents rising from the depths bring nutrient-rich waters to the surface. In both cases, nutrients feed plankton blooms fueled by the sun's light energy.

This dance of life continues up through the food web to top predators such as ourselves. Humans not only participate in the food web, but we adapt habitats and influence natural processes, sometimes unintentionally and with unforeseen consequences. Much of the B.C. coast is still relatively pristine, but the impacts of our activities extend far beyond human population centers. Plastic and other trash is finding its way to remote beaches, disease in sea stars remains a mystery, increasing underwater noise from boats and ships makes it harder for whales to find food, and the ecological consequences of ocean warming and sea level rise have no boundaries.

Economic indicators suggest that coastal residents are less well off than elsewhere in B.C., but long-term connections to the marine environment provide a positive sense of place, and increasing volunteer participation in science and conservation boosts overall wellbeing.

Humpback whales are now returning to near historic numbers coast-wide, collaborative governance is garnering successes, sustainable seafood is gaining popularity, and the value of seafood production and exports continues to grow. The signals are mixed – nature is resilient, but we are applying greater pressures. More than ever, we need to foster stewardship, collaborate, and share information to learn from and correct our mistakes.

[1] McLaren D, Fedje D, Dyck A, Mackie Q, Gauvreau A, Cohen J. 2018. Terminal Pleistocene epoch human footprints from the Pacific coast of Canada. PLoS ONE 13(3): e0193522. https://doi.org/10.1371/journal.pone.0193522

About this report

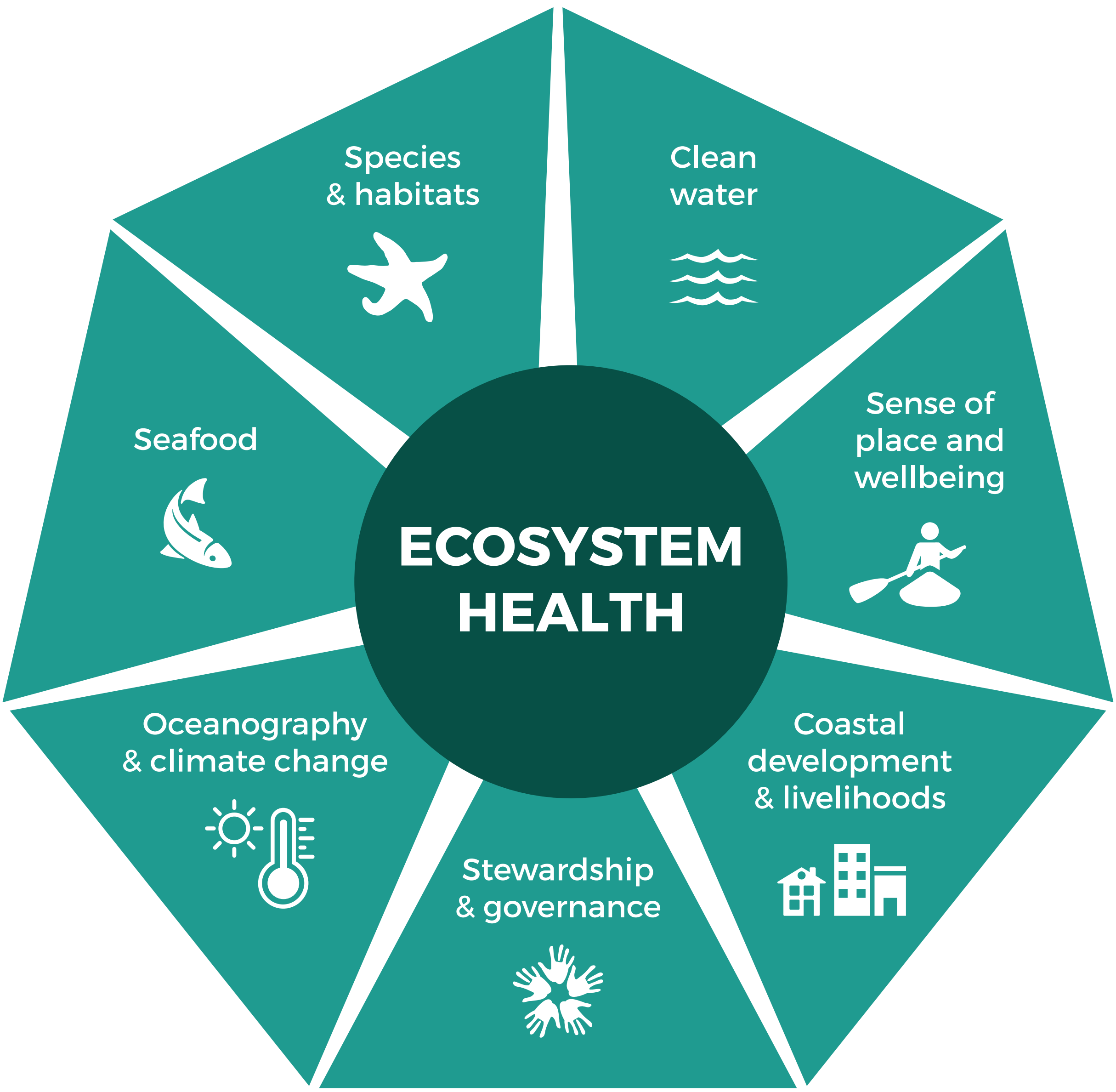
AUTHOR
Karin Bodtker, MRM, Manager, Coastal Ocean Health Initiative, Coastal Ocean Research Institute, an Ocean Wise initiative

Based on several years of research focusing on marine ecosystem indicators, CORI identified seven reporting themes for its Ocean Watch series. These themes taken together touch on ecological, socioeconomic, cultural, and governance aspects of ecosystem health and provide a window to the whole picture of what is happening in an area.

This B.C. coast edition of the Ocean Watch report follows on the success of our pilot, the Howe Sound edition. The same seven themes provide the backbone for both reports. The collection of topics for this B.C. coast edition grew from CORI's research programs, strengths of other Ocean Wise initiatives, Canada's 2016 census data, and emerging issues related to coastal ecosystem health.

Articles present status and trends of various aspects of the ecosystem, taking advantage of publically available data and information for the most part. There are certainly gaps from a technical standpoint (e.g., thousands of species and habitats do not have individual health reports), but because several topics are presented in each theme, the overall assessment is holistic.

Most articles, with a few exceptions, received a technical review by an expert in the appropriate field. We asked reviewers to identify any inaccuracies and unsupported statements and most reviewers provided additional editorial corrections and suggestions. We welcome comments on the accuracy of the information presented.


Species
& habitats
Clean
water
Seafood
Sense of
place and
wellbeing
ECOSYSTEM
HEALTH
Oceanography
& climate change
Coastal
development
& livelihoods
Stewardship
& governance

In order to provide a snapshot assessment of all the status information we compiled, a rating scheme was developed. The ratings say as much about the need for action related to any topic as they say about the health status overall. Ratings were assigned by CORI staff based on the authored papers. Authors were asked to review and comment. Due to limited data and expert capacity, it was not possible to undertake a solely quantitative assessment based on defined benchmarks, targets, and reference points.

Ocean Watch 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.

B.C. Coast Edition Snapshot Assessment

SPECIES AND HABITATS

Phytoplankton

One of the smallest organisms in the sea, phytoplankton have a huge impact on the wellbeing of aquatic ecosystems as an integral part of the food chain. Monitoring spring 'blooms' of this essential species yields important information about the overall dynamics of the entire marine environment. Monitoring is insufficient along the B.C. coast, except in the Strait of Georgia.

LIMITED DATA

Sea Star Wasting

Despite anecdotal reports of recovery in some areas, a mysterious condition continues to ravage sea star species along North America's west coast.

CRITICAL

Rockfish

Twenty-five years after several rockfish species were severely depleted, stock assessment models predict 90 years or more before meaningful recovery occurs for long-lived species such as quillback rockfish.

CRITICAL

Lingcod

After a decline in lingcod population triggered restrictions on commercial and recreational fisheries, indices show no clear trends in populations. Catches are quite restricted in the Strait of Georgia and decreasing elsewhere, even though these outside stocks are assessed as healthy.

CAUTION

Humpback Whales

After being hunted to near extinction in the Salish Sea, humpback whale populations have rebounded significantly. While this is a great win for conservation efforts, the return of humpbacks comes with risks, such as boat strikes and entanglements in what is now a busy urban waterway.

CAUTION

Marine Birds

Once considered out of sight, out of mind, declining populations of marine birds on B.C.'s coast have come to the public's attention due to multiple die-off events. Citizen science audits are critical in monitoring the health of marine bird populations and assessing potential threats.

CAUTION

CLEAN WATER

PCBs in Sediments and Mussels

Starting in 2015, the Coastal Ocean Research Institute launched *PollutionTracker*, a coast-wide initiative aimed at monitoring pollution levels at 55 sites along the B.C. coast. As human activity continues to impact the marine environment, the initiative is an important tool in monitoring how and where legacy pollutants and contemporary contaminants continue to impact coastal ecosystems.

CAUTION

Microplastics

From microbeads to fibres from fleece and other textiles, microplastics are finding their way into marine ecosystems and entering the food chain.

CAUTION

Radiation after Fukushima

Following the Fukushima nuclear disaster in 2011, agencies began monitoring waters of coastal B.C. for radiation contamination. While radiation associated with the disaster has been detected, levels determined to date are far below those considered harmful to human or marine health.

HEALTHY

Persistent Organic Pollutants in Seals

Despite the phasing out of many persistent organic pollutants (POPs) from industrial use in Canada, marine organisms are still testing positive for these harmful chemicals. Careful monitoring of indicator species, such as harbour seals, is an important tool in tracking contaminant hotspots and identifying new substances of concern.

CAUTION

Contaminant Trends in Seabirds

Due to their status at the top of the food chain, seabirds are an important indicator of contaminant levels in marine ecosystems, and the effectiveness of regulations. Long-term studies show substances like mercury, brominated flame-retardants and PFAs are present at different levels in various seabird populations.

CAUTION

Shoreline Cleanup

Between 2014 and 2016, more than 10 metric tons of marine debris was removed annually from the west coast of Vancouver Island, much of it tsunami debris from the 2011 Tohoku earthquake off the coast of Japan.

HEALTHY

SENSE OF PLACE AND WELLBEING

Population profile

Coastal regions account for nearly three-quarters of British Columbia's growing population, but uneven distribution impacts living standards on the coast. While some coastal communities are growing, others are shrinking, and yet many shoulder high rates of dependent populations — children and the elderly – compared to those of working age.

LIMITED DATA

Citizen Participation

Participation in volunteer conservation groups is growing throughout B.C., adding valuable human power to citizen science initiatives. In addition to providing crucial data used to monitor the health of coastal ecosystems, citizen science initiatives also create strong community ties that boost overall wellbeing for participants.

HEALTHY

Pacific Marine Life Surveys

What started as underwater observations by a local marine naturalist has turned into a growing taxonomy of nearshore species in the Pacific region. To date, information from nearly 5,000 dives in 1,200 locations has created a searchable database that has become a critical tool in monitoring the biodiversity of B.C.'s coast.

HEALTHY

Fishing and Sense of Place

The benefits of the fishing industry in coastal communities go far beyond the economy. Fishing, particularly in smaller communities, promotes strong cultural ties, intergenerational exchange and deeper community trust, however recent changes in the industry may be threatening these intangible benefits.

CAUTION

Income Disparity and Wellbeing

Income inequality has been on the rise throughout Canada for decades, a troubling trend linked to poorer health and wellbeing outcomes. B.C. experiences a higher rate of income disparity than the national average, with some coastal communities particularly affected.

CRITICAL

COASTAL DEVELOPMENT AND LIVELIHOODS

Population & Major Projects

B.C.'s growing population is increasing development pressure along B.C.'s coastline, particularly in the province's more densely populated south. This growth is highlighting the need for a cohesive system of tracking the cumulative effects of development – both positive and negative – in coastal communities.

CAUTION

Income & Employment

With few exceptions, incomes in coastal B.C. are lower than the provincial average, while the percentage of low-income residents and unemployment is higher. These indicators suggest large parts of coastal B.C. may be struggling economically, leading to possible negative effects on health and wellbeing.

CRITICAL

Underwater Noise

Underwater noise from shipping, construction, recreation and shoreline development has been doubling in intensity every decade since the 1950s. This is having a marked impact on whales and other marine life as noise from ship traffic, recreation and industry impedes their ability to hunt, communicate, rest and breed.

CRITICAL

Seafood Industry Jobs

Jobs related to seafood production have been on the decline in coastal communities since 1984, but these numbers don't tell the entire story. Fewer registered fishing vessels and licences are associated with commercial fisheries today, but benefits such as greater diversity in catch, improved sustainability, and increasing opportunities for stable employment have emerged in exchange.

CAUTION

STEWARDSHIP AND GOVERNANCE

Marine Protected Areas

Several new marine refuges and marine protected areas in British Columbia have been established or proposed as part of Canada's goal to conserve 10 percent of its coast by 2020. However, comprehensive oversight is still needed to ensure various marine protection areas function as a cohesive network.

HEALTHY CAUTION

Evolution in Governance

Once strictly top-down, a more collaborative approach to conservation is beginning to emerge in B.C.'s coastal regions. Indigenous peoples are increasingly being recognized for their role in stewardship and the governance of conservation efforts on land and sea.

HEALTHY

OCEANOGRAPHY AND CLIMATE CHANGE

Ocean Warming

The world's oceans are warming, including those in B.C. where surface temperatures in recent years have been consistently warmer than the 30-year baseline. More observation and study is needed to track ocean warming and understand its effect on aquatic ecosystems and human settlements.

CRITICAL

Sea Level Rise

New science suggests sea levels may be rising faster, and by a greater amount, than initially predicted, rendering many planning guidelines and adaptation tools in B.C. insufficient. Updates to community plans and policies are needed throughout the coast to protect infrastructure, homes and livelihoods along the coast from the threat of rising waters.

CRITICAL

SEAFOOD

Sustainable Seafood

Interest in sustainable seafood has grown exponentially since the Vancouver Aquarium established its Ocean Wise Seafood Program in 2005. To date, the program includes more than 700 partners and has recently launched its own monitoring program for small-scale Canadian fisheries.

HEALTHY

Industry Productivity

Seafood production contributes hundreds of millions of dollars to B.C.'s economy each year, with 2016 reaching over $400 million. But while the sector's value continues to grow, balance must be achieved between environmental sustainability and the economic wellbeing of those who work in the industry.

HEALTHY

Key trends and actions

The British Columbia coast hosts a diverse human population and several distinct ecological regions, each with unique characteristics. Socio-economic conditions along much of the coast have changed significantly over the last few decades, and ecological systems are now facing emerging issues, such as climate change. This report touches on emerging threats, highlights a few unhealthy trends, and acknowledges areas of positive action and change. Here, we summarize reported-on trends, positive and negative, that are influencing the state of B.C.'s coastal ecosystems. Further, we share ideas for actions that we can all take to reverse the negative and bolster the positive. The bottom line is – we are all connected to the ocean.

Unhealthy status and trends

1. Recovery from depletion is prolonged due to continued harvest of some fish species.
2. The increasing volume of underwater noise is a clear threat to endangered marine mammals.
3. Some contamination introduced in past decades still lingers and new pollutants pose emerging concerns.
4. Economic indicators suggest that coastal areas of B.C. are less prosperous and have fewer employment opportunities than the provincial average. Household income in coastal areas is below the provincial median and unemployment is higher, except in the more populated south coast.
5. Income disparity is increasing throughout the province, emphasizing that not all citizens benefit from growth in GDP, or traditional economic prosperity.
6. Commercial fishing quota prices and quota lease prices are increasing rapidly.
7. Employment is falling in the seafood production sector.

Patterns that generate concern or uncertainty

1. Changing weather patterns, warming seas, and rising seas mean changing conditions. Sea star recovery is spotty and uncertain. Coastal waterbird declines may be a warning sign that favourable conditions for these species are shifting.
2. Humpbacks, no longer hunted, are returning to the Salish Sea to face new threats, such as ship-strike or entanglement.
3. Biodiversity needs room to thrive without anthropogenic threat.
4. Coastal developments, whether it be expansion of human population centres or commercial, industrial, and residential construction, are not equally dispersed along the coast. Neither are areas set aside to mitigate threats and to protect natural ecosystems. Costs — such as threats to the environment —, economic benefits, and clusters of marine protected areas are concentrated in some areas more than in others. Without integrated planning, can we know this is the healthiest arrangement?
5. Limiting the study area for socio-economic indicators to truly coastal communities — those in close proximity to the marine environment — is not supported by publicly available census data.

Photo: Jenn Burt

Positive trends to encourage and foster

1. Increasing focus on designating areas to protect species and habitats from threats resulting in more Marine Protected Areas.
2. Increasing co-management and collaboration among governments.
3. Increasing awareness and recognition of First Nations' rights and title and the importance of reconciliation.
4. Increasing participation in citizen science, monitoring, stewardship, and conservation initiatives, as these activities increase individuals' ecological knowledge, boost wellbeing, and foster a positive sense of place.
5. Increasing seafood production – kept within ecologically sustainable limits.
6. Increasing sustainable seafood choices and increasing access to those choices.
7. Monitoring of plankton blooms, and other sea life, all along the coast.
8. Ongoing monitoring of seabirds, marine mammals, sediments and mussels for contaminant levels and emerging threats.

Photo: Kim Wright

What we can all do

1. Share monitoring data publically, as the default.
2. Support local fishermen and support initiatives to revitalize the fishing industry in smaller coastal centres.
3. Follow posted fishing regulations and stay well away from rockfish conservation areas with fishing gear.
4. When boating, slow down to reduce noise and modify your route to avoid whales.
5. Choose sustainable and local seafood; eat lower on the trophic level.
6. Get involved in coastal monitoring through a citizen science program or conservation initiative.
7. Avoid purchasing things with plastic packaging, recycle responsibly, and properly dispose of garbage to prevent debris from entering the marine environment.
8. Eliminate the use of toxic chemicals and single-use plastics around the house and garden.
9. Follow, promote, develop, discuss, and share best development practices.
10. Acknowledge and respect the Indigenous peoples' territories where you live and work.
11. Reduce personal energy use to produce fewer greenhouse gasses.
12. Continue to learn, share, and adapt.

> **"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."**
>
> ALDO LEOPOLD (1968)

Species and Habitats

Photo: Jenn Burt

Summary

Life under the ocean's surface is an intricate web connecting all organisms, from the microscopic species at the bottom of the food chain to some of the world's largest animals at the top. After being hunted to near extinction, humpback whales are returning to the Salish Sea in greater numbers than we've seen for decades, signaling a significant achievement for conservation efforts. Their return may signal an overall improvement in the health of the aquatic environment, but their presence is also a complicating factor. In addition to competing with other animals for food sources, the humpbacks are also competing with humans for space in what has become a busy waterway. Boat strikes and entanglements in fishing gear are just some of the potential threats they face.

Recoveries of other species have been less robust. Several decades after fisheries of rockfish were restricted or closed, populations have yet to meaningfully rebound, while coastal waterbird populations in the Salish Sea demonstrate an overall declining trend. Meanwhile, a mysterious wasting disease continues to ravage populations of sea stars all along the North American coast, although anecdotal evidence of recovery in some areas has surfaced.

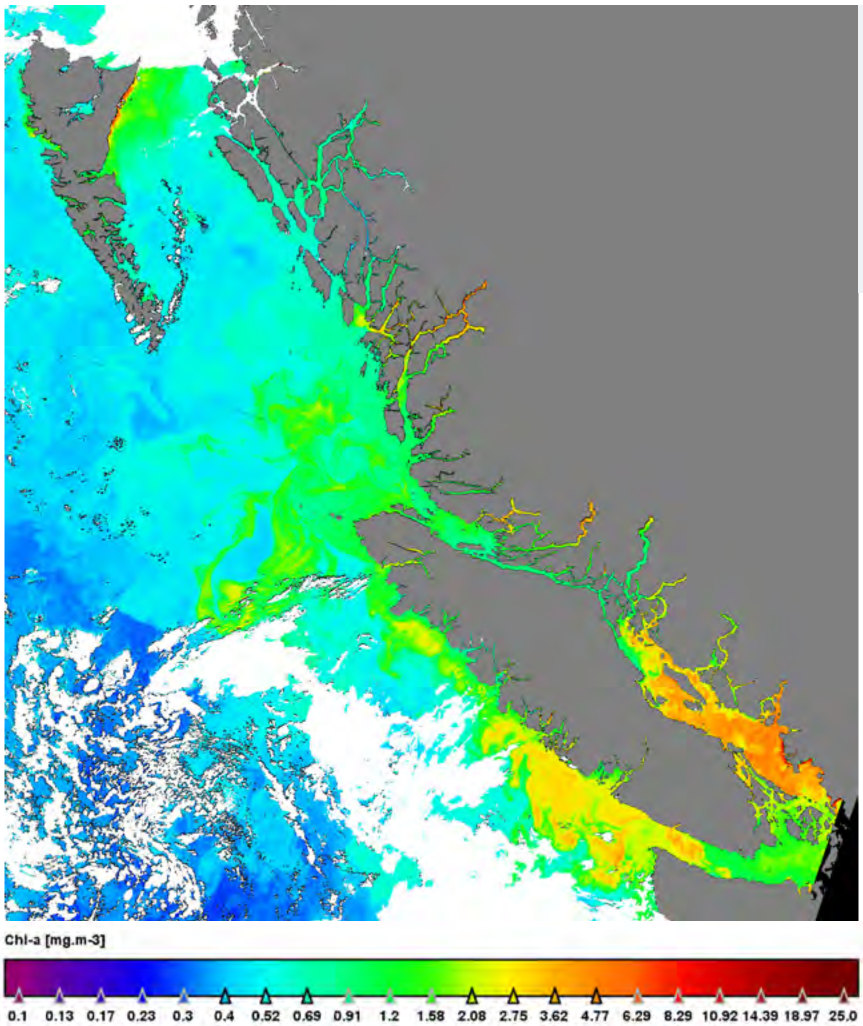
With B.C.'s coastal ecosystems under increasing pressure from human activity and climate change, scientists and citizen scientists are keeping a close eye on even the most microscopic species, like phytoplankton, to help build the body of knowledge about the underwater world, and how best to protect it.

Species and Habitats Snapshot Assessment

Phytoplankton

One of the smallest organisms in the sea, phytoplankton have a huge impact on the wellbeing of aquatic ecosystems as an integral part of the food chain. Monitoring spring ‘blooms’ of this essential species yields important information about the overall dynamics of the entire marine environment. Monitoring is insufficient along the B.C. coast, except in the Strait of Georgia.

LIMITED DATA



Chlorophyll-a concentration, measured with satellite images, represents phytoplankton abundance. This image shows Chlorophyll-a concentration along the British Columbia coast on March 15th, 2018. Satellite image from Sentinel-3 OLCI sensor from EUMETSAT, processed with POLYMERv4.7 algorithm (Steinmetz et al 2011), provided by Dr. Fernanda Giannini from Costa's Spectral and Remote Sensing Laboratory at University of Victoria.

Sea Star Wasting

Despite anecdotal reports of recovery in some areas, a mysterious condition continues to ravage sea star species along North America's west coast.

CRITICAL

Rockfish

Twenty-five years after several rockfish species were severely depleted, stock assessment models predict 90 years or more before meaningful recovery occurs for long-lived species such as quillback rockfish.

CRITICAL

Lingcod

After a decline in lingcod population triggered restrictions on commercial and recreational fisheries, indices show no clear trends in populations. Catches are quite restricted in the Strait of Georgia and decreasing elsewhere, even though these outside stocks are assessed as healthy.

CAUTION

Humpback Whales

After being hunted to near extinction in the Salish Sea, humpback whale populations have rebounded significantly. While this is a great win for conservation efforts, the return of humpbacks comes with risks, such as boat strikes and entanglements in what is now a busy urban waterway.

CAUTION

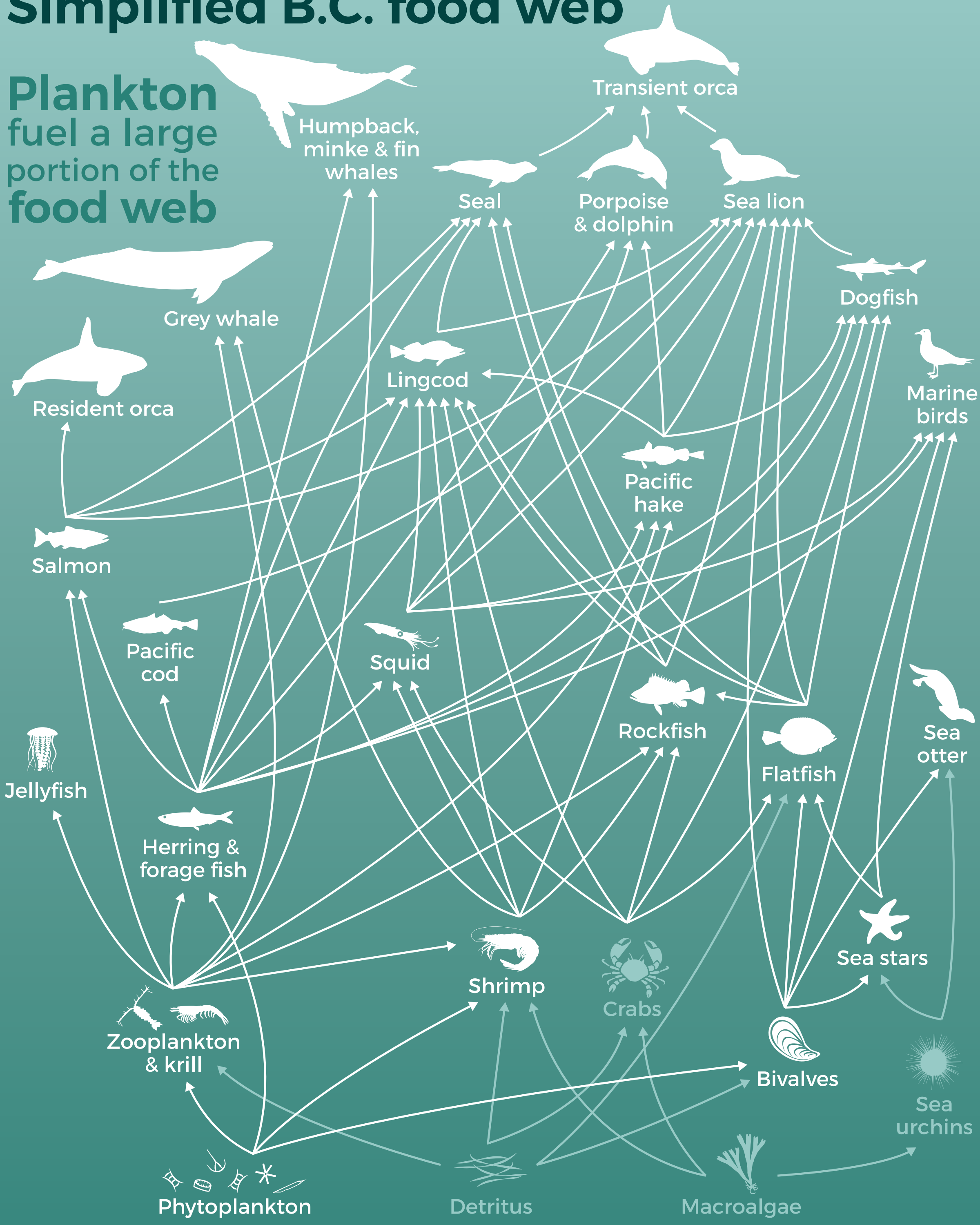
Marine Birds

Once considered out of sight, out of mind, declining populations of marine birds on B.C.'s coast have come to the public's attention due to multiple die-off events. Citizen science audits are critical in monitoring the health of marine bird populations and assessing potential threats.

CAUTION

Simplified B.C. food web

Plankton fuel a large portion of the **food web**



The spring plankton bloom in coastal B.C.

AUTHOR
Stephanie King, Sea This Consulting

REVIEWER
Angelica Peña, Institute of Ocean Sciences, Fisheries and Oceans Canada

What's happening?

Phytoplankton are the microscopic plants in the ocean at the base of the marine food web (Figure 1). Just like plants on land, they need nutrients, carbon dioxide, and light to grow. They also contain chlorophyll, which helps convert light into chemical energy through photosynthesis. Under the right ocean conditions phytoplankton abundance can explode or 'bloom', so that concentrations double in several hours to days. The spring bloom is the first rapid increase of phytoplankton after months of low winter light levels.

Monitoring the timing and magnitude of the spring bloom can be a challenge because of high variability in space and time; bloom timing can vary by several weeks each year, or by several weeks in the same year for different areas. For example, the spring bloom in the northern Strait of Georgia started on February 21 in 2015[1] and on March 28 in 2016.[2] On the Central Coast, the spring bloom was observed on April 15 in 2016.[2]

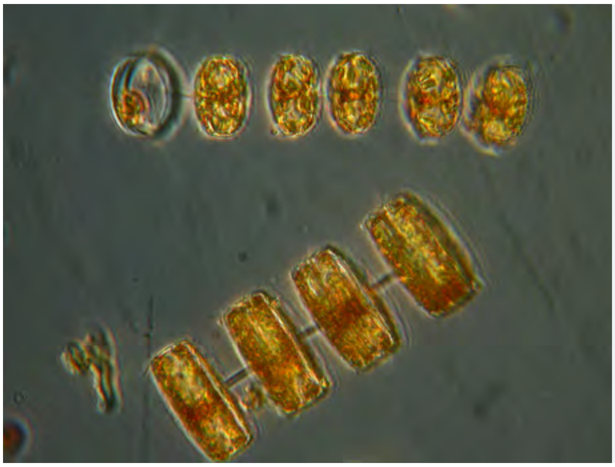


Figure 1. *Thalassiosira* are a type of diatom and one of many phytoplankton species that can be found in the spring bloom in coastal B.C. waters. Their size is usually in the range of 5 to 30 microns across the cell. Diatoms usually dominate the phytoplankton biomass in the spring on the continental shelf.[2] (Photo: Moira Galbraith, DFO)

Ocean colour satellites are often used to monitor the spring bloom because they provide a snapshot of the spatial extent and concentration (Figure 2), but clouds can prevent a clear image for weeks at a time on the B.C. coast. Furthermore, the standard satellite chlorophyll (an index of phytoplankton biomass) images can return bad data in nearshore waters (e.g., the Strait of Georgia) so additional in situ observations (i.e., measurements in the water) are needed to validate the data. Alternatives to the standard satellite chlorophyll images include regional chlorophyll products such as those being developed by the University of Victoria Spectral Lab, or the fluorescence line height (FLH) shown in Figure 2.[3] Other monitoring methods include sensors deployed in the water which give bloom timing, but only at one location unless a network of instruments is used. Periodic ship-based monitoring can accurately measure phytoplankton biomass, but ships are usually expensive to operate and have spatial and temporal limitations as well. The best option for monitoring the spring phytoplankton bloom in B.C. is to use a combination of approaches.

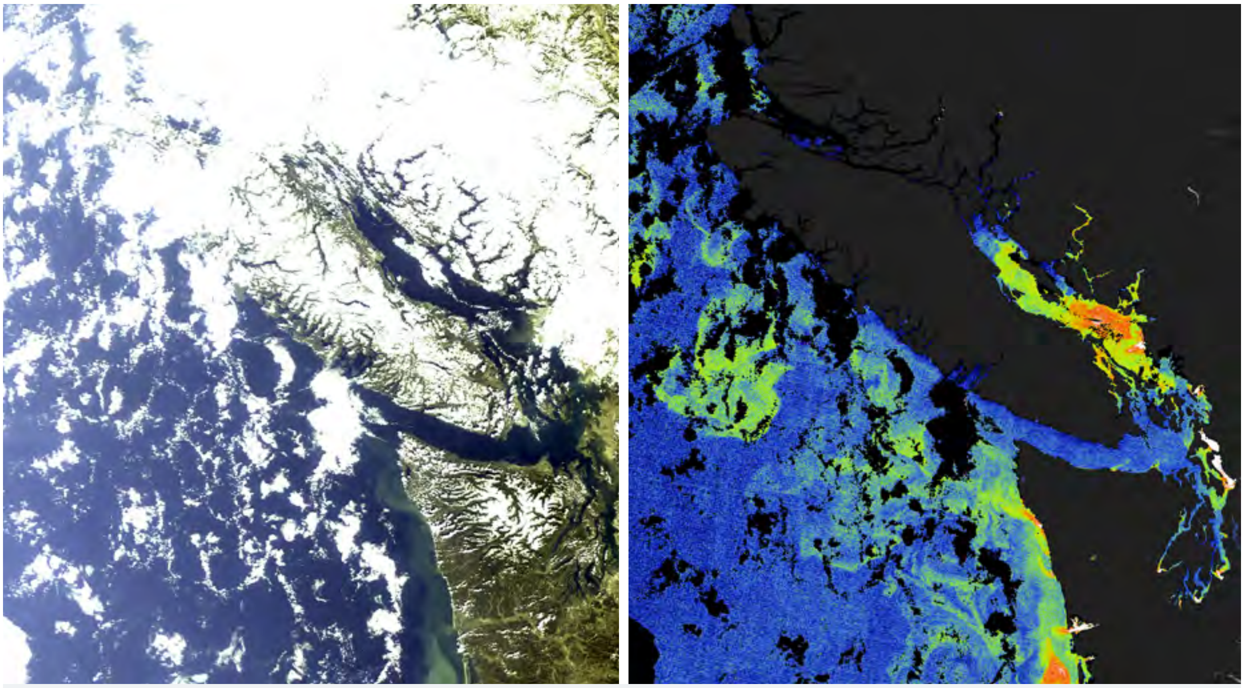


Figure 2. The true colour (left) and fluorescence line height (FLH; right) satellite images for March 19, 2017, at about the peak of the spring bloom in waters around Vancouver Island. FLH is a proxy for chlorophyll and tends to give better results than the standard satellite chlorophyll in nearshore waters. Colours represent low chlorophyll (blue; <1 mg/m^3) to high chlorophyll (red; ~20 mg/m^3). These are the 300 metre spatial resolution data from the European Space Agency's OLCI sensor which was launched in early 2016. Source data: European Space Agency.

Why is it important?

The timing and magnitude of the spring bloom depends on a number of environmental factors and has implications for marine organisms that directly or indirectly depend on phytoplankton for food. If the timing is too early or too late, or the concentrations are too low, there may not be enough food for the zooplankton that eat the phytoplankton, and in turn for the fish or seabirds that eat the zooplankton. For example, a study in the Strait of Georgia found that the lowest juvenile herring abundance occurred in years when there was a mismatch between the timing of the herring spawn and the timing of the spring bloom.[4]

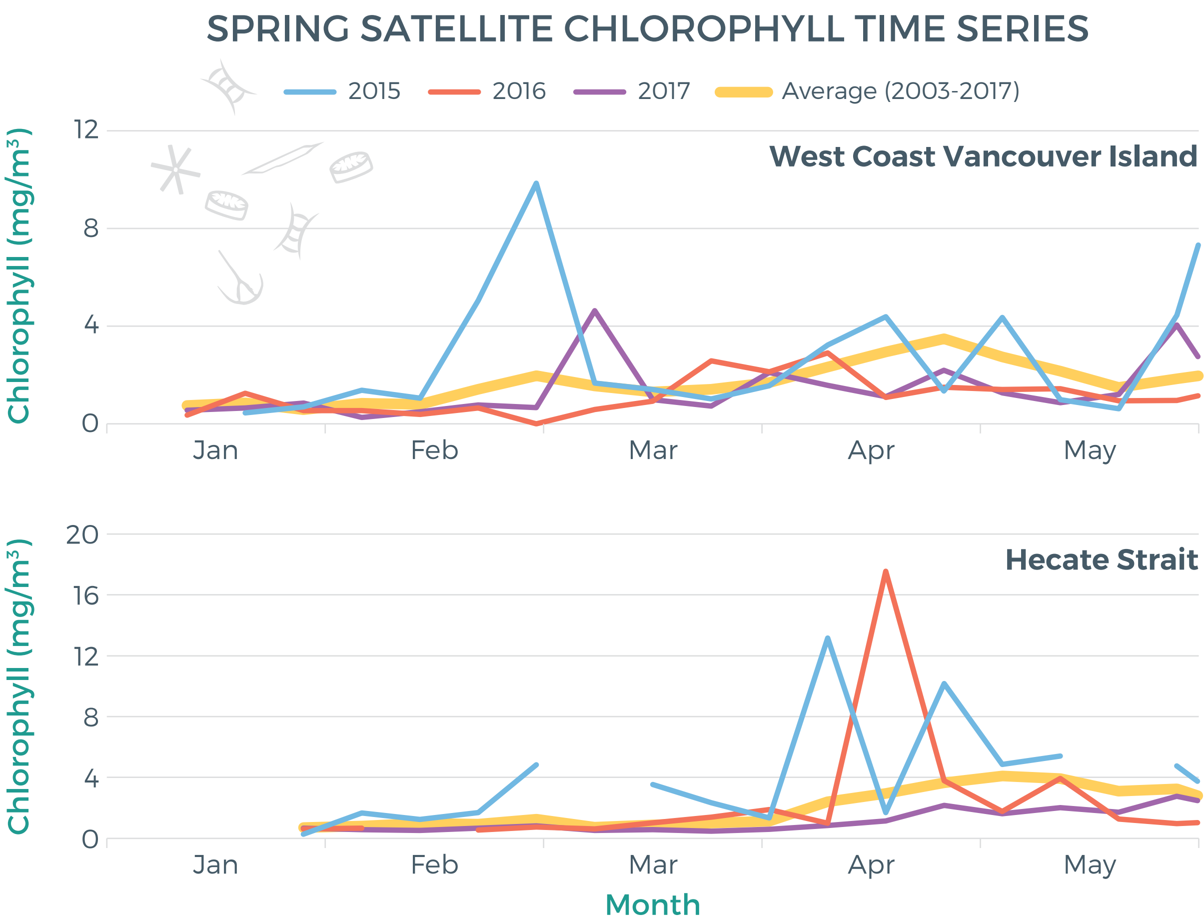


Figure 3. Satellite chlorophyll time series in spring averaged for 1-degree squares off the west coast of Vancouver Island (top plot; 48–49° N, 126–127° W) and in Hecate Strait (lower plot; 51–52° N, 129–130° W). The most recent three years are shown with the average for the MODIS time series (2003–2017). Source data: NOAA ERDDAP

Phytoplankton bloom in the Salish sea on August 19, 2016 from Landsat 8. (Photo: Pierre Markuse, Flickr CC BY 2.0)

What is the current status?

The most complete time series of spring bloom timing for the B.C. coast can be derived using the satellite data from several sensors starting in 1997. Figure 3 shows the bloom timing and magnitude in recent years using satellite chlorophyll from NASA's MODIS sensor for areas off the west coast of Vancouver Island and in Hecate St.[5] For both areas, the bloom was earlier in 2015 compared to 2016 and 2017, and the bloom is usually earlier off the west coast of Vancouver Island compared to in Hecate Strait.

In the Strait of Georgia, time series of higher temporal resolution (i.e., hourly or daily, rather than weekly or monthly measurements) from a sensor deployed in the central Strait demonstrates another method for monitoring blooms (Figure 4).[6] In 2017, there was a slow start to the spring bloom with chlorophyll concentrations gradually increasing from the beginning to the middle of March. The satellite image for March 19, 2017 shows that the bloom covered most of the Strait with the highest concentrations in the central Strait (Figure 2). The bloom timing in the central Strait of Georgia was similar to the bloom on the west coast of Vancouver Island in recent years (Figure 3 and Figure 4).

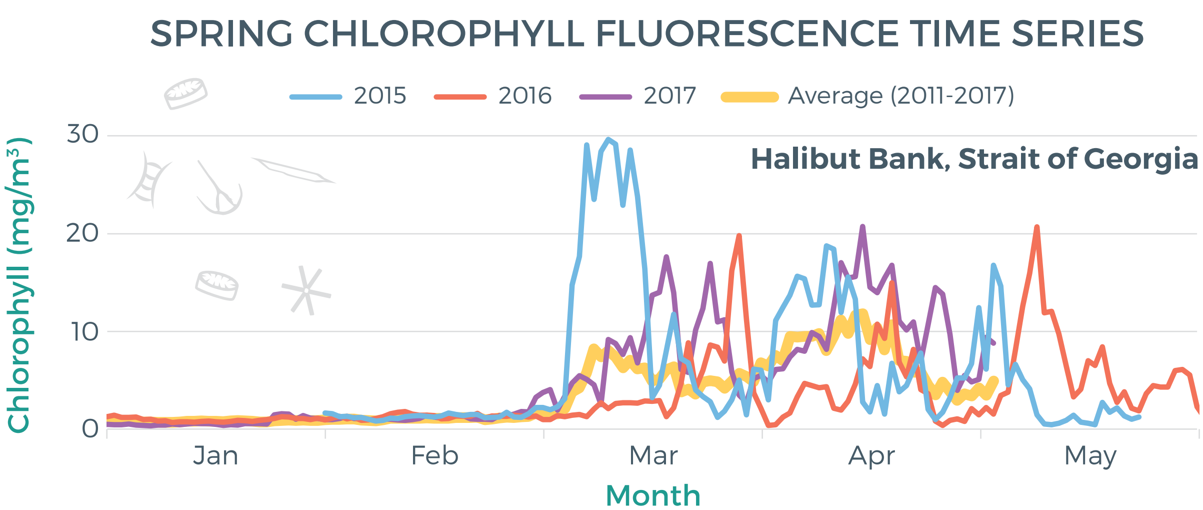


Figure 4. Chlorophyll fluorescence data from the Halibut Bank buoy in the central Strait of Georgia for the three most recent springs (2015, 2016, and 2017) and the average for the buoy data time series (2011–2017). Source data: Strait of Georgia Data Centre.

What is being done?

There are a number of organizations and programs monitoring the spring bloom around B.C.:

- **Pacific Salmon Foundation**
  Through the Salish Sea Marine Survival Project (SSMSP) several efforts monitor spring bloom timing using deployed sensors, shipboard measurements, and satellites. Data are found online at http://sogdatacentre.ca
- **Fisheries and Oceans Canada (DFO)**
  A number of monitoring and research initiatives monitor phytoplankton in B.C. waters, including:
  - In situ measurements such as those made on the La Perouse and Strait of Georgia research cruises.
  - The remote sensing lab's research on bloom timing in the Strait of Georgia.[7,8]
  - Various reports in the annual State of the Pacific Ocean (SOPO) technical report: http://www.dfo-mpo.gc.ca/oceans/publications/index-eng.html
- **Susan Allen's lab at the University of B.C.**
  Strait of Georgia spring bloom timing prediction using a biophysical model: https://salishsea.eos.ubc.ca/bloomcast/spring_diatoms.html
- **Ocean Networks Canada**
  In situ measurement from instrumented BC Ferries in the Strait of Georgia: http://www.oceannetworks.ca/
- **University of Victoria's Spectral lab**
  Research on monitoring methods including improved atmospheric correction for Strait of Georgia satellite chlorophyll (Hilborn et al. SOPO contribution[2])
- **Hakai Institute**
  Oceanographic monitoring in the northern Strait of Georgia and on the Central Coast (Hunt el al. SOPO contributions[1,2]); Satellite chlorophyll on the B.C. coast, 1997–2010.[9]

What can you do?

Phytoplankton variability is a key factor for understanding largescale changes to the ecosystem due to climate change and variability. Continued and improved monitoring is imperative for characterizing this variability and understanding the effects.

Individual and Organization Actions:

- Interested individuals can monitor the timing of the spring bloom using satellite imagery at: https://worldview.earthdata.nasa.gov
- Become involved in citizen scientist programs. For example, the Pacific Salmon Foundation organized a three-year sampling program conducted primarily by citizen scientists.

Government Actions and Policy:

- Continue in situ monitoring in areas that have ongoing time series (e.g., Strait of Georgia, Central Coast).
- Implement monitoring for other areas that currently have little or no data on spring bloom timing (e.g., the west coast of Vancouver Island, North Coast, and Haida Gwaii).

Footnotes

[1] Various individual reports in Chandler, P.C., King, S.A., and Perry, R.I. (Eds.). 2016. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2015. Can. Tech. Rep. Fish. Aquat. Sci. 3179: viii + 230 p.

[2] Various individual reports in Chandler, P.C., King, S.A., and Boldt, J. (Eds.). 2017. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2016. Can. Tech. Rep. Fish. Aquat. Sci. 3225: vi + 243 p.

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[4] Schweigert, J.F., Thompson, M., Fort, C., Hay, D.E., Therriault, T.W., and L.N. Brown. 2013. Factors linking Pacific herring (Clupea pallasi) productivity and the spring plankton bloom in the Strait of Georgia, British Columbia, Canada. Progress in Oceanography 115: 103–110, http://dx.doi.org/10.1016/j.pocean.2013.05.017

[5] Data from MODIS Aqua NPP/L3SMI 4km 8-day global dataset downloaded from NOAA's ERDDAP http://coastwatch.pfeg.noaa.gov/erddap/griddap/erdMH1chla8day.html

[6] Data are daily averages of nighttime measurements. Hourly measurements are available online from the Strait of Georgia Data Centre at http://sogdatacentre.ca

[7] Gower, J., S. King, S. Statham, R. Fox, E. Young. 2013. The Malaspina Dragon: A newly-discovered pattern of the early spring bloom in the Strait of Georgia, British Columbia, Canada. Prog. Oceanogr. (2013), http://dx.doi.org/10.1016/j.pocean.2013.05.024

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[9] Jackson, J. M., R. E. Thomson, L. N. Brown, P. G. Willis, and G. A. Borstad (2015), Satellite chlorophyll off the British Columbia Coast, 1997–2010, J. Geophys. Res. Oceans, 120, https://doi.org/10.1002/2014JC010496.

Sea star wasting – update!

AUTHOR
Jessica Schultz, MSc, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWERS
Ian Hewson, Cornell University
Jackie Hildering, Marine Education and Research Society
Andy Lamb, Zoologist and Author
Neil McDaniel, McDaniel Photography

What's happening?

Starting in the spring of 2013, a widespread sea star mass mortality event spread up and down the west coast of North America in what might be the largest wildlife die-off event in recorded history.[1,2] At least 20 species are affected,[1] with trickle-down ecological effects at multiple levels of the food web.[3] Despite progress in understanding the causes and consequences of the outbreak,[4,5,6,7] many mysteries remain, and sea star wasting syndrome is ongoing.

Prior to October 2013, there were thousands of large sunflower stars, *Pycnopodia helianthoides*, at this site near Defence Island in Howe Sound. On April 3 2017, only six small individuals were found. (Photo: Neil McDaniel)

What is the current status?

The current status of sea stars varies widely by species and location. Although there are anecdotal reports of recovery, the frequency of sea star sightings continues to decline for many species (Figure 1A), and signs of wasting persist. At the same time, sea star distribution is increasingly patchy and abundance is quite variable (Figure 1B).

The sunflower star (*Pycnopodia helianthoides*) was the most severely depleted subtidal species overall, with declines of 90 percent or more in some areas.[3] Numbers remain extremely low compared to pre-mortality levels (Figure 1, bottom panel), and sightings are rare.

The purple star (*Pisaster ochraceus*) was also among the most severely affected, with populations disappearing from some sites, such as on Thetis Island (Andy Lamb, personal communication). However, the status of this species is highly variable from one location to the next. There are reports of this species returning to some areas, but not others.

Mottled stars (*Evasterias troschelii*) are similar to purple stars in that they were heavily impacted by sea star wasting overall but the severity and current status vary widely by location.

Predatory sun stars (*Solaster* spp.) were severely affected and remain a rare sighting throughout B.C. The striped sun star, *Solaster stimpsonii*, was more heavily impacted within B.C. than on other areas of the Pacific coast.

The leather star (*Dermasterias imbricata*) was not as severely affected as other species in the Strait of Georgia, and appeared to increase in some areas following the disease outbreak (Figure 1, bottom panel). However, leather stars were more severely affected near Port Hardy than in other areas.

(Photos: Lee Newman and Bernie Handby)

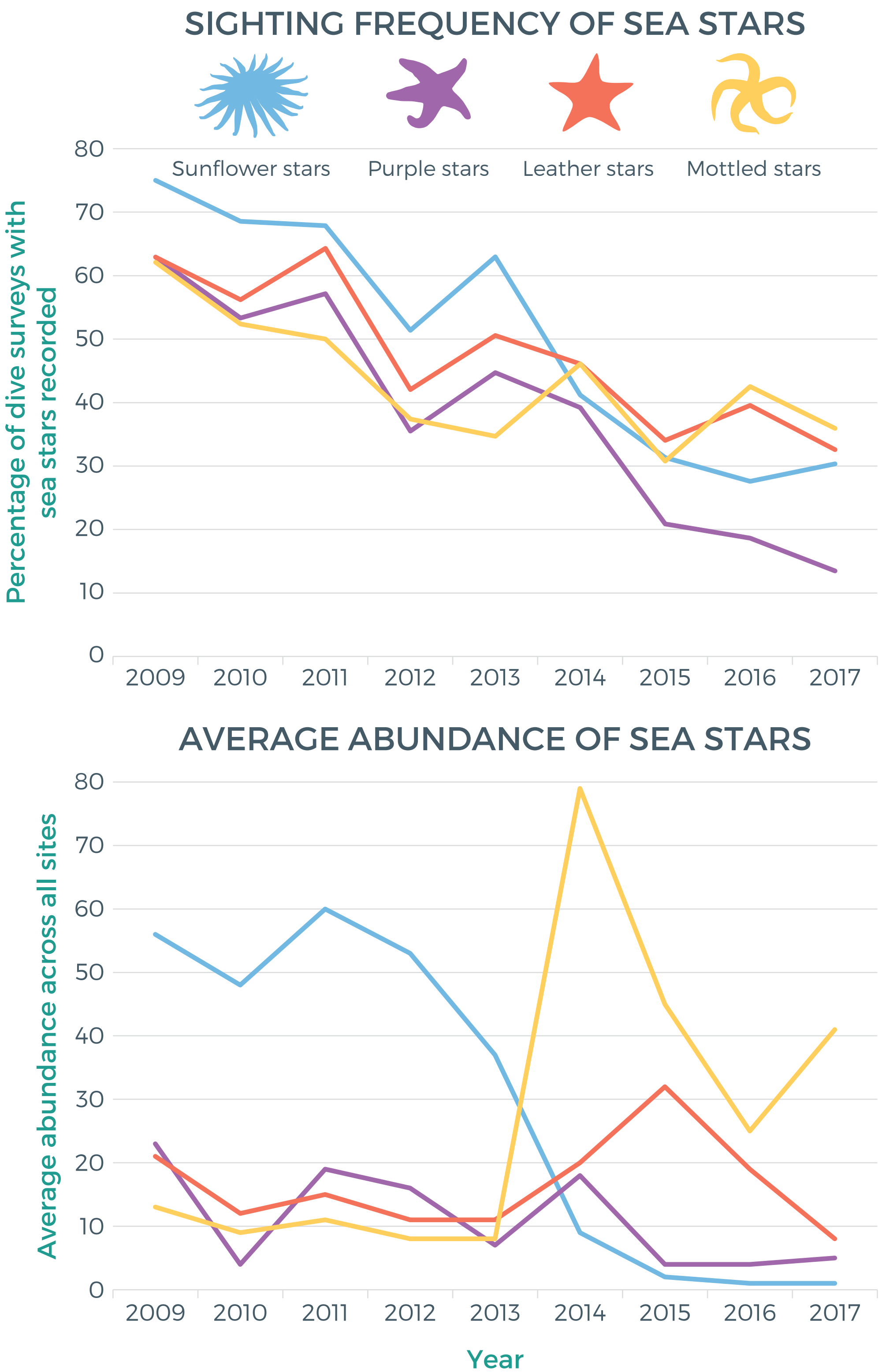


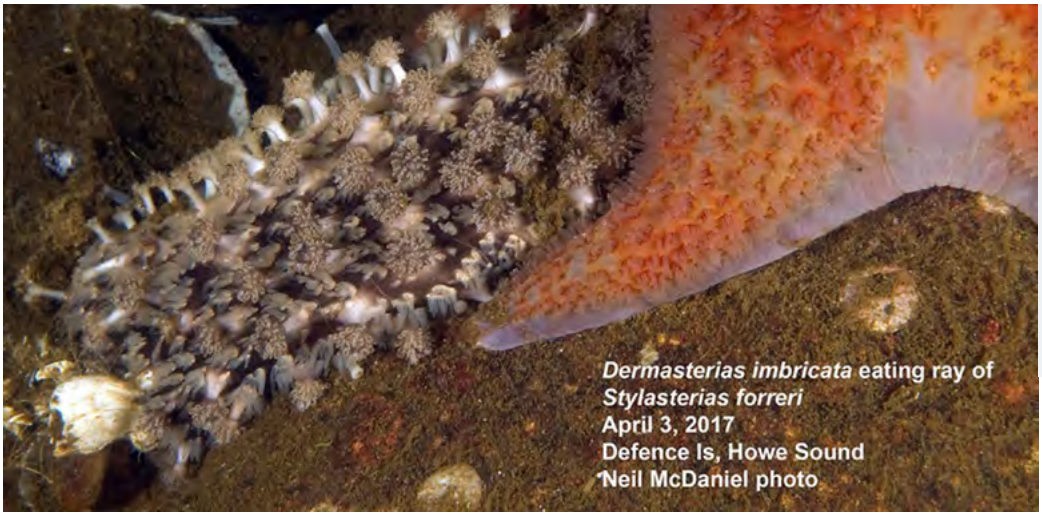
Figure 1. Between 2009 and 2017, the sighting frequency (i.e., the proportion of dive surveys where sea stars were recorded) of four common sea star species in the Strait of Georgia declined (top panel), but the average abundance for all sites surveyed in the Strait of Georgia (as estimated visually using roving dive surveys) was variable (bottom panel). Represented species include: sunflower stars (*Pycnopodia helianthoides*), purple stars (*Pisaster ochraceus*), leather stars (*Dermasterias imbricata*) and mottled stars (*Evasterias troschelii*). Data source: Pacific Marine Life Surveys Database of opportunistic SCUBA-based observations, accessed 15 Aug 2017.

Interestingly, there was an unusual boom in the abundance of juvenile sea stars of several species in 2014 and 2015. Juvenile sunflower stars, in particular, were extremely abundant at several locations in the Strait of Georgia, Puget Sound and elsewhere. Similarly, juvenile mottled stars (*Evasterias troschelii*) formed ultra-dense aggregations at some sites for a short period of time (see photo at end of article). Unfortunately the abundance was short-lived; the juveniles disappeared over a period of weeks to months, and no evidence of their abundance has so far been reflected in adult populations.

What is being done?

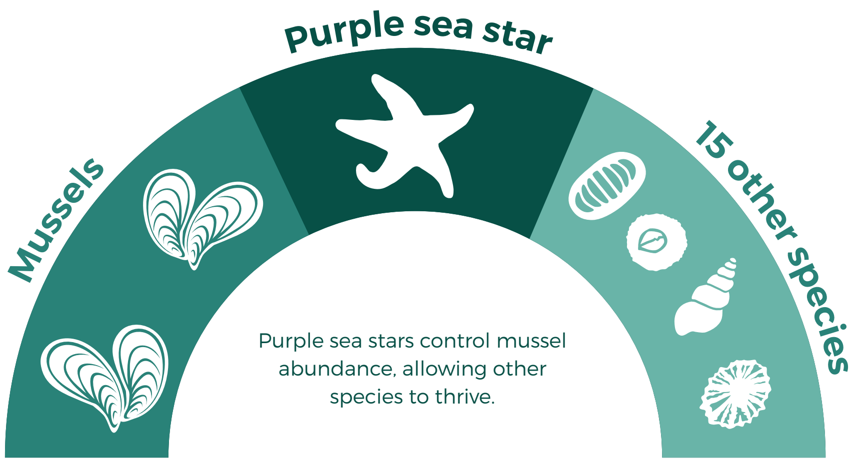
Research into the pathology (characterization), etiology (causes and origins), epidemiology (distribution and contributing factors), and ecology of the disease are ongoing at several institutions across North America. In British Columbia, monitoring efforts are ongoing at the Hakai Institute, Simon Fraser University, the University of B.C., the Coastal Ocean Research Institute, and elsewhere. A Sea Star Wasting Disease Task Force, coordinated by researchers at Oregon State University and the University of California, recently formed to develop a coordinated research strategy, consider mitigation and recovery approaches, and develop new legislation to improve disease response and management. Ongoing concern about the status of sunflower stars has led to initiatives to have sunflower stars assessed for listing under Canada's Species at Risk Act.

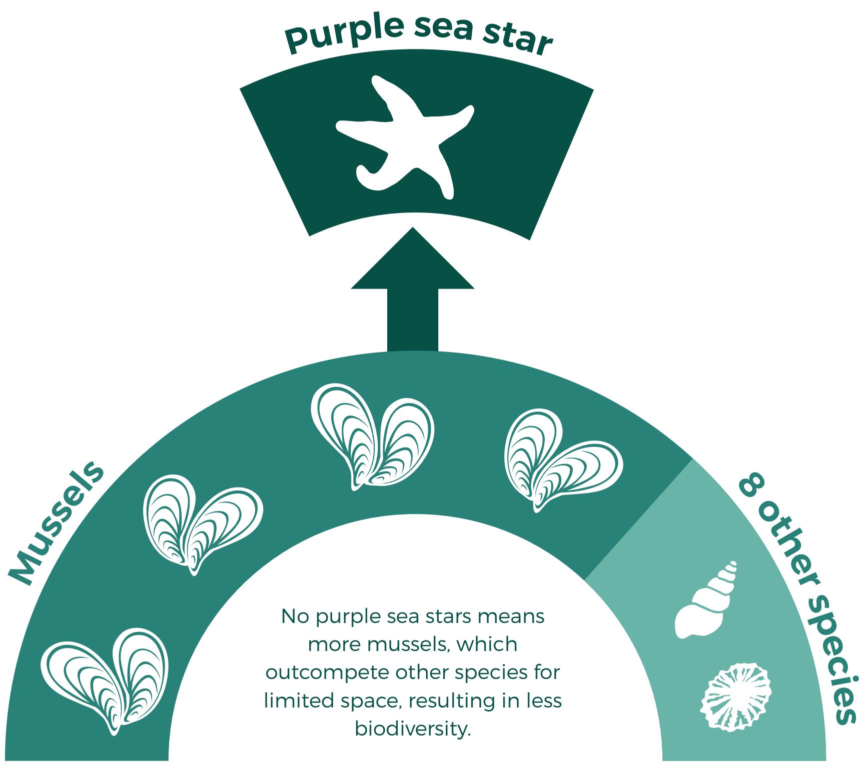
Sea star wasting continues to serve as a stark indicator of how much there is to learn about the complexity of ocean systems. Further research into the disease will help forward our understanding about wildlife mortality events, and how human actions and management might prevent or mitigate similar outbreaks in the future.



The leather star, *Dermasterias imbricata* (right), is a generalist opportunistic feeder, but it was unusual to see one eating the remains of a velcro star, *Stylasterias forreri* (left), that appeared to have died due to sea star wasting disease. (Photo: Neil McDaniel)

Purple sea star is a keystone predator





Hordes of mottled stars (*Evasterias troschelii*) sit with purple stars (*Pisaster ochraceus*) in Cates Bay, Bowen Island on July 17 2014. (Photo: Donna Gibbs)

Footnotes

[1] Stokstad, E. 2014. Death of the stars. Science 344, 464–7.

[2] Hewson, I. et al. 2014. Densovirus associated with sea-star wasting disease and mass mortality. Proc. Natl. Acad. Sci. U. S. A. 111, 17278–83.

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[4] Eisenlord, M.E. et al. 2016. Ochre star mortality during the 2014 wasting disease epizootic: role of population size structure and temperature. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 371, 20150212.

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[8] Hildering, J. 2017. Wasted: What is happing to the sea stars of the NE Pacific Ocean? The Marine Detective. Accessed: 26th October 2017 Available at: https://themarinedetective.com/category/marine-invertebrates/sea-stars/

Threatened rockfish species may have a long road to recovery

AUTHOR
Laura Borden, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Jeff Marliave, Senior Scientist, Coastal Ocean Research Institute, an Ocean Wise initiative

What's happening?

Rockfish populations along the B.C. south coast remain depressed since a record low in the 1990s, following high levels of harvest from the 1970s through the 1990s.[1] Quillback rockfish, an inshore rockfish species listed as threatened by COSEWIC in 2009[2] and the focus of this article, have shown year-to-year variation in abundance both in inside waters of the Strait of Georgia and in outside waters of the West Coast of Vancouver Island since the mid-1990s (Figure 1 and 2). Longline surveys conducted by Fisheries and Oceans Canada (DFO) (some in collaboration with industry)[3] also show year-to-year variation in the abundance of quillback rockfish in inside and outside waters from 2003 to 2016. Only in areas on British Columbia's north

Adult quillback rockfish. (Photo: Lee Newman) coast are indices of quillback rockfish populations showing a slight positive trend.

Quillback (and copper) rockfish were prime targets in the live market fishery of the 1980s, which led to their serial depletion on a reef-by-reef basis.[4] As quillback rockfish are one of the longest-lived rockfish species, recovery of this species may take decades of favourable environmental conditions coinciding with sufficient reproductive-age adults. An example of these two parameters coinciding occurred during a climate regime[5] between 2000 and 2010. During this period, observed quillback rockfish abundance was higher in inside waters than either before or after (Figure 2), primarily due to a high survival rate for young of the year rockfish in multiple years during that climate regime.[6] Abundant year classes do occur from time to time – we have received reports that 2016 was an exceptional year class for some rockfish species along large stretches of the Pacific Coast in outside waters. Perhaps related to this, high abundances of young yellowtail rockfish were observed in 2017 in inside waters, during Ocean Wise Rockfish Abundance Surveys.

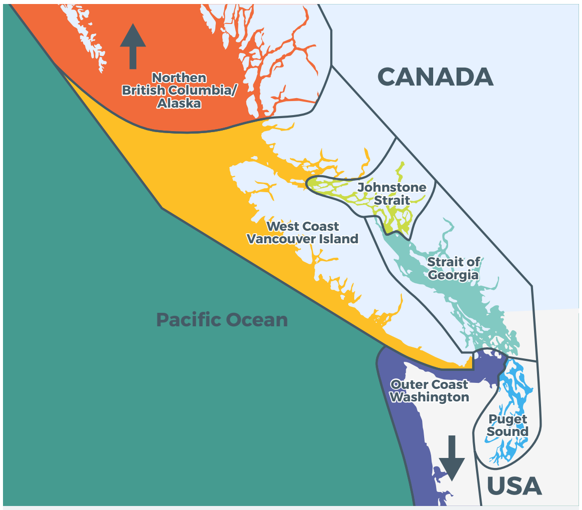


Figure 1. Zoogeographic map of regions along the B.C. coast (reproduced from Marliave et al. 2011). Inside waters refer to waters between Vancouver Island and the mainland of British Columbia, and everything else is generally referred to as outside waters.

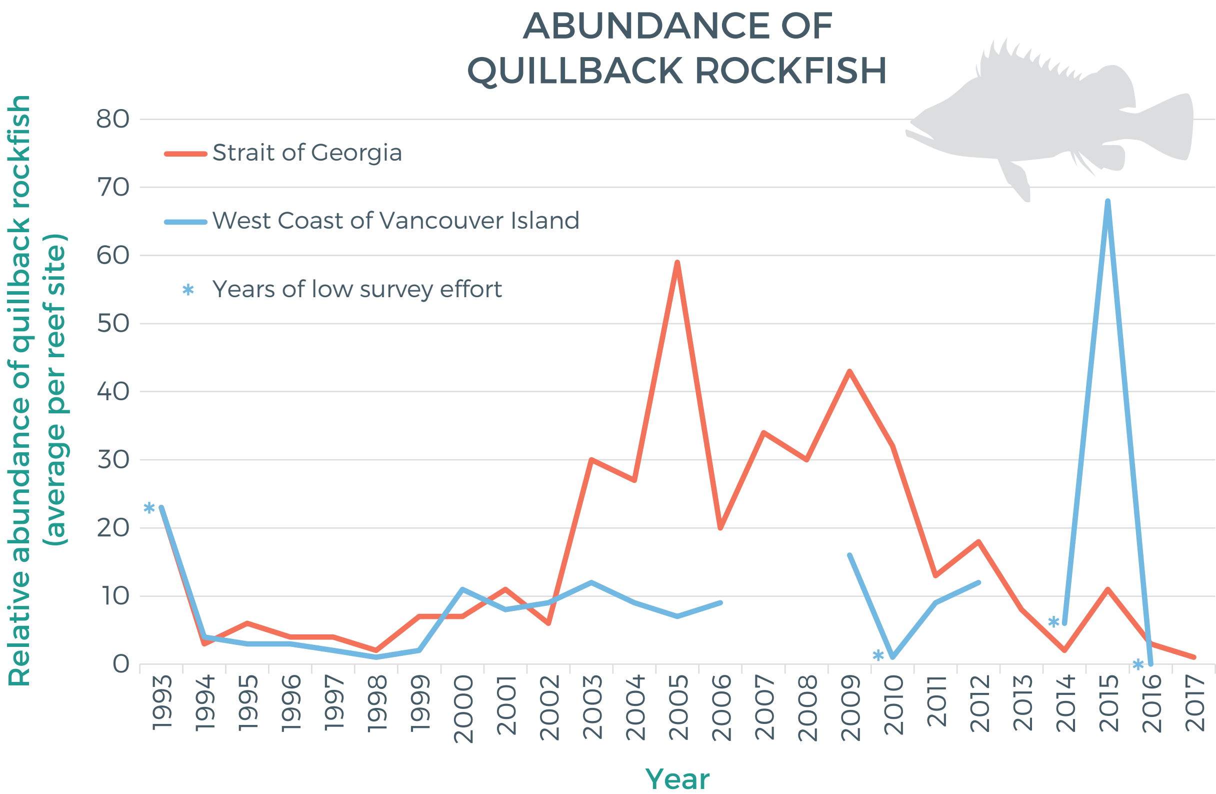


Figure 2. Relative abundance of quillback rockfish in the Strait of Georgia and the west coast of Vancouver Island between 1993 and 2017. Data presented, from citizen science surveys, are relative abundance based on survey enumeration methods used by Pacific Marine Life Surveys.[7] Years of low survey effort in the west coast of Vancouver Island (less than 10 surveys) are indicated. No surveys were conducted in 2007, 2008 or 2013. Average number of surveys per year, excluding years without surveys, in the region was 17. Average number of surveys per year in the Strait of Georgia through the same time period was 119, with a minimum of 71 surveys in any given year. Data source: Donna Gibbs, Pacific Marine Life Surveys.

Young rockfish abundance takes off in 2016

2016 marked an exceptional year class for some rockfish species. An unprecedented abundance of young of the year was documented by the diving community along the Pacific coast from Neah Bay, Washington to the central coast of British Columbia.[8] This booming year class highlights what can occur when the necessary environmental and food conditions are just right. Records of young rockfish counted during dive surveys based out of the Hakai Institute on B.C.'s central coast demonstrate a spike in abundance in 2016, such that counts more than doubled what had been observed in any of the three previous years (Figure 3, 4).

Figure 3. Unusually high abundances of young rockfish observed in 2016 on the central coast of B.C. (Video capture: Jenn Burt)

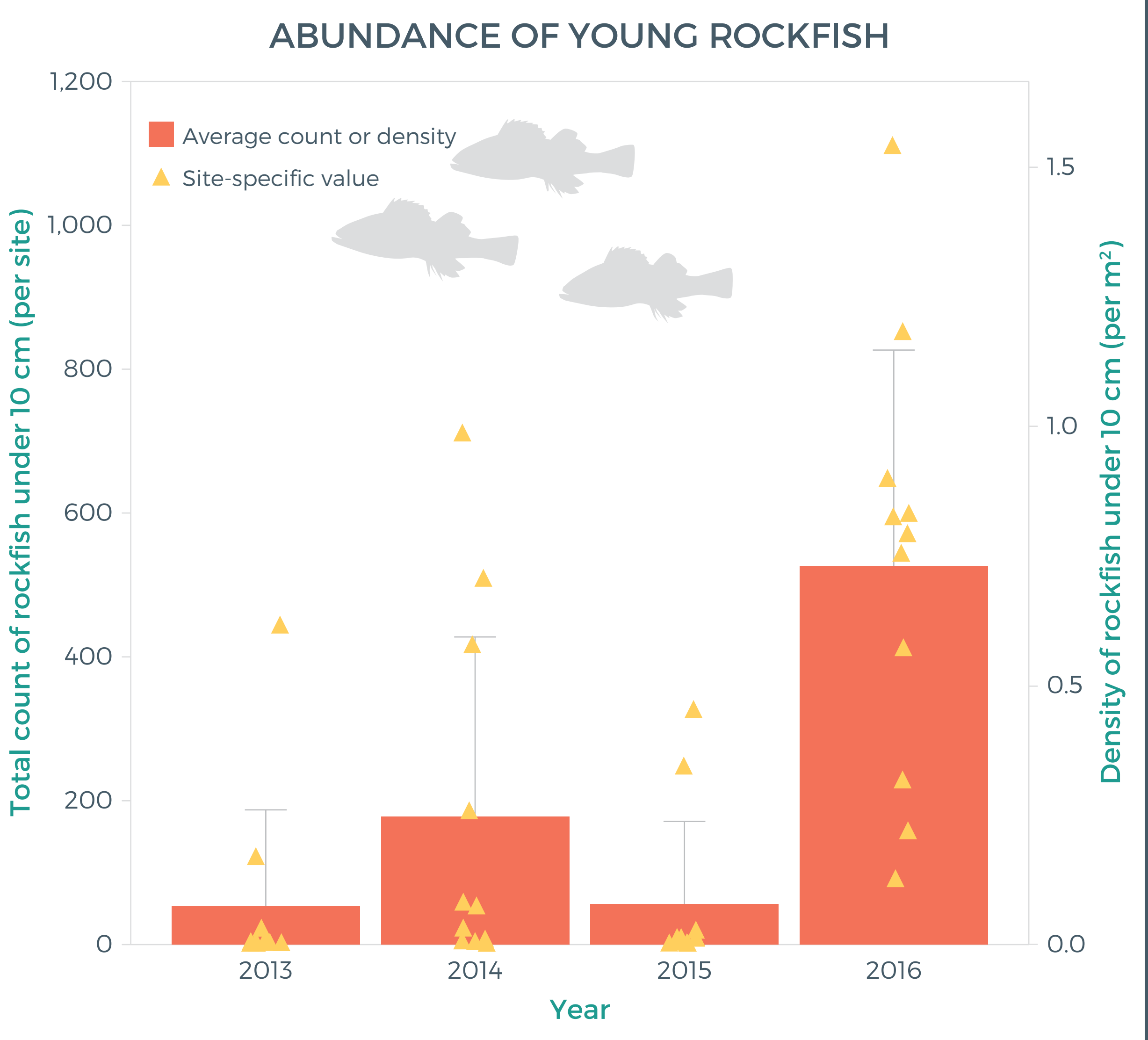


Figure 4. Abundance of young rockfish (10 cm or smaller) that were recorded by divers during scuba surveys at 11 rocky reef sites on the central coast of B.C. The bars indicate the average total count or density of young rockfish across all sites (+ standard deviation). The triangles show the actual values for each individual reef site. These data were collected by Jenn Burt and Anne Salomon as part of the reef monitoring surveys supported by Coastal Marine Ecology and Conservation Lab at Simon Fraser University and the Hakai Institute. For more information regarding these data, contact Anne.Salomon@sfu.ca.

Juvenile quillback rockfish. (Photo: Bernie Hanby)

Why is it important?

Thirty-seven species of rockfishes occur in British Columbia waters. Some species are only regionally abundant such as canary rockfish, China rockfish and deacon rockfish that predominantly occur on the outer coast. Some rockfishes have quite small home ranges and high site fidelity,[9] and many are long-lived species – quillback and yelloweye rockfishes live approximately a century – making them highly susceptible to overfishing.[10] As populations were severely depleted just 25 years ago, detectable population recovery may still be decades away.

Rockfishes are an important link in the rocky reef communities of the Northeast Pacific.[11] These mid-level predators eat crustaceans and small fishes and are consumed by larger reef fish and small marine mammals.

Is there a particular importance or connection to First Nations?

Quillback rockfish and other species of rockfish are an important component of Coastal First Nations' diets, as they provide food security year-round.[12] An archeological study conducted in Barkley Sound on the west coast of Vancouver Island recovered and examined skeletal remains of rockfish species, indicating regular use by First Nations communities for over 1,500 years.[13] In three communities in Barkley Sound, remains of rockfish species were found in 96 percent of excavation unit assemblages. Further supporting the importance of rockfish species to Coastal First Nations, a meta-analysis of 40 years' worth of zooarcheological data from this coast found widespread inclusion of rockfish in First Nations diets.[14]

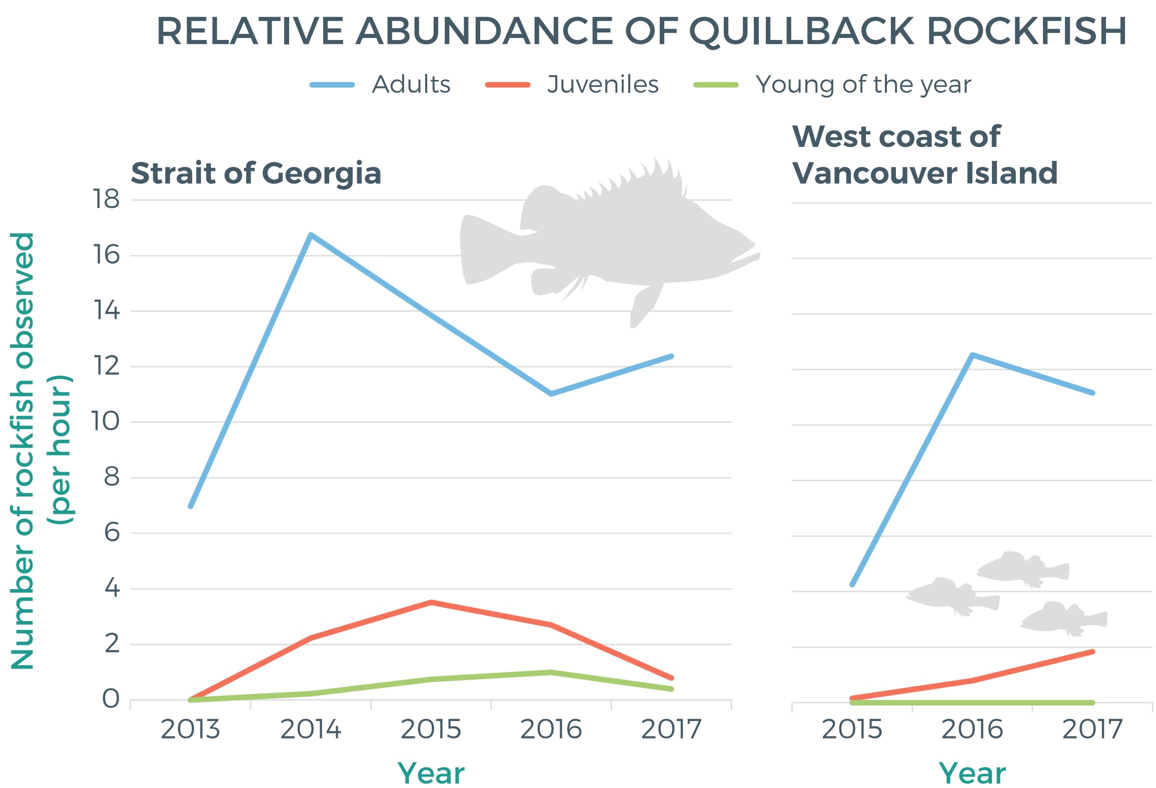


Figure 5. Relative abundance (individuals sighted per hour) of quillback rockfish of different life stages, observed in the Strait of Georgia (2013-2017) and the west coast of Vancouver Island (2015-2017). Data for 2013 and 2014 on the west coast of Vancouver Island is not available. Data Source: Roving diver biodiversity surveys, Howe Sound Research and Conservation, Coastal Ocean Research Institute, an Ocean Wise initiative.

What is the current status?

Long-term abundance records for quillback rockfish indicate little recovery since overfishing into the 1990s. Roving-diver biodiversity surveys from 1993 to 2017[15] show an average abundance (including adults, juveniles and young of the year[16]) of quillback rockfish of 10 and 16 individuals per reef site for the west coast of Vancouver Island and Strait of Georgia regions, respectively (Figure 2). (Note that counts as high as 1,000 fish per hour have been recorded for other species of rockfish in years of high abundance.) An apparent spike in abundance in the west coast of Vancouver Island for 2015 was the result of a very high count at one site on northeast Vancouver Island, demonstrating high site-to-site variability. Removing this outlier reduces the abundance score from 68 to 15 quillback rockfish for that year. Owing to the small home ranges of quillback rockfish, high site-to-site variability of abundances is expected.

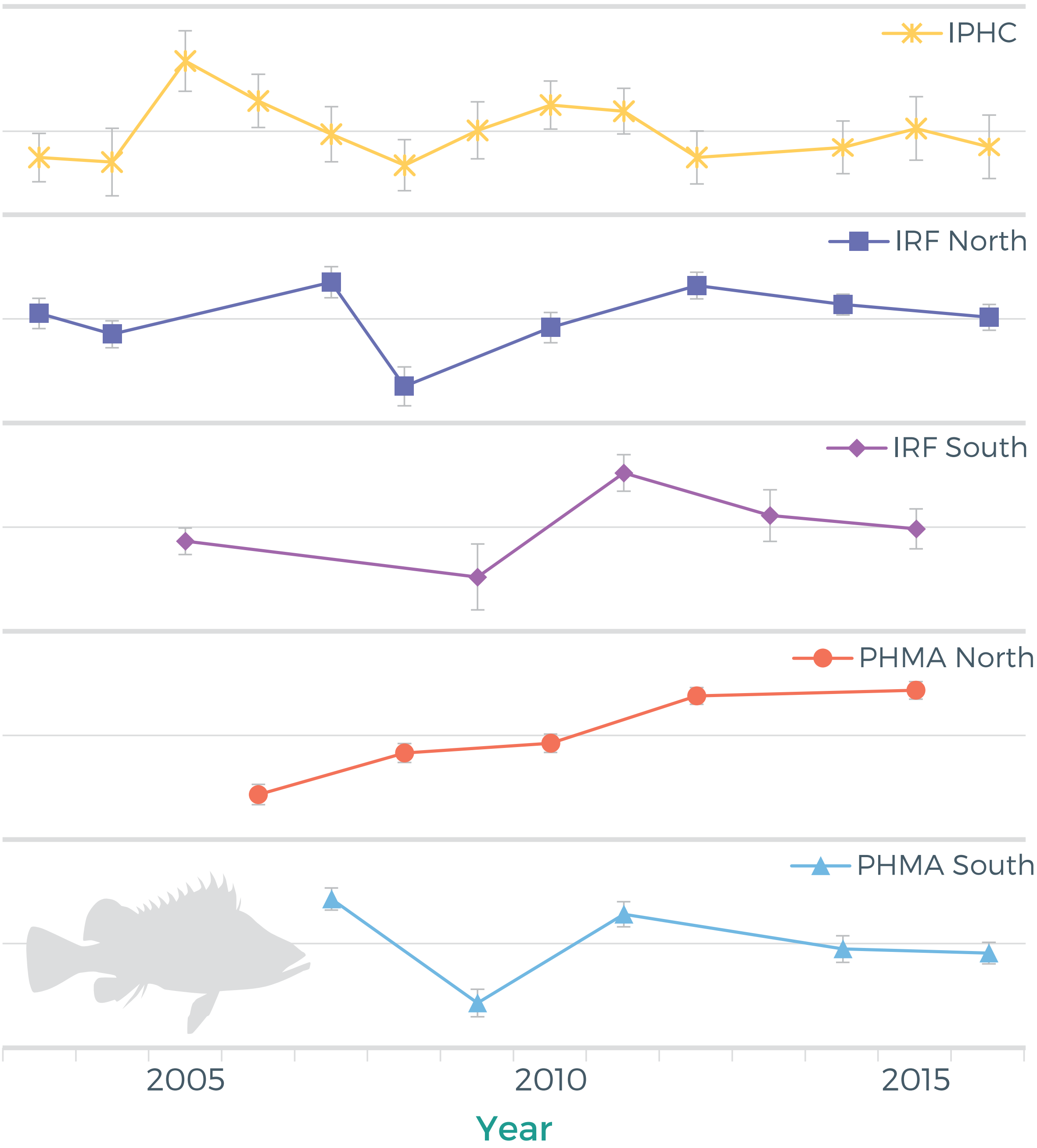
A notable increase in observations of quillback rockfish in the Strait of Georgia occurred between 2002 and 2011, especially observations of juvenile and young of the year[17] (Figure 2). This decade-long increase began shortly after the millennial climate regime shift[18] and ended in about 2011. A climate regime shift for 2011 has been proposed, based in part on the period of increase observed for quillback rockfish, and in part on additional long-term biodiversity data.[19] Climate regimes are characterized by either warm or cold patterns in sea surface temperature (tracked by the National Oceanic and Atmospheric Administration's (NOAA) Oceanic Niño Index[20]) and can relate to trends in biodiversity.[21] The current climate regime starting in 2011 corresponds with lower recruitment success of quillback rockfish in the Strait of Georgia.[22] However, the relationship may not be causal. Not only do abiotic conditions need to be ideal, but biotic conditions, or food sources that rockfish rely on, need to be in abundance for each developmental stage of the rockfish in order to see significant year class success such as in 1926, 1946, and 1968. These quillback year classes supported the commercial fisheries for the latter half of the 20th century.

Limited years of data from an age-based survey of rockfish populations conducted by the Coastal Ocean Research Institute, an initiative of Ocean Wise, and citizen scientists indicate that quillback rockfish abundance in both the Strait of Georgia and the west coast of Vancouver Island has not changed significantly in the last few years (Figure 5). Both areas show evidence of low overall recruitment (indicated by low numbers of young of the year) and a predominantly adult population.

It is not surprising that indices from longline surveys undertaken by DFO (some surveys in collaboration with industry) also provide little evidence of consistent positive or negative trends in quillback rockfish abundance between 2003 and 2016 (Figure 6). The possible exception is the Pacific Halibut Management Association (PMHA) North longline survey that shows a slightly positive trend in the quillback rockfish index, but little change between 2012 and 2015. Trawl surveys do not provide a reliable index for quillback rockfish abundance, as the relative error associated with estimates provided by DFO indicated that most estimates were unreliable. Therefore, trawl survey data are not included here.

The most recent stock assessment for quillback rockfish, from 2011,[25] concludes that both outside and inside stocks appear to be in the "cautious" zone using DFO's Precautionary Approach and Fisheries Reference Points framework – however, the uncertainty associated with these estimates is high. This assessment document also discusses recovery potential as estimated by the stock assessment model. Assuming catches occur at the level of 2017 total allowable catch (TAC) – 147 tonnes outside and 22 tonnes inside[26] – for 90 years hence, outside quillback stocks have about a 75 percent chance of recovering to the "healthy" zone, and inside stocks have about an 88 percent chance of similar recovery. If we are looking for 95 percent probability of recovery to the "healthy" zone in 90 years, the model estimates that catch must be lower than 60 tonnes outside and nil in inside waters.[27]

QUILLBACK ROCKFISH BIOMASS INDICES FROM LONGLINE SURVEYS



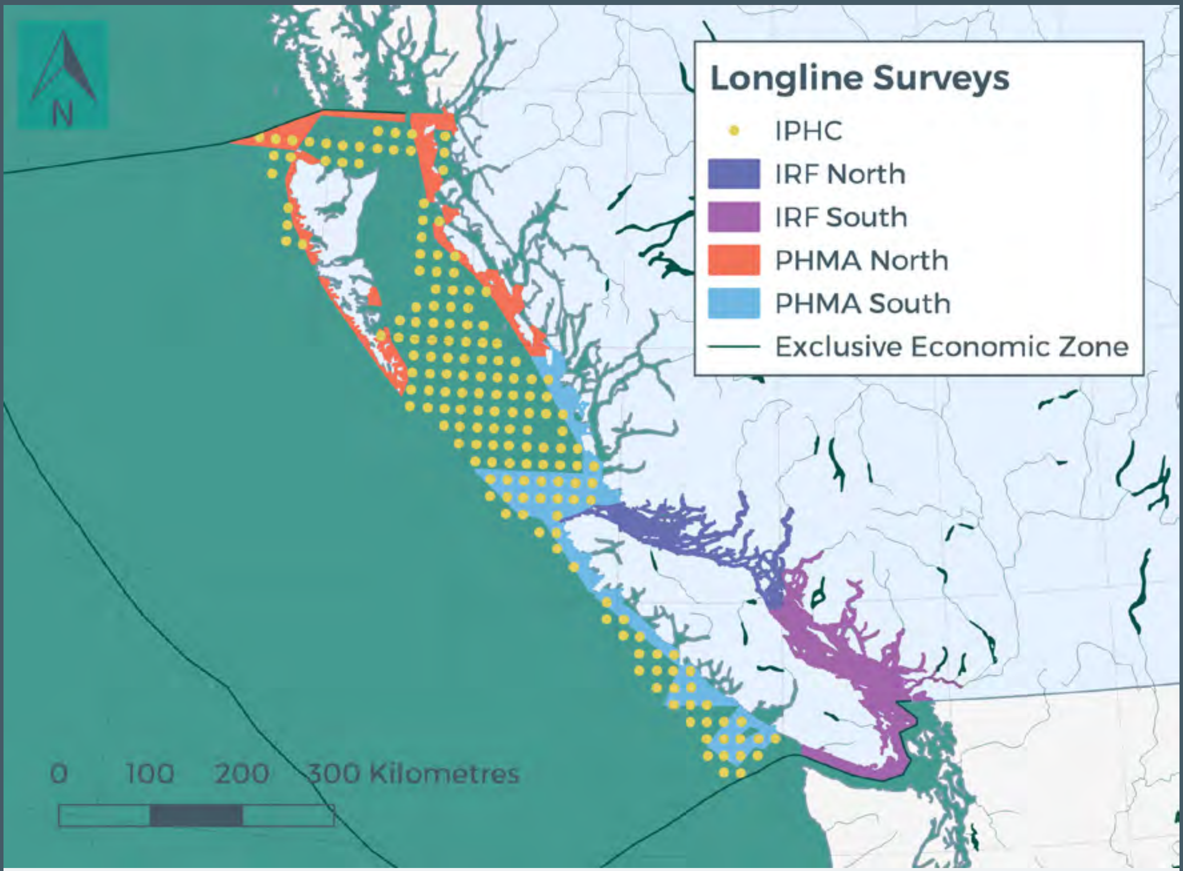


Figure 6. Quillback rockfish biomass indices (scaled anomalies[23]) from longline surveys that cover five areas. These surveys are named International Pacific Halibut Commission (IPHC), Inshore Rockfish North (IRF North), Inshore Rockfish South (IRF South), Pacific Halibut Management Association North (PHMA North), and Pacific Halibut Management Association South (PHMA South). Error bars illustrate relative error; all values are less than 0.4. Data provided by DFO.[24] Map: Corresponding longline survey areas.

What is being done?

In an effort to protect and recover declining rockfish populations, Fisheries and Oceans Canada (DFO) developed a management strategy for inshore rockfish in 2002. Implementation of 164 Rockfish Conservation Areas (RCAs) along the B.C. coast was completed in 2007.[28] Fifteen RCAs were designated in Johnstone Strait, 21 in central and northern B.C. including Haida Gwaii, 49 on the west coast of Vancouver Island, and the remaining 79 were located in the Strait of Georgia.[29] Only 10 years have elapsed since RCAs were put in place and, given the long life span of many rockfish species, it is too early to determine if RCAs or other conservation measures have had an impact on inshore rockfish recovery. One study has shown that sport fishery compliance with fishing restrictions in RCAs is low.[30]

Regional fishing closures put in place to conserve inshore rockfish, following the implementation of Rockfish Conservation Areas in 2007, including many on the South Coast have been renewed annually. Recreational and commercial catches are tracked by DFO and formal stock assessment is undertaken approximately every five years. Limits to commercial catch (i.e., total allowable catch [TAC]) of quillback rockfish are set annually in the Integrated Fisheries Management Plan for groundfish.[31] The 2011 quillback rockfish stock assessment recommended separating quillback rockfish allowable catch from that for an aggregate of rockfish species in order to strengthen commercial management and mitigate the possibility of overharvest. This change was implemented in 2015.[32] TACs are specific to Pacific Fishery Management Areas and gear type (i.e., hook-and-line versus trawl).

DFO actively monitors commercial groundfish fisheries to ensure high accountability for what and how much is caught. Since 2006, all fishing trips targeting groundfish are tracked spatially and 100 percent of the catch, whether it is destined for market or not, is accounted for against quotas. In 2009, DFO developed its Sustainable Fisheries Framework (SFF),[33] which includes policies such as the precautionary approach and ecosystem-based management. Implementation of these policies is a work in progress.[34]

The DFO's Offshore Assessment and Monitoring Section of the Aquatic Resources Research and Assessment Division runs the survey program, which includes the longline surveys mentioned in this article. The Coastal Ocean Research Institute (CORI) annually collects data on rockfish abundance through citizen science scuba surveys, known as the Rockfish Abundance Survey.

What can you do?

Individual and Organization Actions:

- Participate in citizen science SCUBA surveys.
- Report illegal fishing practices to DFO 604-666-3500 (1-800-465-4336).
- Follow posted fishing regulations.

Government Actions and Policy:

- Commit more resources to understanding the effects of RCAs. For example, monitor rockfish populations in RCAs with suitable habitat.
- Simplify regulations in RCAs.
- Increase public education and awareness of closures to commercial and recreational fisheries, and the status of rockfish populations.

Resources

COSEWIC report on Quillback Rockfish
https://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_Quillback%20Rockfish_0810_e.pdf

Fisheries and Oceans Canada Rockfish Conservation Areas (RCAs), Pacific Region
www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/rcaacs/index-eng.html

Integrated Fishery Management Plan – Groundfish
http://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/2017/ground-fond-sm-2017-eng.html

Stock Assessment and Recovery Potential Assessment for Quillback Rockfish
http://www.dfo-mpo.gc.ca/Library/346320.pdf

Footnotes

[1] Yamanaka, K., and G. Logan. 2010. Developing British Columbia's Inshore Rockfish Conservation Strategy. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 2: 28-46. doi: 10.1577/C08-036.1.

[2] COSEWIC. 2009. COSEWIC assessment and status report on the Quillback Rockfish Sebastes maliger in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 71 pp. Accessed Dec 15, 2017 www.sararegistry.gc.ca/status/status_e.cfm.

[3] The PMHA survey is a random, depth-stratified survey that industry does in collaboration with DFO.

[4] Yamanaka and Logan 2010.

[5] A climate regime is a period of years, often a decade or so, when a set of climate conditions persist. Regimes are often characterized by either warm or cold patterns in sea surface temperature.

[6] Marliave, J.B., Senior Research Scientist, Coastal Ocean Research Institute, Personal Communication, 2017.

[7] The relative abundance of quillback rockfish observed during a dive was estimated visually and grouped into a numerical category: none = 0; few ≤ 10; some ≤ 25; many ≤ 50; very many ≤ 100; abundant ≤ 1,000; very abundant = thousands. To calculate annual averages, maximum values for each category were used (3,000 for "very abundant") and these values were summed and divided by the total number of dives to account for sighting frequency.

[8] Reports from Janna Nichols at Neah Bay and Jenn Burt on the central coast of B.C., personal communication with each by email in 2017. See photographs at https://www.eikojonesphotography.com/rockfish-explosion/

[9] Hannah, R.W., and P.S. Rankin. 2011. Site Fidelity and Movement of Eight Species of Pacific Rockfish at a High-Relief Rocky Reef on the Oregon Coast. North American Journal of Fisheries Management 31(3):483-494. https://doi.org/10.1080/02755947.2011.591239

[10] Love, M., Yoklavich, M. and L. Thorsteinson. 2002. The Rockfishes of the Northeast Pacific. Los Angeles, University of California Press.

[11] Frid, A., Connors, B., Cooper, A.B. and Marliave, J. 2013. Size-structured abundance relationships between upper- and mid-trophic level predators on temperate rocky reefs. Ethology, Ecology & Evolution. 25(3): 253-268.

[12] McGreer, M., and A. Frid. 2017. Declining size and age of rockfishes (Sebastes spp.) inherent to indigenous cultures of pacific Canada. Ocean & Coastal Management 145: 14-20.

[13] McKechnie I. 2007. Investigating the complexities of sustainable fishing at a prehistoric village on western Vancouver Island, British Columbia, Canada. Journal for Nature Conservation 15(3): 208-222.

[14] McKechnie, I. and M.L. Moss 2016. Meta-analysis in zooarchaeology expands perspectives on Indigenous fisheries of the Northwest Coast of North America. Journal of Archaeological Science: Reports. 8: 470-485.

[15] Data Source: Pacific Marine Life Surveys

[16] Small fish, from reproduction in the current year

[17] Marliave, J.B., Senior Research Scientist, Coastal Ocean Research Institute, Personal Communication, 2017.

[18] Marliave, J.B., C.J. Gibbs, D.M. Gibbs, A.O. Lamb & S.F.J. Young. 2011. Biodiversity stability of shallow marine benthos in Strait of Georgia, British Columbia, Canada through climate regimes, overfishing and ocean acidification, pp. 49-77 In: Biodiversity loss in a change planet, Oscar Grillo and Gianfranco Venora (Eds.), ISBN: 978-953-307-707-9.

[19] Marliave, J. B., D. M. Gibbs, L. A. Borden & C. J. Gibbs. (Accepted). Seabed Biodiversity shifts identify climate regimes: the 2011 climate regime shift. InTech Publishing, Positive signals in biodiversity protection.

[20] https://www.climate.gov/news-features/understanding-climate/climate-variability-oceanic-ni%C3%B1o-index

[21] Marliave et al. 2011

[22] Marliave, J.B., Senior Research Scientist, Coastal Ocean Research Institute, Personal Communication, 2017.

[23] Anomalies shown are deviations from the mean biomass estimate for that survey over the time period illustrated. Error bars illustrate relative error of each estimate. We charted scaled anomalies to enable comparison of trends through time, regardless of relative abundance. Our illustration of the survey index data has been reviewed by DFO.

[24] The methodology for calculating abundance indices was developed for trawl surveys, and may not adequately index line surveys due to the different survey methodologies. The IPHC survey was designed for halibut, therefore caution is required when examining trends in other species. Relative error of estimates, a measure of precision, or the capability of a survey to track changes in a population over time, was provided with the data. Estimates with high relative error (greater than 0.4) are unreliable.

[25] DFO. 2012. Stock Assessment And Recovery Potential Assessment For Quillback Rockfish (Sebastes Maliger) Along The Pacific Coast Of Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/072.

[26] TAC is documented in the Integrated Fisheries Management Plan: DFO. 2017. Pacific Region. Integrated Fisheries Management Plan. Groundfish. Effective February 21, 2017. http://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/2017/ground-fond-sm-2017-eng.html

[27] The paragraph describing stock assessment and recovery potential was added by Karin Bodtker, editor of this Ocean Watch series, following an anonymous review. Karin has a background in Fisheries Science.

[28] http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/rca-acs/index-eng.html

[29] Yamanaka and Logan 2010.

[30] Haggarty, D.R., S.J.D. Martell & J.B. Shurin. 2016. Lack of recreational fishing compliance may compromise effectiveness of Rockfish Conservation Areas in British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 10.1139/cjfas-2015-0205.

[31] DFO 2017.

[32] DFO. 2015. Pacific Region. Integrated Fisheries Management Plan. Groundfish. Effective February 21, 2015. Accessed February 28, 2018. http://waves-vagues.dfo-mpo.gc.ca/Library/40596837.pdf

[33] DFO. 2016. Sustainable Fisheries Framework. Accessed January 23, 2018. http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/overview-cadre-eng.htm.

[34] Office of the Auditor General of Canada. 2016. Report 2 – Sustaining Canada's Major Fish Stocks – Fisheries and Oceans Canada. 2016 Fall Reports of the Commissioner of the Environment and Sustainable Development. Accessed February 28, 2018 http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201610_02_e_41672.html

Lingcod

AUTHORS
Laura Borden and **Karin Bodtker**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWERS
Jeff Marliave, Senior Scientist, Coastal Ocean Research Institute, an Ocean Wise initiative

Dana Haggarty, Research Biologist, Pacific Biological Station, Fisheries and Oceans Canada

What's happening?

Lingcod in British Columbia experienced extensive fishing from the 1950s through the 1990s. Current commercial catches in outside waters (i.e., north and west of Vancouver Island, Figure 1) are about one sixth of the historical peak (Figure 2). In 2011, stock status in outside waters was assessed as healthy,[1] even though estimated biomass was lower than in any previous year.[2] Annual commercial catch in the outside waters has declined by about 25 percent since this last assessment (Figure 2).

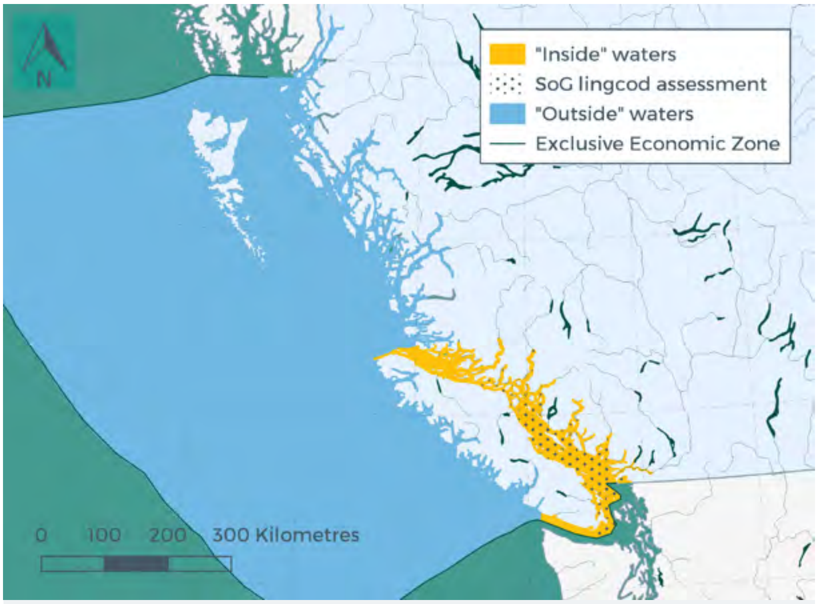


Figure 1. Inside waters include the Strait of Georgia (SoG), Juan de Fuca Strait and Queen Charlotte Strait, while outside waters refer to everything else in the Canadian Pacific Exclusive Economic Zone.

Lingcod (Photo: Lee Newman)

Fishing for lingcod in the Strait of Georgia (SoG) (Figure 1) began in the 1800s but catches were not recorded separately from other species until 1927.[5] Catch statistics show that lingcod were fished heavily in the strait in the early 20th century, with a peak of over 4,000 tonnes in 1944[6] (Figure 3). One reconstruction suggests the SoG stocks reached a historic low in 1991, to an estimated 2.6 percent of the biomass in 1951.[7] These stocks were recently assessed as being in the critical to cautious zone,[8] despite commercial fishing restrictions that were put in place in 1990 and a prohibition of recreational retention between 2002 and 2006. Currently, most of the inside waters are closed to commercial lingcod retention, therefore reported catch, which is minimal (Figure 3), comes from small areas that are open or is non-targeted (i.e., bycatch). Retention by recreational fisheries is restricted through area and seasonal closures, size restrictions (65 cm), and daily and annual bag limits. Both 2005 and 2014 assessments of SoG stocks conclude that lingcod spawning biomass in the Strait of Georgia is increasing, albeit slowly.

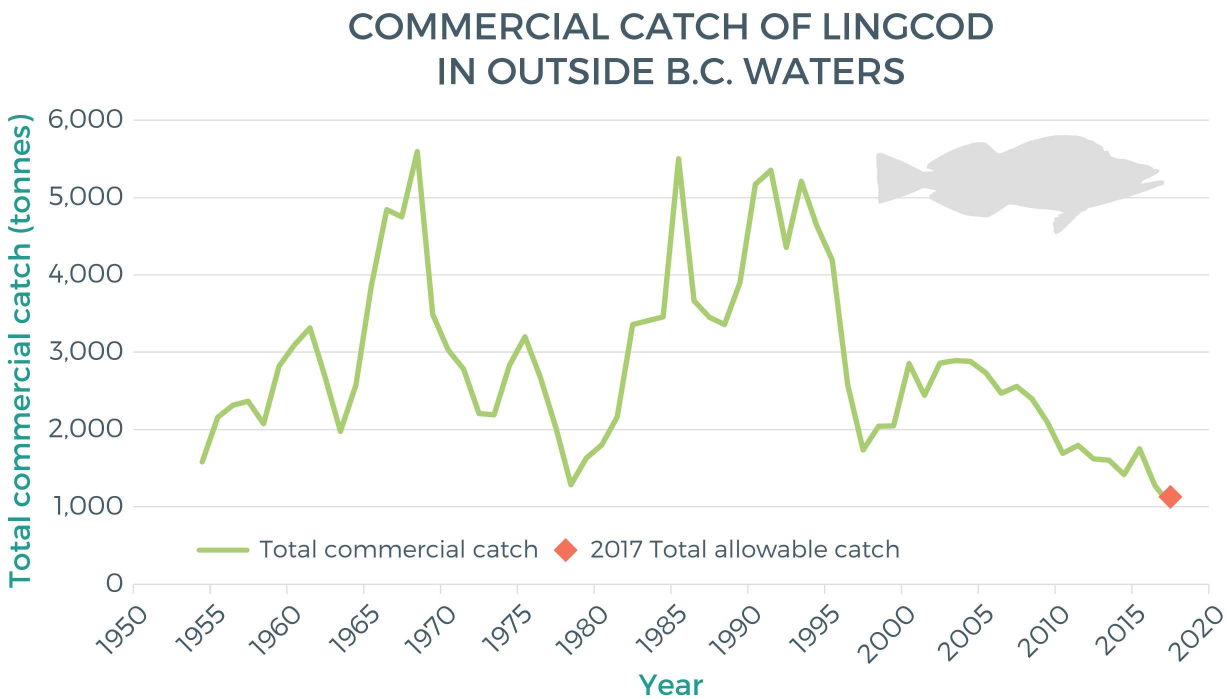


Figure 2. Total commercial catch (tonnes, hook and line and trawl gear combined) of lingcod in outside British Columbia waters. TAC is total allowable catch, set to 1,130 tonnes for the outside waters in the 2017 Integrated Fisheries Management Plan.[3] Source: Fisheries and Oceans Canada; data illustrated may be incomplete.[4]

Why is it important?

Lingcod range from Northern California to the Aleutian Islands in Alaska and are unique to this coast of North America. They are an ecologically important top predator on rocky reefs throughout their range, consuming smaller fish such as hake, herring, rockfish and other small fishes.[12,13] Lingcod rely on the nooks and crannies around large boulders or crevices with good water flow for successful spawning during the winter months. Research has shown that male lingcod, who actively guard their egg masses, return to the same spawning locations year after year.[14]

Lingcod have a long history of commercial and recreational exploitation in B.C. The commercial fishery for lingcod was ranked fourth in importance throughout the first half of the 20th century.[15] This status as a top commercial fishery has waned, but the sport fishery still targets and prizes lingcod. Fishing is one

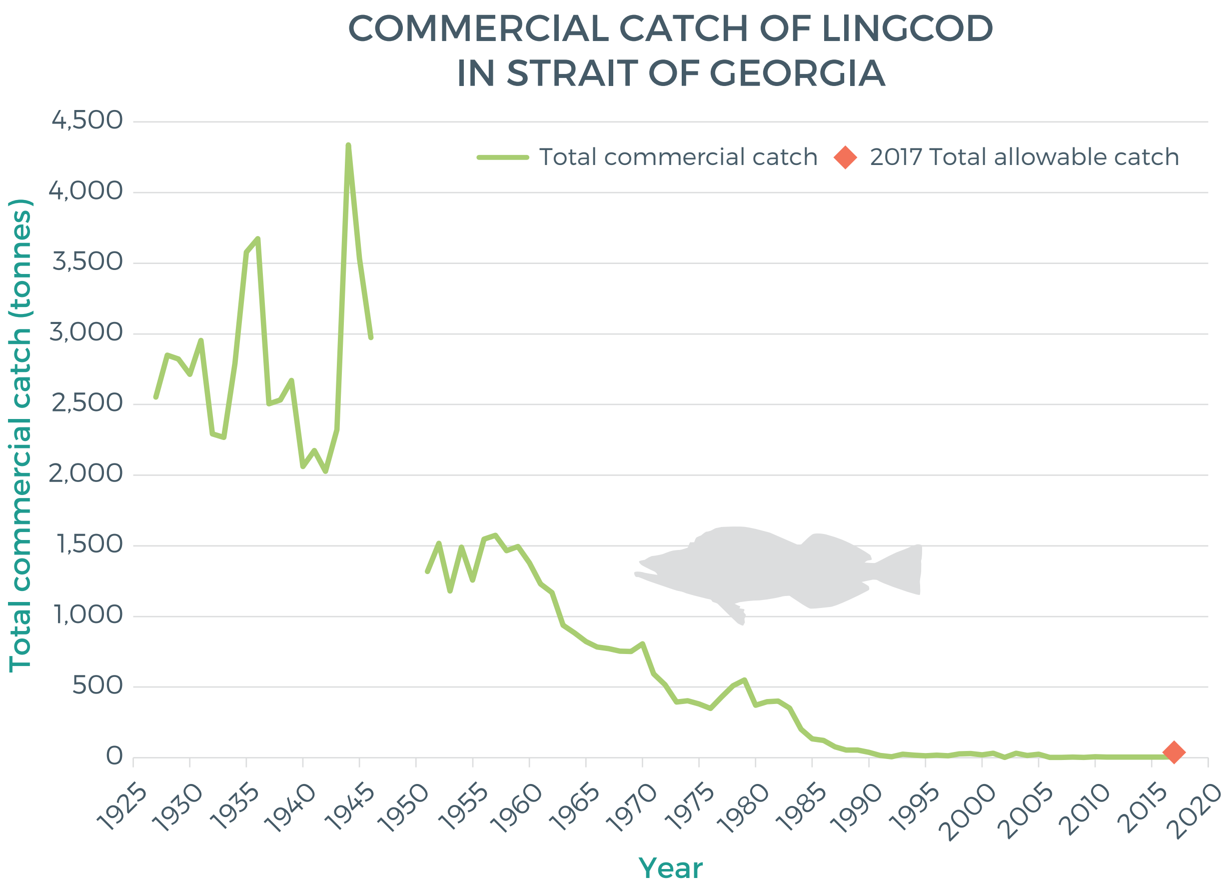


Figure 3. Total commercial catch[9] (tonnes, hook and line and trawl gear combined) of lingcod in the Strait of Georgia (missing data for 1947-1950). TAC is total allowable catch, set to 38 tonnes for inside waters in the 2017 Integrated Fisheries Management Plan.[10] Data from 1986 to present[11] are for all "inside" waters (Figure 1). Source: Fisheries and Oceans Canada. Data illustrated may be incomplete.

of the main threats to lingcod populations, likely including illegal poaching. In addition, populations of sea lions and harbour seals, both significant predators of non-juvenile lingcod,[16] are increasing in abundance.[17,18,19] Large numbers of Steller sea lions are known to feed in the Strait of Georgia in winter and early summer.[20] The magnitude of the threat that these predators pose to lingcod recovery is not well understood. For example, analyses of harbor seal scat in Howe Sound have not been conducted since the 1980s, but scat studies could provide clarity on predation rates of local lingcod.

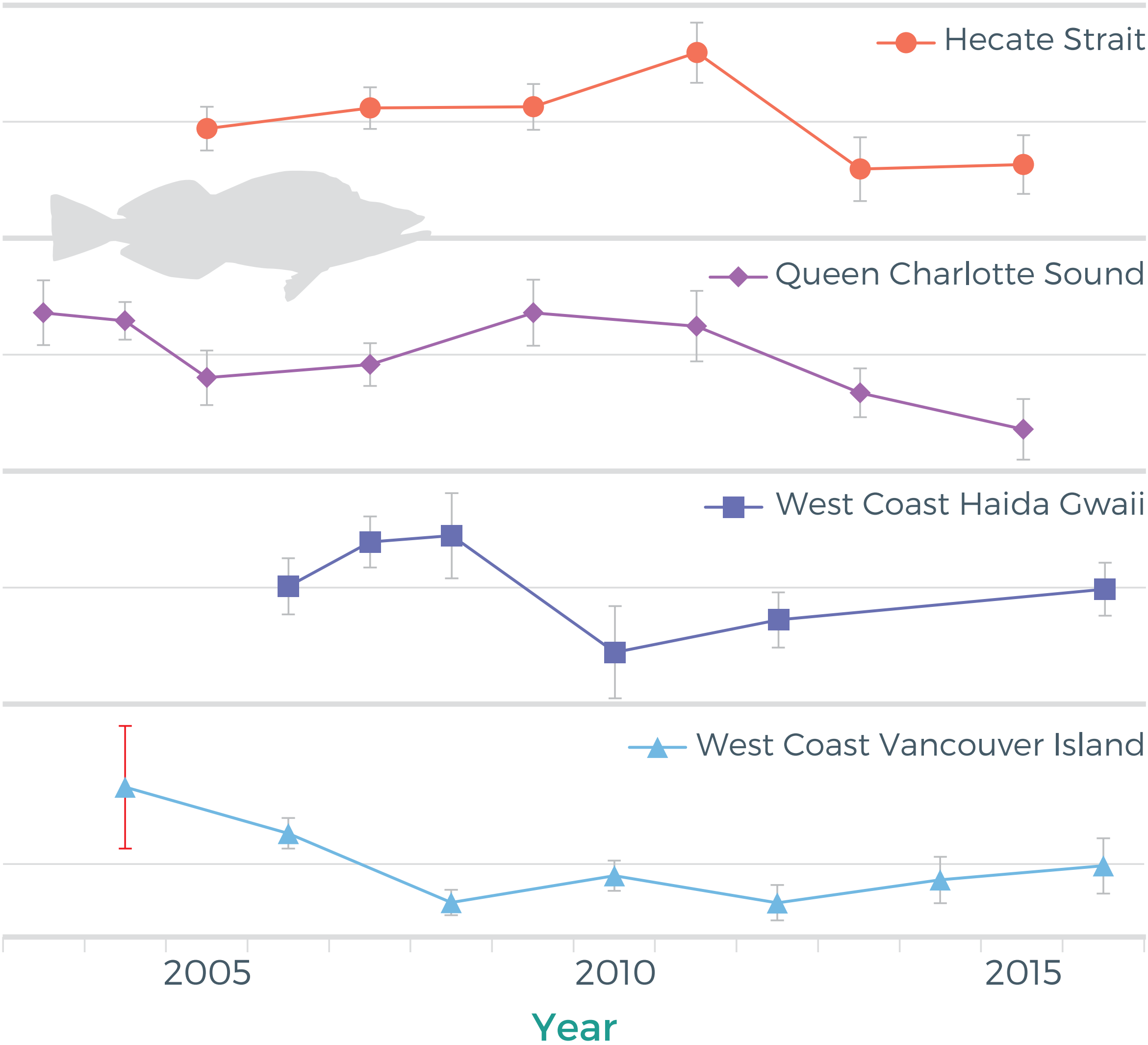
Diver surveying the spawning population of lingcod in 2013. (Photo: Ocean Wise)

What is the current status?

Data used to estimate stock status come from trawl surveys (for outside stocks only) and from records of commercial and recreational catch (e.g., commercial catch in Figures 2 and 3). Lingcod biomass indices developed from groundfish trawl survey data (2003–2016) show high year-to-year variability, with an overall decline except in the region to the west of Haida Gwaii (Figure 4, indices and survey areas).

Additional surveys using hook and line gear are used for research and to monitor status, but to date have not been used in the formal stock assessments. These surveys are named International Pacific Halibut Commission (IPHC), Inshore Rockfish North (IRF North), Inshore Rockfish South (IRF South), Pacific Halibut Management Association North (PHMA North), and Pacific Halibut Management Association South (PHMA South). Biomass indices from these surveys also show great year-to-year variability, but show overall increases in inside waters (e.g., IRF North and South) and decreases in outside areas (e.g., PHMA North and South surveys, Figure 5 indices and survey areas). The declining trend in the PHMA South survey was noted in the Fisheries and Oceans Canada (DFO) State of the Pacific Ocean report for 2016,[23] as was the increasing trend illustrated in the northern inside waters of Johnstone Strait (IRF North survey, Figure 5).[24]

LINGCOD BIOMASS INDICES FROM GROUNDFISH TRAWL SURVEYS



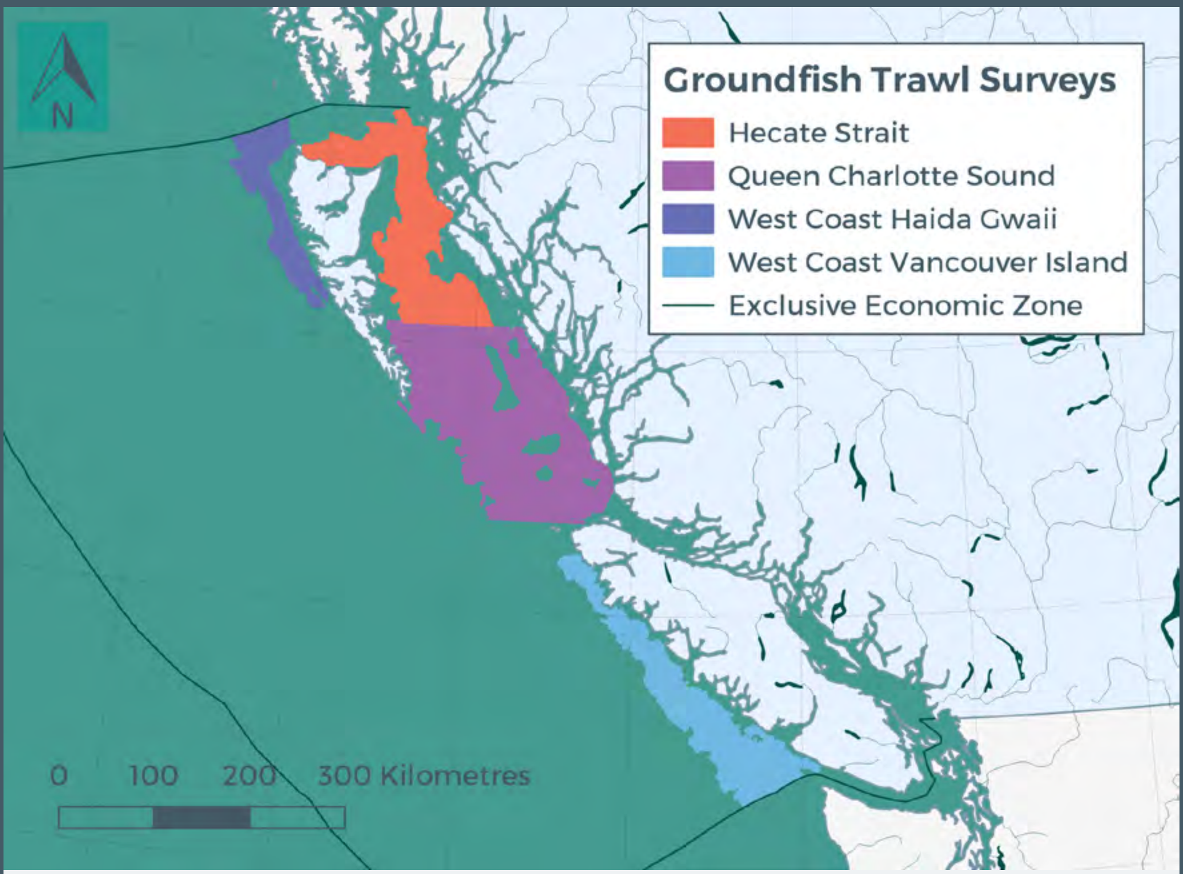
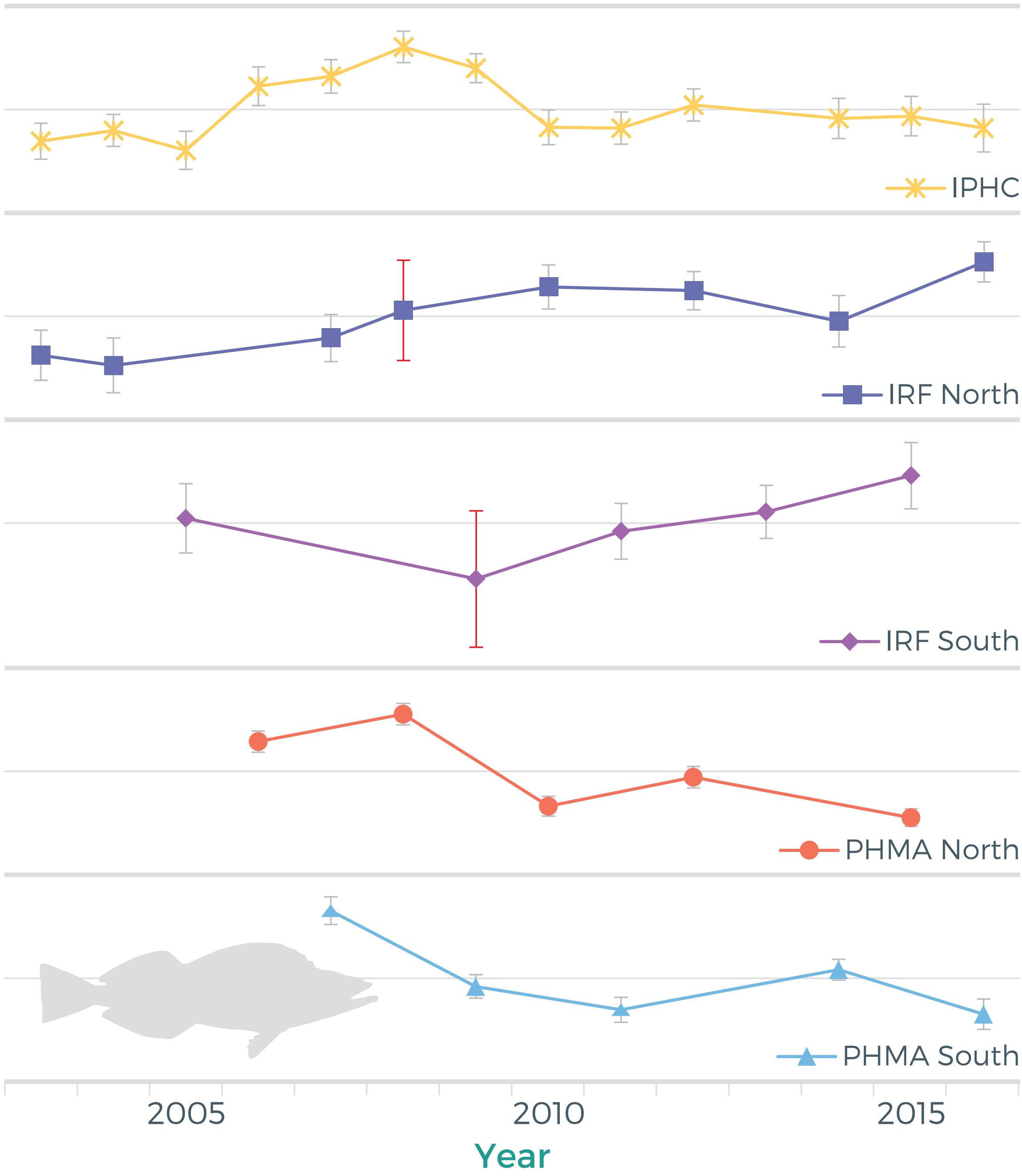


Figure 4. Lingcod biomass indices (scaled anomalies[21]) from groundfish trawl surveys in four areas: Hecate Strait, Queen Charlotte Sound, West Coast Haida Gwaii, and West Coast Vancouver Island (WCVI). The 2004 estimate from the WCVI survey is unreliable due to high relative error.[22] Source: DFO. Map: Corresponding groundfish trawl survey areas.

LINGCOD BIOMASS INDICES FROM LONGLINE SURVEYS



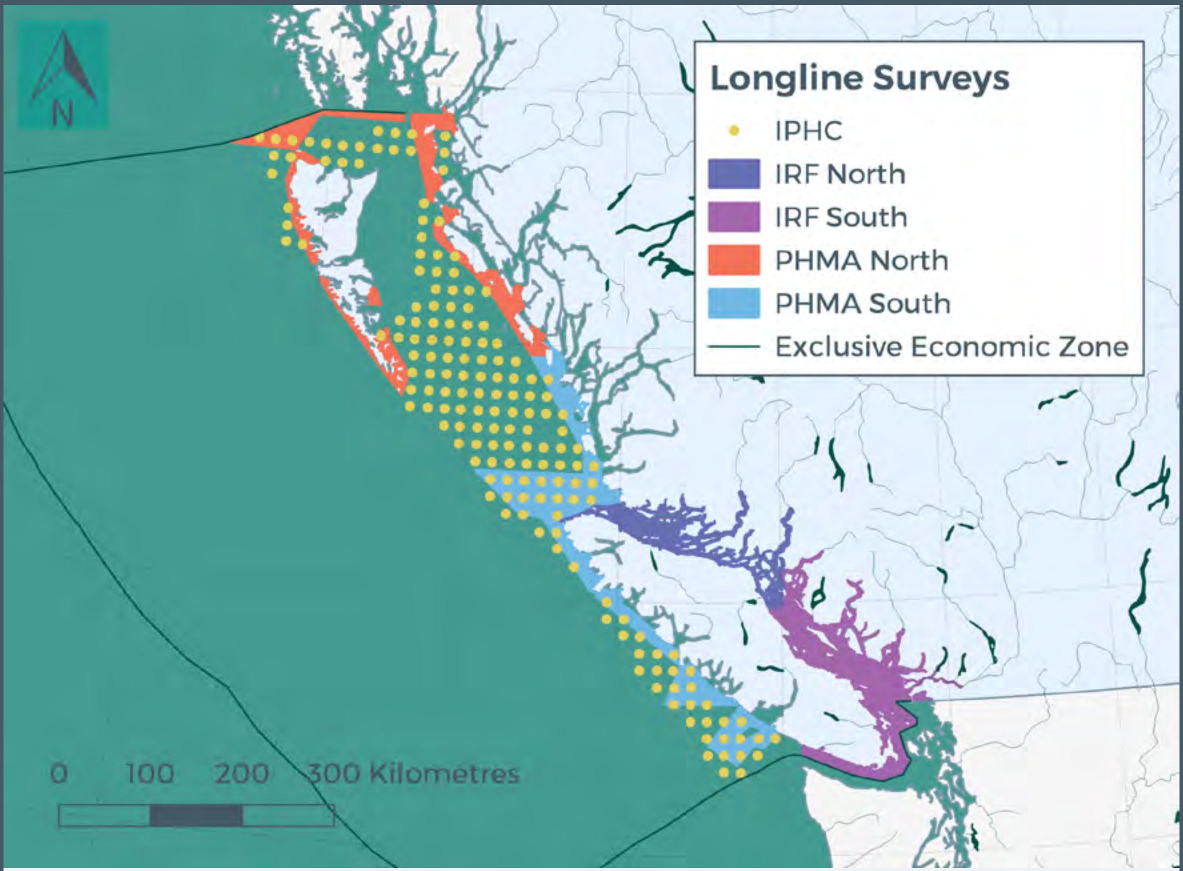


Figure 5. Lingcod biomass indices (scaled anomalies[21]) from longline surveys that cover five areas. The 2008 IRF North and 2009 IRF South estimates are unreliable due to high relative error.[22] Source: DFO. Map: Corresponding longline survey areas.[25]

Egg mass surveys, undertaken by citizen scientists and organized by the Coastal Ocean Research Institute, track the reproductive population of lingcod by recording a count of egg masses observed per hour. Data from these surveys also illustrate variability, but show no overall trend since 1996 (Figure 6). Three areas have been surveyed including the Strait of Georgia, northeast Vancouver Island, and the west coast of Vancouver Island. Some sub-regions such as Howe Sound did show an increase in spawning lingcod abundance, according to this survey, at the turn of the millennium.[26]

The spawning population survey data also show no long-term trend in the abundance of large egg masses, belonging to older lingcod and contributing disproportionately more to future generations, except possibly in the northeast Vancouver Island area (Figure 6), determined only by visual inspection. This potentially corroborates an increasing trend illustrated in the Inshore Rockfish North survey in the northern inside waters of Johnstone Strait (Figure 5).

We report on available data, but trends in indices from any of these surveys are not definitive of lingcod stock status, as many additional factors can influence the amount of lingcod caught in both trawl and longline surveys, or observed at scuba depths. For example, changing climatic conditions could be affecting the spatial or depth distribution of these populations.[28] However, trends that suggest increases in some areas and declines in other areas are not surprising, given that lingcod tend to have small home ranges.[29] It may be beneficial to examine population status and trends on a finer spatial scale, looking specifically at sub-regions of inside waters and outside waters to better understand local populations.

What is being done?

Regional closures and catch limits are in place to conserve lingcod, such as the closures in Howe Sound and winter recreational closures in the Strait of Georgia to hook-and-line jigging for rockfish and lingcod. Recreational and commercial catches are tracked by DFO and formal stock assessment is undertaken approximately every five years. Limits to commercial catch (i.e., total allowable catch [TAC] as shown for 2017 in Figures 2 and 3) of lingcod are set annually in the Integrated Fisheries Management Plan for groundfish. TACs are specific to Pacific Fishery Management Areas and gear type (i.e., hook-and-line versus trawl).[30] Scuba surveys of spawning lingcod populations are conducted annually through the Coastal Ocean Research Institute (Ocean Wise) citizen science Lingcod Egg Mass Survey.

The Fisheries and Oceans Canada (DFO) Offshore Assessment and Monitoring Section of the Aquatic Resources Research and Assessment Division runs the survey program, which includes several surveys mentioned in this article. Surveys use bottom trawl fishing gear, longline hook fishing gear, or longline trap gear (not discussed in this article) and cover most of the B.C. coast. Some of these surveys are conducted in collaboration with the commercial fishing industry.

DFO actively monitors commercial groundfish fisheries to ensure high accountability for what and how much is caught. Since 2006, all fishing trips targeting groundfish are tracked spatially and 100 percent of the catch, whether it is destined for market or not, is accounted for against quotas. In 2009, DFO developed its Sustainable Fisheries Framework (SFF),[31] which includes policies such as the precautionary approach and ecosystem-based management. Implementation of these policies is a work in progress.[32]

Lingcod (Photo: Jenn Burt)

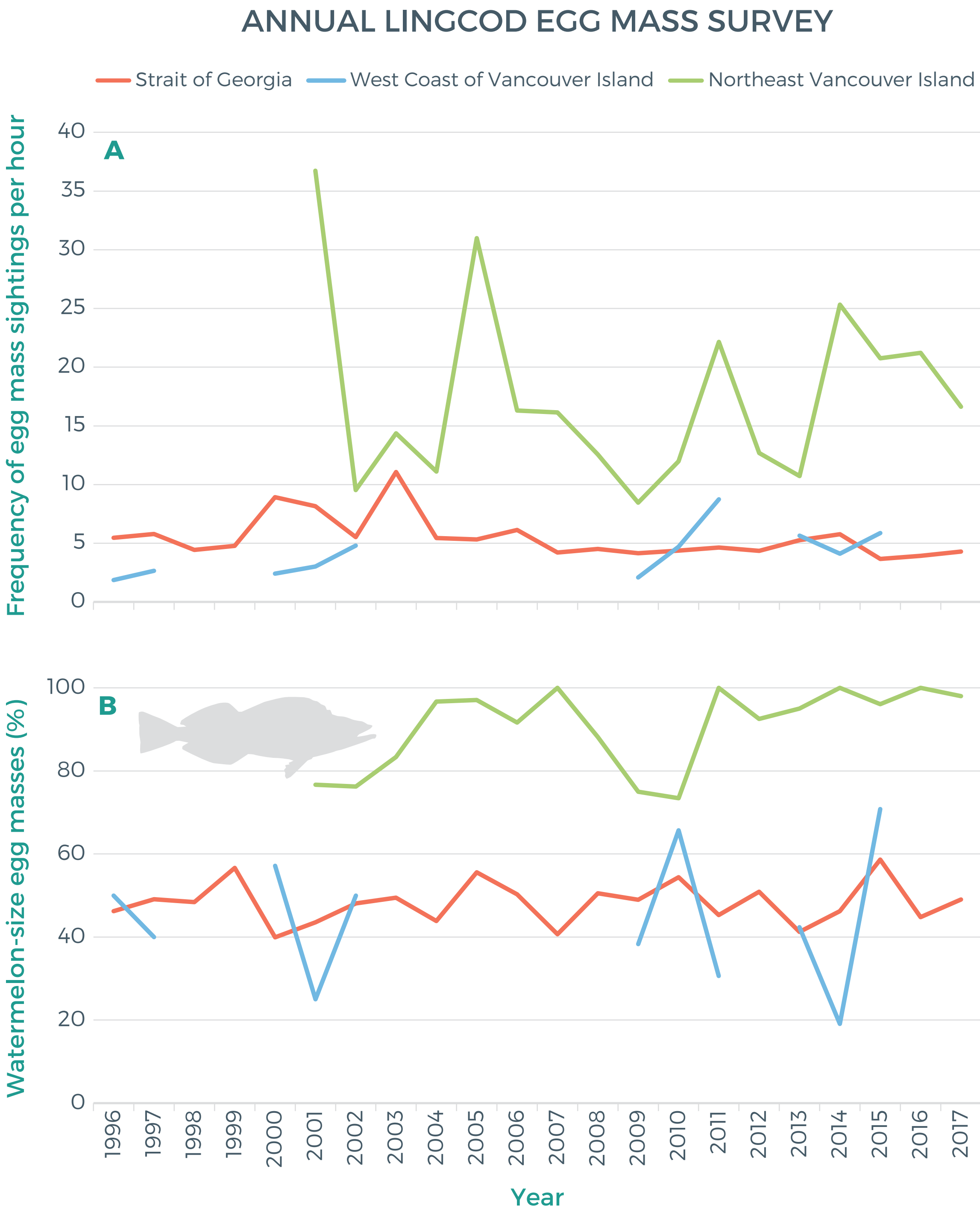


Figure 6. A: Frequency of lingcod egg mass sightings per hour diving effort. B: The percentage of watermelon size egg masses produced by females older than five years old. Areas surveyed from 1996 to 2017 are the Strait of Georgia (average of 91 surveys per year), West Coast of Vancouver Island (average of eight surveys per year), and northeast Vancouver Island (average of 4 surveys per year). Source: citizen science scuba surveys conducted for the Coastal Ocean Research Institute's annual Lingcod Egg Mass Survey.[27]

What can you do?

Individual and Organization Actions:

- Participate in citizen science SCUBA surveys.
- Report illegal fishing practices to DFO (604-666-3500).
- Follow posted fishing regulations.

Government Actions and Policy:

- Designate more resources to effective monitoring and enforcement of fishing closures.
- Increase public awareness of fishing regulations and closures for commercial and recreational fisheries.
- Undertake scat studies of lingcod predators (i.e., seals and sea lions) in areas where predators have increased and lingcod populations remain depressed.
- Consider undertaking stock assessments for lingcod at a finer spatial scale.

Footnotes

[1] Assessment of current stock status follows the Fishery Decision-making Framework Incorporating the Precautionary Approach with the definition of three stock status zones (i.e., healthy, cautious and critical). DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach. (Accessed 7 November 2017) http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/precaution-back-fiche-eng.htm

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[3] DFO. 2017. Pacific Region. Integrated Fisheries Management Plan. Groundfish. Effective February 21, 2017. http://www.pac.dfo-mpo.gc.ca/fm-gp/mplans/2017/ground-fond-sm-2017-eng.html

[4] Data provided by DFO are not considered "official" or "final" and may be incomplete. Data were provided in September 2017; catches illustrated for 2017 are through Sept. 25 only.

[5] McFarlane, G. and J. King. 2014. The history of the fisheries. pp 323–352. In: The Sea Among Us: The Amazing Strait of Georgia. R. Beamish and G McFarlane (eds). Harbour Publ. Madiera Park, BC, Canada. (see p. 337)

[6] DFO. 2015. Stock assessment for Lingcod (Ophiodon elongatus) for the Strait of Georgia, British Columbia in 2014. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/014.

[7] Martell S.J.D. and S. S. Wallace. 1998. Estimating historical lingcod abundance in the Strait of Georgia. Pages 45–47 in D. Pauly and D. Preikshot, eds. Back to the future: reconstructing the Strait of Georgia ecosystem. Fisheries Centre, Univ. British Columbia, Vancouver. 211 p

[8] DFO 2015.

[9] Holt, K., King, J. R., and Krishka, B.A. 2016. Stock Assessment for Lingcod (Ophiodon elongatus) in the Strait of Georgia, British Columbia in 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/013. xi + 186 p. Accessed Dec. 12, 2017. http://waves-vagues.dfo-mpo.gc.ca/Library/363960.pdf

[10] DFO 2017. The allowable catch is set to cover trip limits in the SoG and is not allocated to license holders, nor is it transferable.

[11] Data provided by DFO are not considered "official" or "final" and may be incomplete. Data were provided in September 2017; catches illustrated for 2017 are through Sept. 25 only.

[12] Frid, A., Connors, B., Cooper, A.B. and Marliave, J. 2013. Size-structured abundance relationships between upper- and mid-trophic level predators on temperate rocky reefs. Ethology, Ecology & Evolution. 25(3): 253-268.

[13] Cass, A.J., R.J. Beamish, and G.A. McFarlane. 1990. Lingcod (*Ophiodon elongatus*). Can. Spec. Publ. Fish. Aquat. Sci. 109: 40 p.

[14] King, J. R. and R. E. Withler. 2005. Male nest site fidelity and female serial polyandry in lingcod (*Ophiodon elongatus, Hexagrammidae*). Molecular Ecology 14(2): 653-660.

[15] Cass et al. 1990

[16] Cass et al. 1990

[17] Olesiuk, P.F. 2010. An assessment of population trends and abundance of harbour seals (*Phoca vitulina*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/105.

[18] http://www.dfo-mpo.gc.ca/fm-gp/seal-phoque/seal-species-eng.htm

[19] COSEWIC. 2013. COSEWIC assessment and status report on the Steller Sea Lion Eumetopias jubatus in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 54 pp. http://www.registrelep-sararegistry.gc.ca/default_e.cfm

[20] Holt et al. 2016

[21] Anomalies shown are deviations from the mean biomass estimate for that survey over the time period illustrated. Error bars illustrate relative error of each estimate. We charted scaled anomalies to enable comparison of trends through time, regardless of relative abundance. Our illustration of the survey index data has been reviewed by DFO.

[22] The methodology for calculating abundance indices was developed for trawl surveys, and may not adequately index line surveys due to the different survey methodologies. The PHMA line survey was designed for inshore rockfish and the IPHC line survey was designed for halibut, therefore we are cautious using the results here for lingcod. Relative error of estimates, a measure of precision, or the capability of a survey to track changes in a population over time, was provided with the data. Estimates with high relative error (greater than 0.4) are unreliable.

[23] Workman, G. 2017. A review of groundfish surveys in 2016. p.97-104. In Chandler, P.C., King, S.A., and Boldt, J., eds. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2016. Can. Tech. Rep. Fish. Aquat. Sci. 3225: 243 + vi p.

[24] Workman 2017.

[25] Survey areas illustrated are approximate and meant to illustrate the general area of the coast that each survey series covers.

[26] Borden, L. and J. Marliave. 2016. Lingcod Egg Mass Survey Report. Available at: http://www.vanaqua.org/files/4314/8459/0928/LEMS_2016_survey_report.pdf

[27] The Lingcod Egg Mass Survey (LEMS) is not comparable to the DFO surveys that fisherman contribute to/assist with. Areas covered in these citizen science supported dive surveys are limited and located in Barkley Sound for the WCVI and near Port Hardy and Port McNeil for the Northeast Vancouver Island. The Strait of Georgia surveys cover a wider area. Details of survey effort can be seen online in survey reports at http://www.vanaqua.org/act/research/fish/lingcod-survey

[28] Workman 2017

[29] Cass et al. 1990

[30] DFO 2017

[31] DFO. 2016. Sustainable Fisheries Framework. Accessed January 23, 2018. http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/overview-cadre-eng.htm.

[32] Office of the Auditor General of Canada. 2016. Report 2 – Sustaining Canada's Major Fish Stocks – Fisheries and Oceans Canada. 2016 Fall Reports of the Commissioner of the Environment and Sustainable Development. Accessed February 28, 2018 http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201610_02_e_41672.html

Humpback whales are returning to the Salish Sea

AUTHOR
Chad Nordstrom, Coastal Ocean Research Institute, an Ocean Wise initiative
Caitlin Birdsall, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Lance Barrett-Lennard, Coastal Ocean Research Institute, an Ocean Wise initiative

What's happening?

North Pacific humpback whales (*Megaptera novaeangliae*) are returning to the Salish Sea 100 years after being extirpated by commercial whaling, and well after humpbacks began re-occupying large tracts of British Columbia's coast. At least 100 humpbacks were hunted and killed in the mid-1800s from the Strait of Georgia and Queen Charlotte Strait and later, between 1908 and 1967, at least 5,618 humpbacks were harvested and processed by the five main whaling stations along the coast.[1] Humpback whales are now returning to near historic numbers coast-wide, with the Salish Sea being one of the last areas to be re-occupied. Using this area as a case study for documenting a humpback comeback allows us to highlight the efforts of coastal citizens, who have been critical in recording this recovery in what is now a major urban waterway.

Humpback whale flukes (Photo: Ocean Wise)

Why is it important?

The return of large rorquals (the family of baleen whales characterized by heavily pleated throats) to the Salish Sea will have widespread ecological impacts. Humpbacks require large volumes of prey and it's estimated the population in B.C. could consume as much as 250,000 to 320,000 tonnes of feed (euphasids, or krill, and forage fish such as herring and sardines).[2] Commercial fish species such as salmon and hake, as well as marine mammals such as dolphins, porpoises, seals, and sea lions in the region may be impacted, as humpbacks will compete directly with them for the same prey resources. Humpbacks are also susceptible to boat strikes and entanglements involving marine debris or commercial fishing gear, which could be problematic given high volumes of commercial and recreational boat traffic in the Salish Sea. An increase in the number of whales, paired with an increasing number of vessels, is a recipe for more frequent whale-boat collisions and/or entanglements.

The return of humpbacks to the Salish Sea highlights the need for new conservation and research efforts, such as programs to reduce ship-strike risk and to measure and understand ecosystem changes that will necessarily result from the return of large consumers after a century of absence.

What is the current status?

North Pacific Humpback whales have recovered substantially from commercial whaling and have reoccupied large tracts of former feeding grounds on the west coast of North America.[3] A notable area where humpbacks were conspicuously absent during their return to British Columbia over the past 30 years was the inner Salish Sea – the inland waters of the Strait of Georgia extending south to Puget Sound (Figure 1A) – where a small and possibly resident population of humpbacks was extirpated by 1909.[4]

The highly urbanized area is home to a large number of citizen scientists who regularly report their sightings of whales, dolphins, porpoises, and sea turtles to the B.C. Cetacean Sightings Network (see the Citizen Science and Participation article under the Sense of Place and Wellbeing Theme) and their reports have documented the return of humpbacks to the inner Salish Sea.

The B.C. Cetacean Sightings Network (BCCSN) currently curates more than 29,500 humpback whale sightings collected coast wide over 35 years (1981– 2016), with 10.3 percent or 3,052 of those reports originating from the study area (Figure 1B). By limiting reports to those graded as reliable or certain, the BCCSN began consistently receiving 50 or more humpback sightings per year from the inner Salish by 2003-2004 (Figure 2). This was approximately 15 years after similar numbers of sightings were made regularly along the west side of Vancouver Island, a known high-density area in B.C.[5] By 2013, humpbacks were the most fre-

HUMPBACK WHALE SIGHTINGS REPORTED

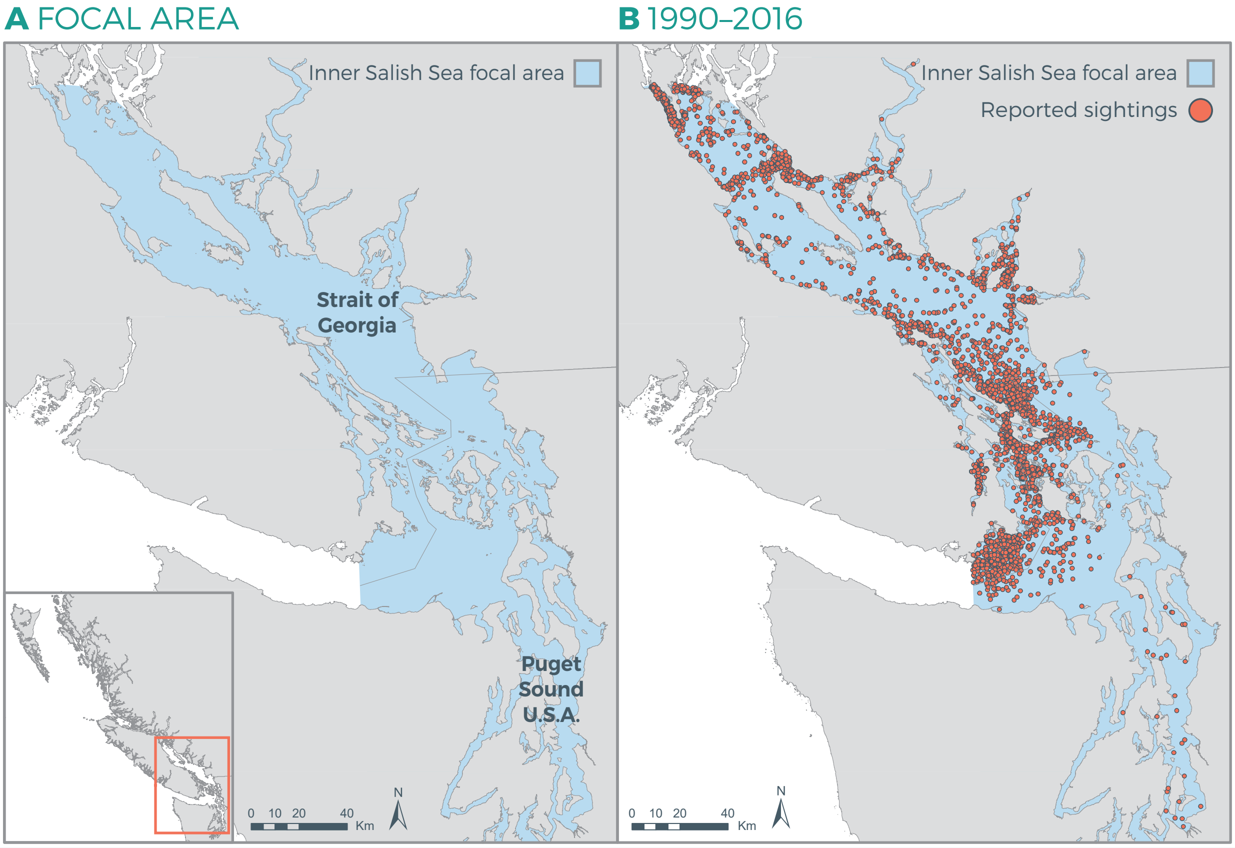

Figure 1. A: Inner Salish Sea focal area which includes the Strait of Georgia (B.C.) and the waters around the San Juan Islands and Puget Sound (WA); B: 3,052 locations of humpback whales in the focal area reported to the B.C. Cetacean Sightings Network from 1990 through 2016.

quently reported cetacean in the province and 19 percent of humpback sightings were located in the inner Salish Sea.

In order to account for uneven observer effort and increasing awareness of the Sightings Network over time, the data were analyzed using an effort-corrected Geographic Information System (GIS) model.[6] The coast-wide model confirmed the delayed but notable increase of whales in the area: humpbacks were considered entirely absent from the inner Salish Sea prior to 2004 (Figure 3A) and sighting density per unit effort increased to a maximum of 0.11 per square kilometre when modelling data from 2004 through 2016 (Figure 3B). This value represents roughly 20 percent of the maximum sighting density per unit effort predicted for major hotspots along the west side of Vancouver Island and is notable given that the model accounts for the large observer base in the inner Salish Sea.

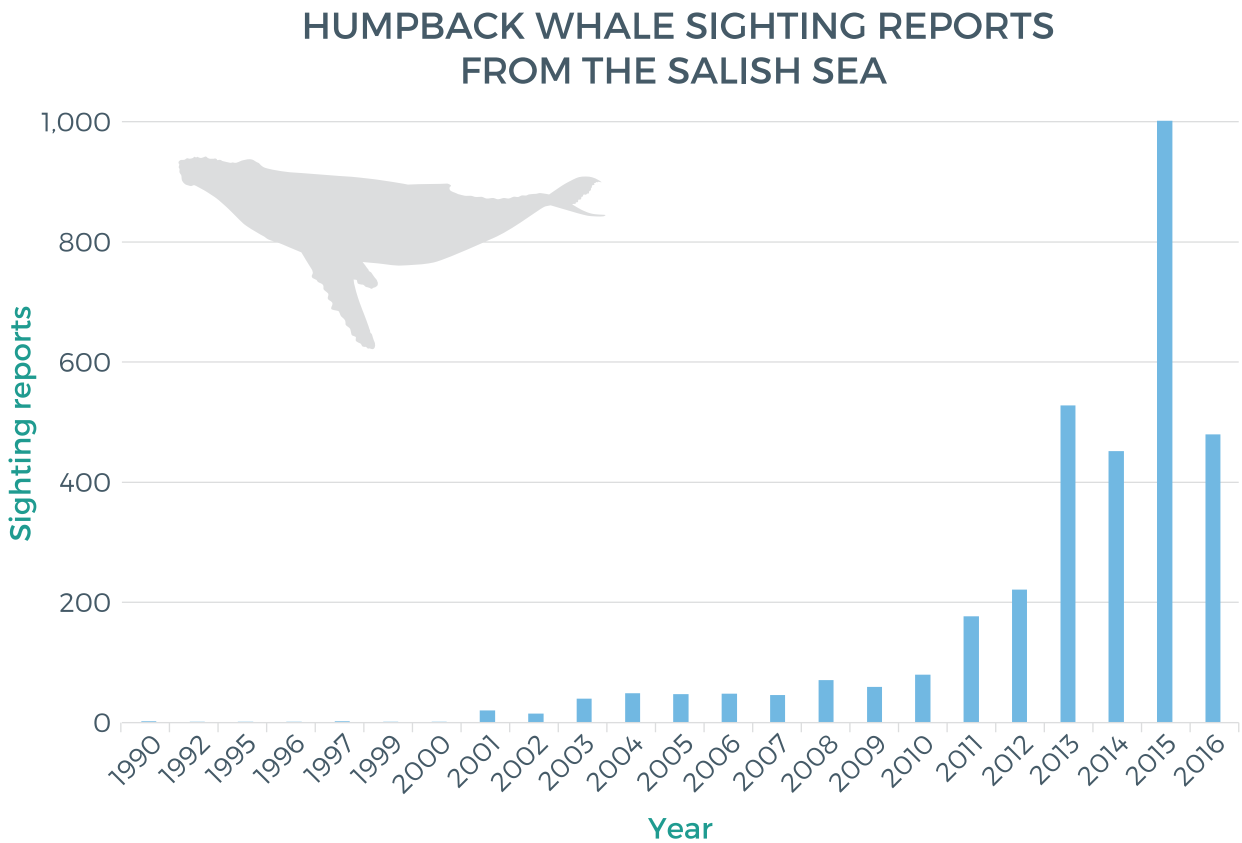

Figure 2. The number of humpback whale sightings in the inner Salish Sea reported to the B.C. Cetacean Sightings Network from 1990 through 2016.

HUMPBACK WHALE DENSITY ESTIMATES

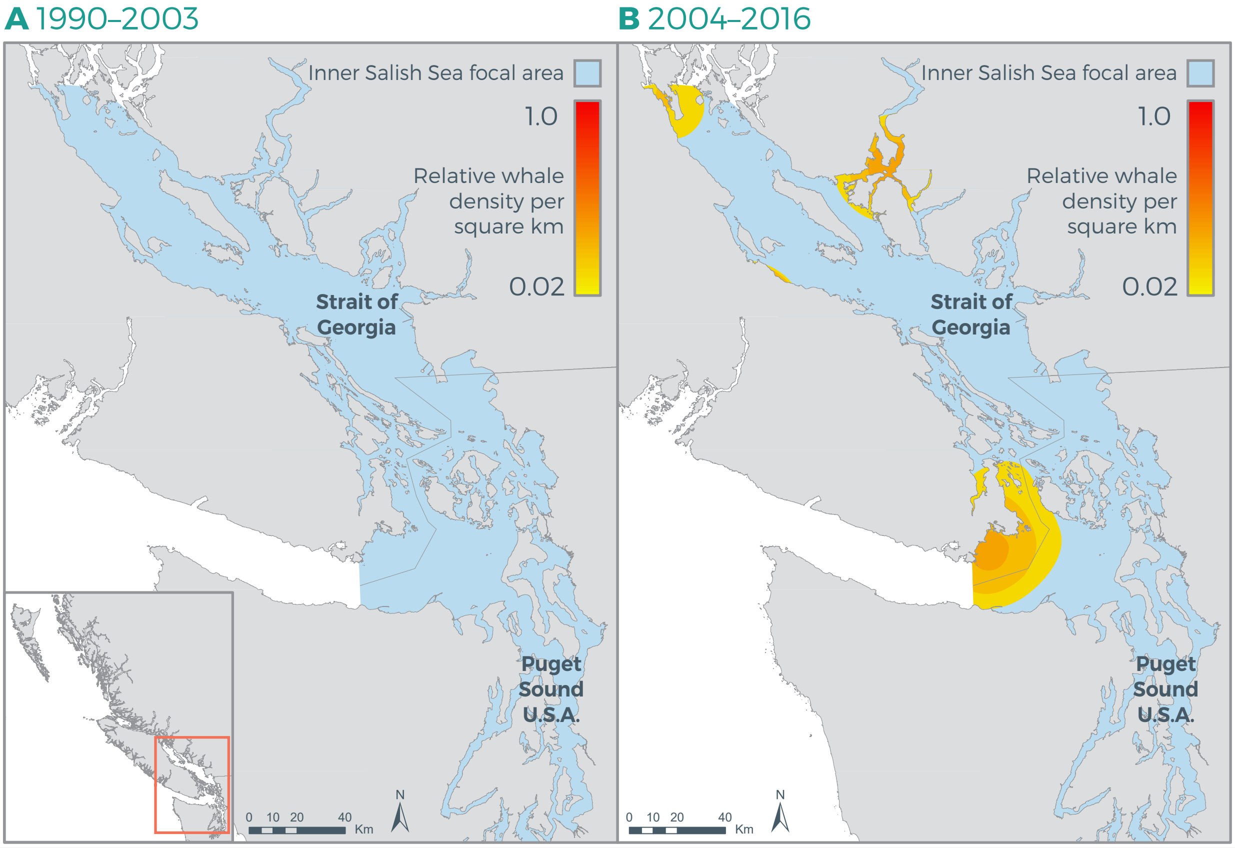

Figure 3. Coast-wide effort-corrected humpback whale density estimates (relative density per square kilometre) in the inner Salish Sea for two time periods. A: 1990–2003 (no whales estimated); and B: 2004–2016.

What is being done?

Humpback population growth in Pacific Canada was most recently estimated to be 4.1 percent annually (95 percent confidence limits, 3.9-5.1 percent) and identified threats did not seem to be affecting the population growth rate.[7] As such, the independent Committee on the Status of Endangered Wildlife in Canada (COSEWIC) determined that the population had reached a point where the species could be re-classified. The Committee assessed the population as a species of special concern in 2011 and upheld that designation in 2014. A reclassification from threatened to special concern under the federal Species at Risk Act in Canada occurred in July of 2017.

Despite their downlisting, reports of entanglements and ship strikes have continued to occur. The number of these types of incidents is likely to increase as humpback density increases in inland waters. Boater education and outreach may be a practical step to addressing the issues with select campaigns underway including:

- Marine Education & Research Society (MERS): “See a blow, Go slow”
- BCCSN: Dock Talk series

The Aquatic Ecosystems and Marine Mammal Science group (Pacific Biological Station) at Fisheries and Oceans Canada regularly monitor the abundance and distribution of large whales, including humpbacks, on B.C.’s north coast, central coast, and the west coast of Vancouver Island through aerial and ship transect surveys.

Humpback whale in the inner Salish Sea off the city of Nanaimo between Newcastle and Gabriola Islands on August 31, 2016. (Photo: Chad Nordstrom)

What can you do?

Individual and Organization Actions:

- Report your cetacean and sea turtle sightings, including humpbacks, from anywhere in British Columbia to the B.C. Cetacean Sightings Network online at www.wildwhales.org or via *WhaleReport* – the free smartphone application available for iOS and Android devices.
- Follow the Be Whale Wise guidelines if you encounter any cetaceans while on the water.
- Slow down and stay vigilant in areas of known humpback whale activity to avoid collisions from unpredictable humpback surfacing.
- 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.
- Report incidents of entangled whales immediately to the BC Marine Mammal Incident reporting line: 1 800 465 4336
- Contribute photos of humpback whale tail flukes for photo identification catalogues to sightings@ocean.org or mersociety@gmail.com.

Government Actions and Policy:

- Consider humpback nutritional requirements when regulating the commercial catch of B.C. euphasids, particularly in the Strait of Georgia.
- Implement and enforce slow-down zones for large vessel traffic in areas of high overlap between humpback and vessel densities. Studies have shown that travel below 10 knots greatly decreased the likelihood of fatal vessel strikes.[8]
- Continue to support and facilitate growth of the Marine Mammal Response Network to ensure timely and safe incident responses coast-wide.
- Provide large vessel captains and pilots with cetacean resources that include distribution of species, and how to safely transit when whales are in the area (e.g., The Mariner's Guide to Whales, Dolphins and Porpoises of B.C.).
- Legislate mandatory safe-distance for vessels from cetaceans (e.g., using Be Whale Wise Guidelines).

Resources

Species at Risk Public Registry (Humpback Whale, North Pacific Population)
http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=148

Ford, John K. B. Marine Mammals of British Columbia. Victoria: Royal British Columbia Museum, 2014. Paperback, 464 pages, ISBN 978-0-7726-6734-2.

Footnotes

[1] Nichol et al, 2002. British Columbia Commercial Whaling Catch Data 1908 to 1967: A Detailed Description of the B.C. Historical Whaling Database. Can. Tech. Rep. Fish. Aquat. Sci. 2396: viii + 76 p

[2] Ford et al, 2009. An assessment of the potential for recovery of humpback whales off the Pacific Coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/015. iv + 33 p.

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[4] Merilees, 1985. Humpbacks in our strait. Waters, J. Vanc. Aquarium. 8: 7-24.

[5] Fisheries and Oceans Canada. 2013. Recovery Strategy for the North Pacific Humpback Whale (*Megaptera novaeangliae*) in Canada. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. x + 67 pp.

[6] The Sightings Network team, along with marine mammal researcher Erin Rechsteiner, created a GIS model to adjust or correct Sightings Network data to reflect the distribution of observer effort.

[7] Ford et al, 2009. An assessment of the potential for recovery of humpback whales off the Pacific Coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/015. iv + 33 p.

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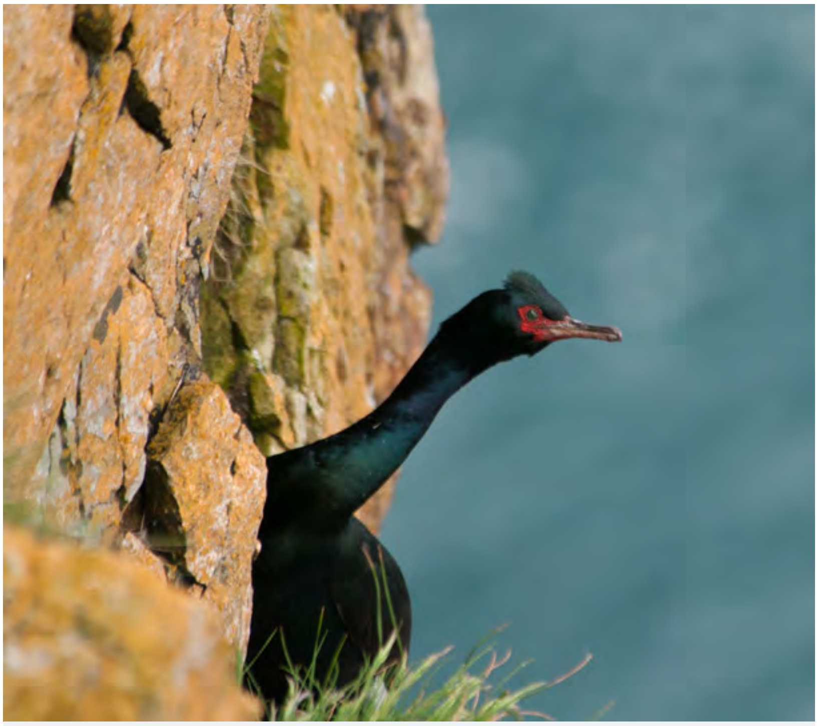
Coastal waterbirds are in decline

AUTHORS
Karen Devitt, Program Coordinator, Bird Studies Canada
Dr. David Bradley, Program Manager, Bird Studies Canada

REVIEWER
D.F. Bertram, Environment and Climate Change Canada, Wildlife Research Division

What's happening?

British Columbia's diverse coastline is a mecca for marine birds. Not only does B.C. fall within the Pacific Flyway – a superhighway for migratory birds – the Salish Sea and areas along the North Coast are important staging habitat for numerous overwintering marine birds. Additionally, remote coastal islands provide breeding habitat for rarely seen birds that spend most of their time offshore like tufted puffin and ancient murrelets.



Pelagic cormorant. (Photo: Catherine Jardine)

Studies in the Salish Sea suggest that the abundance of wintering marine birds have been declining since the 1990s.[1,2] Declines are most prominent among species that prey on forage fish and that do not breed locally. Although it is likely that there are many contributing factors to these declines, shifts in the availability of prey is thought to be driving these trends.[3,4,5] Other factors that threaten our marine birds include oil spills, fisheries bycatch, human disturbance,[8,9] habitat loss, and introduced predators.[10]

Until recently, the plight of marine birds and the habitats they depend on have been out of sight and out of mind for many British Columbians. However, multiple die-off events over the past few years have brought marine bird carcasses ashore on some of the province's most popular beaches, highlighting the importance of the region to marine birds and the threats they face. For example, during the winter of 2014–2015, over 100,000 Cassin's auklets washed ashore along beaches from Haida Gwaii down to central California. Carcasses that were examined indicate that many of the birds died of starvation.[11,12] More recently, during the summer of 2016 over 1,000 rhinoceros auklets washed ashore on beaches that ring the Juan de Fuca Straight and outer coast of Washington. The cause of death in this case was attributed to a bacterial infection. The bacteria involved are poorly characterized and have not been reported in seabirds before.[13] Though the causes of these events differ, both likely signal larger environmental changes in our marine waters.

Tufted Puffin (Photo: Catherine Jardine)

Why is it important?

The high visibility of marine birds coupled with their role in coastal ecosystems means that many are excellent indicators of our marine environmental health.[14] Many coastal communities have also long understood the importance of our coastal environments for marine birds from both an ecological and an economic perspective. With bird related tourism on the rise, municipalities across B.C. are embracing the concept and are striving to make their regions a destination for birders.[15,16,17]

B.C. also has a global responsibility towards the stewardship of our marine birds as our coastal environment supports nationally and globally significant populations of marine birds. As such, Birdlife International has designated over 50 sites along B.C.'s coast as Important Bird and Biodiversity Areas (IBAs) – a global initiative that aims to protect and manage a network of sites that are significant for the long-term viability of bird populations.[18]

Black oystercatcher. (Photo: Catherine Jardine)

What is the current status?

The BC Coastal Waterbird Survey is a long-term monitoring program coordinated by Bird Studies Canada. This monthly survey involves more than 700 volunteer citizen scientists at over 200 sites along B.C.'s coast (Figure 1) and aims to assess the annual changes and long-term trends in the population and distribution of coastal waterbirds.

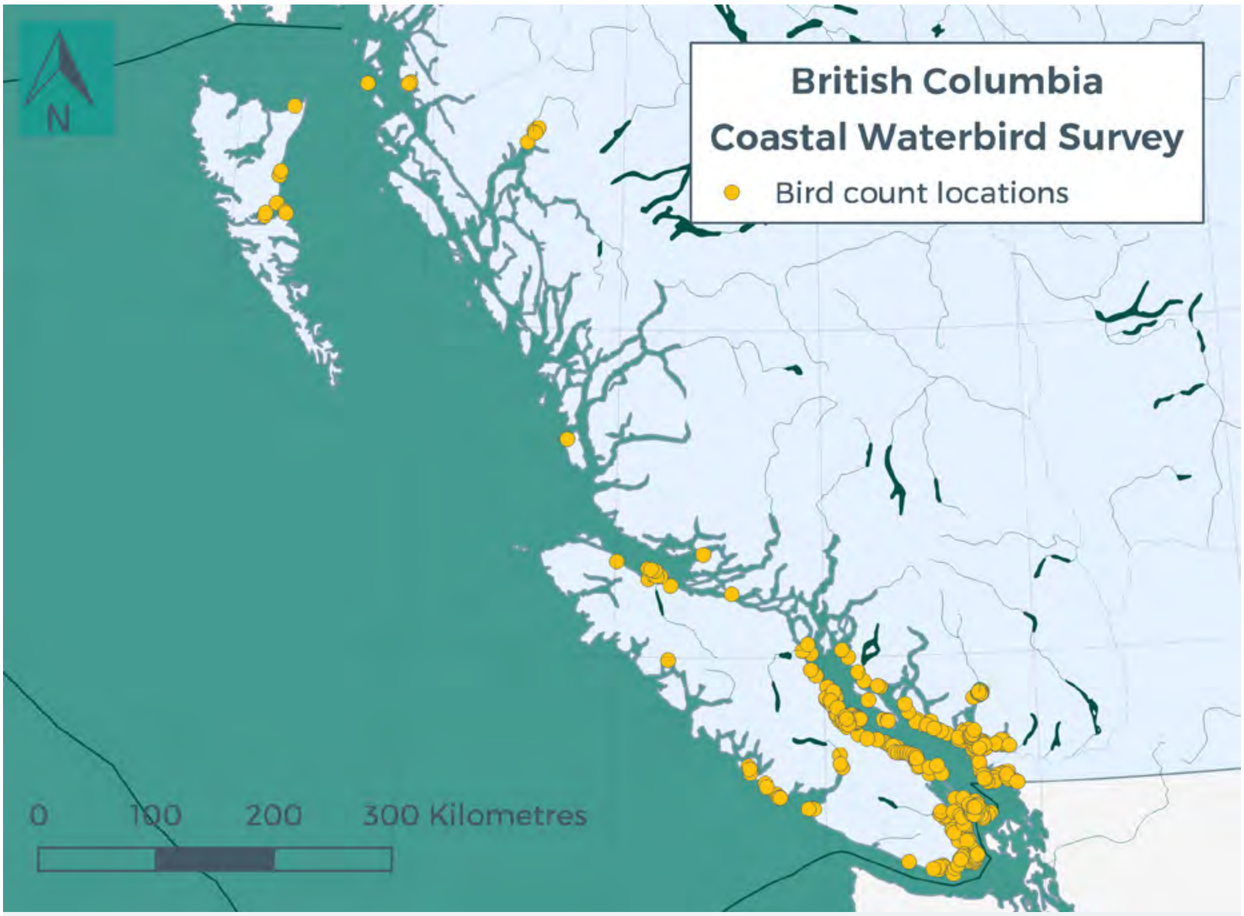


Figure 1. B.C. Coastal Waterbird Survey bird count locations.

Recent analysis of the 17-year dataset (1999–2016) showed significant changes for a number of marine birds (Figure 2).[19,20] At the guild level (groups of species), all birds showed declining trends, however some individual species showed increasing trends, such as the Canada goose, black oystercatcher, and ring-necked duck. Species that showed the greatest declines included the western grebe, canvasback, black scoter, and dunlin. Similar to the findings of other studies in the region, at the guild level declines in grebes and diving waterfowl were observed. Among other factors, changes in the availability of forage fish is likely causing shifts in the overwintering ranges of these birds.[21,22,23] Distributional shifts have been demonstrated through the analysis of Christmas Bird Count data along the Pacific Northwest, which indicate a 95 percent decline of grebe species in the Salish Sea over 36 years, while coastal counts from California for the same time period indicate an increase by over 300 percent.[24]

Climatic changes can cause birds to misjudge the timing of migration, resulting in lower reproductive success.[25,26] A proxy to measure this impact is migra-

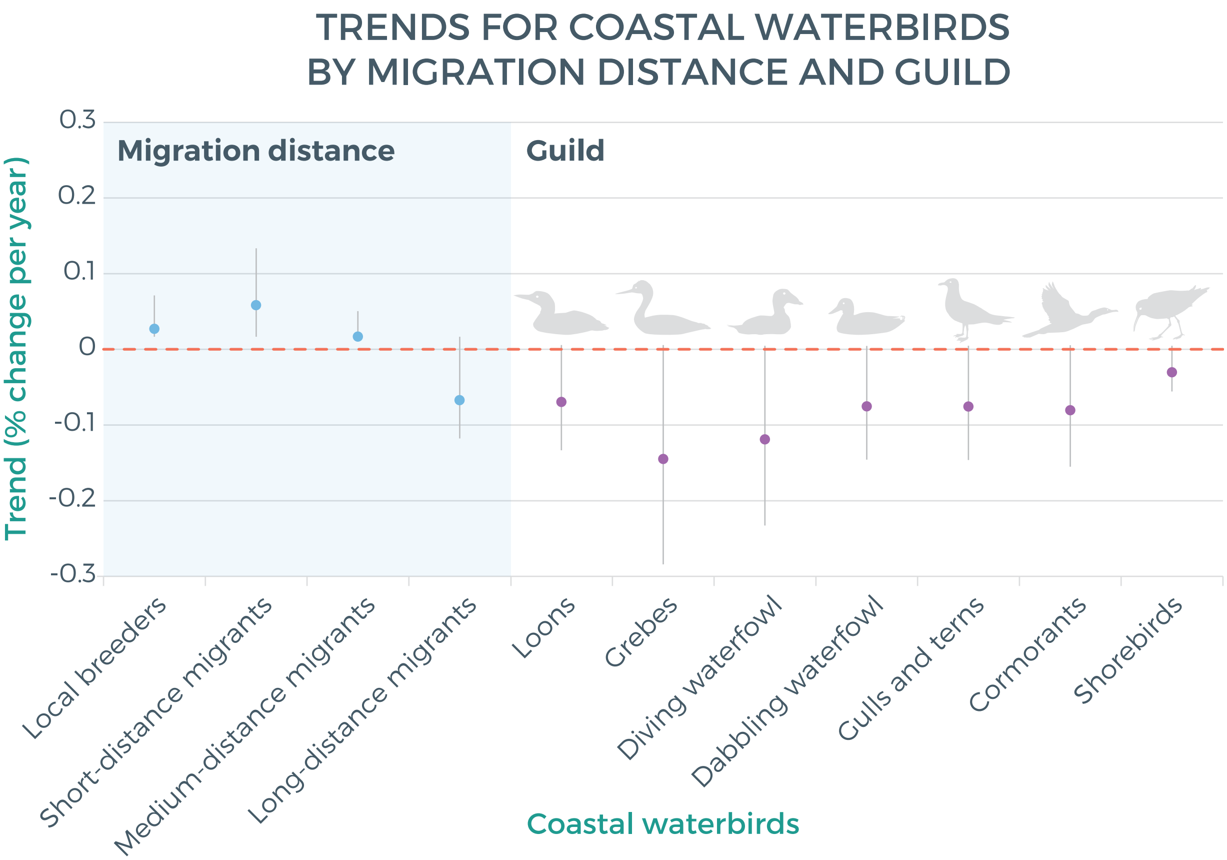


Figure 2: Trend analysis results for the Coastal Waterbird Survey (1999–2016) by migration distance (local breeders, short-distance migrants, medium-distance migrants, long-distance migrants); and guild (loons, grebes, diving waterfowl, dabbling waterfowl, gulls and terns, cormorants, shorebirds). Error bars represent the 95 percent and 2.5 percent quantiles of the mean value. Source: Bradley (2016).

tion distance. Categorizing B.C.'s marine birds into migration distance bands showed statistically significant declines in long-distance migrants, such as dunlin, while short-distance migrants (e.g., common goldeneye), and birds that breed locally (e.g., Canada goose) showed slight increasing trends.

Alcids are a group of marine birds that spend the majority of their lives at sea, coming to shore only to breed on remote islands. Some of B.C.'s coastal islands support globally significant numbers of alcids. Reliable estimates of overwintering alcids are challenging to obtain as they are not always visible to shore-based observers. However, Environment and Climate Change Canada's Seabird Colony Counts provide a reliable data source for some alcid species including rhinoceros auklet, ancient murrelet, and Cassin's auklet. The Seabird Colony Count data indicate that rhinoceros auklet breeding colonies showed slight increasing trends at all colonies monitored, except for one where a slight but significant decline has been noted.[27] The abundance of Cassin's auklets at six of the monitored colonies have been declining since 1985.[28] Ancient murrelet were listed as Special Concern under the Species at Risk Act in 1993 due to dramatic declines on colonies around Haida Gwaii. Though this population has not recovered to historic levels, abundance has changed little since the 1970s.[29] All three species of alcids monitored by Environment and Climate Change Canada's Seabird Colony Count nest in burrows in the ground. As a result, their populations are vulnerable to introduced mammalian predators such as rats and raccoons.[30]

What is being done?

There are many groups working on the stewardship of marine birds, including numerous volunteers with various naturalist groups and non-profit environmental organizations. The IBAs are stewarded by volunteer caretakers through BC Nature and over 30 Christmas Bird Counts in coastal regions of the province are organized by local groups. Other long-term citizen science programs that monitor marine birds in the region include the BC Coastal Waterbird Survey and the Beached Bird Survey. Various groups are also working together to monitor seabirds, including Environment and Climate Change Canada, Parks Canada, Mitlenatch Island Stewardship Team, Laskeek Bay Conservation Society, the Council of the Haida Nation, and Bird Studies Canada.

Threats to marine birds don't stop at the Canadian border. As a result, there are multiple international initiatives that are working to protect marine birds across the Pacific Flyway such as the Migratory Shorebird Project and the Pacific Birds Habitat Joint Venture.

What can you do?

Individual and Organization Actions:

- Learn to identify our coastal species, connect with the natural world, and take the first step to conservation action by borrowing natural history books from the library, joining your local naturalist group for an outing, and participating in Citizen Science programs.
- Give birds space on the beach and on the water. Maintain a distance of at least 50 metres from marine birds on the water and on shore.[31]
- Choose sustainably caught seafood.

Government Actions and Policy:

- Improve policies and develop legislation to protect forage fish, one of the most vital components in our marine food webs, to ensure protection of our marine birds, ecosystems, and fisheries.
- Improve monitoring and mitigation to reduce bycatch in B.C.
- Provide local governments and Indigenous communities with better training, equipment, and support for internal planning for oil spill response.
- Follow through on global Achi Biodiversity Targets – specifically Target 11 – to protect 17 percent of terrestrial and inland waters, and 10 percent of coastal and marine habitats by 2020.

Footnotes

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[30] Bailey and Kaiser, 1993.

[31] Chatwin and Burger, 2013.

Clean Water

Photo: Stephen Hargreaves

Summary

Human activity has a lasting impact on our oceans – although its effects are not always obvious. Years after many persistent organic chemicals (POPs) were phased out of use in Canada, tests show these legacy pollutants are still present in many organisms along the west coast. Samples of seabird eggs in B.C. also show contaminants such as mercury, flame-retardants and perfluoroalkyl substances (PFAs) are making their way to the top of the food chain. Meanwhile, microplastics from man-made products such as microbeads and fibres from synthetic textiles have emerged as a new area of concern for marine health as they too enter the food chain. These harmful substances are linked to everything from disruption of immune and reproductive systems to starvation.

Given the threat contamination poses to marine and human life, careful monitoring of water quality and cleanup efforts are more important than ever. Conservation groups are stepping up to the plate. In 2015, the Coastal Ocean Research Institute launched its *PollutionTracker* program with 55 sites across B.C. sampled and tested for a large array of contaminants. As well, environmental agencies have been keeping a close eye on radiation levels in west coast waters following the Fukushima nuclear disaster caused by the 2011 earthquake and tsunami off of Tohoku, Japan. While some radiation has been detected in B.C.'s coastal waters, levels remain far below those considered harmful to human or animal health.

Back on land, however, debris from the tsunami, and other marine pollution, has washed up on all B.C.'s shorelines. On the west coast of Vancouver Island, it has been met by an army of dedicated shoreline cleanup volunteers. Each summer for three years, more than 10 metric tons of garbage was removed from beaches along the iconic West Coast Trail in an effort to preserve and restore this critical coastal habitat. As our oceans face increased pressure from human activity, it is imperative that we keep a close eye on the underwater world and remember that the ocean connects us all.

Clean Water Snapshot Assessment

PCBs in Sediments and Mussels

Starting in 2015, the Coastal Ocean Research Institute launched *PollutionTracker*, a coast-wide initiative aimed at monitoring pollution levels at 55 sites along the B.C. coast. As human activity continues to impact the marine environment, the initiative is an important tool in monitoring how and where legacy pollutants and contemporary contaminants continue to impact coastal ecosystems.

CAUTION

Microplastics

From microbeads to fibres from fleece and other textiles, microplastics are finding their way into marine ecosystems and entering the food chain.

CAUTION

Radiation after Fukushima

Following the Fukushima nuclear disaster in 2011, agencies began monitoring waters of coastal B.C. for radiation contamination. While radiation associated with the disaster has been detected, levels determined to date are far below those considered harmful to human or marine health.

HEALTHY

Persistent Organic Pollutants in Seals

Despite the phasing out of many persistent organic pollutants (POPs) from industrial use in Canada, marine organisms are still testing positive for these harmful chemicals. Careful monitoring of indicator species, such as harbour seals, is an important tool in tracking contaminant hotspots and identifying new substances of concern.

CAUTION

Contaminant Trends in Seabirds

Due to their status at the top of the food chain, seabirds are an important indicator of contaminant levels in marine ecosystems, and the effectiveness of regulations. Long-term studies show substances like mercury, brominated flame-retardants and PFAs are present at different levels in various seabird populations.

CAUTION

Shoreline Cleanup

Between 2014 and 2016, more than 10 metric tons of marine debris was removed annually from the west coast of Vancouver Island, much of it tsunami debris from the 2011 Tohoku earthquake off the coast of Japan.

HEALTHY

PollutionTracker: A new coast-wide initiative in British Columbia

AUTHORS
Kelsey Delisle and **Peter S. Ross**, Ocean Pollution Research Program, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Cecilia Wong, Senior Ecosystem Scientist, Environment and Climate Change Canada

What's happening?

PollutionTracker was launched in 2015 by the Ocean Pollution Research Program (OPRP) of Ocean Wise's Coastal Ocean Research Institute (CORI) to generate high quality, comparable contaminant data for sediment and mussel samples collected along the coast of British Columbia. Results from Phase 1 show that several contaminants of concern, such as polychlorinated biphenyls (PCBs), are present in samples coast-wide – particularly in industrialized areas.

During Phase 1 of this program (2015–2017), data were compiled from 55 sites along the coast (Figure 1). The goal of *PollutionTracker* is to sample at each site every three years, as well as to add new sites to address geographical gaps and the interests of new partners.

Mussel filter feeding. (Photo: Ocean Wise)

Sampling bottom sediment and mussels. (Photos: *Ocean Wise*)

Sediment and mussels (*Mytilus sp.*) were collected in collaboration with government agencies, port authorities, community groups, and First Nations, and samples were submitted to specialized laboratories for high quality contaminant analysis. Samples were analyzed for over 400 contaminants, including hydrocarbons, flame-retardants, pesticides, pharmaceuticals and personal care products, and microplastics.

Bottom sediments are widely used to evaluate contaminant inputs into aquatic environments, as they are regarded as both contaminant 'sinks' and as potential 'sources' for adjacent food webs. Mussels are useful for monitoring as they are immobile, they are exposed to all of the contaminants present in the surrounding water, and they do not tend to metabolize contaminants.

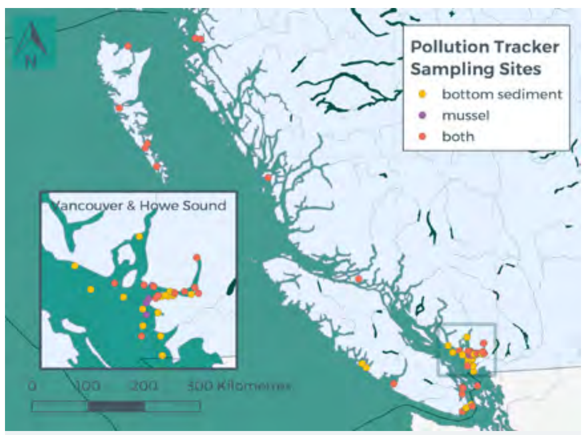

Figure 1. Phase 1 of *PollutionTracker* includes 55 sites along the coast of British Columbia.

Why is it important?

A multitude of chemicals and other contaminants are released or deposited into the marine environment on a continual basis. Contaminants may be of local or global origin, as both chemical and physical contaminants can be transported over long distances by oceanic and atmospheric currents. Monitoring helps to identify the priority pollutants of concern in coastal environments, locate potential sources, and inform

PollutionTracker tiered approach

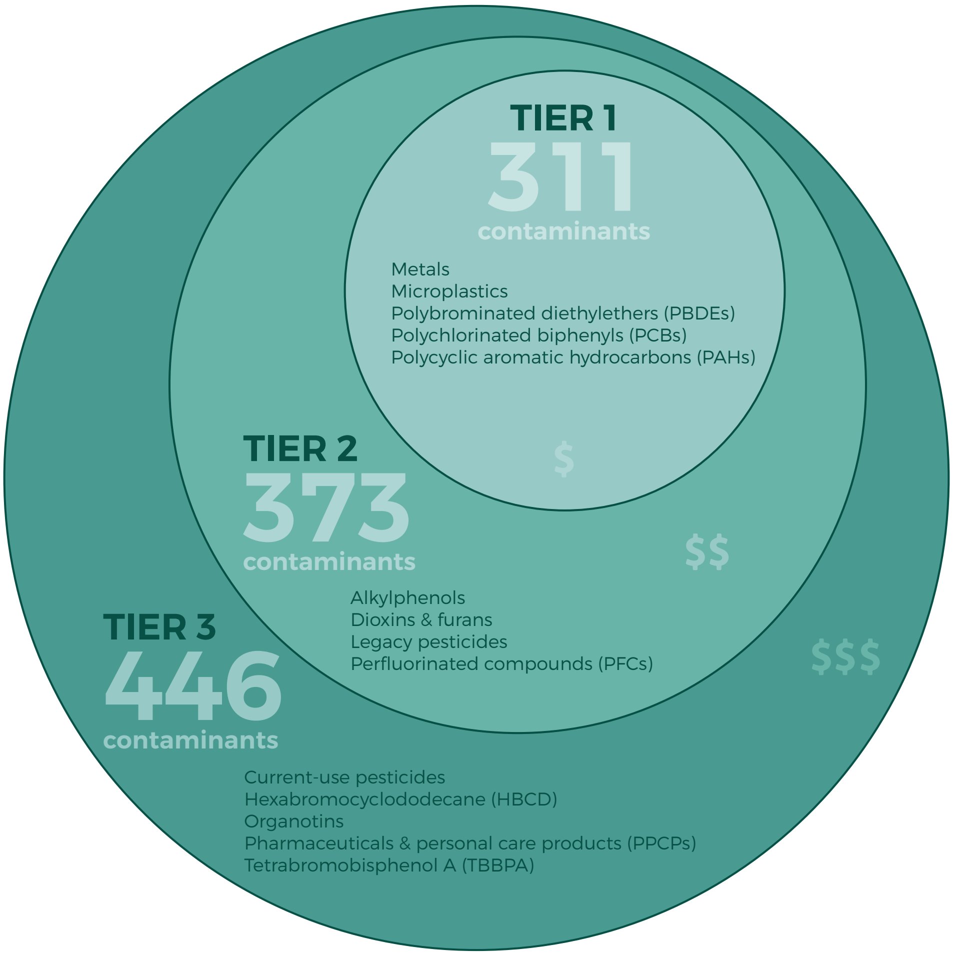

Figure 2. The *PollutionTracker* tiered approach to sample analysis. As high resolution contaminant analysis is costly, different options were provided to partners and choices reflect partner interests, current and historical anthropogenic activities in the region, and available funds. Tier 3 level analysis includes over 400 contaminants.

source control practices. *PollutionTracker* can include testing for over 400 contaminants (Figure 2).

British Columbia relies on a healthy marine environment – ecologically, culturally, and financially. Pollution threatens the relationships between humans, wildlife, and the marine environment and puts the existence of all marine organisms at risk. Some chemical contaminants, such as PCBs, accumulate in the marine food chain and are known to cause developmental, immunological, and reproductive impairment in animals. British Columbia's killer whale populations are among the most PCB-contaminated marine mammals in the world,[1] and contaminants have been identified as a threat to the recovery of all four British Columbia killer whale populations. The potential effects of many newer contaminants are largely unknown, as is the extent of their presence in the B.C. marine environment.

What is the current status?

Contaminant data from 51 of the 55 sites sampled along the coast have been collated and analyzed, and a summary of these results is available online at http://pollutiontracker.org/

Both legacy and current-use contaminants were detected in *PollutionTracker* samples. Legacy contaminants are those that are no longer being produced or used in new products in Canada, but that tend to persist in the marine environment (e.g., PCBs, tributyltin, and organochlorine pesticides), and these compounds were widely detected along the coast. Newer contaminants – such as the flame-retardants hexabromocyclododecane (HBCD) and tetrabromobisphenol A (TBBPA), current-use pesticides, and pharmaceuticals and personal care products – were also detected in some samples but were less widespread.

Total PCB concentrations in sediment and mussel samples varied along the B.C. coast (Figure 3). The highest PCB concentrations were found in industrialized and port areas. Despite their persistence, PCB concentrations have been declining in the marine environment since regulations were put in place. For example, concentrations measured in blubber biopsies from free-ranging harbour seal pups in Puget Sound, USA, declined by 81 percent between 1984 and 2003.[2]

Levels of PCBs measured in mussels did not necessarily correspond to levels measured in bottom sediments at a given site (i.e., while PCB levels in sediment were high relative to the other sites, levels in mussels from the same site may have been low relative to other sites, or vice versa). This likely reflects the partitioning of PCBs between bottom sediments and the water column. The specific PCB composition, bottom sediment characteristics, and the amount of particulate matter in the water column all affect the degree to which PCBs will adsorb to particulate matter, thereby affecting their uptake by mussels from the water column.

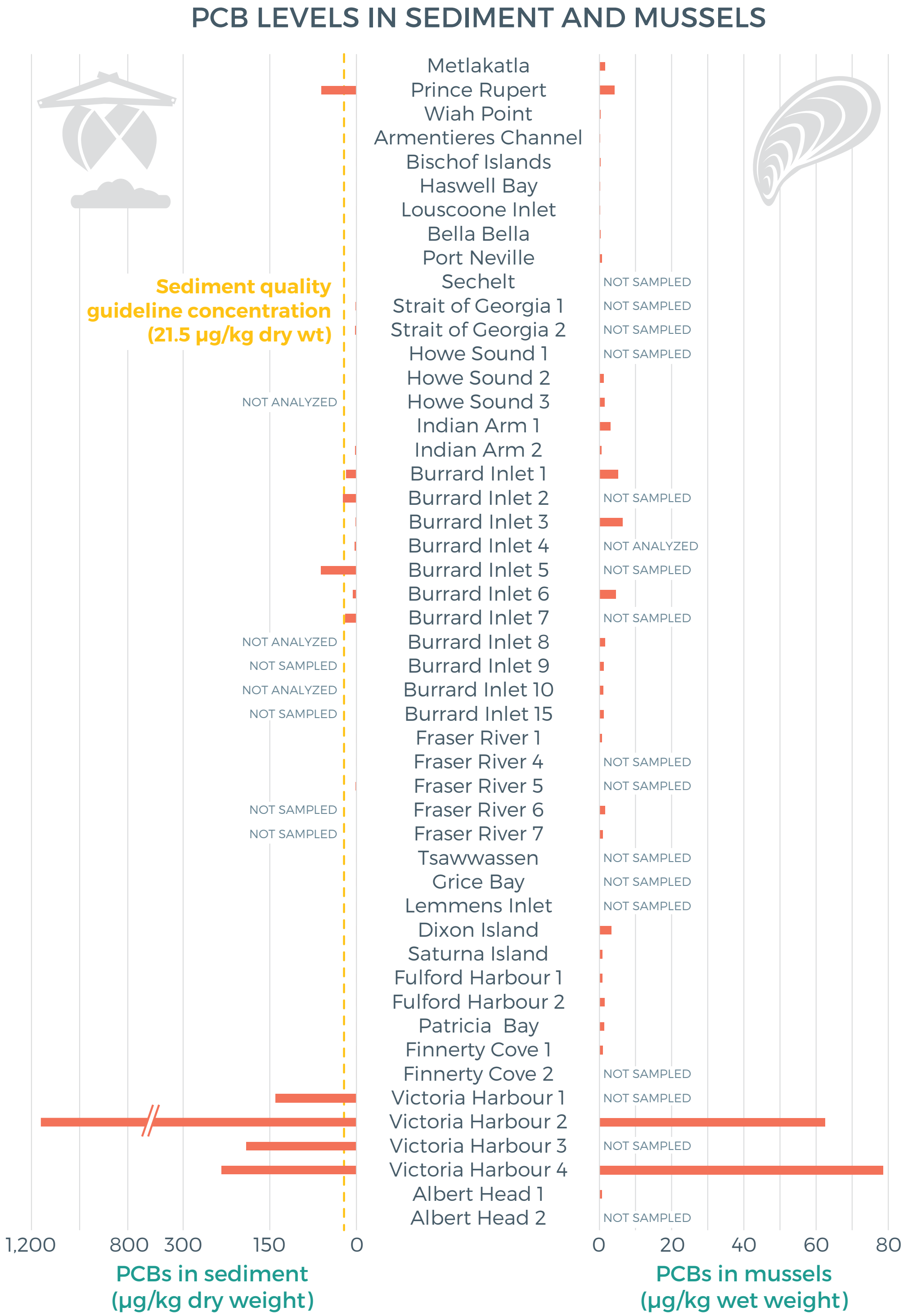

Figure 3. PCB levels varied along the B.C. coast, but the highest levels in sediment and mussels were found in Victoria Harbour, reflecting historical releases abd a vulnerable receiving environment. Data Source: *PollutionTracker.org*

What is being done?

Prior to the launch of *PollutionTracker*, a coast-wide pollutant monitoring program did not exist for British Columbia. Although individual groups and agencies carry out monitoring for specific parameters in localized areas, *PollutionTracker* aims to create an integrated, coast-wide initiative that provides high quality and comparable contaminant data across space and time.

There are a number of laws and regulations that address the sale, transport, use, disposal, and/or cleanup of different chemicals or pollutants, all of which have implications on the state of the coastal environment. On an international scale, the Stockholm Convention aims to protect human health and the environment from persistent organic pollutants (POPs) by mandating that its signatories discontinue use of certain chemicals. The original twelve POPs covered by the Stockholm Convention include PCBs, dioxins, furans, and several organochlorine (legacy) pesticides. Today, 33 POPs are listed under the Convention. In Canada, the Canadian Environmental Protection Act (CEPA), Health Canada, and Environment and Climate Change Canada (ECCC) control the use, importation, manufacture, storage, and release of toxic substances.

Once released into the environment, the relative health of coastal environments is often evaluated using environmental quality guidelines, which serve to identify specific contaminants of concern, characterize risks to biota, and guide remediation. Environmental quality guidelines are issued federally by the Canadian Council of Ministers of the Environment (CCME) and provincially by the Ministry of Environment in British Columbia. For PCBs, sediment quality guidelines protective of marine aquatic life are available, but a guideline for PCBs in tissues (e.g., mussels) is not available.

PCBs have long been a priority contaminant of concern in the environment. The import, manufacture, and sale of PCBs were banned in Canada in 1977. However, limited continued use in certain types of equipment, contaminated sites, long range transport from other parts of the world, and cycling in the environment all underscore the threat that PCBs continue to pose.

Electrical transformers manufactured prior to 1977 may still contain PCBs. (Photo: Wikipedia)

What can you do?

Individual and Organization Actions:

- Learn more about contaminants of concern using the resource links below.
- Reduce or eliminate the use of toxic chemicals and single-use plastics around the household and garden.
- Recycle and dispose of waste responsibly.
- From Health Canada:
  - Never burn wood that has been treated or painted, since burning materials that contain PCBs can create dioxins and furans.
  - If you are at risk for exposure to PCBs in the workplace, be sure to take appropriate safety precautions and follow all prescribed decontamination procedures.
  - Follow regional/provincial/territorial advice about limiting your consumption of wild game and sports fish. In addition, you can prepare game and sports fish in a way that minimizes your exposure to PCBs. Discard the inner organs and remove the skin and all visible fat. Broil, bake, boil, or grill the flesh, but avoid frying as this cooking method retains the fat.
- *PollutionTracker* is dependent on partner funding and involvement. If your community or organization is interested in becoming involved in *PollutionTracker*, please contact us at oceanpollution@ocean.org.

Government Actions and Policy:

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

Resources

Environment and Climate Change Canada
http://www.ec.gc.ca/pollution/default.asp?lang=En&n=77BC2971-1

http://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=105

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/chemicals-glance.html

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

https://www.canada.ca/en/health-canada/services/healthy-living/your-health/environment/pcbs.html#mi

Government of British Columbia
https://www2.gov.bc.ca/gov/content/environment/waste-management

City of Vancouver
http://vancouver.ca/home-property-development/recycling-and-disposal-facilities.aspx

Pacific Region Contaminant Atlas
http://pacifictoxics.ca/

The Stockholm Convention
http://chm.pops.int/TheConvention/ThePOPs/tabid/673/Default.aspx

Green Science Policy Institute
http://greensciencepolicy.org/

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

Footnotes

[1] Ross, P.S., Ellis, G.M., Ikonomou, M.G., Barrett-Lennard, L.G., and Addison, R.F. 2000. High PCB concentrations in free-ranging Pacific killer whales, *Orcinus orca*: effects of age, sex and dietary preference. Mar. Pollut. Bull. 40: 504–515.

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Microplastics in coastal British Columbia

AUTHORS
Peter Ross and **Marie Noel**, Ocean Pollution Research Program, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Leah Bendell, Professor, Biological Science, Faculty of Science, Simon Fraser University

What's happening?

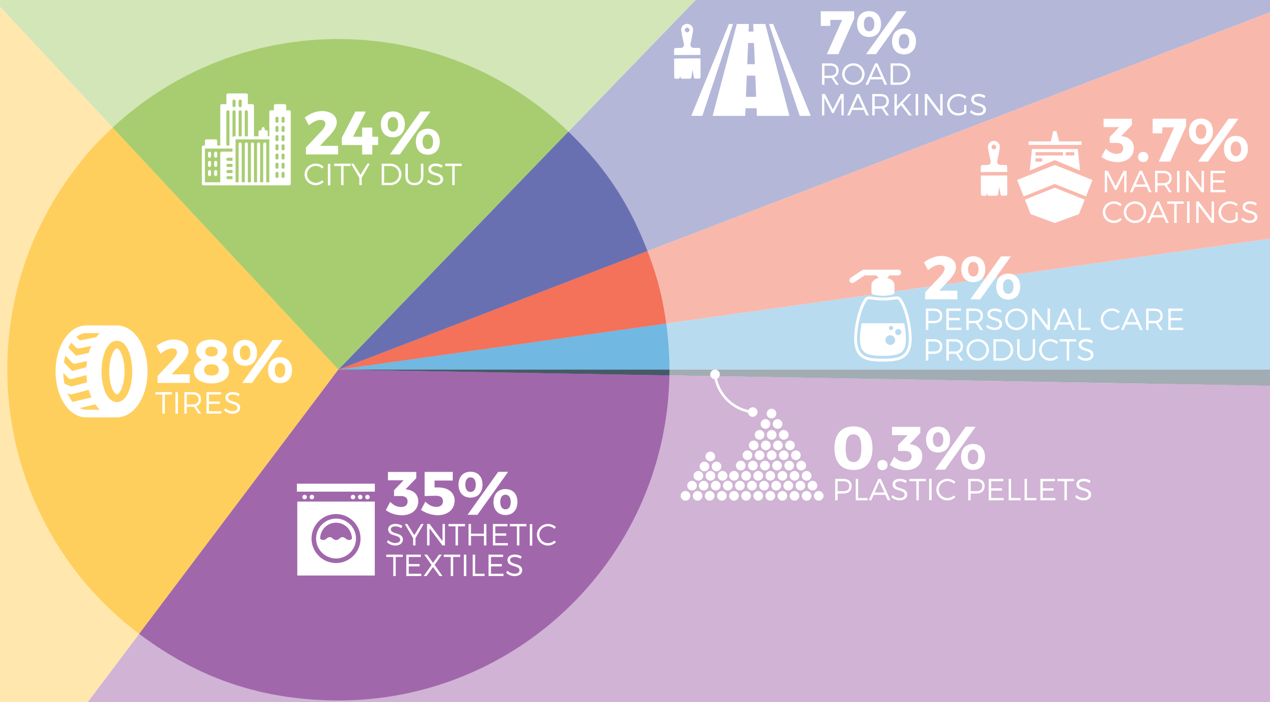
Visible plastic debris has long been recognized as a significant threat to charismatic species such as seabirds, marine mammals, and turtles, but microplastics are now emerging as a concern around the world.[1] Microplastics is a generic term that includes thousands of different human-made polymers. They are defined as plastic particles smaller than five millimetres in size and are categorized in the following simple way:

- **Primary microplastics**, which include any deliberately made particles including microbeads for toothpaste, personal care products and industrial abrasives, and nurdles, the commercial feedstock of specific polymers then used for manufacturing of plastic products.
- **Secondary microplastics**, which refer to the particles resulting from the breakdown of larger items, such as beverage and food containers, bags, ropes, and textiles.

Microplastics are increasingly seen as a threat to the marine environment due to their wide distribution, persistence, and risk of adverse health effects in marine life. Despite the never-ending stream of new studies, significant gaps continue to hamper our understanding of source, fate in the environment, and effects of these microplastic particles.

Nurdles spilled from a hopper in Pineville, Louisiana. (Photo: Paul Nettles, with permission, Flickr)

Global sources of microplastics released into the world's oceans



Household activities generate 77% of microplastics during use & maintenance of plastic products

29% PASSENGER TRANSPORT

48% DOMESTIC ACTIVITIES

7% FREIGHT TRANSPORT

16% ECONOMIC ACTIVITIES

77% HOUSEHOLD ACTIVITIES

23% INDUSTRIAL ACTIVITIES

Global sources of microplastics released into the world's oceans. Adapted from: Boucher and Friot (2017).[2]

Why is it important?

Microplastics can be found in the environment in the form of small fragments, sheets, fibres, pellets, and granules. Microplastics have been found in sediment[3,4] and seawater throughout coastal B.C. (Figure 1).[5] Concentrations in seawater were higher near the coast compared with offshore areas, suggesting that human activities on or adjacent to land are resulting in the contamination of marine waters. Fibres were the dominant type of microplastics found in water samples (Figure 2).[6]

It was shown that microplastics are being eaten by species of zooplankton.[7] This highlighted concerns about the vulnerability of ocean food webs and the potential for microplastics to get into Indigenous, commercial, and recreational seafoods as well as into wildlife such as seabirds, seals, and whales. In fact, it was estimated that adult salmon feeding in the Strait of Georgia could be eating as many as 91 microplastic items per day, and humpback whales could be ingesting as many as 300,000 microplastic items per day![8] Microplastics have been detected in various species of fish[9] as well as filter feeding whale species.[10]

Uptake of microplastics by wild and cultured shellfish was also reported – something that could be partly mitigated by a depuration period (storing live animals in clean water after harvest) for several days[11] before human ingestion. In Europe, it was estimated that the average mollusc consumer could ingest between 1,800 and 11,000 microplastics particles per year![12] Humans don't eat the digestive tract of other types of seafoods, so depuration really only make sense for shellfish.

While studies on the effects of microplastics on living organisms that ingest them are limited, it is suggested that, once ingested, potential negative impacts include false satiation, blockage of internal organs, transfer between tissues, and possible accumulation of toxins.[13,14,15,16]

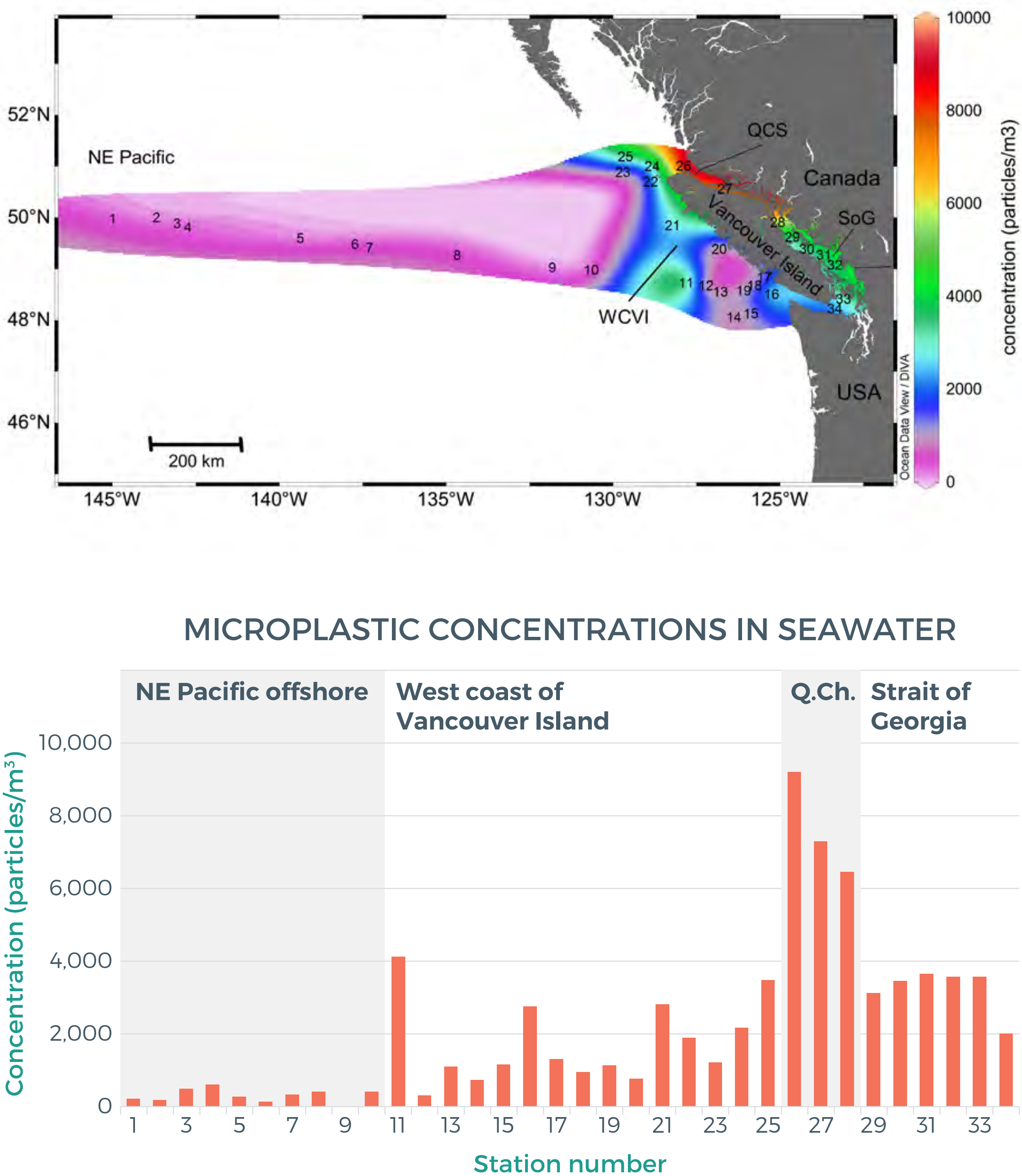


Figure 1. Microplastic concentrations in seawater samples collected in the northeast Pacific Ocean. Q.Ch. stands for Queen Charlotte Strait. Source: Desforges et al. (2014)

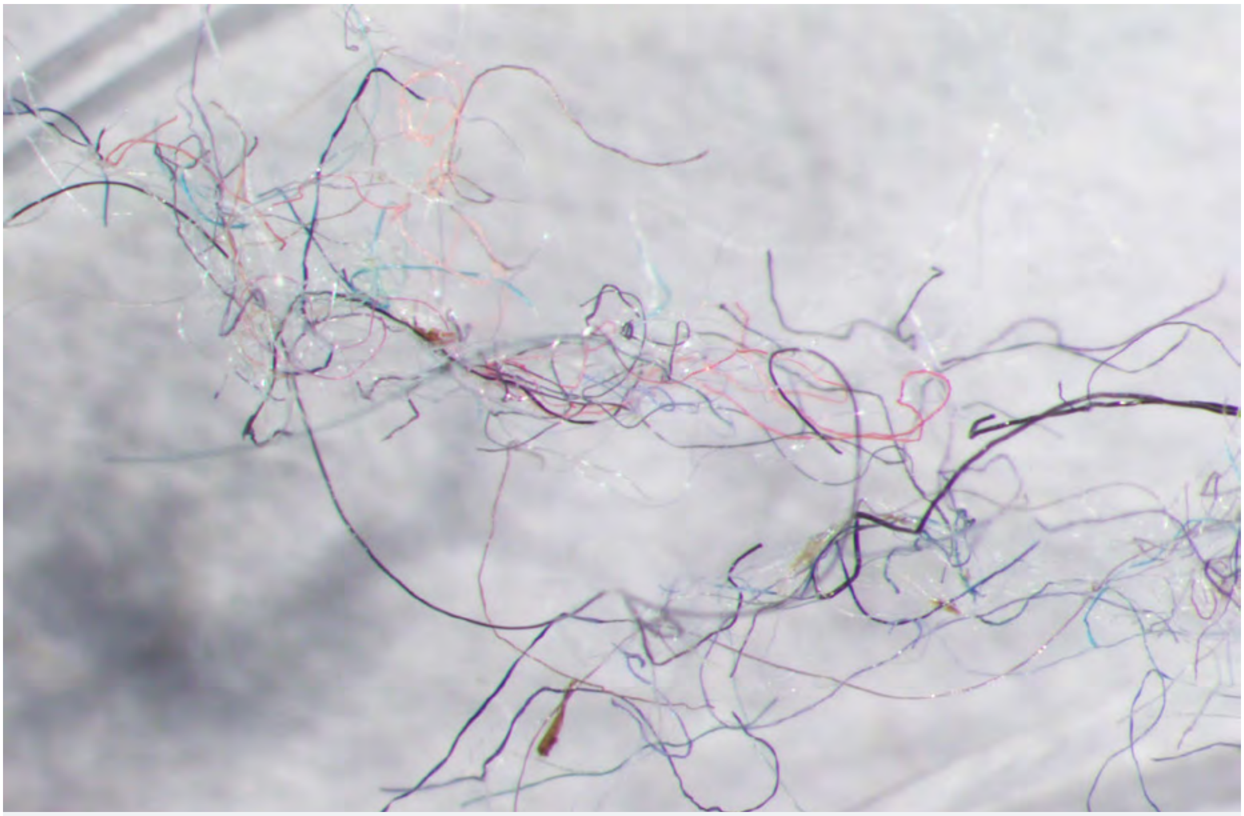


Figure 2. Fibres found in water samples collected in coastal B.C. (Photo: Ocean Wise)

What is the current status?

Microplastic pollution represents a recent topic of scientific and public interest, such that little trend information on contamination of the ocean environment exists. However, the escalating global production and use of plastics, of which only five percent is recycled, provides a stark indication of likely trends in the environment (Figure 3).

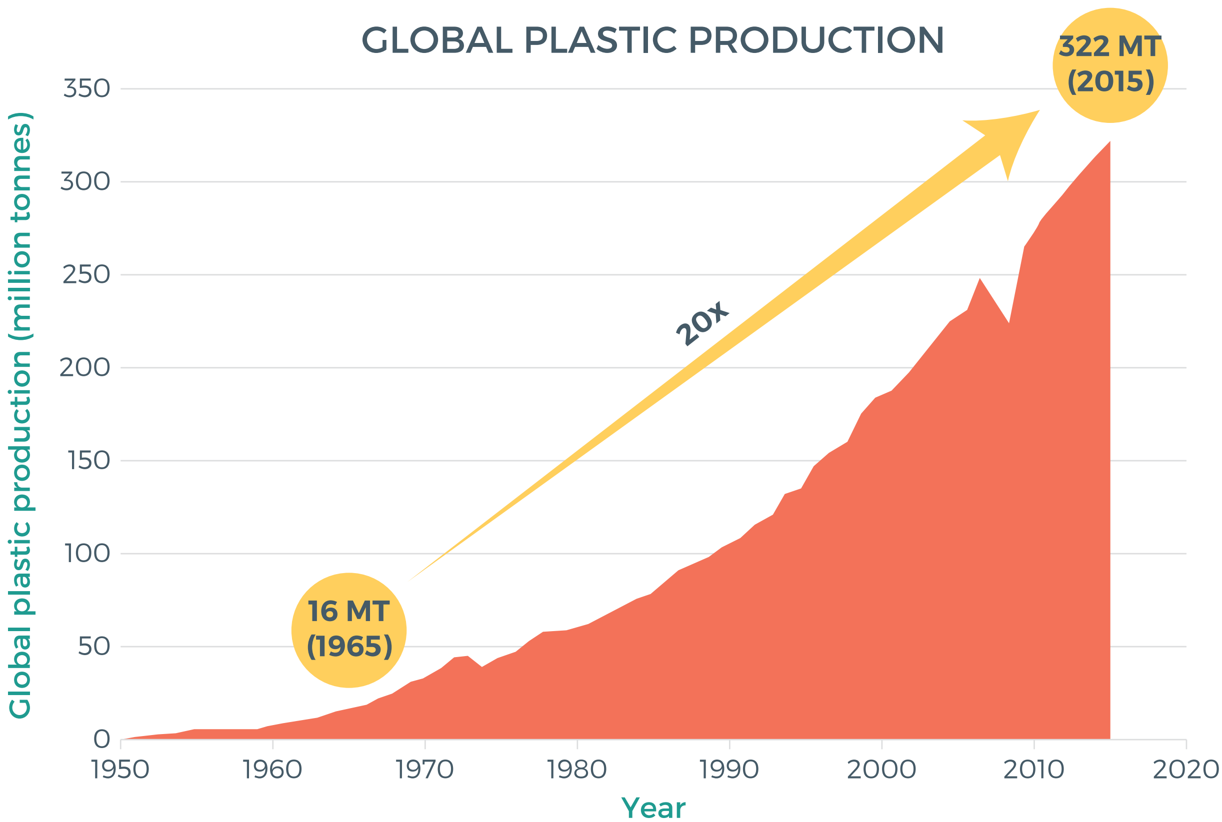


Figure 3. Global plastic production is increasing rapidly, with inadvertent release from countless sources contributing to microplastic pollution in the world's oceans. The most recent data from 2015 indicate global production for that year at 322 million tonnes. Adapted from Ellen MacArthur Foundation (2016).[17]

What is being done?

At the national level, regulations are in place in some countries for one particular type of microplastics – microbeads – found mostly in personal care products. Prior to a ban, it was estimated that the United States was releasing enough microbeads to cover more than 300 tennis courts daily.[18] Now microbeads are banned in the United States[19] and the United Kingdom.[20]

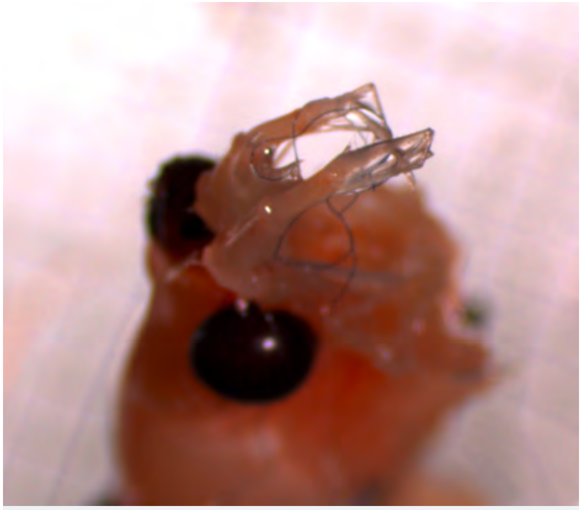
As of January 2018, the manufacture, import, and sale of toiletries containing plastic microbeads will be prohibited in Canada, through an addition to the Canadian Environmental Protection Act (CEPA). These include products used for exfoliating and cleansing, such as face wash or toothpaste. This will prevent the release of plastic microbeads from toiletries that go down household drains and contribute to ocean, river, and lake pollution.[21]

At the local level, several cities across Canada such as Victoria, Vancouver, Montreal, Fort McMurray, and Toronto are taking steps to reduce plastic use by banning or considering banning single-use plastic bags. In addition, as part of its 2040 Zero Waste Goal, the city of Vancouver is looking at banning other single-use plastics such as disposable cups, foam packaging, and take out containers.[22]

In addition to banning plastic straws, cup lids, and cutlery within its premises, the Vancouver Aquarium recently discontinued the sale of single-use plastic water bottles and encourages visitors to bring their own reusable water bottles.[23] Victoria's famous Butchard Gardens has also banned the sale of single-use plastic water bottles.

As fibres have been shown to be the main type of microplastics found in the ocean, the Ocean Pollution Research Program (at the Coastal Ocean Research Institute, an Ocean Wise initiative) has teamed up with Mountain Equipment Coop (MEC), Patagonia, Arc'teryx, Recreational Equipment Inc. (REI) and MetroVancouver to conduct research on microfibres and shed light on the source, transport, and fate of this particular type of microplastics.

Ocean Wise is conducting various research projects to increase our understanding of the sources of microplastics in the marine environment, the efficiency of our wastewater treatment plants for removing microplastics, as well as the effects of microplastics on ocean creatures. This will help develop efficient and local-specific mitigation measures preventing further increase of plastic pollution.



Microplastic fibre caught up in zooplankton antennae (Photo: Ocean Wise)

What can you do?

Individual and Organization Actions:

- Be plastic wise and reduce your plastic waste, for example avoid single-use plastic like plastic bags and plastic cups. Educate yourself and become a leader by promoting your knowledge in your community (Figure 4).
- Install filtering devices on your washing machines to trap fibres being released from your clothes during the wash.
- Choose natural over synthetic textiles.
- Participate in shoreline cleanups to reduce the amount of garbage and plastics circulating in the marine environment.

Government Actions and Policy:

- Ban single-use plastics such as plastic bags, coffee cups, drinking cups, cutlery, Styrofoam, straws, and take-out containers.
- Adopt zero-waste goals and enforce regulations.
- Support microplastics-related research.
- Support educational programs for all ages.
- Support development of recycling technologies and local facilities.
- Enforce recycling regulations.

It's time to shift our thinking about waste.

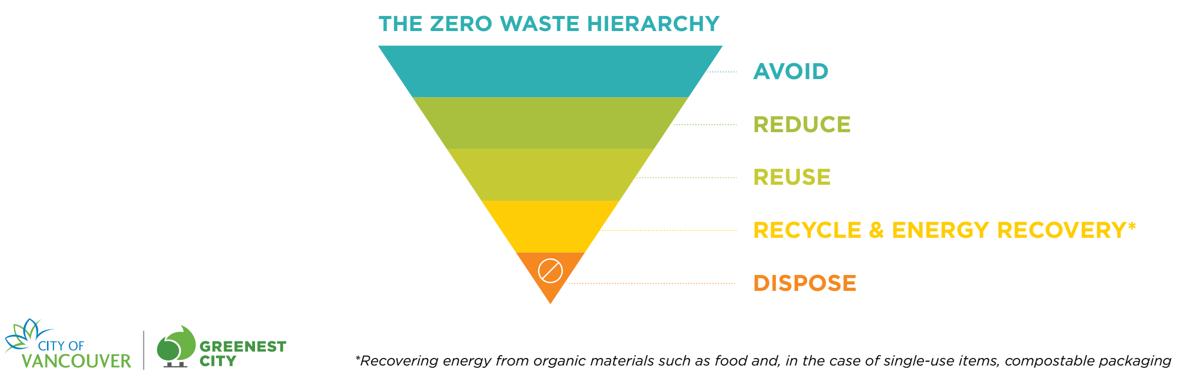


Figure 4. Ways to shift our thinking about waste. Source: City of Vancouver

Resources

Facts on microplastics
https://www.greenfacts.org/en/marine-litter/l-2/3-micro-plastics.htm

City of Vancouver Zero Waste 2040
http://vancouver.ca/green-vancouver/zero-waste-2040.aspx

Great Canadian Shoreline Cleanup
https://www.vanaqua.org/act/direct-action/great-canadian-shoreline-cleanup

UNEP report on plastic debris and microplastics
https://wedocs.unep.org/rest/bitstreams/11700/retrieve

Footnotes

[1] Ross, P.S., Morales-Caselles, C. 2015. Microplastics: Out of sight but not out of mind: Microplastics as a global pollutant. Integrated Environmental Assessment and Management 11: 721–722.

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[4] Cluzard, M., Kazmiruk, T.N., Kazmiruk, V.D., Bendell, L.I. 2015. Intertidal concentrations of microplastics and their influence on ammonium cycling as related to shellfish industry. Archives of Environmental Contamination and Toxiclogy 69, 310–319.

[5] Desforges, J.-P.W., Galbraith, M., Dangerfield, N., Ross, P.S. 2014. Widespread distribution of microplastics in subsurface seawaters in the NE Pacific Ocean. Marine Pollution Bulletin 79: 94-99.

[6] Desforges et al., 2014

[7] Desforges, J.-P., M. Galbraith, Ross, P.S. 2015. Ingestion of microplastics by zooplankton in the Northeast Pacific Ocean. Archives 69: 320–330.

[8] Desforges et al., 2015

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Photo: Jenn Burt

Risks and radiation impacts in the B.C. coastal-marine environment following the Fukushima nuclear accident

AUTHORS

Juan José Alava, Ocean Pollution Research Program, Coastal Ocean Research Institute, an Ocean Wise initiative, & Institute for the Oceans and Fisheries, University of British Columbia

Nikolaus Gantner, Adjunct Professor, Environmental Science Program, University of Northern British Columbia

REVIEWER

Dr. John N. Smith, Bedford Institute of Oceanography, Fisheries and Oceans Canada

What's happening?

Although Fukushima-associated radiation has been detected in seafood, water, soil, and air in B.C., the levels detected are consistently low and do not present immediate cause for concern for human health or marine organisms. The nuclear accident at the Fukushima Daiichi reactor plant caused by the Tōhoku earthquake (9.0 magnitude) and tsunami on the eastern coast of Japan on March 11, 2011 was considered a looming threat for the Pacific Ocean in terms of human health and marine biodiversity.[1–5] Following the nuclear aftermath, researchers from major universities in B.C. and across Canada, as well as the Government of Canada, started monitoring along the B.C. coast. To assess the level of radiation released from Fukushima, three major tracers or isotopes – known as cesium 134 (^{134}Cs), cesium 137 (^{137}Cs), and iodine (^{131}I) – were measured in seawater, seafood, and fish samples.[6–11] This was an important step because the potential contamination of seafood through bioaccumulation of radioisotopes in marine and coastal food webs was a major public health concern for coastal communities – particularly the bioaccumulative ^{137}Cs isotope.

Fukushima Daiichi Nuclear Power Station, Fukushima, Japan in 2007. (Photo: IAEA Imagebank, Wikimedia Commons, CC BY-SA 2.0)

Why is it important?

Understanding radiation or radioactivity released from nuclear accidents is important because of the potential human health effects, such as thyroid gland cancer, leukemia, genetic disorders, and other diseases. Direct exposure to radiation or consumption of contaminated food (i.e., above safe limits or thresholds identified by government to protect public health) is a risk to human health. For instance, radioactive iodine (^{131}I) can affect the thyroid gland immediately and fatally[5] if levels are higher than a given "action level" (i.e., safe limit or threshold) recommended in guidelines.

While the concentrations of ^{137}Cs in marine fish and other seafood in the B.C. marine environment have been reported to be low since the Fukushima accident,[6–11] the trends of radioactive ^{134}Cs and ^{137}Cs activities in organisms have differed greatly among taxonomic groups, habitats, and spatial distributions.[11–14] Contamination through trophic transfer of radioactive isotopes through food webs is likely to affect long-lived predators feeding at the top of the food web, including fish-eating seabirds and marine mammals inhabiting offshore and coastal habitats of the region. Simulations that model the biological accumulation of ^{137}Cs in Chinook salmon (*Oncorhynchus tshawytscha*) and fish-eating southern resident killer whales (*Orcinus orcas*) from B.C. predicted trophic magnification of ^{137}Cs via the food web in these species (Figure 1).[10] The potential confounding impacts of higher ocean surface temperatures or of ocean acidification on radioisotopes in food webs are unknown.

Is there a particular importance or connection to First Nations?

Although radioactivity levels in fish products are not considered to pose a risk to people at the present time,[7–9,11] concerns remain about the long-term exposure and bioaccumulation of radioactivity in marine food webs of the North Pacific.[10] Particularly vulnerable are First Nations peoples who are intimately connected with the oceans and rely strongly on the harvest and consumption of traditional seafood and fish products (e.g., Pacific salmon). Understanding pollution risks is critical, as healthy ocean food webs are key to the socioeconomic viability of coastal B.C. communities in terms of spiritual ecology, culture, and human connections. Seafood consumption by coastal First Nation communities in B.C. is 15 times higher than the average Canadian consumer,[15] and 64 percent of consumed seafood is salmon, thus indigenous people could be exposed to much more radioactivity (e.g., ^{137}Cs) than non-indigenous people in the long-term.

While uncertainties linger concerning the cancer risk assessment at low doses of radiation to humans, the Fukushima-derived doses received from fish consumption (e.g., tuna fish) by subsistence fishers were estimated to be two additional fatal cancer cases per ten million similarly exposed people.[16] According to a study on Fukushima-derived radioactivity in sockeye salmon (*Oncorhynchus nerka*) from West Vancouver Island[9], if it is assumed that all seafood has as much radiocesium as the most contaminated sockeye salmon sample measured, then the added annual dose from radiocesium to an adult individual with average Canadian seafood consumption would be 0.046 microsieverts (μSv) per year.[17,9] This is a very low dose with no risk to public health. In other words, this radiation dose is more than 10,000 times lower than the levels of concern to human health, meaning that traditional seafood is still safe for human consumption.

Bioaccumulation of radioactive isotopes

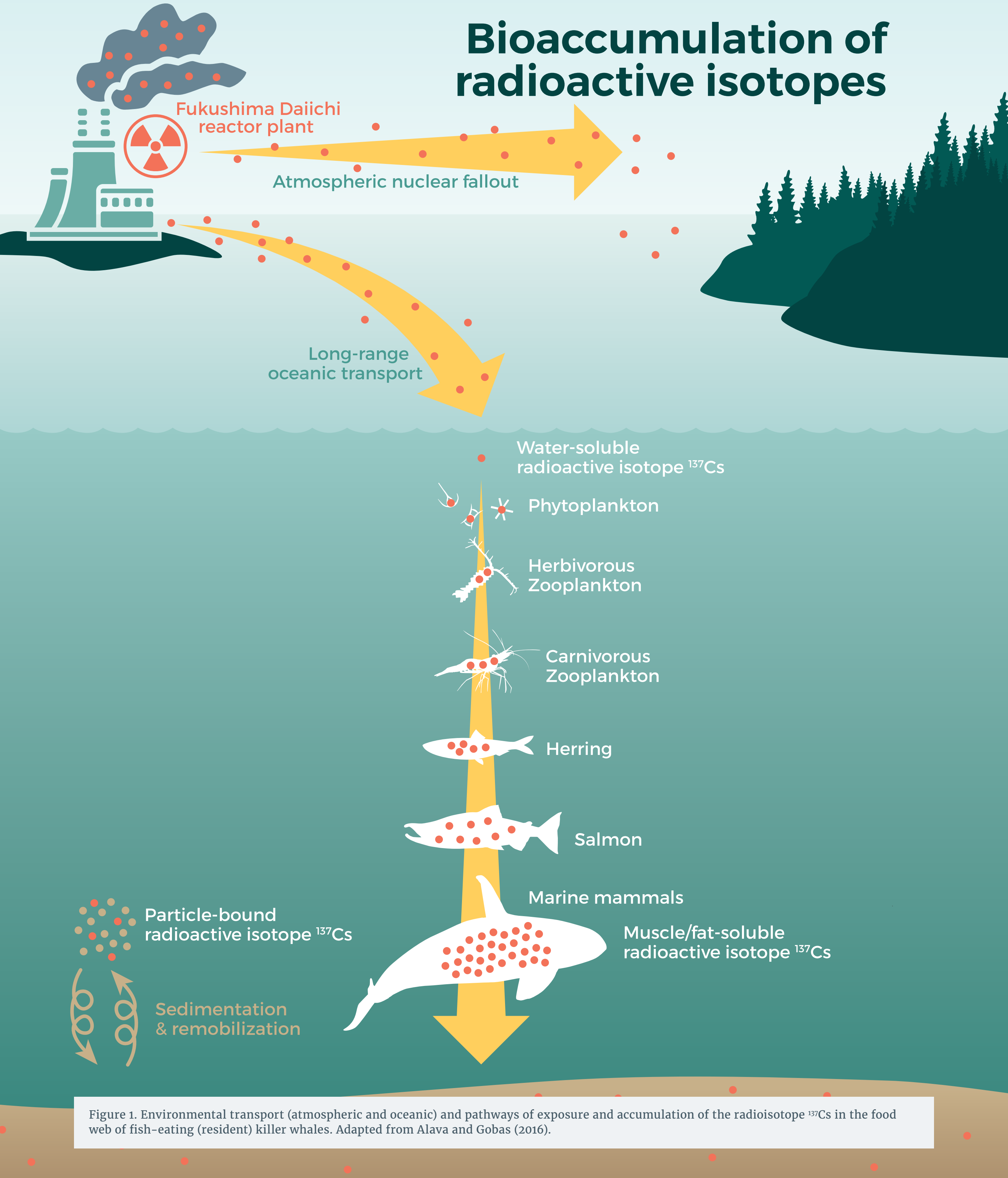

Figure 1. Environmental transport (atmospheric and oceanic) and pathways of exposure and accumulation of the radioisotope ^{137}Cs in the food web of fish-eating (resident) killer whales. Adapted from Alava and Gobas (2016).

What is the current status?

The arrival of seawater carrying one of the radioisotopes (^{137}Cs) associated with the Fukushima accident was detected in offshore waters west of Vancouver Island (1,500 kilometres west of B.C.) at depths of 0–100 metres starting in 2012.[18,19] The measured concentrations of ^{137}Cs were extremely low in 2012 and increased to values in excess of 0.008 Bq/L by 2016 (Figure 2).[20] The 2014 measurements were consistent with seawater activities of 0.001 Bq/L which were projected according to ocean circulation model simulations and expected to reach the northwestern coast of North America over the 2014–2020 time period.[18,21,22]

FUKUSHIMA-ASSOCIATED RADIATION IN SEAWATER

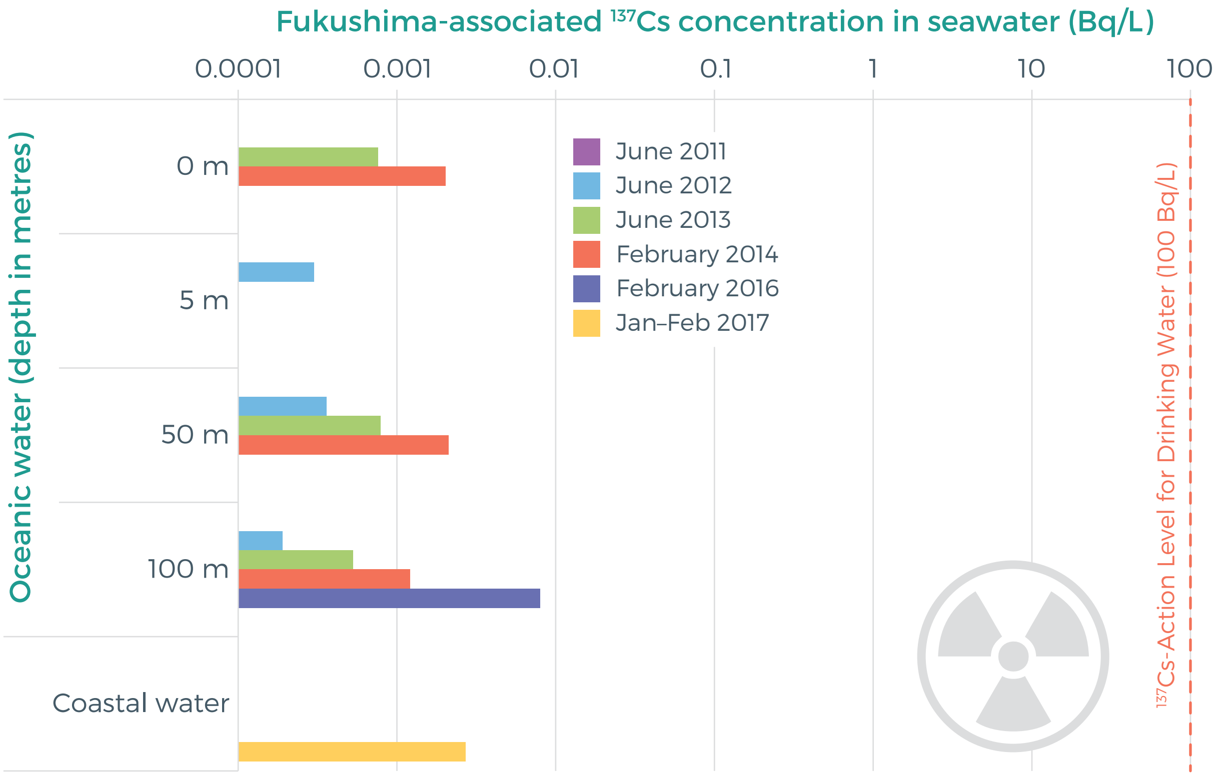

Figure 2. Concentrations of Fukushima-associated ^{137}Cs measured in oceanic waters off the west coast of Vancouver Island from 2011 to 2016, and coastal seawater in British Columbia in 2017. There was no detection of Fukushima-associated ^{137}Cs in 2011. The red dashed line represents the Canadian Action Level for ^{137}Cs in water as recommended by the Canadian Guidelines for the Restriction of Radioactively Contaminated Water Following a Nuclear Emergency. Data from Smith et al. (2015), Smith et al. (2017) and Fukushima InFORM.

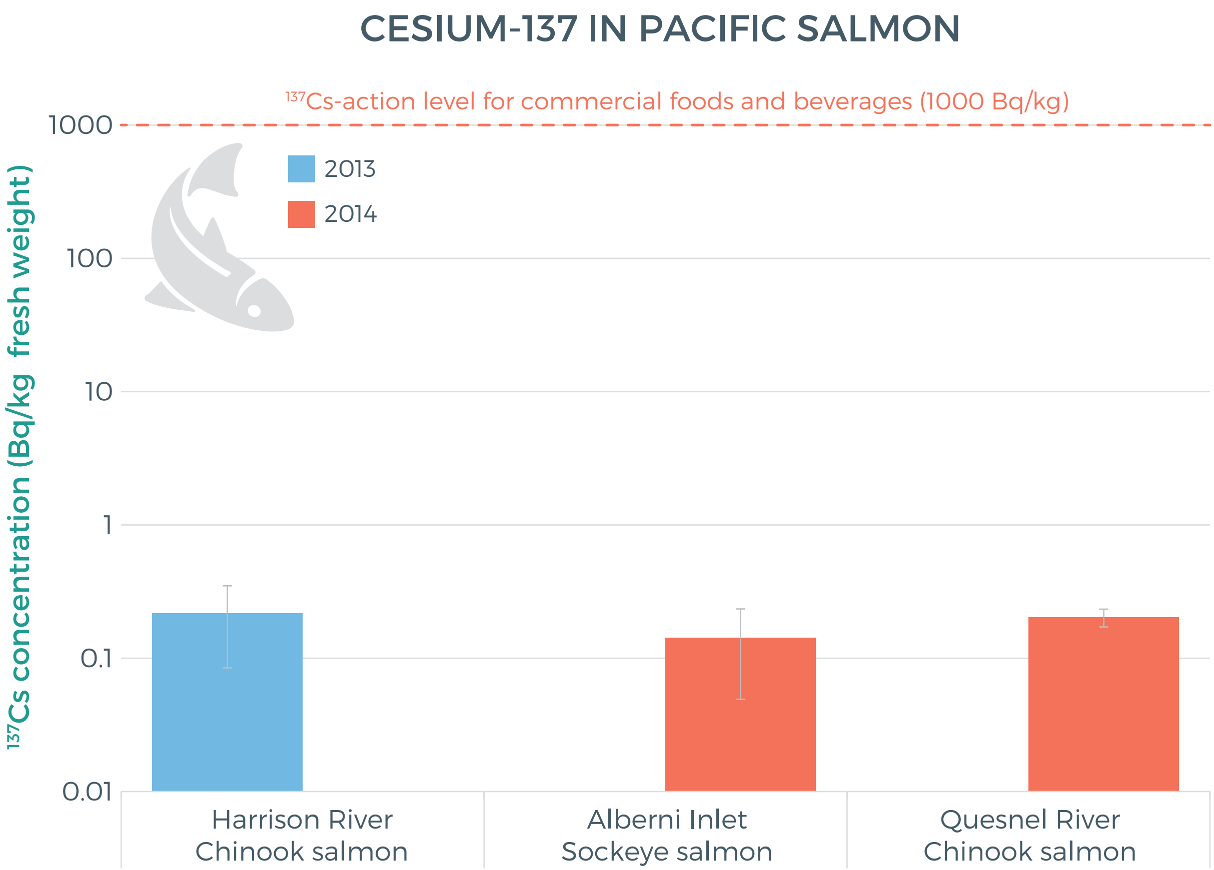

Figure 3. Mean concentrations (Bq/kg fresh weight) of ^{137}Cs measured in Pacific salmon species from two rivers (Harrison and Quesnel) and Alberni Inlet, on the west coast of Vancouver Island. Chinook salmon samples collected from the Harrison River in 2013 and Quesnel River in 2014, and half of sockeye salmon samples collected from the Alberni Inlet revealed detectable concentration for ^{137}Cs. Error bars are standard deviations calculated from the number of sockeye and Chinook salmon samples analyzed.[9,11] Data from Domingo et al (2016, 2017)

According to the data posted by the Integrated Fukushima Ocean Radionuclide Monitoring or Fukushima InFORM network (https://fukushimainform.ca/), the average concentration of ^{137}Cs in coastal seawater reached 0.003 Bq/L in January and February 2017 (Figure 2). These levels are still well below the recommended Canadian Action Levels for Radionuclides in Drinking Water of 100 Bq/L.[23]

Other research shows that levels of ^{137}Cs in several species of Pacific salmon are either below detection levels[7,8] or well below the recommended action level (Figure 3).[9,11] For example, in sockeye salmon collected from the west coast of Vancouver Island at Alberni Inlet, ^{137}Cs was detected in 50 percent of the samples with activity concentrations ranging from 0.23 to 1.43 Bq/kg dry weight, and the ^{134}Cs isotope was detected in a single sockeye salmon with activity concentrations measured in the two subsamples of 0.31 and 0.37 Bq/kg dry weight. Concentrations of ^{137}Cs in Chinook salmon samples collected in 2013 from the Harrison River (Kilby Provincial Park, B.C.) were also well below the action level (Figure 3).[11] Of particular interest is the possible temporal increase in ^{137}Cs concentrations from 2013 to 2015 in Chinook salmon in B.C.; and the first evidence of ^{134}Cs (an unambiguous or unequivocal tracer that confirms contamination from Fukushima radiation in particular) was observed in samples of adult Chinook salmon collected from spawning grounds located in the Quesnel River.[24] Due to their four to five year lifecycle, Pacific salmon returning to B.C. streams in more recent years will have spent longer feeding in the radiation-contaminated marine environment than those that returned, for example, in 2011, the year of the Tōhoku earthquake. Overall, these findings will further contribute to the understanding of the fate of radioactive contamination from Fukushima in ecosystems in B.C.

Projections using food web modelling indicate that the ^{137}Cs levels in Pacific herring, sablefish, halibut, Pacific salmon (pink, chum, and Chinook), and killer whales will remain far below the Canada Action Level for food consumption (i.e., 1000 Bq/kg).[10]

In this context, while no radiation risks are expected thus far to the general public and coastal communities from the consumption of Pacific salmon and other fish products harvested from marine coastal waters off B.C., environmental radiation is still not well understood. Thus an understanding of the basic nature of radiation's adverse effects on human bodies and other organisms (i.e., internal exposure dose in the human body versus external exposure dose found in contaminated food, water, and soil), as well as the mechanisms for how radiation affects the chemical world is strongly warranted.[4,5]

Following the upriver migration and spawning in breeding grounds, samples of Pacific salmon were collected from the Harrison River (Kilby Provincial Park, B.C.) in 2013 to measure radioisotopes (e.g., ^{137}Cs). Some species of Pacific salmon (e.g., Chinook and sockeye) can be used as sentinel species, because of their role as biovectors of pollution, to track anthropogenic radioisotopes such as ^{134}Cs and ^{137}Cs in the Northeastern Pacific. (Photo: Citizen scientist, Aki Sano)

What is being done?

With the aim of improving our understanding of the potential impacts of Fukushima radiation, several academic research groups at Simon Fraser University, University of Northern British Columbia, University of British Columbia, and University of Victoria are currently monitoring and analyzing radionuclides in seawater, salmon, other seafood, and soil samples. The Fukushima InFORM network (https://fukushimainform.ca/) is an integrated effort to collate and interpret published data and technical reports from the government and academia, as well as to monitor radionuclides in seawater and seafood in B.C. to inform the general public and scientists. Fisheries and Ocean Canada (DFO), Health Canada, citizen scientists, and several non-profit organizations from B.C. such as the Surfrider Vancouver Island, Georgia Strait Alliance, David Suzuki Foundation, Raincoast Education Society, the Clayoquot Biosphere Trust, and Living Oceans Society are also involved with this initiative. The Ocean Pollution Research Program (OPRP) at the Coastal Ocean Research Institute (an Ocean Wise initiative), in close collaboration with researchers from Simon Fraser University, conducted ecotoxicological risk assessments in traditional seafood consumed by First Nations Communities (Nuu-Chan-Nulth People and Tribal Council) in B.C. This project, called "Safeguarding Our Seafood Project," was initiated following the 2011 Fukushima nuclear accident to assess potential pollution risks to local seafood and communicate research findings.

What can you do?

Individual and Organization Actions:

- Get involved as citizen scientists and continue to support regional efforts to monitor Fukushima radiation on our B.C. coast (contact the Fukushima InFORM network (https://fukushimainform.ca/).
- Get involved as citizen scientists to collect samples in other less studied areas.
- Inform yourself on levels of radiation that are considered dangerous and harmful.

Government Actions and Policy:

- Reach out to citizens with regular information on radiation levels and risks related to seafood consumption.

Resources

The Fukushima Daiichi Accident
http://www-pub.iaea.org/books/IAEABooks/10962/The-Fukushima-Daiichi-Accident

Canadian Guidelines for the Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency
https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/environmental-contaminants/canadian-guidelines-restriction-radioactively-contaminated-food-water-following-nuclear-emergency-guidelines-rationale.html

International Atomic Energy Agency
https://www.iaea.org/

Fukushima InFORM
https://fukushimainform.ca/

http://meopar.ca/research/project/inform-international-fukushima-ocean-radionuclide-monitoring-network

Canadian Radiological Monitoring Network
http://open.canada.ca/data/en/dataset/21b821cf-0f1c-40ee-8925-eab12d357668

TRIUMF
Canada's national laboratory for particle and nuclear physics and accelerator-based science
http://www.triumf.ca/home/about-triumf

Footnotes

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[17] μSv = symbol for the microsievert, an International System of Units (SI) used for measuring radiation levels and dose equal to 10-6 sieverts (Sv). 1 Sv = 1000 mSv (millisieverts) = 1,000,000 μSv (microsieverts); 100 Sv is known to kill a person instantly.

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Persistent organic pollutants in marine mammals

AUTHORS
Marie Noel and **Peter S. Ross**, Ocean Pollution Research Program, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Juan José Alava, Institute for the Oceans and Fisheries, University of British Columbia

What's happening?

The marine environment is at the receiving end of thousands of chemicals being released intentionally or unintentionally every year. Persistent contaminants including polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) are found throughout the global environment and accumulate in the aquatic food chain. Many marine mammals are long-lived, have a thick blubber layer, and are at the top of the food chain. These factors predispose them to accumulating persistent organic pollutants (POPs) at harmful levels (Figure 1).

Despite the implementation of regulations on the production and use of these chemicals, they are still found in the marine environment and wildlife at relatively high concentrations due to their persistence and ability to move in the environment.[1] PCBs were widely used as stable, heat resistant coolants and lubricants for electrical transformers and capacitors – they were banned in 1977 in Canada. PBDEs were widely used as flame retardants in electronics, furniture, and other products. Two of the three commercial formulations of PBDEs (penta- and octa-) were withdrawn from the market in 2004 while the third product was phased out in 2013.

Bioaccumulation in marine mammals

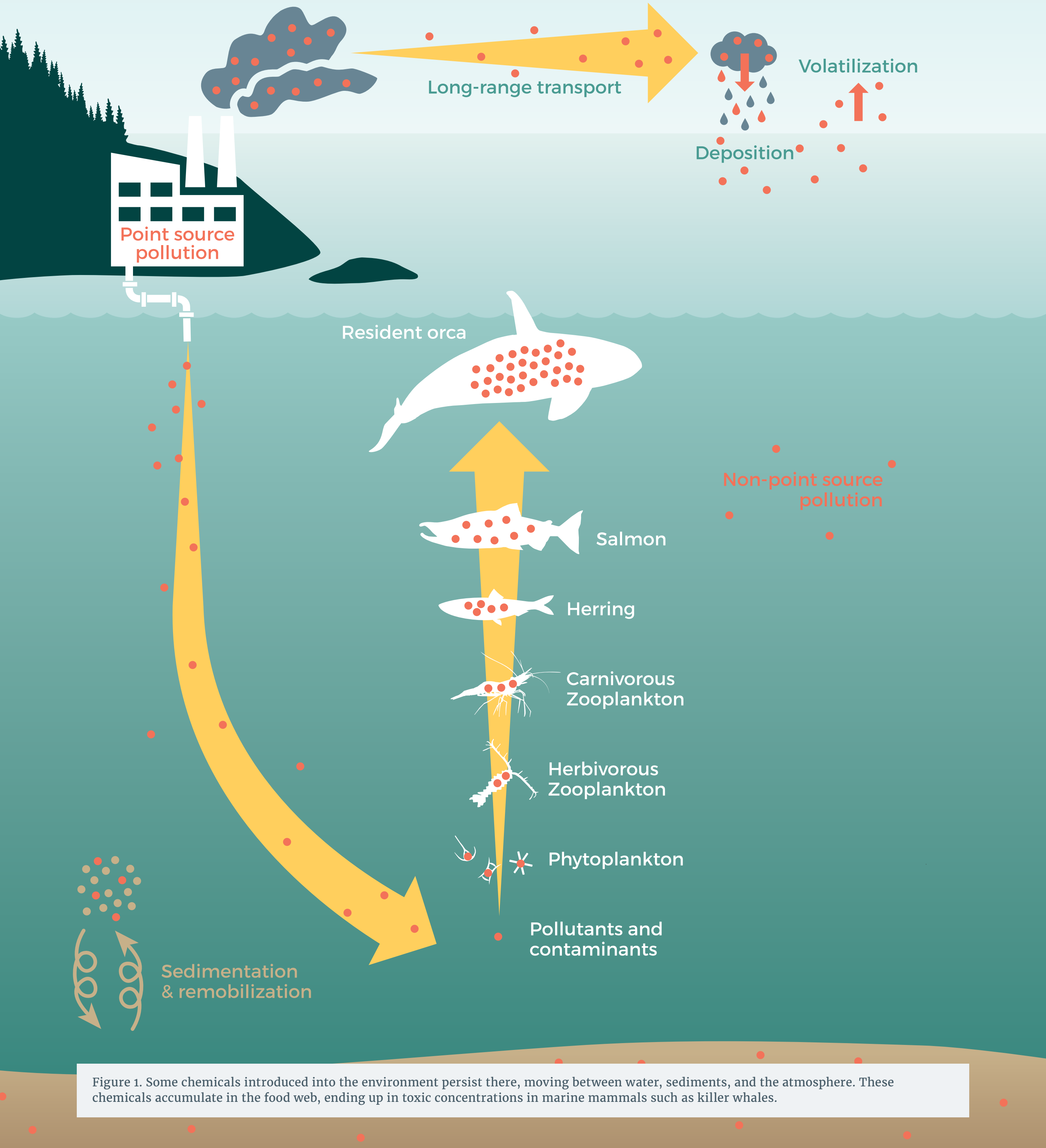


Figure 1. Some chemicals introduced into the environment persist there, moving between water, sediments, and the atmosphere. These chemicals accumulate in the food web, ending up in toxic concentrations in marine mammals such as killer whales.

B.C.'s killer whales exhibit high concentrations of flame retardant chemicals. (Photo: Marie Noel)

Why is it important?

PCBs represent a major toxicological concern for many high trophic level species. They have been associated with reproductive problems, tumors, disruption of the immune system, and hormonal imbalances.[2–5] While less is known about the toxicity of PBDEs to marine mammals, similarities in chemical structures suggest similar toxic effects.[6] PBDE-associated disruption of the immune system has been reported in harbour seals.[7]

British Columbia's killer whale (*Orcinus orca*) populations are among the most PCB-contaminated marine mammals in the world[8] and also exhibit one of the highest concentrations of PBDEs.[9,10] Contaminants have been identified as a threat to the recovery of all four B.C. killer whale populations under the auspices of the Species at Risk Act (SARA). It is therefore important to monitor such contaminants in order to identify priorities, design mitigation measures, and monitor progress.

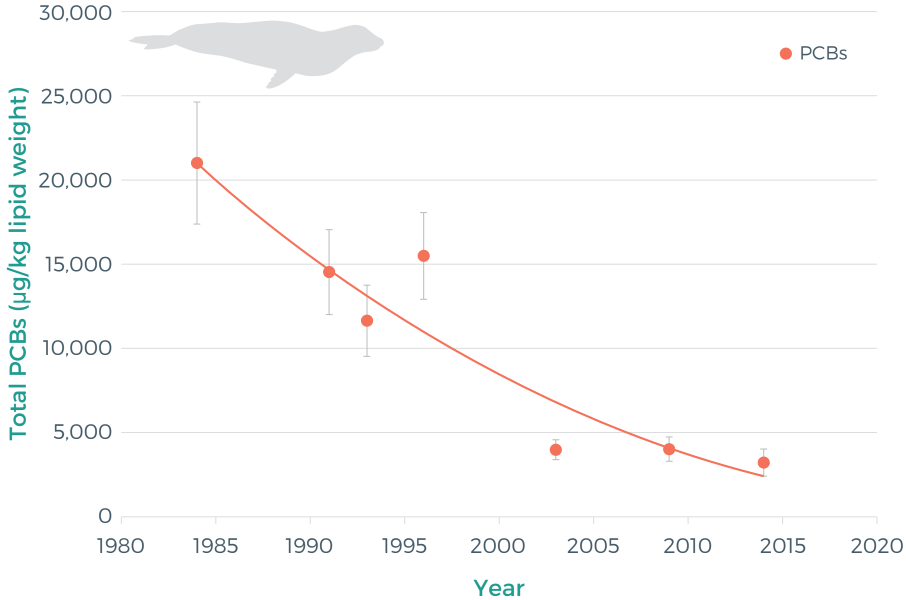
What is the current status?

Harbour seals (*Phoca vitulina*) provide insight into local killer whale habitat quality and help shed light on source, transport, fate, exposure, and effects of contaminants of concern to SARA-listed resident and transient killer whales. Harbour seals have proven to be useful indicators of marine environmental quality, and research on contaminants in harbour seals has helped to identify regional hotspots and emerging contaminants of concern. The utility of the harbour seal as a sentinel of food web contamination can be ascribed to their widespread distribution in B.C., their ease of capture and handling, and the extensive knowledge of their biology and ecology. Contaminants of concern have been monitored in the blubber of harbour seal pups since 1984. In this context, harbour seals can be considered as "canaries in the coal mine" in the B.C. marine environment to track POPs and monitor the health status of the ecosystem at spatial and temporal scales over the long-term.[11]

PCB levels in harbour seal pups have been declining since 1984 indicating that regulations enacted in North America have reduced PCB inputs into the local coastal food web (Figure 2). PBDE levels in harbour seal pups increased exponentially from 1984 to 2003, but appear to be declining since then, reflecting the regulations put into place in early 2000s.

Harbour seals accumulate toxic levels of persistent chemicals. (Photo: Marie Noel)

TEMPORAL TRENDS OF PCBs IN SEAL PUPS



TEMPORAL TRENDS OF PBDEs IN SEAL PUPS

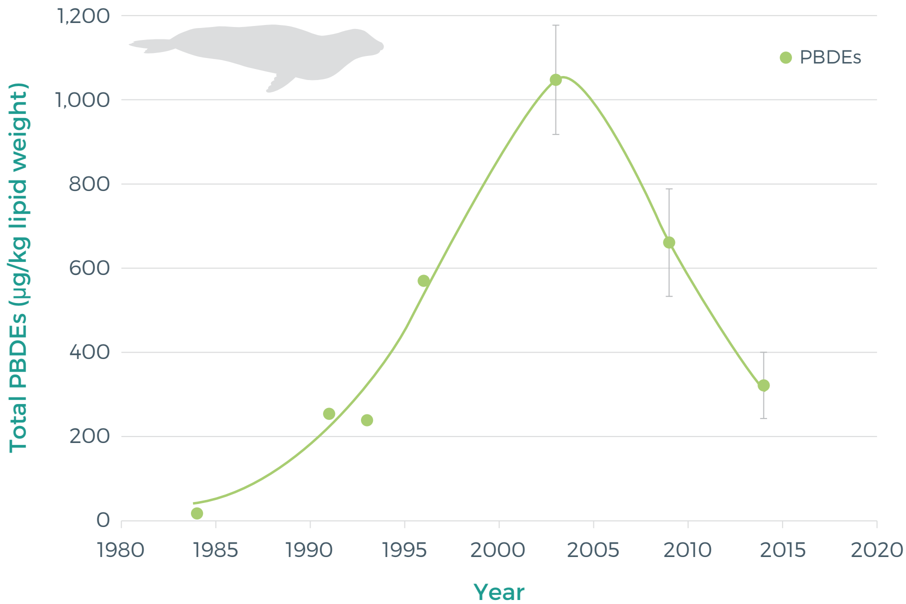


Figure 2. While PCB levels in harbour seal pups have been declining since 1984 in Puget Sound, USA, PBDEs levels increased exponentially until 2003 before declining. Source: Ross et al (2013).[12]

Toxicity reference values (TRV) have been developed for PCBs in marine mammals. The most conservative toxicity reference value of 1.3 mg of PCBs per kilogram of lipid weight is the threshold above which disruption of the immune system, hormonal imbalances, and genetic effects have been observed in harbour seals.[13] While PCB-associated health risks in harbour seals have been declining following regulations, all the pups sampled at Gertrude Island (Puget Sound, USA) exceeded the toxicity reference value (Figure 3). Similarly, PCB concentrations in 80 percent of Steller sea lions (Eumetopias jubatus) sampled in the Strait of Georgia exceeded the toxicity reference value for PCBs.[14] There are currently no toxicity reference values for PBDEs.

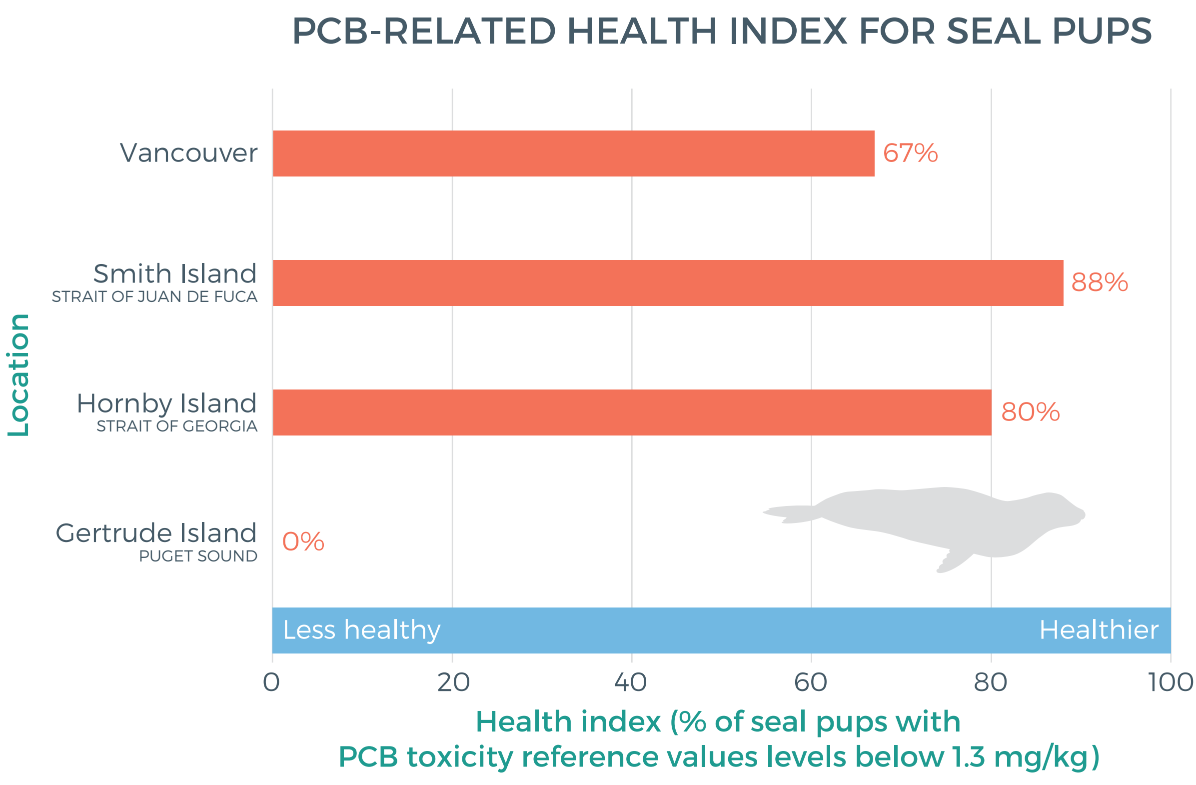


Figure 3. The PCB-related health index of harbour seal pups sampled in British Columbia is relatively good (67–88 percent), however all of the seal pups sampled in the industrialized Puget Sound, USA, exceeded the toxicity reference value for PCBs, giving them a PCB-related health index of zero. Source: Ross et al (2013).

What is being done?

The Stockholm Convention was adopted in 2001 and entered into force in 2004 with the goal of protecting human health and the environment from POPs. PCBs are one of the original 12 POPs covered by the Stockholm Convention – signatories can no longer produce or use PCBs. However, existing equipment containing PCBs may still be used until 2025. Only two of the three PBDE commercial formulations (penta- and octa-) are currently covered by the Stockholm Convention.[15]

At the national level, even though PCBs were not manufactured in Canada, they were imported and used commercially over the period 1929 to 1977 before being banned for importation into Canada in 1980. Under the Canadian Environmental Protection Act (CEPA), Health Canada and Environment Canada control the use, importation, manufacture, storage, and release of PCBs. The Government of Canada has signed a number of international agreements such as the Canada-US Agreement on PCBs and the Basel Convention to ensure safe use, storage, transport, and disposal of PCBs.[16]

In 2016, PBDEs were added to the Prohibition of Certain Toxic Substances Regulation, which prohibits the manufacture of all PBDEs in Canada, as well as restricts the import, use, sale, and offer for sale of PBDEs found in all three commercial mixtures. Additional actions are being developed such as control measures under CEPA and the development of a plan to dispose of or deal with PBDE-containing products at the end of their useful life.[17]

What can you do?

Individual and Organization Actions:

- Learn more about contaminants of concern using the resource links below.
- Reduce or eliminate the use of chemicals for cleaning or gardening.
- When buying furniture, ask about any flame retardants that might be found in products and try to avoid buying items that contain PBDEs.
- Take electronic equipment to a recycling and disposal centre near you.

Government Actions and Policy:

- Develop regulations to prohibit and control currently-used pesticides, flame retardants, and plasticizers that have the same properties that made PCBs problematic – namely chemicals that are persistent, toxic, and accumulate in organisms faster than they can be excreted.

Photo: Kim Wright

Resources

Environment Canada's PCB website
http://www.ec.gc.ca/bpc-pcb/default.asp?lang=En&n=52C1E9EF-1

Environmental Trends in British Columbia: 2007
http://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/reporting/envreportbc/archived-reports/et2007/et2007__contaminant__indicators__summary.pdf

Indigenous and Northern Affairs Canada
http://www.aadnc-aandc.gc.ca/eng/1316112284889/1316112526106

Toxic contaminants in harbour seal pups from Puget Sound
https://fortress.wa.gov/ecy/publications/documents/1110001.pdf

Government of Canada – PBDEs
https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/chemicals-glance/polybrominated-diphenyl-ethers-public-summary.html

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Trends in contaminants of concern in seabirds from the Pacific coast of Canada

AUTHORS

Tanya M. Brown, Biological Sciences, Simon Fraser University

John E. Elliott, Biological Sciences, Simon Fraser University and Applied Animal Science, University of British Columbia, and Environment and Climate Change Canada, Ecotoxicology and Wildlife Health Directorate, Pacific Wildlife Research Centre

Kyle H. Elliott, Department of Natural Resource Sciences, McGill University

REVIEWER

Marie Noel, Research Manager, Ocean Pollution Research Program, Coastal Ocean Research Institute, an Ocean Wise initiative

What's happening?

Decades of monitoring contaminant levels in seabirds on the Pacific coast of Canada show that some contaminants have decreased in concentration – reflecting source controls and regulations – while other contaminants have remained stable or have risen.

Seabirds make effective indicators for examining contamination of marine pollution. They are at the top of the food chain and accumulate high concentrations of contaminants. They also often have large ocean habitats, feeding as they move, and return annually to breed in one location where nonlethal eggs or tissue samples can provide information on contaminant levels over space and time (Figure 1).[1] As such, a variety of seabirds have been used to monitor contaminant levels and trends around the world.[2-4] Environmental contamination by mercury (Hg) and such chemicals as perfluoroalkyl substances (PFAS) and brominated flame retardants (BFRs) (e.g., polybrominated diphenyl ethers [PBDEs], hexabromocyclododecane [HBCDD]) are of concern since they accumulate in food webs, do not readily degrade, and are toxic. Time trends on mercury and emerging contaminant levels in seabirds are unavailable for many coastal regions around the world. However, Environment and Climate Change Canada has been extensively monitoring mercury concentrations and emerging contaminant concentrations (e.g., PFAS, PBDEs, and HBCDD) in seabirds on the west coast of Canada for several decades.

Seabirds as indicators of contamination

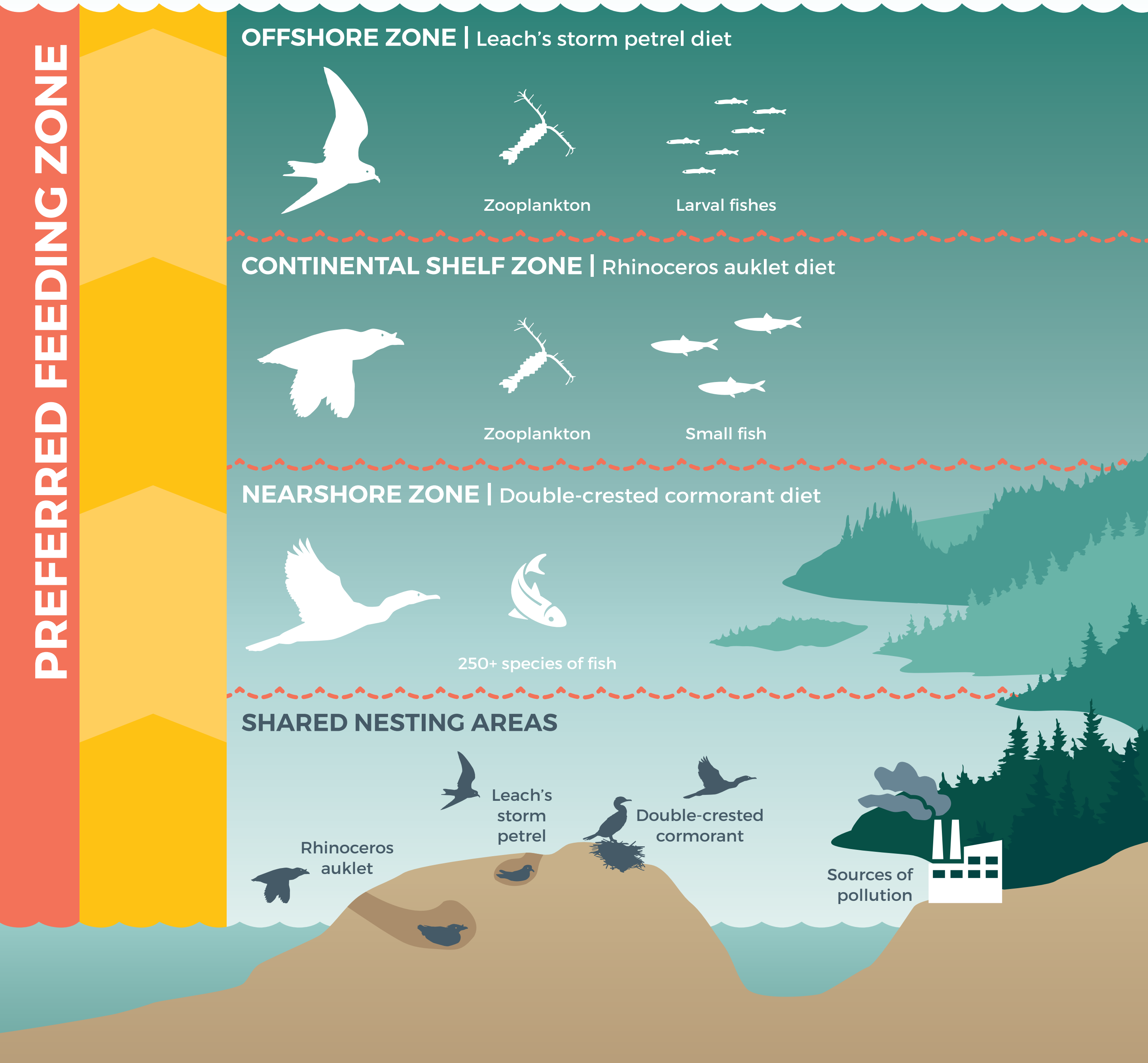

Figure 1. Different seabirds have different feeding strategies. For example, cormorants forage mainly on fishes in the nearshore environment. The rhinoceros auklet tends to feed on smaller fishes and zooplankton on the continental shelf. Pelagic seabirds such as the Leach's storm petrel range across the offshore zone, feeding on zooplankton and larval fishes. All seabirds return to breed in colonies where they can be sampled for contaminants. The inset graph depicts the time trend for the flame retardants PBDEs in the rhinoceros auklet eggs on the Pacific coast. Figure adapted from Elliott and Elliott (2013).

Why is it important?

Human activities release thousands of chemicals into the marine environment, many of which can be harmful to wildlife, including seabirds. Long-term monitoring of contaminant levels in seabirds and other animals at the top of the food chain provides us with insight into ocean health, and allows us to track environmental response to source controls and regulations.

Despite originating from very different sources, mercury (in the form of methylmercury), PFAS, and BFRs can travel long distances in the air and by ocean currents[6–8] and have been found to accumulate in food webs across the globe.[9–11]

Mercury is a naturally occurring element found in various forms.[12] Natural sources of mercury include volcanoes, forest fires, fossil fuels, petroleum, and cinnabar ore.[13] However, numerous human activities also release mercury, such as fossil fuel combustion, mining, smelting, solid waste combustion, fertilizers, and industrial wastewater disposal. Various consumer products contain mercury, such as thermometers, some electrical switches, dental fillings, and batteries.

Methylmercury is the most toxic form to animals and humans, and can accumulate to high levels in marine food webs.[14] Mercury exposure in birds can affect brain development, endocrine and immune function, reproduction, and survival.[15–17] For example, mercury affects reproductive success through poor egg viability[18] and by changes in behaviour.[19] Mercury in birds has also been associated with decreased nesting attempts and nest attentiveness.[20]

PFAS have been used in a wide range of industrial and consumer applications including firefighting foams, grease-proof paper, stain repellents in textiles, and processing aids in fluoropolymer manufacturing. The use of PFAS has released large amounts to municipal waste waters and directly to the air. PFAS compounds typically do not break down in the environment and may be toxic.[21]

Flame retardants (BFRs) are produced to reduce the flammability of textiles, plastics, and construction materials.[22] BFRs are toxic and have been found to disrupt hormone function in birds.[23–26]

What is the current status?

Mercury

Mercury trends have been measured in eggs from three seabirds species on the west coast of Canada: an offshore pelagic indicator, the Leach's storm petrel (*Oceanodroma leucorhoa*) (1968–2015); and two continental shelf indicators, the ancient murrelet (*Synthliboramphus antiquus*) (1968–2009) and the rhinoceros auklet (*Cercohinca monocerata*) (1970–2014). Mercury concentrations in seabirds on the west coast have shown no clear time trends (Figure 2), except for a decrease over time in murrelets (Figure 2) and in cases where diet changed.[27] This is consistent with observations in fish and mammals where trends have remained generally stable over the past 50 years.[28] Seabird eggs from Atlantic Canada have also shown no clear trends. Despite three to five-fold increases in mercury deposition in the Pacific since the Industrial Revolution,[29] levels in seabirds have increased by less than two-fold during that period.[7] This is somewhat surprising because mercury levels in the Pacific Ocean surface waters have increased, presumably as a result of coal burning in Asia.[30,31] This disconnect between environmental emissions and accumulations in seabirds of the Pacific may be because mercury accumulation is constrained by availability of another element, called sulphur.[32]

Rhinoceros auklet at sea. (Photo: Kyle Elliot)

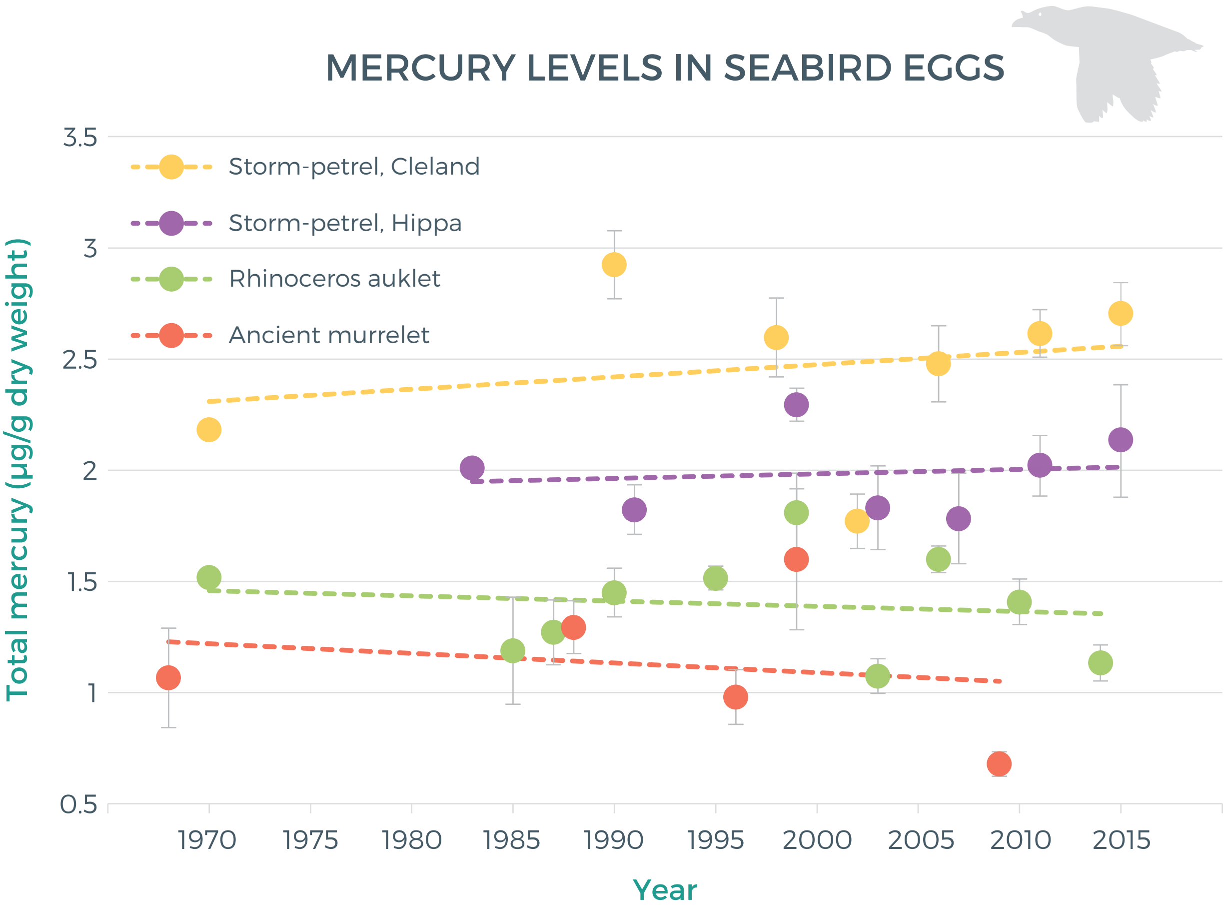

Figure 2. Mercury levels in seabird eggs show little discernable trends between 1968 and 2015 from the Pacific coast of Canada.

Perfluoralkyl substances (PFAS)

Trends in PFAS have been monitored pre- and post-production phase out of the chemicals. Eggs of two oceanic seabird species were tested: the continental shelf species, rhinoceros auklet (1990–2010); and the offshore pelagic indicator, Leach's storm petrel (1991–2011). Despite regulations implemented in North America in 2000 for some of these substances,[33,34] PFAS levels have not declined in petrels and auklets, and instead have increased over time. These results are consistent with trends in other wildlife (e.g., herring gulls (*Larus argentatus*) from Norway[35] and coastal German regions[36]) as well as selected seabirds from the Canadian Arctic.[37] Increasing concentrations of substances such as PFCA over time in wildlife are an ongoing cause for concern (Figure 3).

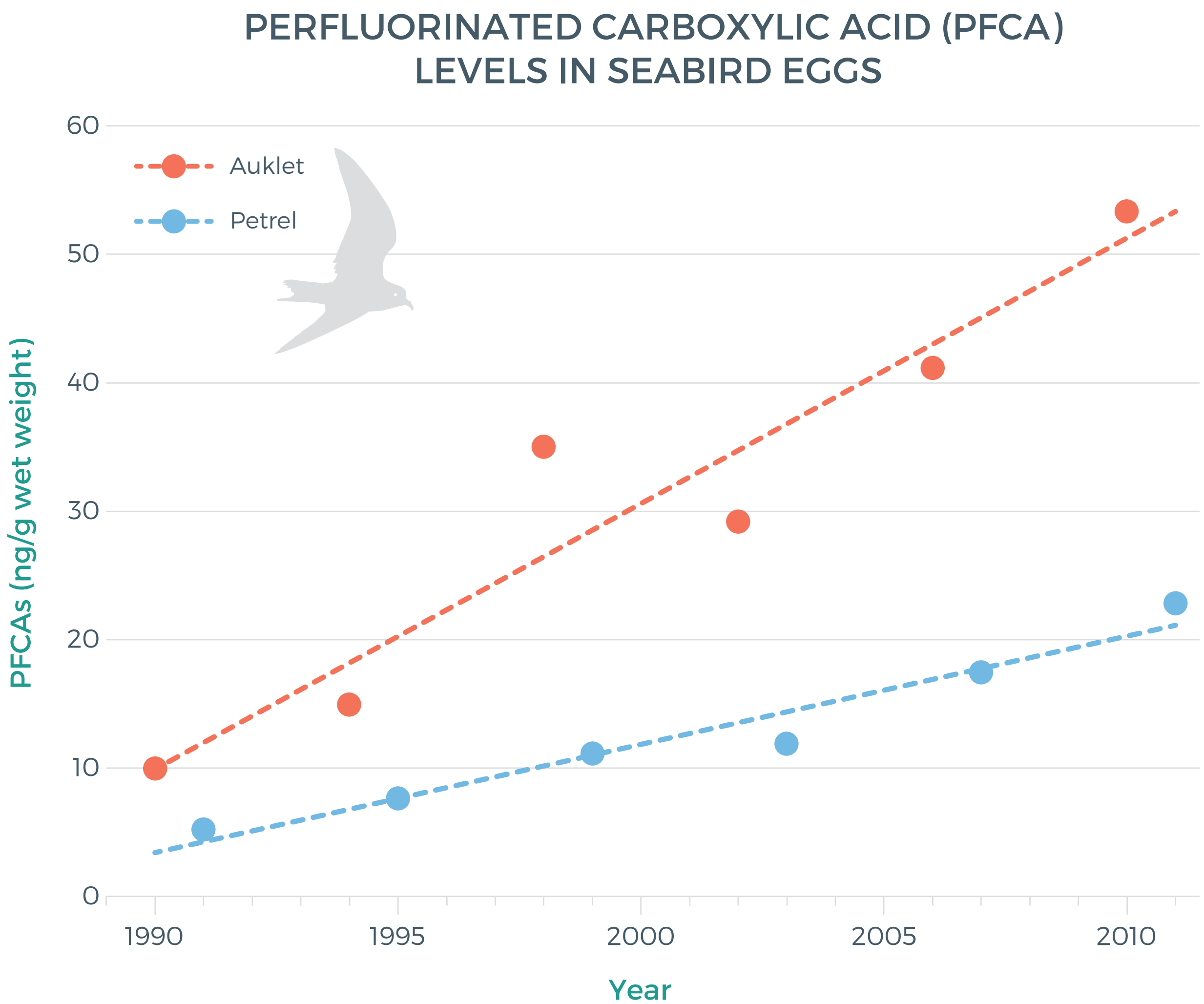

Figure 3. Perfluorinated carboxylic acid (PFCA) levels in seabird eggs are increasing over time.

Brominated Flame Retardants

The levels of PBDEs declined in rhinoceros auklet eggs following regulations of two (penta- and octa-BDE) of the three BFR mixtures in 2004 (Figure 4). However, that trend was not apparent for storm-petrel eggs collected at Hippa Island (Figure 4), which may be the result of this population of birds feeding farther from North America and closer to Asia. The brominated flame retardant (HBCDD) is higher in storm-petrel eggs compared to auklet eggs. This may be due to the fact that petrels feed further from shore and closer to Asia.

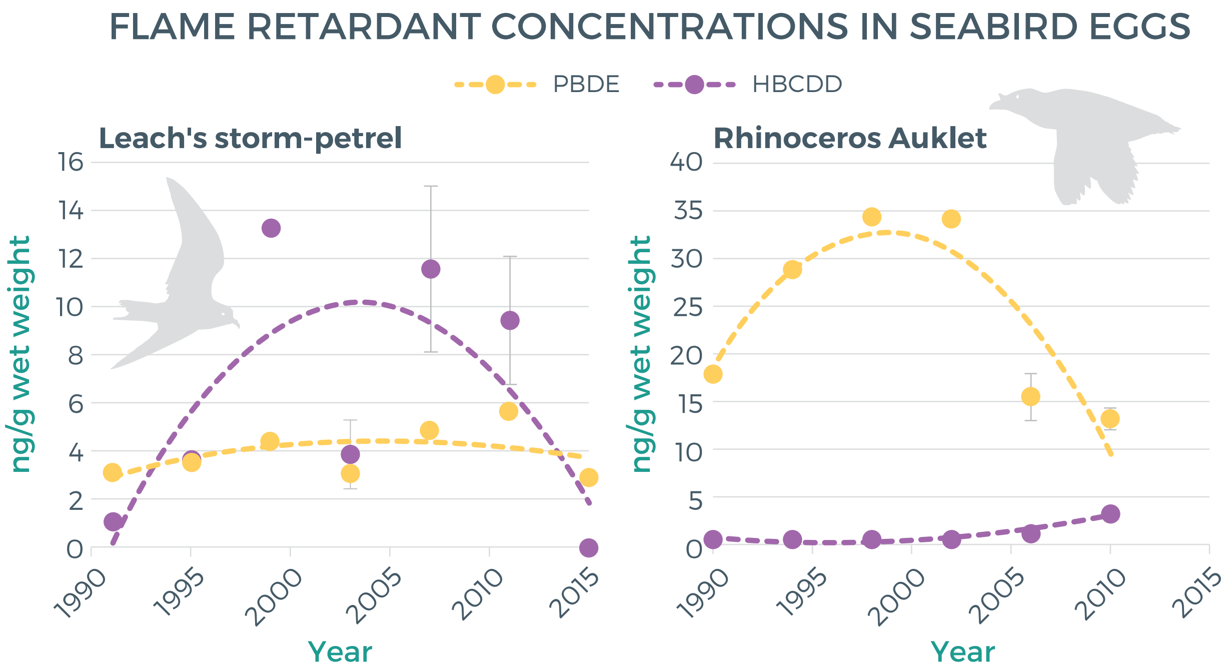

Figure 4. HBCDD and PBDE concentrations over time in Leach's storm-petrel eggs from Hippa Island and rhinoceros auklet eggs from Cleland Island. Figure modified from Miller et al. (2014)[38]

What is being done?

Mercury has been released in large quantities from multiple sources, with coal burning representing a major source. In April of 2017, the Government of Canada signed onto the Minamata Convention, an international agreement to reduce human-related mercury emissions. Prior to Minamata, Canada had legislation on mercury emissions from coal-fired facilities, the USA had a Mercury and Air Toxics Standard, and the European Union had an Industrial Emissions Directive. Further, many of the coal burning plants in these countries had emission control systems in place, which were helping to significantly lower mercury emissions. China and India on the other hand, have rapidly growing populations and economies which presents a challenge when attempts are being made to bring all plants up to acceptable emission limit standards.

The Stockholm Convention on persistent organic pollutants (POPs) regulates more than 30 chemicals and groups of chemicals of which PBDEs, HBCDD, and PFAS are included. The goal of this treaty is to eliminate the release of contaminants which accumulate in food webs, do not degrade in the environment, and are toxic. In 2000, the 3M Company – the major global producer of one PFAS compound known as PFOS – announced a phase out of the production of some PFAS and other related products. Further restrictions in the US, Canada, and Europe were implemented throughout the 2000s,[39] however, the production of some PFAS in China continue.

There are three major PBDE products: PentaBDE, OctaBDE, and DecaBDE, of which two (Penta- and OctaBDE) were added to Stockholm Convention in 2009, and DecaBDE and HBCDD have been added to the elimination list. Lower PBDE levels in North American and European wildlife reflect these controls, however, the increasing HBCDD levels in seabird eggs are troubling. That said, the inclusion of HBCDD under the Stockholm Convention should lead to reductions of this chemical in wildlife.

Rhinoceros auklet with forage fish. (Photo: Kyle Elliott)

Monitoring of all these contaminants have been ongoing for decades due to their high production volume, occurrence in the environment, and toxic potential. Continued monitoring of a range of wildlife found at all levels in the food chain – which include seabirds – will provide a better basis to inform the public about contaminants, to understand the causes of contaminant trends in marine ecosystems, and to track environmental response to source controls instituted under international conventions.

What can you do?

Individual and Organization Actions:

- Use less energy: coal-fired electricity generation is the largest source of mercury emissions to the environment, and hydro-electric dams also increase mercury levels in water reservoirs.
- Reduce your uses of mercury, PFAS, and brominated compound-containing products. For example:
    - Use energy efficient LED bulbs which are a mercury-free alternative for lighting. Fluorescent bulbs contain very small amounts of mercury, but are still more energy efficient than incandescent bulbs and can also help reduce overall mercury emissions.
    - Purchase “green” furniture that does not contain flame retardants.
- Avoid purchasing non-stick pans, household cleaners, clothing, furniture, packaged food containers, and stain repellants that can contain PFAS.
- Continue to educate yourself and share what you have learned with others.

Government Actions and Policy:

- Support federal and national programs for marine pollution to promote long-term monitoring that will protect ocean and human health from human made chemicals.

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Tons of debris removed from the West Coast Trail

AUTHOR
Rachel Schoeler, Manager, Great Canadian Shoreline Cleanup, an Ocean Wise initiative

REVIEWER
Chloé Dubois, co-founder of The Ocean Legacy Foundation, a partner in The Vancouver Island Marine Debris Working Group

What's happening?

Three consecutive summer shoreline cleanups on Canada's iconic West Coast Trail resulted in the removal of over 10 metric tons of marine debris and drifted materials. Eleven kilometres of shoreline were cleaned over 119 person-days of effort, and 87 supersack bags plus loose items of human-made material were collected and removed (Figure 1). Each supersack bag holds about one cubic metre or 100 to 200 kilograms of material.

After the 2011 Tōhoku earthquake and tsunami the Government of Japan estimated 1.5 million tonnes of driftage – commonly referred to as tsunami

Photo: Kate Le Souef

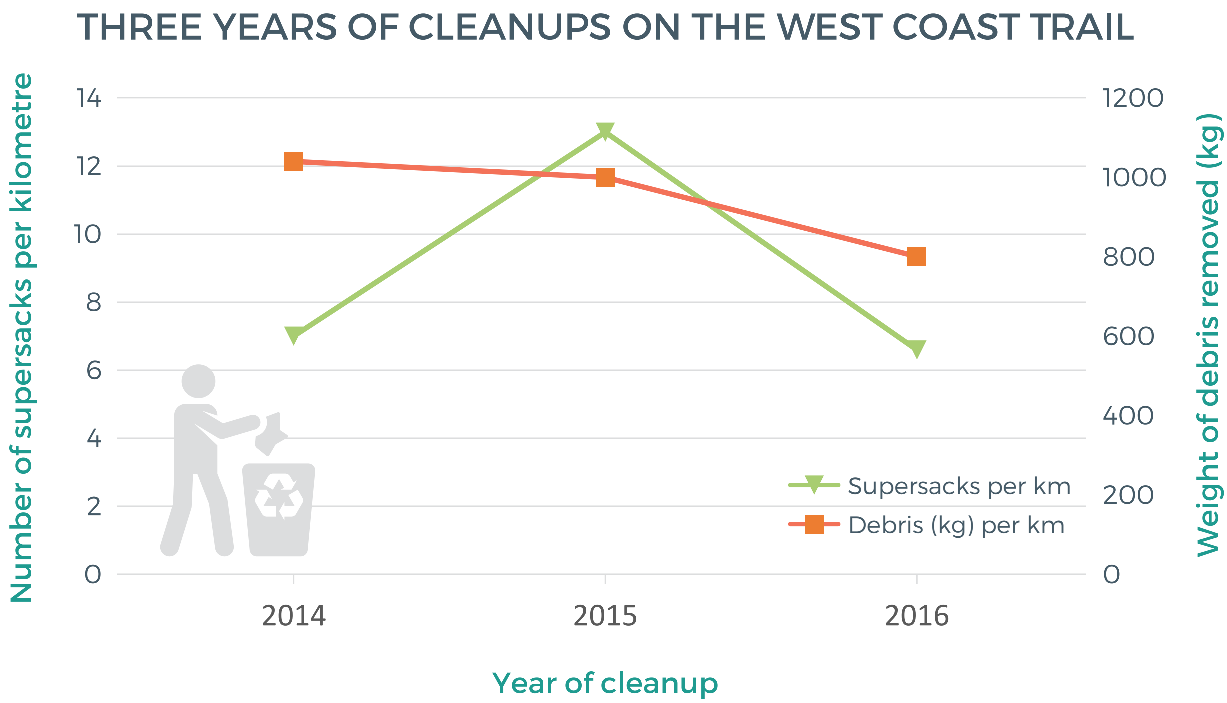


Figure 1. Cleanups along the West Coast Trail produced roughly the same amount of trash each year for three years with consistent effort in each year of 39 or 40 person days.

debris – was left floating in the Pacific Ocean.[1] Ocean surface currents have brought much of this debris to the West Coast of North America. The Government of Japan provided a gift of $1 million dollars to the Government of British Columbia to assist with cleanup efforts; this funding was dispersed to a number of B.C.-based organizations.

The Great Canadian Shoreline Cleanup – a conservation initiative of the Vancouver Aquarium and WWF Canada that is dedicated to inspiring Canadians to keep all shorelines free of litter – received funding to host remote cleanups along the West Coast Trail from 2013 to 2016 (Figure 2). In 2016, Shoreline Cleanup staff and volunteers made their way out to the West Coast Trail for the last time with the Tsunami debris funding to remove as much as they could from this remote and rugged shoreline. Without this funding the future of these remote cleanups is uncertain.

Figure 2. Shoreline cleanups along the West Coast Trail in 2014, 2015, and 2016.

Why is it important?

Marine pollution is one of the biggest issues facing our waterways today. There are often stories in the news about fish, seabirds, and even whales with stomachs full of litter. For example, scientists recovered four kilos of plastic bags from the stomach of a whale found stranded in Scotland.[2] But if we are all disposing of our personal litter properly, then where is all of this litter coming from?

Shoreline litter can come from a number of different sources:

1. **RECREATIONAL ACTIVITIES**
   This litter is created at picnics, festivals, and other outdoor events. It usually includes items such as food wrappers, drink containers, caps, and larger lids.
2. **SMOKING RELATED ACTIVITIES**
   Every year cigarette butts are the most common litter item found on our shorelines, last year we picked up 132,544 cigarette butts in B.C. alone.
3. **FISHING AND SHIPPING**
   This category includes litter from many activities, including recreational fishing and boating, and commercial activities such as fishing, shipping, and cruise ships.
4. **DUMPING**
   Many shorelines are destroyed by garbage that is not properly disposed of at the landfill, this can include mattresses, construction materials and household appliances.
5. **MEDICAL AND PERSONAL HYGIENE**
   Items can come from storm water overflows or personal carelessness. These items require special care if you are picking them up.
6. **NATURAL DISASTERS**
   Natural disasters such as typhoons, hurricanes, and tsunamis can wash huge volumes of debris into waterways in a short period of time.

Many of these sources of debris and shoreline litter can be reduced by human behavioral changes but as we continue to see more and more extreme weather events, the need to better understand how to address shoreline litter from natural disasters increases significantly. Staff and volunteers from the Great Canadian Shoreline Cleanup were able to learn first-hand just how different a cleanup from a natural disaster can be compared to a typical community cleanup.

Sorting trash for recycling on a West Coast beach in 2016. (Photo: Kate Le Souef)

What is the current status?

While out on the cleanup, staff and volunteers were sure to keep an eye out for any materials that may have writing with different languages, especially Japanese characters, as this was reported to funders. As debris was collected from the shorelines and pulled from under large logs at the high tide line, it was sorted and tracked item by item to be reported on afterwards.

The relative volume of different items found on a more remote shoreline, such as the section of the West Coast Trail that was cleaned, differs from what is found on a more urban cleanup. Along the West Coast Trail, many larger items and more fishing-related items were found instead of your typical garbage bag full of cigarette butts and plastic bottle caps (Figures 3 and 4).

It is also important to note that even though this last cleanup on the West Coast Trail was supported by the Tsunami Debris fund, it is often hard to track the items back to Japan and from that one single natural disaster. There were definitely items found that came from other parts of the world, reminding us that we are all connected by our oceans. Cleanups need to continue along our coastlines to protect the health of our oceans and wildlife.

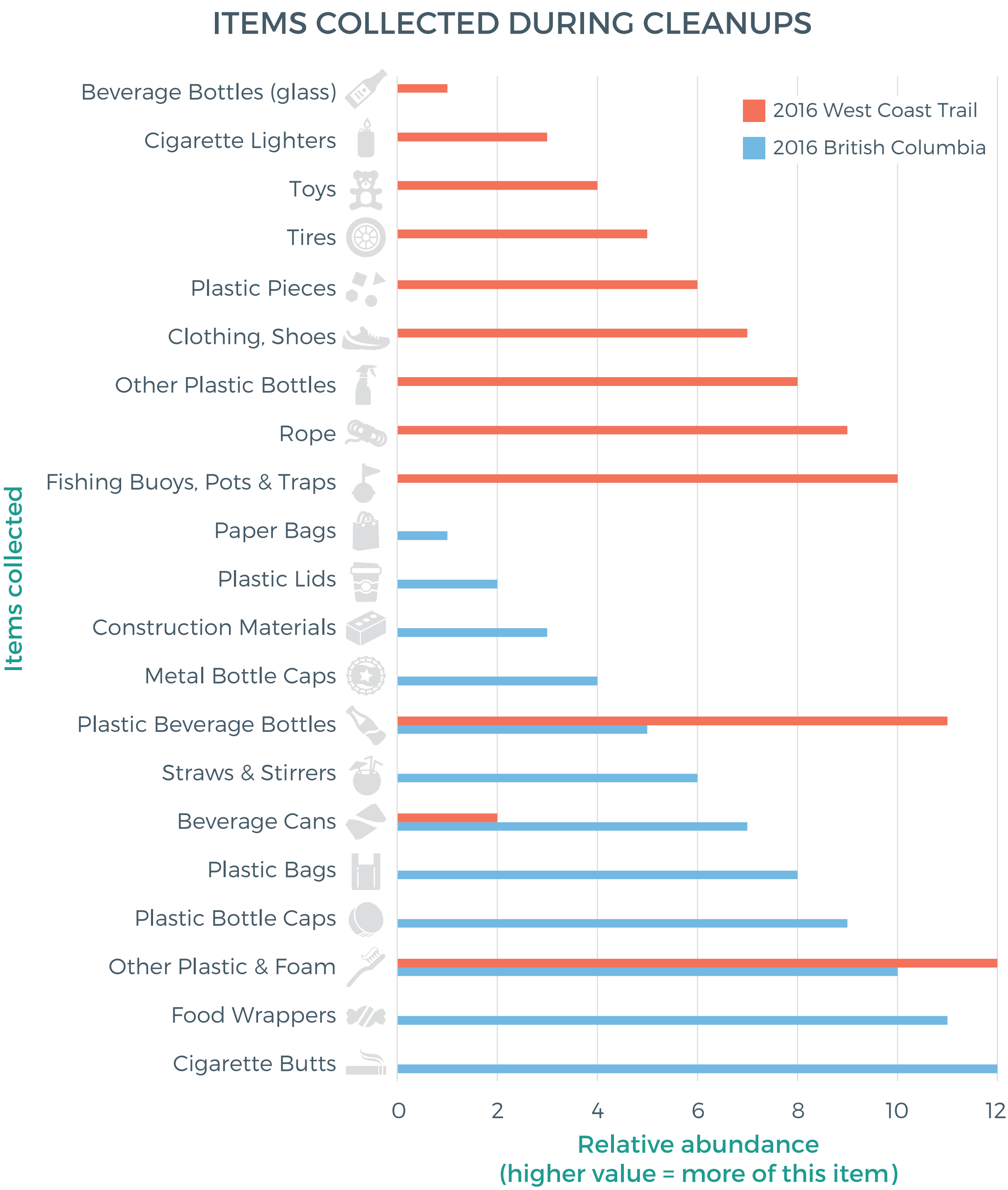


Figure 3. Relative amount of items of different types picked up B.C.-wide versus along the West Coast Trail in 2016.

What is being done?

There are many groups in B.C., including Great Canadian Shoreline Cleanup, who are hard at work collecting marine debris from our remote coastlines, be it debris from natural disasters or any other source of shoreline litter.

Clayoquot Cleanup, Ocean Legacy, Surfrider Foundation (specifically the Pacific Rim and Vancouver Island Chapters), and Living Oceans all continue to plan trips to some of our more remote shorelines.

These organizations and countless others along the coast of B.C., continue to stay united by their passion and dedication to protecting our oceans and shorelines from the polluting effects of debris and litter.

Figure 4. Buoys, styrofoam, and rope collected along the West Coast Trail in 2015. (Photo: Stephen Hargreaves)

What can you do?

Individual and Organization Actions:

- Learn how plastic impacts the environment, and how you can make a difference with everyday actions, such as reducing your use of single-use plastics like plastic bags, straws, cutlery, and cups.
- Attend a cleanup effort as a volunteer or provide support in other ways (monetary, in-kind donations) to help the groups that are already out there.
- Keep asking questions about the shoreline litter you find in your community, track it, and determine the sources of shoreline litter that are of high concern in your area.
- Let all levels of government, from municipal to federal, know how you feel about the impacts of shoreline litter. Use the data from your shoreline cleanup to back up your points.
- Lead or Join a Shoreline Cleanup. Rally together a group of your friends, family members, or colleagues to clean a shoreline near you.
- Keep your collected shoreline items out of the landfill by repurposing and recycling as many of them as possible.

Government Actions and Policy:

- Implement policies to reduce or ban single-use plastics.

Footnotes

[1] BC Gov News. Province awards final round of tsunami debris funding. May 2, 2016. https://news.gov.bc.ca/releases/2016ENV0021-000697. Accessed July 6, 2017.

[2] http://www.bbc.com/news/uk-scotland-highlands-islands-40354561

Sense of Place and Wellbeing

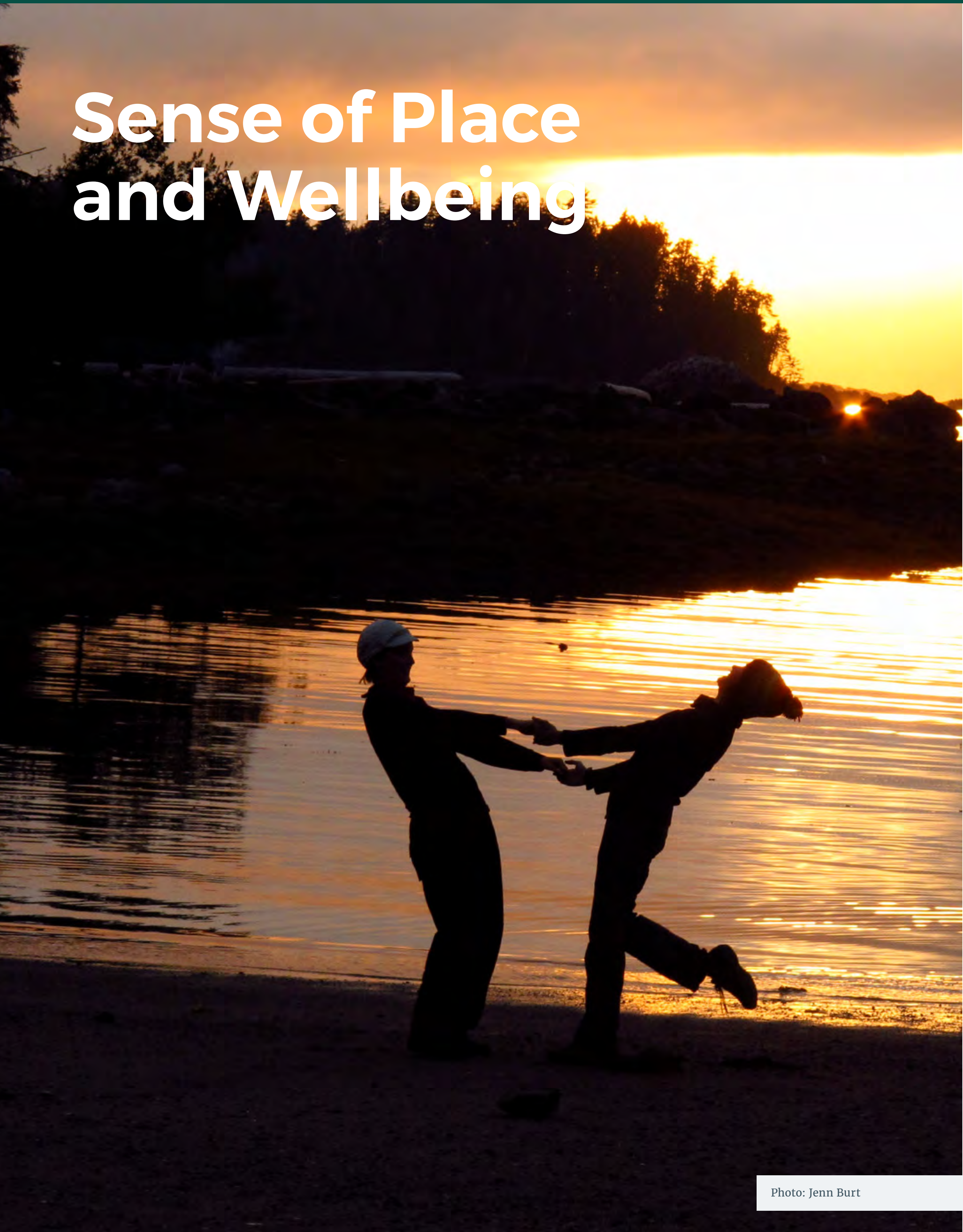


Photo: Jenn Burt

Summary

For generations, life in B.C.'s coastal communities has revolved around the rhythms and cycles of the sea. But increasingly, global shifts in population and economic prosperity are changing life for coastal residents, with profound impacts on health, wellbeing and livelihoods.

B.C.'s population continues to grow each year, with the vast majority of residents living near the sea. But uneven growth is changing the character of coastal cities and towns, with many northern communities shrinking – and losing access to services, jobs and community supports – while those in the south grapple with the pressures of increasing populations. At the same time, income disparity – the gap between the rich and the poor – is growing throughout the province with some coastal communities particularly affected as jobs in core industries like fishing and shellfish harvesting continue to decline.

Yet in the face of all this change, coastal peoples continue to find a sense of place and community through their connection with the natural world. Sustainably managed wild fisheries are recognized in some smaller communities as important pillars of society, with benefits that reach far beyond the economy. As fishing continues to evolve, it remains an important source of income for local residents, but more than that it provides a vehicle for cultural, intergenerational, and spiritual connection. Meanwhile, participation in conservation organizations is growing all along the coast, with citizen scientists dedicating thousands of hours toward monitoring the health of coastal ecosystems – and in the process building a robust culture of stewardship and connection to the environment and each other.

Sense of Place and Wellbeing Snapshot Assessment

Population profile

Coastal regions account for nearly three-quarters of British Columbia's growing population, but uneven distribution impacts living standards on the coast. While some coastal communities are growing, others are shrinking, and yet many shoulder high rates of dependent populations — children and the elderly – compared to those of working age.

LIMITED DATA

Citizen Participation

Participation in volunteer conservation groups is growing throughout B.C., adding valuable human power to citizen science initiatives. In addition to providing crucial data used to monitor the health of coastal ecosystems, citizen science initiatives also create strong community ties that boost overall wellbeing for participants.

HEALTHY

Pacific Marine Life Surveys

What started as underwater observations by a local marine naturalist has turned into a growing taxonomy of nearshore species in the Pacific region. To date, information from nearly 5,000 dives in 1,200 locations has created a searchable database that has become a critical tool in monitoring the biodiversity of B.C.'s coast.

HEALTHY

Fishing and Sense of Place

The benefits of the fishing industry in coastal communities go far beyond the economy. Fishing, particularly in smaller communities, promotes strong cultural ties, intergenerational exchange and deeper community trust, however recent changes in the industry may be threatening these intangible benefits.

CAUTION

Income Disparity and Wellbeing

Income inequality has been on the rise throughout Canada for decades, a troubling trend linked to poorer health and wellbeing outcomes. B.C. experiences a higher rate of income disparity than the national average, with some coastal communities particularly affected.

CRITICAL

Population profile of B.C.'s coastal regions

AUTHORS
Karin Bodtker and **Raissa Philibert**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
No technical review

What's happening?

Examining the population profile for a region is akin to studying the character of its communities. We looked at some demographic indicators to profile B.C.'s coastal regions and compare them to the province as a whole. Some aspects of demography, the study of human population change, can be related to community wellbeing. The population of B.C. increased by 1.1 percent annually between 2011 and 2016. However, we found that population increase is uneven. Growth is occurring in some coastal regions, but not others (Figure 1).[1] Population in the central coast and parts of the southern coast, including some areas of Vancouver Island, grew at a higher rate than the provincial growth rate.

We also found that while age and gender distribution in the coastal regions as a whole does not differ significantly from age and gender distribution in B.C., the dependency rate (i.e., the number of young and old as a proportion of the working-age population) is higher in a few specific coastal areas. In general, the north and central coastal areas have fewer elders and more youth in their populations than other coastal areas (see Current Status section).

Photo: Jenn Burt

Photo: Geralt, pixabay.com, CC0 1.0

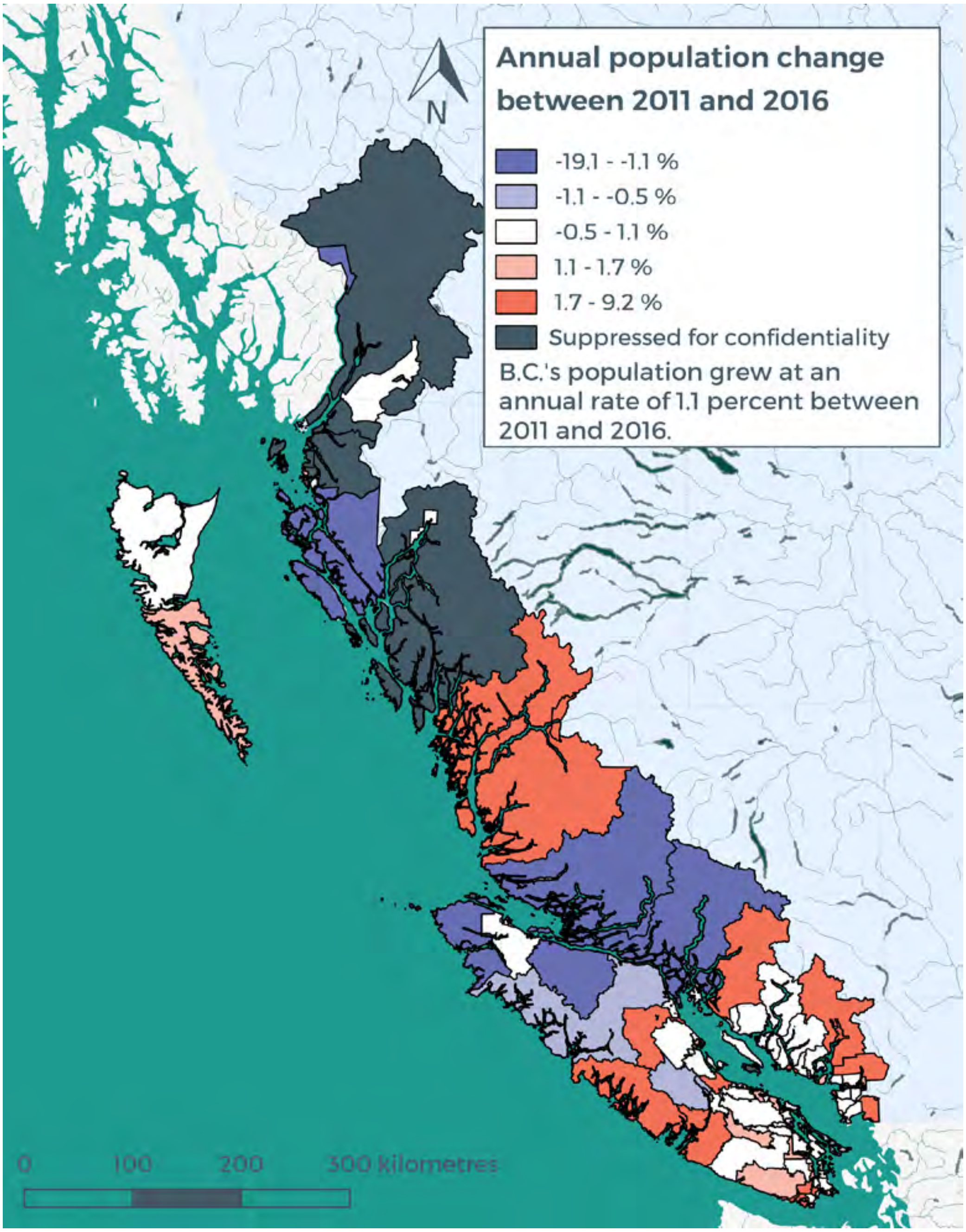


Figure 1. Annual population change (percent) between 2011 and 2016, mapped by census subdivision. Source: Statistics Canada

Why is it important?

The population, growth, and age and gender distribution of a regional population have an impact on prospects for raising or maintaining the standard of living.[2] Growth can also bring challenges in terms of demand for housing, jobs and services,[3] and increase pressures on the natural environment. All of these factors influence community wellbeing.

Tracking the distribution of the population by age and gender has many important implications, ranging from the relative size of the labour force to school enrollment to needs in the health services realm.[4] Status and trends in age and gender distribution are useful for determining the age-based needs of the residents. At the same time, these metrics describe the current and changing nature of communities and regions.

In general, population growth (Figure 1) is viewed as a strong sign of community vitality. Age structure that does not deviate from the provincial pattern signals that the region is supporting the needs of people of all ages, while a skewed distribution with an absence of specific age groups implies an unbalanced community. Population indicators also provide context that helps to understand trends in other indicators, including economic and environmental indicators[5] (see article in the Development Theme on Income and Labour).

Is there a particular importance or connection to First Nations?

We did not look at First Nation communities in particular.

What is the current status?

The population of coastal B.C. in 2016 was 3.35 million (72 percent of B.C.'s total population) and is unevenly distributed, with more people in the south (Figure 2).[6] Population growth follows this pattern, with small pockets of growth occurring mostly in southern areas (Figure 1). Haida Gwaii and the Central Coast are exceptions in northern B.C. with average annual growth rates ranging from 0.56 to 1.21 percent.

Age and gender distributions for the coastal regions show the same patterns as the province as a whole (Figure 3).[7] Generally, females slightly outnumber males and the largest age groups are just over 50 years of age. Notably, males and females in older age classes are present in the coastal regions at roughly the same proportion as in B.C. overall.

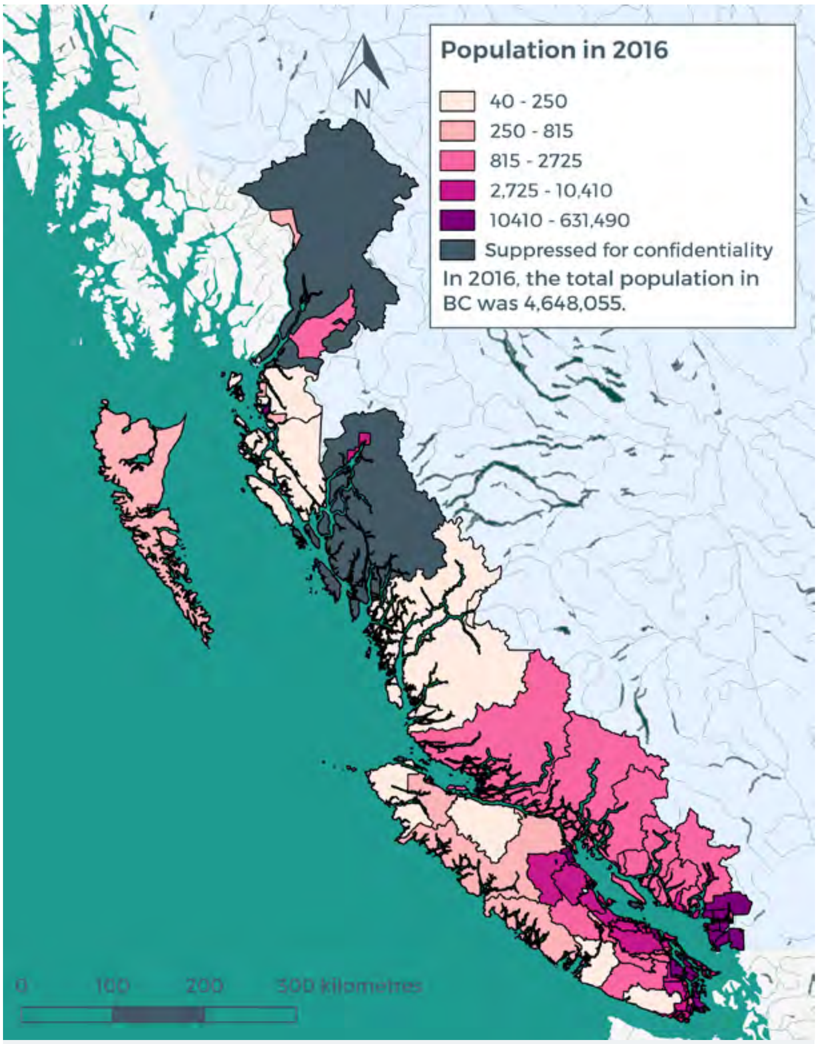


Figure 2. 2016 population per census subdivision. Source: Statistics Canada

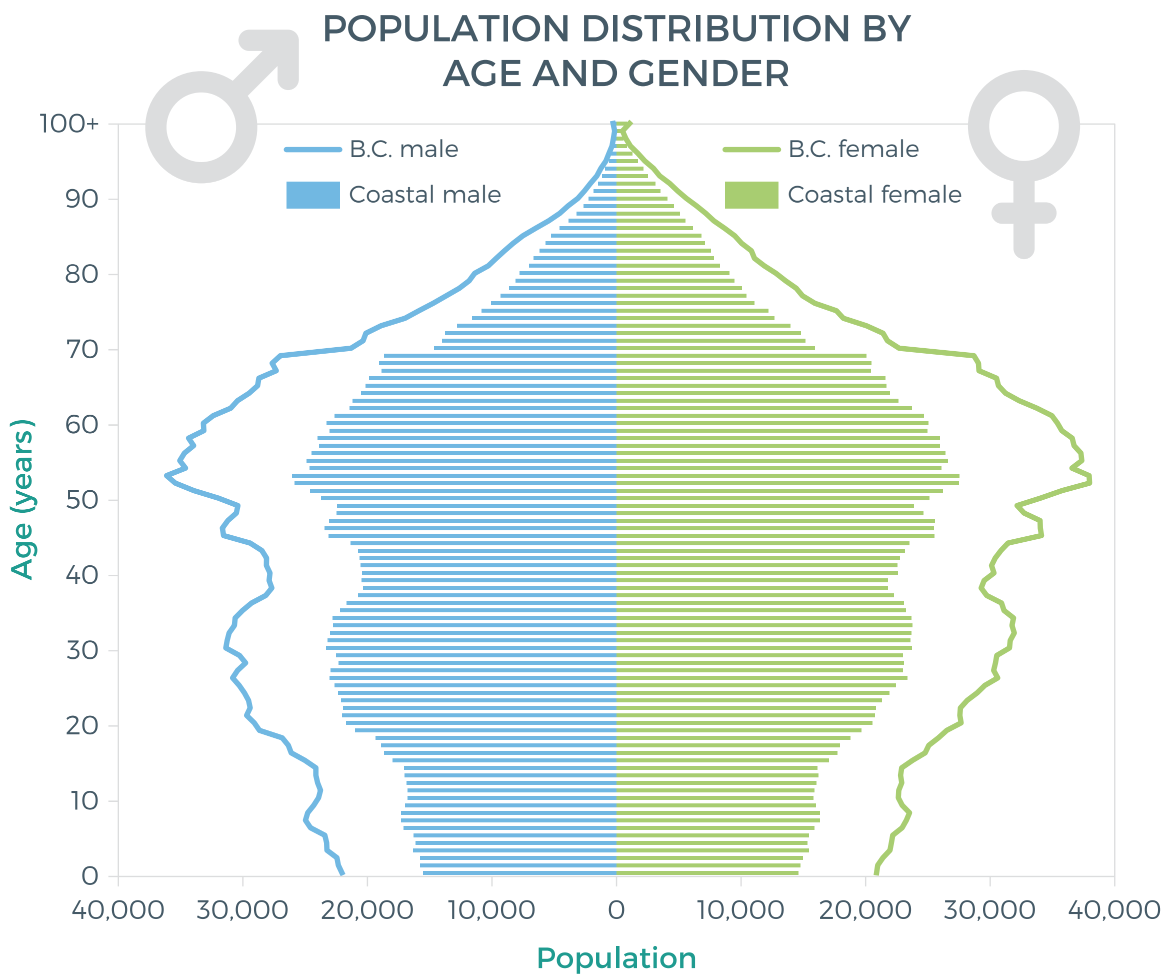


Figure 3. Population distribution by age and gender for coastal regions compared to all of B.C. Source: Statistics Canada

Examining the distribution of age classes, in terms of young (aged 19 and younger), elders (aged 65 and older), and those of working age (20 to 64 years), at a finer geographic scale along the coast reveals some differences (Figure 4).[8] The north and central coastal areas (including Kitimat-Stikine, Skeena-Queen Charlotte, Central Coast, and Mount Waddington) all have lower proportions of elders than most areas to the south – except Greater Vancouver. These same north and central areas also have greater proportions of young, aged zero to 19.

Another demographic indicator related to community wellbeing is the dependency ratio, or the number of youth (persons under 20) and elders (over 65) per 100 persons aged 20 to 64 (i.e., those typically in the work

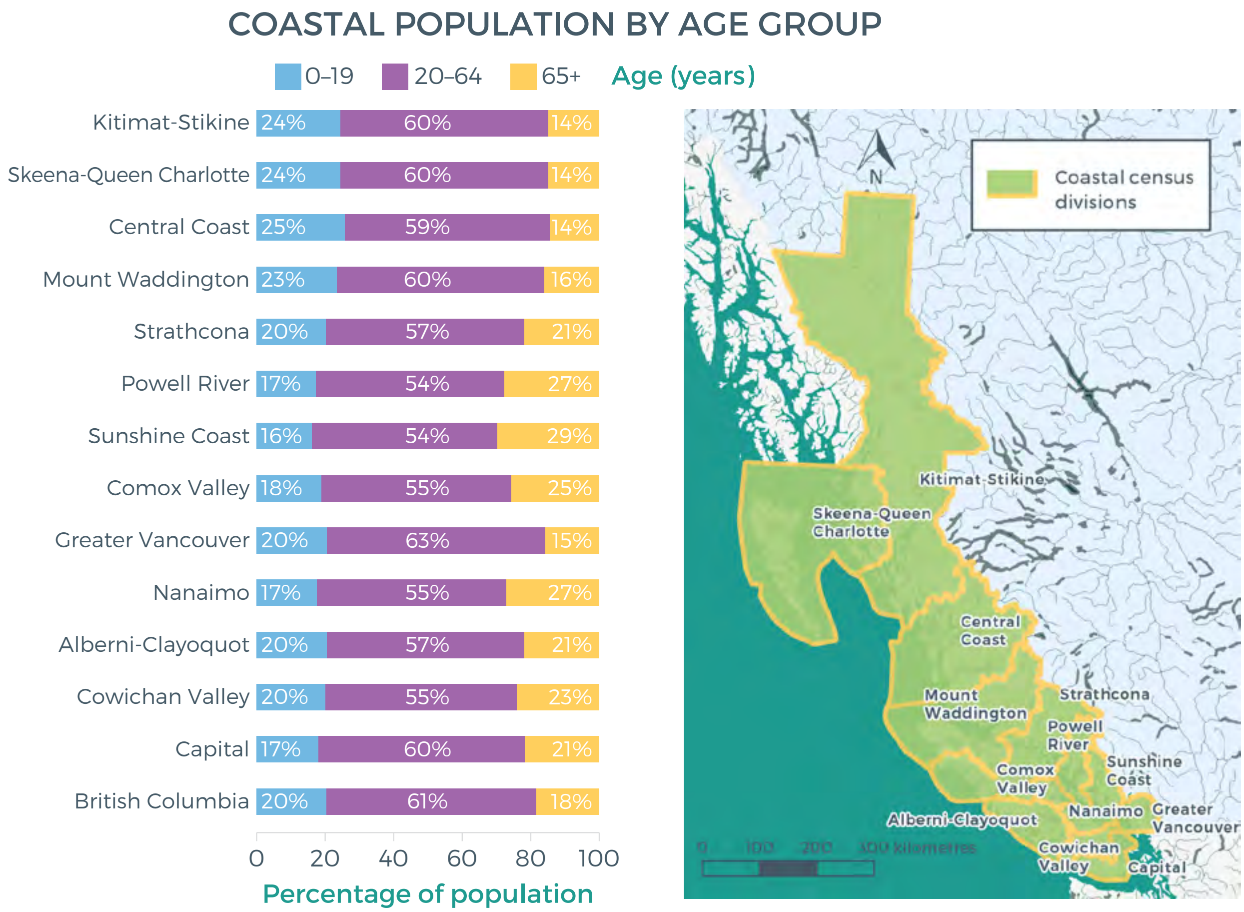


Figure 4. Percentage of population broken into three age groups for each coastal census division (left). Map of coastal census divisions (right). Source: Statistics Canada

force)[9] (Figure 5).[10] The only coastal census division with a dependency ratio lower than the provincial average is Greater Vancouver. This means that a larger proportion of youth and elderly are residing in coastal areas (outside of Greater Vancouver) than in the rest of B.C. With the exception of Vancouver and Victoria (Capital division), the further north you go along the coast the lower the dependency rate for those over 65 becomes. This is not surprising, as the elderly are better supported, in terms of health care, in population centers with access to community resources (and we assume there are more of these in the south). However, overall wellbeing may not be improved if moving to access care comes at the expense of leaving family behind. Higher rates of youth dependency in the north and central coast (e.g., Central Coast and Kitimat-Stikine divisions) are notable.

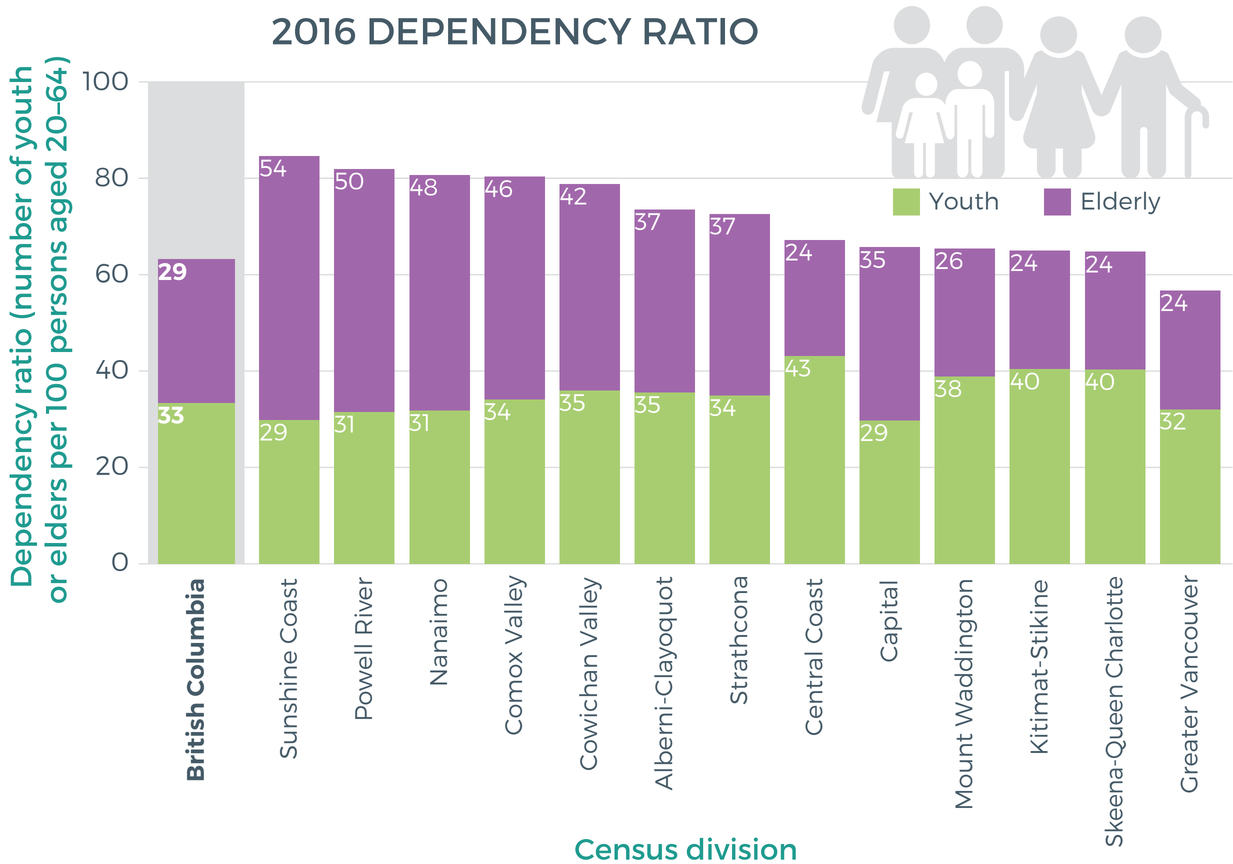


Figure 5. 2016 dependency ratio for B.C. overall and for coastal census divisions. Dependency ratio is the number of youth or elderly per 100 persons aged 20 to 64. Source: Statistics Canada

What is being done?

Most of the information reported here is derived from the 2016 Canada Census. A regular census is crucial to tracking demographics, but suppression of data for confidentiality purposes and to maintain accuracy does occur. Statistics are not released for areas with small populations (less than 40), or for areas with a response rate under 50 percent, as the risk of inaccuracy is high.[11]

Both Statistics Canada and BC Stats release reports that describe and track demographic profiles. BC Stats also develops projections for the future. However, to date, the B.C. coast has not been profiled as a region of interest.

Vital Signs is a national program led and coordinated by Community Foundations of Canada that leverages local knowledge to measure the vitality of communities and support action towards improving collective quality of life.[12] Twenty different communities in B.C., not all coastal, have reported on their vital signs one or more times since 2006 through this program.[13] Some communities include demographic indicators as part of their community profile.

The Canadian Index of Wellbeing (CIW) defines wellbeing as a state of comfort, health, or happiness that reflects community vitality, democratic engagement, education, environment, healthy populations, leisure and culture, living standards, and time use.[14] Until recently, economists and politicians equated economic growth, such as Gross Domestic Product (GDP), with wellbeing. Now the social, cultural, environmental, and psychological dimensions of wellbeing are more commonly acknowledged and studied. Tracking the demographic characteristics of regions helps to shed light on these aspects of wellbeing.

What can you do?

Individual and Organization Actions:

- Be aware of population and demographic trends in your community and support government action to address change and imbalance.

Government Actions and Policy:

- Establish a Coastal Zone Management Act in B.C. to reaffirm B.C.'s commitment to the conservation and sustainable management of estuarine, coastal and marine resources and to development a comprehensive Coastal Management Strategy.

Resources

Statistics Canada Census Program
http://www12.statcan.gc.ca/census-recensement/index-eng.cfm

BC Statistics, People, Population & Community
https://www2.gov.bc.ca/gov/content/data/statistics/people-population-community/population

Canadian Index of Wellbeing
https://uwaterloo.ca/canadian-index-wellbeing/

Community Foundations of Canada Vital Signs Program
http://communityfoundations.ca/vitalsigns/

Footnotes

[1] Statistics Canada, "Census Profile, 2016 Census," Statistics Canada Catalogue No. 98-316-X2016001&, November 29, 2017. http://www5.statcan.gc.ca/olc-cel/olc.action?ObjId=98-316-X2016001&ObjType=46&lang=en&limit=0.

[2] The Sheltair Group. 2009. Ecosystem Based Management Human Well Being Indicators, 2006 Baseline Report – Final. Report prepared for Ecosystem Based Management Working Group, B.C. 159pp.

[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Statistics Canada, "2016 Census of Canada: Data Tables – Age (in Single Years) and Average Age (127) and Sex (3) for the Population of Canada, Provinces and Territories, Census Divisions, Census Subdivisions and Dissemination Areas, 2016 Census - 100% Data," Statistics Canada Catalogue No. 98-400-X2016003., May 3, 2017, http://www12.statcan.gc.ca/global/URLRedirect.cfm?lang=E&ips=98-400-X2016003

[7] Statistics Canada, "2016 Census of Canada."

[8] Statistics Canada, "2016 Census of Canada."

[9] "Dependency Ratio," accessed November 9, 2017. https://www.statcan.gc.ca/pub/82-229-x/2009001/demo/dep-eng.htm

[10] Statistics Canada, "2016 Census of Canada."

[11] Statistics Canada, "Guide to the Census of Population, 2016. Chapter 11 – Dissemination," Statistics Canada Catalogue No.98-304-X2016001, February 8, 2017, http://www12.statcan.gc.ca/census-recensement/2016/ref/98-304/chap11-eng.cfm

[12] http://communityfoundations.ca/vitalsigns/

[13] http://communityfoundations.ca/vitalsigns/reports/

[14] From CIW - https://uwaterloo.ca/canadian-index-wellbeing

Growing stewardship and citizen science programs provide benefits

“When you already love a place, having… a way to share your observations that connects you to others and adds to the body of knowledge simply increases and magnifies that love… reporting to the B.C. Cetacean Sightings Network adds another layer of intention, connection, and meaning to my sense of my homeplace. It feels a tiny bit reciprocal, as if I have a small something to give back, where I have received so much.”

YVONNE MAXIMCHUK, ARTIST, SEAROSE STUDIO, A BCCSN PARTICIPANT

AUTHOR

Karin Bodtker, MRM, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWERS

Jessica Torode, B.C. Cetacean Sightings Network Coordinator, Coastal Ocean Research Institute, an Ocean Wise initiative

ZoAnn Morten, Pacific Streamkeepers Federation

Karen Devitt, BC Program Coordinator, Bird Studies Canada

Rachel Schoeler, Manager, Great Canadian Shoreline Cleanup, an Ocean Wise initiative

What is happening?

Many programs along the B.C. coast which rely on volunteers to undertake stewardship and citizen science activities are growing. Citizens give a variety of reasons for participating, including a sense of satisfaction, self-worth, stewardship of the environment around them, and the pleasure of working with like-minded people. All of this adds up to improved sense of place and personal wellbeing, with numerous benefits to the larger community and the natural environment.

Participation in citizen science increases scientific literacy and sense of place. One study reported that 90 percent of its participants learned more about bird ecology from participating in the citizen science project.[1] In addition, nearly all participants reported an increase in their awareness of birds and the habitat value of their own back yards (i.e., greater sense of place). Authors of this study argue that both scientific literacy and sense of place

Photo: S. Valderrama

are necessary to understand the influence that humans have on ecological systems. They also provided evidence that the learning and appreciation gained through the project were translated into tangible activities to preserve or enhance the habitat value of their local environment. For example, more than half of the participants changed some behavior in relation to their yard (i.e., planting shrubs to provide shelter or food for birds). In short, participating in citizen science can lead to knowledgeable citizens taking action to improve the environment within their realm of control.

Why is it important?

Programs that rely on volunteers often tackle problems and issues that would not otherwise be adequately addressed due to limited government resources. For example, 12 of B.C.'s 23 cetacean species (whales, dolphins, and porpoises) are listed as either endangered, threatened, or of special concern under Canada's Species at Risk Act.[2] Monitoring of these species is both logistically and financially challenging due to B.C.'s vast and remote coastline. In response to this issue, the British Columbia Cetacean Sightings Network (BCCSN) was formed. The program relies on volunteers spread over a vast geography to report observations, which are then tallied, analyzed, and used for conservation-based research.

Similarly, Bird Studies Canada takes advantage of a large network of volunteer observers to undertake bird surveys to monitor the distribution and numbers of a huge variety of waterbirds. Another volunteer organization, the Pacific Streamkeepers Federation, assists groups in the monitoring of fish populations and stream health. Many of these groups also work on stream enhancement projects and other projects to monitor and restore fish habitat.

Finally, the Great Canadian Shoreline Cleanup, an initiative of Ocean Wise and WWF-Canada, tackles the polluting aspect of litter head-on. Over 80 percent of marine pollution comes from land-based activities according to the World Wildlife Fund.[3] Shoreline cleanups along ocean shores, lakes shores and streams, and even in schoolyards, around storm drains and roadside ditches all reduce the amount of pollution contaminating the ocean.

Killer whales near the shore of Stanley Park. (Photo: Ocean Wise)

What is the current status?

We highlight four example programs that illustrate increasing volunteerism and participation in activities related to environmental stewardship and/or citizen science. Increasing participation means greater awareness of habitat values and an understanding of human influence on habitat quality, both good and bad. These factors combined with outdoor activity strengthen participants' sense of place and wellbeing.

Example 1: B.C. Cetacean Sightings Network

Contributed by Jessica Torode, BCCSN Coordinator, Coastal Ocean Research Institute, an Ocean Wise initiative

The B.C. Cetacean Sightings Network (BCCSN) was formed in 2000 by the Marine Mammal Research Program in collaboration with Fisheries and Oceans Canada. The BCCSN is a citizen science program in which coastal citizens can help to protect cetaceans and sea turtles by reporting their sightings. Participation has grown to over 6,200 observers who report their whale, dolphin, porpoise, and sea turtle sightings to the net-

"Lightkeeping on the edge of the West Coast gives me the opportunity to view and observe the daily comings and goings of the marine mammals and their behaviours. I feel it is important to share this opportunity in the form of providing observations to the B.C. Cetacean Sightings Network."

KAREN ZACHARUK, LIGHTKEEPER, CANADIAN COAST GUARD

"Five Star Whale Watching has been a supporter of the B.C. Cetacean Sightings Network for several years. Reporting a whale sighting to the B.C. Cetacean Sightings Network is important as it is contributing to the research and increasing the knowledge of cetacean sightings in the Salish Sea. We encourage anyone who spends time on or near the local waters to get involved in this wonderful network and their invaluable service!"

ANDREW LEES, GENERAL MANAGER, FIVE STAR WHALE WATCHING

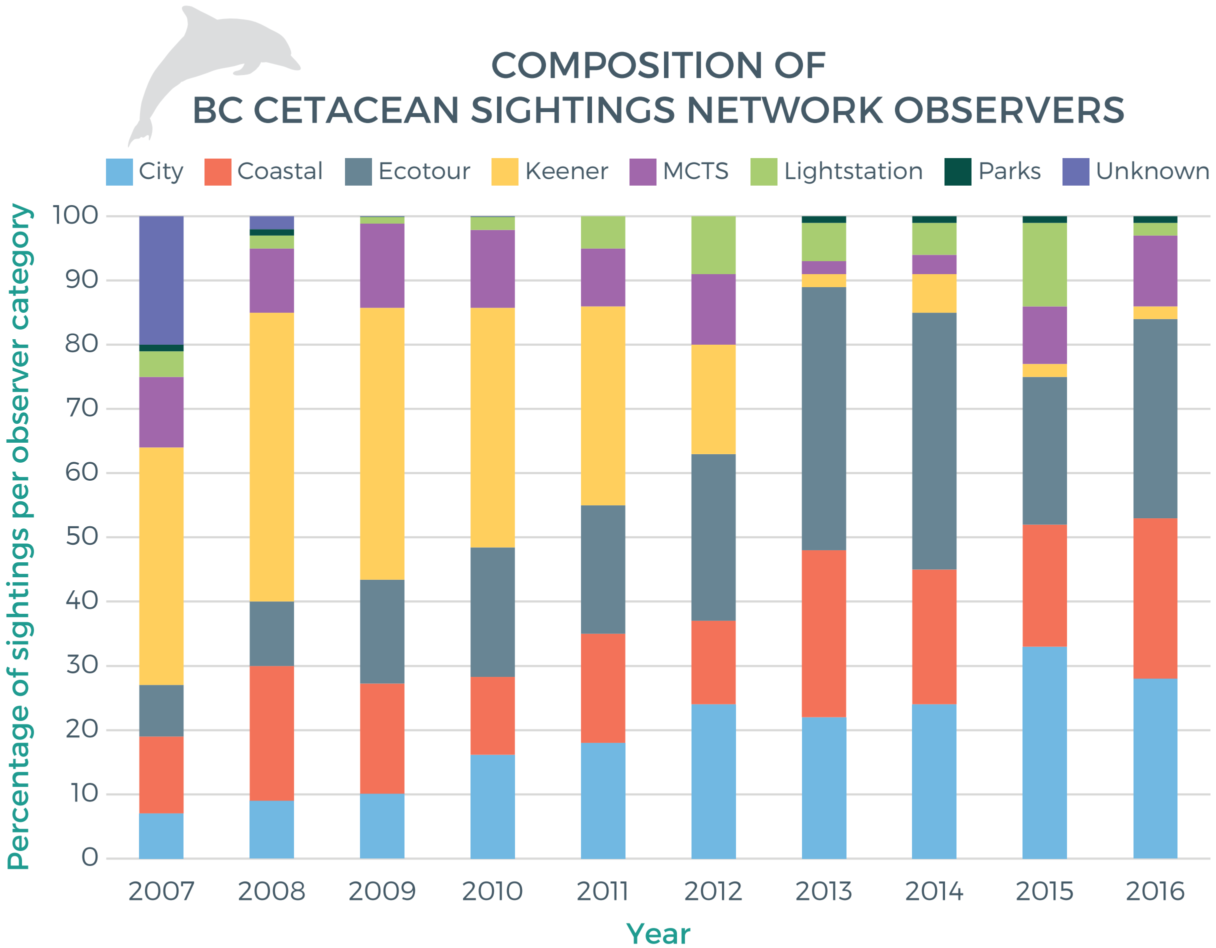


Figure 1. Changes in types of volunteer observers from 2007 through 2016. Each observer is placed into an effort category, to reflect the amount of time they spend on the water. “City” = Observers with no affiliation to an organization, including coastal residents, recreational boaters, and residents with waterfront properties. “Coastal” = Observers that spend time on the B.C. coast, including researchers, fisheries observers, employees of aquaculture operations, and sea plane pilots. “Ecotour” = Observers that work as naturalists on whale watching boats or kayak tour companies. “Keener” = Frequent observers that are often out on the water and have reported over 450 sightings each. “MCTS”= Marine pilots, tug boat operators, ferry captains and crew, Canadian Coast Guard personnel, and personnel on navy vessels. “Lightstation” = Observers stationed at staffed lighthouses. “Parks” = Observers visiting parks, park wardens, interpreters, and rangers.

work as a way of giving back to the environment that they cherish. Since its inception, the BCCSN has collected over 108,000 sightings from participants such as coastal residents, ferry and tugboat captains, fishers, naturalists, and floatplane pilots.

Over the last 10 years, the BCCSN has seen changes in the types of observers who report to the program (Figure 1). In 2007, the majority of sightings were reported by a small number of "keener" observers, who spend a lot of time on the water and frequently report to the network. Most "keeners" work on the water, mainly in research or ecotourism. As outreach efforts increased at local marinas, schools, and community events, more and more coastal citizens began reporting their sightings. The BCCSN also worked to develop strong relationships with ecotourism companies, the majority of which now report their sightings regularly. The WhaleReport App – which includes an identification guide – was launched in 2015, making it more convenient for observers to participate. Since then, BCCSN has witnessed an increase in reports by coastal citizens. As of early 2017, ecotourism naturalists and coastal citizens represent the majority of the observer base (Figure 1).

Example 2: Bird Studies Canada bird surveys

In 1999 Bird Studies Canada began the BC Coastal Waterbird Survey to coordinate the efforts of people who care about waterbirds in British Columbia. Since 1999, the number of volunteers involved in this survey has more than tripled (Figure 2). Volunteers count waterbirds at specific locations along the B.C. coast each month[4] and they can submit data and view results on the website.


Beached bird workshop. (Photo: D. Bradley)

Similarly, through the BC Beached Bird Survey, Bird Studies Canada engages B.C. citizens to collect information about seabirds found on the beach. Volunteer Beached Bird Surveys were first coordinated by Alan Burger out of the University of Victoria between 1986 and 1997. After a five-year hiatus, Bird Studies Canada reinitiated the program in late 2002, and the number of volunteers has been roughly consistent since then (Figure 2).

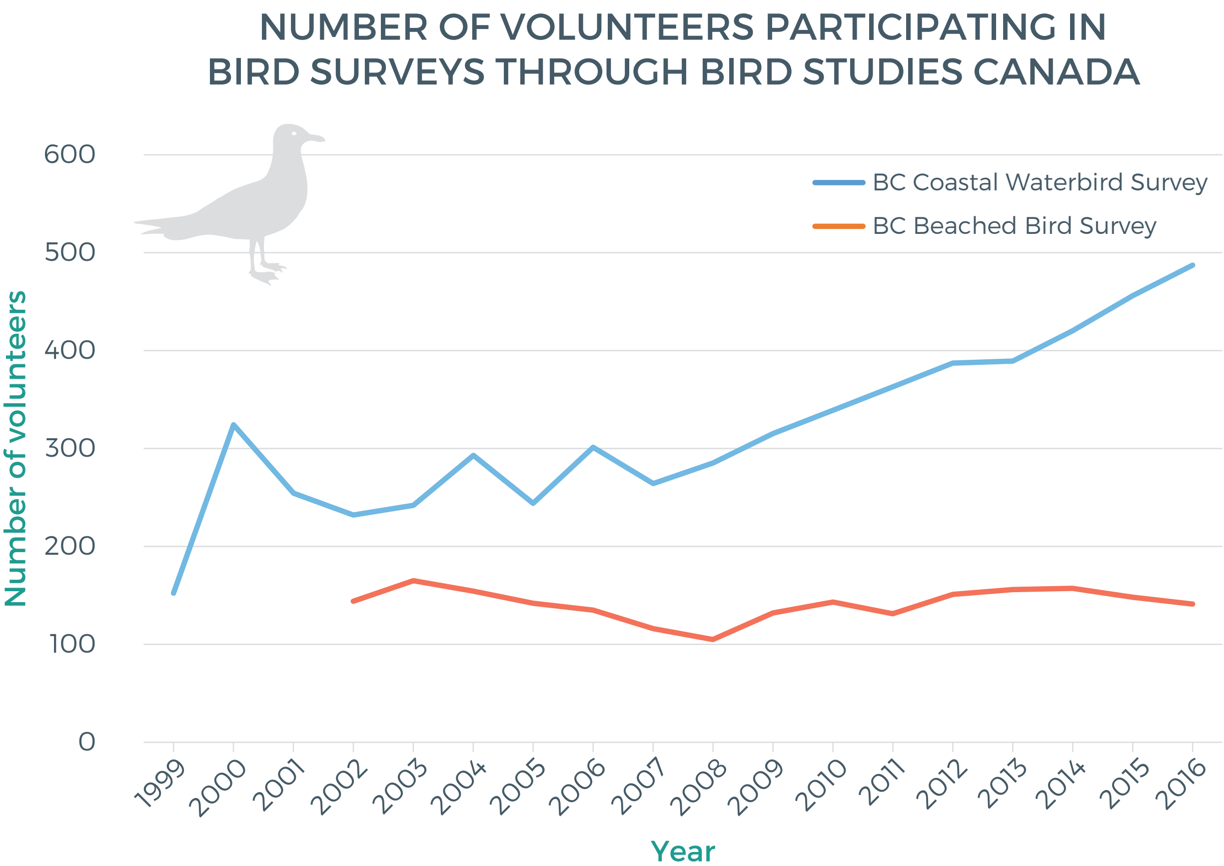


Figure 2. The number of volunteers participating in bird surveys through Bird Studies Canada has more than tripled since 1999.

Example 3: Streamkeepers

Since 2013 when counting began, 3,473 volunteer Pacific Streamkeepers have logged over 4.5 million volunteer hours. That's over 8 weeks of full-time work per volunteer per year! The Pacific Streamkeepers groups are volunteers that do everything from salmon stream restoration work to monitoring, planning, and organizing others. More than 100 Streamkeeper groups were active in B.C. and the Yukon in 2010–2011, according to the latest information available.[5] Zo Ann Morten, who keeps the Pacific Streamkeepers Federation going, says the number of groups has been growing steadily since 1995, when the organizing non-profit was initiated to support volunteers. She said each group has a handful of core individuals and then thousands of other volunteers drop in at various "meetups" and for specific projects.[6] Streamkeepers themselves come from all walks of life: many are students, retirees, and professionals. They all take an active interest in preserving and enhancing their waterways.

Example 4: Great Canadian Shoreline Cleanup®

Contributed by Rachel Schoeler, Manager, Great Canadian Shoreline Cleanup, an initiative of Ocean Wise and WWF-Canada

Since 2010, participation in shoreline cleanups tracked by the Great Canadian Shoreline Cleanup has nearly doubled, and so has the number of cleanup events (Figure 3). A growing number of citizens are pitching in to clean up litter and reduce the impacts of pollution, including potential impacts on aquatic creatures.

As one of Canada's largest community-led, volunteer-powered, direct action programs, Shoreline Cleanup's success is thanks to the energy and dedication of volunteers. In 2016, there were 979 Site Coordinators in B.C. who took a leadership role in rehabilitating their shorelines through cleanups. These volunteers take on the role of leading a cleanup for a number of different reasons. Many people

Shoreline cleanup participants and some of the litter they have collected. (Photo: Susan Debreceni) are concerned about the wildlife, or would like to raise awareness about the trash our society produces. Others lead cleanups to keep their shorelines clean for their community or to meet like-minded people.

Participants of the Great Canadian Shoreline Cleanup become citizen scientists working to protect the health of our oceans by tracking litter data for their local shorelines. Each participant contributes to national and international litter databases by submitting their litter data tracking cards (Figure 4). Tracking litter item-by-item gives participants real time results that measure their positive impact and they are able to report back to friends, family, and colleagues on specific items of local concern.

Many different types of groups participate in Shoreline Cleanups, from school groups and youth-serving agencies (such as Scouts, Guides, Cadets, etc.) to municipalities and workplace groups (Figure 5). In 2016, over 29,000 British Columbians from 110 different municipalities participated in Shoreline Cleanup. Last year alone British Columbians removed 46,117 kg of litter from B.C. shorelines, wherever land meets water (See our interactive map).

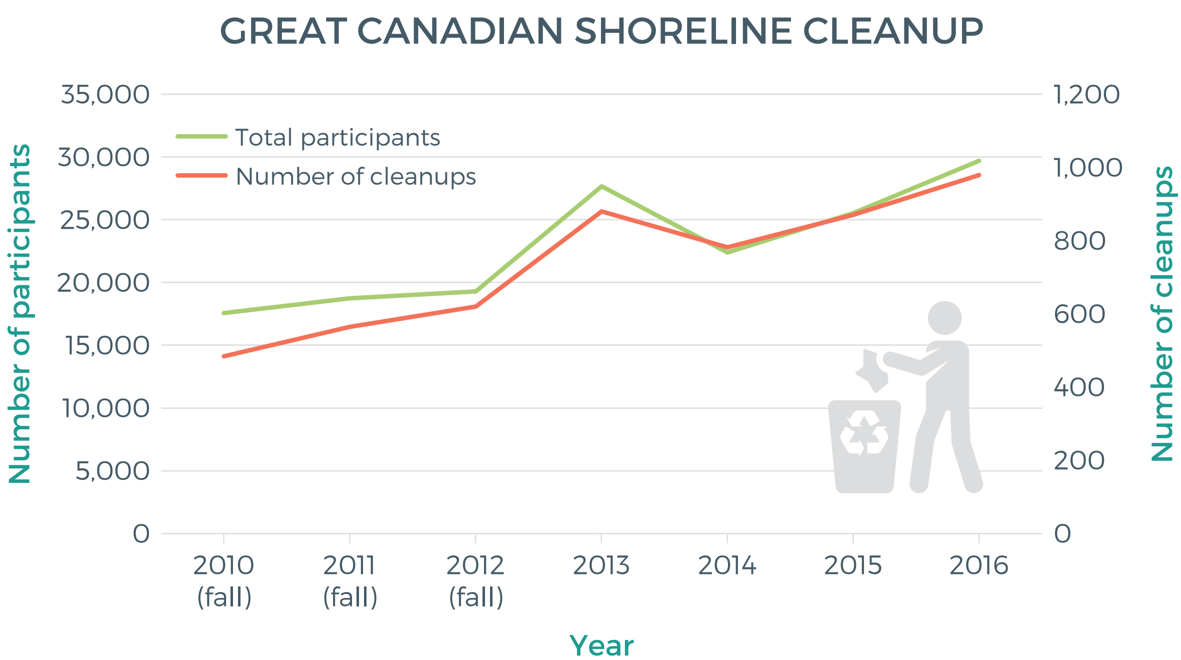


Figure 3. Total participants and total number of cleanups accomplished by the Great Canadian Shoreline Cleanup program across British Columbia between 2010 and 2016.

PARTICIPANTS SAY:

"Cleaning up our shorelines is a responsible, caring act that unifies a community. And it's so easy!"

"I am a dedicated conservationist, and as a teacher I want to inspire and motivate my students to become lifelong environmental stewards. The best way to do this is to lead by example."

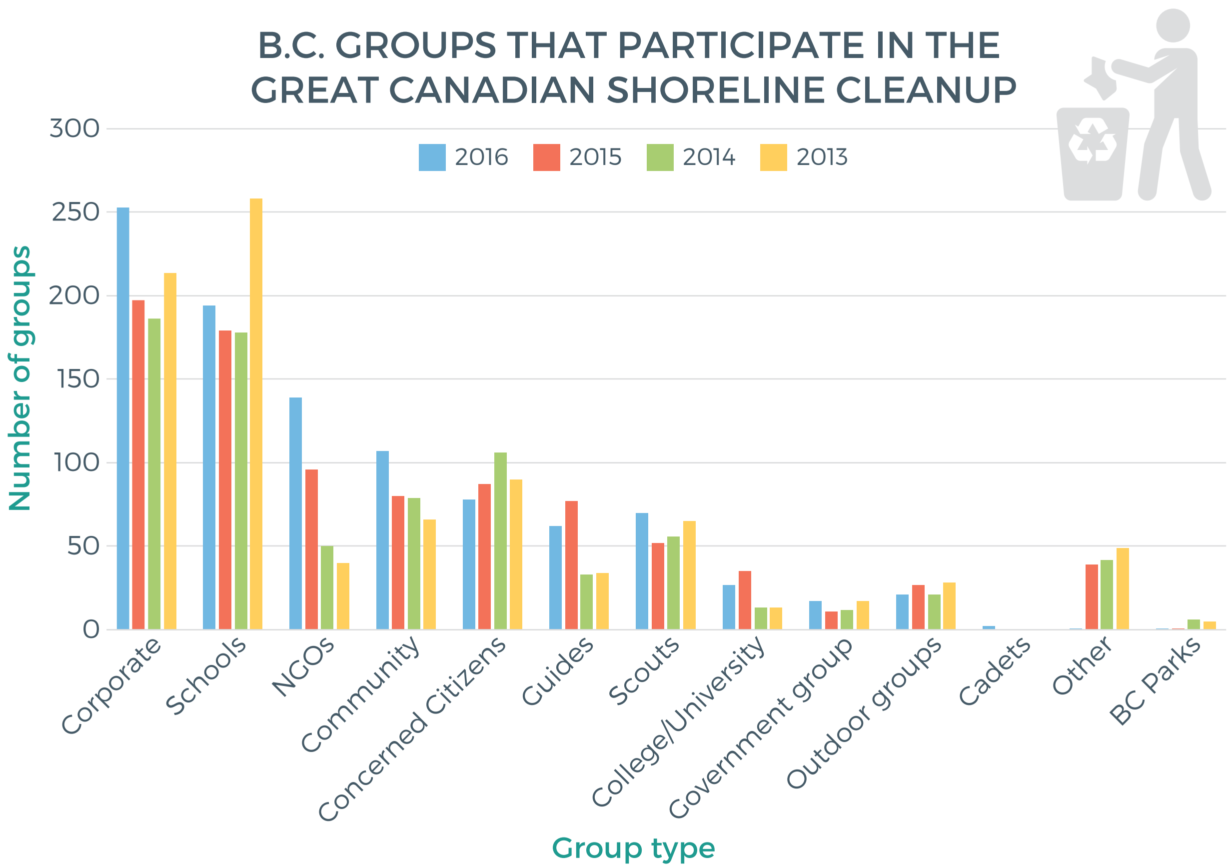


Figure 5. Types of groups participating and/or organizing Shoreline cleanups in B.C. since 2013. The number of Non-government Organizations (NGOs) is steadily increasing.

Trash Collected

MOST LIKELY TO FIND ITEMS:

	TOTAL #
Beverage Cans:	=
Bottle Caps:	=
Cigarette Butts:	=
Coffee Cups:	=
Containers:	=
Food Wrappers:	=
Glass Bottles:	=
Paper:	=
Plastic Bags:	=
Plastic Bottles:	=
Plastic Cups:	=
Six Pack Holders:	=
Straws:	=
Utensils:	=

TOP 3 ADDITIONAL ITEMS:

Identify the top 3 items found that are not listed on the card

	TOTAL #
1:	=
2:	=
3:	=

FISHING GEAR:

	TOTAL #
Fishing Buoys, Pots or Traps:	=
Fishing Net:	=
Rope (1 metre = 1 piece):	=

OTHER PACKAGING

Plastic or foam packaging, strapping bands, tobacco packaging

	TOTAL #
	=

PERSONAL HYGIENE:

Condoms, diapers, syringes, tampons

	TOTAL #
	=

TINY TRASH LESS THAN 2.5 CM:

	TOTAL #
Foam Pieces:	=
Plastic Pieces:	=

OTHER TRASH:

	TOTAL #
Balloons:	=
Clothing, Shoes:	=
Foam:	=
Tires:	=
Toys:	=

Thank you for contributing to trash free shorelines.

/shorelinecleanup @shorelinecleanup @cleanshorelines

Figure 4. Sample litter tracking card.

What is being done?

Cetacean sightings data is used for conservation-based research such as critical habitat analysis[7] and species recovery strategies.[8,9] Recently, the B.C. Cetacean Sightings Network collaborated with the Port of Vancouver and the Prince Rupert Port Authority to create the Mariners Guide to Whales, Dolphins, and Porpoises of Western Canada, which was distributed to the pilots of large commercial vessels.

Bird survey data collected by volunteers are collated and analyzed by scientists at Bird Studies Canada. The data contribute to assessing annual change and long-term trends in population size and distribution, and advancing the understanding of B.C. coastal waterbird ecology. The Beached Bird survey helps to assess the causes and levels of seabird mortality, and provides an early detection system for changes in ocean conditions and events such as oil spills.

All of the data from Bird Studies Canada are freely available for download. These data have been used for a number projects including oil spill response planning, species recovery strategies, student research projects, and to inform environmental assessments. Long-term data are invaluable when it comes to assessing the impacts of increasing coastal development and human activity.

When the Pacific Streamkeepers Federation was initially started, the focus was on "salmonid enhancement programs" including hatcheries and rearing fry – but when the number of returning salmon didn't necessarily increase, people started asking why. Interest grew in monitoring water quality and restoring habitat. Fisheries and Oceans Canada (DFO) and the Pacific Streamkeepers Federation armed volunteers with a comprehensive handbook of 14 instructive modules and videos. Volunteers can complete surveys that document stream habitats, assess water quality, identify invertebrates (stream bugs), count spawning salmon, and help to monitor sport fishing activities, among many other activities. A database, made possible by a small grant from the Pacific Salmon Foundation and countless hours of programming by volunteer Pat Morten, keeps an active count of volunteers (3,473) and volunteer hours (4,538,204) logged since 2013 along with the data from surveys that groups have conducted.

Shoreline Cleanup site coordinators from varying backgrounds continue to lead shoreline cleanups year after year to connect to their local shorelines. The Great Canadian Shoreline Cleanup is a powerful national network of shoreline cleanups. Connection to this network keeps site coordinators and participants engaged beyond their first cleanup, which in turn maintains the strength of the network and encourages behavioural changes that will reduce shoreline litter in the future. Connections are fostered several ways: the Shoreline Cleanup website provides an outlet for storytelling and sharing experiences through its blog; monthly e-newsletters provide additional opportunities to be involved; and the recent launch of an online community with open discussions, activities, and information aims to keep participants – youth in particular – connected to each other and their shorelines.

What can you do?

Individual and Organization Actions:

- Report cetacean and sea turtle sightings to wildwhales.org, or 1.866.I.SAW.ONE (1.866.472.9663) or sightings@vanaqua.org or use the WhaleReport smartphone app (on either iOS or Android devices).
- Report cetacean-vessel strikes or animals in distress to 1.800.465.4336 or on VHF Channel 16.
- Be Whale Wise while out on the water – if you encounter whales, slow down and stay at least 100 metres away.
- Lead or join a Shoreline Cleanup. Rally together a group of your friends, family members, or colleagues to clean a shoreline near you.
- Buy less and make smart purchases by saying no to excess packaging and single-use plastic items.
- Get crafty and reinvent items for new uses. Buy second hand products to give them an even longer life.
- Switch to reusable items like glass water bottles, metal straws, and cloth bags. Focus on items made from sustainable materials.
- Follow local municipal instructions for proper disposal using all waste streams like paper, plastic, organics, and electronics.
- Create discussion about plastic use, how it impacts the environment, and how you can make a difference with everyday actions.
- Inspire your friends, family, and workplace to follow in your zero-waste lifestyle by helping each other make small changes that have big impact.
- Learn to identify our coastal species, connect with the natural world, and take the first step to conservation action by borrowing natural history books from the library, joining your local naturalist group for an outing, and participating in Citizen Science programs.
- Directly contribute to conservation and stewardship of our coastlines by participating in Bird Studies Canada’s coastal monitoring programs. Contact BCvolunteer@birdscanada.org to learn how you can help.
- Give birds space on our beaches and on the water – disturbing birds while they rest and refuel can negatively impact birds that are migrating through or overwintering on our coastlines.
- Get involved in a Streamkeeper group near you!

Government Actions and Policy:

- Implement the Marine Plan Partnership's Protection Management Zones.
- Commit to continued participation in the Pacific Habitat Joint Venture and collaborate with parties along the entire Pacific Flyway.
- Follow through on global Achi Biodiversity Targets, specifically Target 11 to protect 17 percent of terrestrial and inland waters, and 10 percent coastal and marine habitats.
- Deliver on the CEAA 2012 expert review panel recommendation for Impact Assessment (IA) legislation to require that all phases of IA integrate the best available scientific information and methods, and integrate the best evidence from science, Indigenous knowledge, and community knowledge through a framework determined in collaboration with Indigenous Groups, knowledge-holders, and scientists.
- Implement policies to reduce or ban single-use plastics.
- Sign on to be a Clean Shoreline Community with the Great Canadian Shoreline Cleanup and mark your municipality as a leader by actively addressing the important issue of shoreline litter.
- Support community cleanup and volunteer efforts by offering supplies (garbage bags, gloves, etc.) to groups. "Keep Vancouver Spectacular" provides a great example.

Resources

B.C. Cetacean Sighting Network
wildwhales.org

WhaleReport App
http://wildwhales.org/sightings/

Mariner's Guide
http://wildwhales.org/learn/mariners-guide/

Be Whale Wise Guidelines
http://www.bewhalewise.org/

Great Canadian Shoreline Cleanup – Create an account and login to access additional resources including a Site Coordinator Guide and Checklist.
shorelinecleanup.ca

Footnotes

[1] Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L. and P.P. Marra. 2005. The Neighborhood Nestwatch Program: Participant Outcomes of a Citizen-Science Ecological Research Project. Conservation Biology 19(3): 589–594.

[2] Species at Risk Act (2002, c. 29). Retrieved from the Justice Laws website : http://laws-lois.justice.gc.ca/eng/acts/S-15.3/page-1.html#h-1

[3] http://wwf.panda.org/about_our_earth/blue_planet/problems/pollution/

[4] For a map of current survey sites, see http://www.birdscanada.org/volunteer/bccws/index.jsp?targetpg=bccwsinvolve

[5] http://www.pskf.ca/

[6] Zo Ann Morten, personal communication; phone call with the author, Karin Bodtker, May 25, 2017.

[7] Ford, J.K.B (2006). An Assessment of Critical Habitats of Resident Killer Whales in Waters off the Pacific Coast of Canada. http://www.dfo-mpo.gc.ca/csas/

[8] Gregr, E.J., J. Calambokidis, L. Convey, J.K.B. Ford, R.I. Perry, L. Spaven, M. Zacharias (2006). Recovery Strategy for Blue, Fin, and Sei Whales (*Balaenoptera musculus*, *B. physalus*, and *B. borealis*) in Pacific Canadian Waters. In Species at Risk Act Recovery Strategy Series. Vancouver: Fisheries and Oceans Canada. vii + 53 pp.

[9] Fisheries and Oceans Canada (2011). Recovery Strategy for the Northern and Southern Resident Killer Whales (*Orcinus orca*) in Canada. Species at Risk Act Recovery Strategy Series, Fisheries & Oceans Canada, Ottawa, ix + 80 pp.

50 years of recorded SCUBA observations link authors to their marine "home"

"About 20 years ago someone asked me, 'Who funds this database?' I looked at them rather blankly and said, 'We do!'"

DONNA GIBBS, TAXONOMIST WITH PACIFIC MARINE LIFE SURVEYS, INC.

AUTHORS
Charlie Gibbs and **Donna Gibbs**, Pacific Marine Life Surveys, Inc.

REVIEWERS
Jeff Marliave, Senior Research Scientist, Coastal Ocean Research Institute, an Ocean Wise initiative

Jessica Schultz, Coastal Ocean Research Institute, an Ocean Wise initiative

Neil McDaniel, Marine Naturalist

What's happening?

For 50 years, diver and marine naturalist Andy Lamb has been meticulously recording and quantifying everything he sees underwater. For 25 of those years, Donna and Charlie Gibbs have been augmenting the list with observations made on their own dives. To preserve this invaluable history of marine life, Donna, a taxonomist, painstakingly entered 1,600 of Andy's hand written records (Figure 1) into a digital database, while Charlie, a software engineer, developed systems to manage and easily extract data based on specific searches. The result of this "labour of love" is a searchable database of species-specific observations from over 4,920 dives at 1,200 locations in B.C., Alaska, Washington, Oregon, and California. The effort that has gone into developing and maintaining this store of knowledge epitomizes the strength of the connection between these divers and their marine home.

For many years some folks "in-the-know" have been aware of this effort, called Pacific Marine Life Surveys Inc. (PMLS), although it has not been widely recognized, nor publicly accessible. Donna receives and answers requests for data regularly.

Dive # 715
Date : July 31, 1986
Weather : Sunny, hot, calm
Buddy : John Rawle
Place : Eagle Point, San Juan Island
Depth : 0-114 ft ; 40 ft vis
Purpose : Collecting
P.

Time : 1:10 - 2:11 pm
Tide ↗ High

Specimens observed :

Nereocystis, woody stem kelps, short branching reds, corallines (several kinds) flat codium, ulva

Tetilla arb (few)
Phakktia sp. (few)
Suberites montingiger
Isodictya quatsinoensis (some)
Oplitospongia pennata (some)
Metridium senile (large white abund)
* Cribrinopsis fernaldi (abund)
Stomphia didemon (1)
Tealia crassicornis (many)(various colours)
Epiactis prolifera (many, red on woody stem kelps)
Epizoanthus scotinus (some)
Balanophyllia elegans (many)
Clavularia sp. (some, shallow)
Allopora petrograpta (some)
Abietinaria greeni (much)
Garveia annulata (much)
Hydractinia milleri (some)
Tubularia crocea (much)
Corymorpha palma (few)
Aequorea aequorea (abund)
Cyanea capillata (few)
Phlidium sp. (abund)
Pleurobrachia bachei (many)
Serpula vermicularis (many)
Spirorbis sp. (many)
Dodecaceria fewkesii (some)
Telephus crispatus (some)
Pista elongata
Membranipora membranacea (much)
Crisia sp (much)
Bugula californica (much)
Schizoporella biconnis (much)

Dendrobeania lichenoides (much)
Phidolopora pacifica (1)
Diaperoecia californica (abund)
Heteropora pacifica (much)
Barentsia / Companularia (much)
Cryptochiton stelleri (many)
Tonicella lineata (many)
T. insignis (few)
Mopalia sp. (some)
Acmaea mitra (v. abund)
Haliotus kamschatkana (1)
Searlesia dira (some)
Trichotropsis cancellata (many)
Fusitriton oregonensis (many)
Ceratostoma foliatum (some)
Calliostoma ligatum (abund)
C. annulatum (some)
Ocenebra lurida (many)
Amphissia columbiana (abund)
Petaloconchus compactus (some)
Sabellaria cementarium (few)
Diopatra ornata (1)
Chlamys sp. with Mycale / Myxilla (abund)
Hinnites giganteus (few)
Mytilmeria nuttalli (few)
Entodesmus saxicola (few)
Dirona albolineata (some)
Hermissenda crassicornis (some)
Coryphella trilineata (many)
Dendronotus dalli (few)
D. diversicolor (some)
Adalaria sp. (some)

* Rossia pacifica (1)
* Podoceros cristatus (1)(red)
* Lebbeus grandimanus (1)
Heptacarpus kincaidi (many)
Pandalus danae (many)
Scyra acutifrons (some)
Phyllolithodes papillosus (1)
Discorpagurus schmitti (1)
Pagurus beringanus (many)
* Elassochirus gilli (1, large)
Cirolana harfordi (2 on blocks)
Balanus nubilus (some)
B. glandula (some)
Dermasterias imbricata (large)
Orthasterias koehleri (few)
Leptasterias hexatilis (many) (various colours)
Pycnopodia helianthoides (few)
Solaster dawsoni (1)
S. stimpsoni (few)
Cucumaria miniata (many)
C. farqua (v. abund)
Eupentacta quinquesemita (some)
Psolus chitonoides (many)
Strongylocentrotus franciscanus (ab)
S. purpuratus (1)
Corella willmeriana (few)
Styela gibbsii (some)
Boltenia villosa (some)
Cnemidocarpa finmarkiensis (few)
Chelyosoma productum (some)
Metandrocarpa taylori (abund)
Pycnoclavella stanleyi (many)

(over)

Notes : dove from Charlies shamrock
nice dive much time shallow, some deep, cruised with black rockfish
found 2 sinkers, 1 buzz bomb, 1 silda

* specimens collected

Figure 1. Handwritten dive log from 1986.

Why is it important?

This database contains information on over 1,200 species – fishes, invertebrates, plants including algae – observed over the past 50 years. These observations have proven useful in many applications to date. For example, in 1998 when Parks Canada requested data to support establishment of a National Marine Conservation Area in the Southern Gulf Islands, the database provided information on 593 species from 325 dives. When sea star wasting syndrome was first recognized in 2013, the PMLS database revealed a history of the vanishing species, including where they had been observed and their abundance. Changes since then have been analyzed as well. More recently, Fisheries and Oceans Canada (DFO) has requested data for locations of interest for an evaluation of nearshore EBSAs (Ecologically and Biologically Significant Areas). The database provided lists of species with relative abundance.

In 2011, the database was used as a source of information to investigate documented climate regime shifts. Authors looked for changes in species biodiversity in the zone observed by SCUBA divers across time periods delineated by regime shifts.[1] Results are inconclusive as statistical tests were not supported, but the data appear to show that a regime shift in 2000 led to reduced biodiversity – likely only for the more rare species.

In 2015, the software was used in the Sitka Field Data Report for a Marine Biodiversity Project.[2] The Sitka Foundation provided the funds for the Vancouver Aquarium to learn how to teach field identification skills to interested divers. We trained professional divers along with sport divers to hone their identification skills and analyzed the results. This project recognises the importance of morphological taxonomy (identifying species by their outward appearance, form, and structural features) as a skill. Fewer professionals specialize in morphological taxonomy, instead focusing on more "cutting edge" skills that take advantage of new technology. Without efforts like the PMLS, the ability to visually identify marine life could be a lost skill in the next generation of marine scientists.

Left to right, Andy Lamb, Donna Gibbs, and Charlie Gibbs. (Photos courtesy of Donna Gibbs)

Is there a particular importance or connection to First Nations?

For over two years the database has been used to report on the settlement of species on the HMCS Annapolis, a decommissioned naval ship sunk in 2015 to become reef habitat in Howe Sound. The Squamish Nation approved the project and tracks the information on species observed there as the diversity increases.

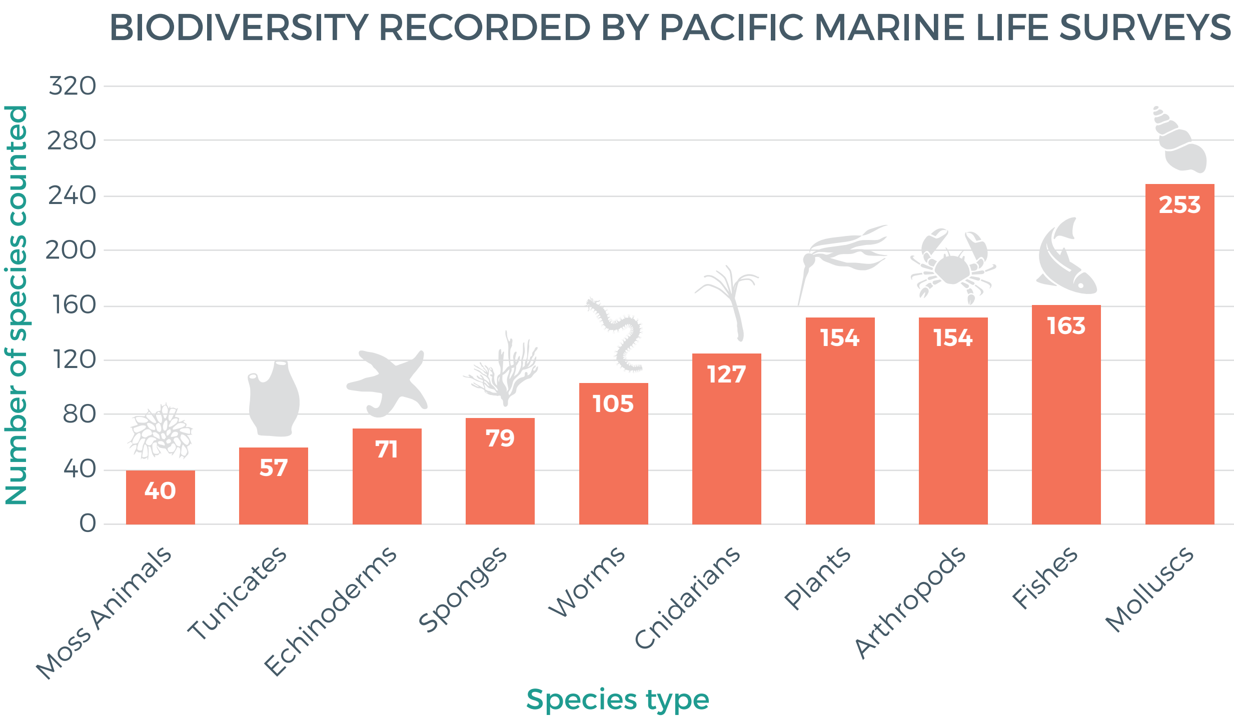


Figure 2. Number of species observed in each of ten taxonomic phyla.

Photo: Jenn Burt

What is the current status?

In 2017, a handful of divers contributed data regularly to the database. A certain level of experience is required to properly identify the range of species observed in coastal B.C., and Donna takes care to ensure each diver has that experience and can identify species accurately. Members of the Howe Sound Research and Conservation dive team at the Vancouver Aquarium are regular contributors.

The database now documents over 1,200 species in ten phyla that have been recorded (Figure 2). The spatial extent of records includes the entire length of the coast of B.C., into Alaska to the north, and as far as California to the south (Figure 3).

Species observations recorded in the PMLS database are better suited for some studies than for others for

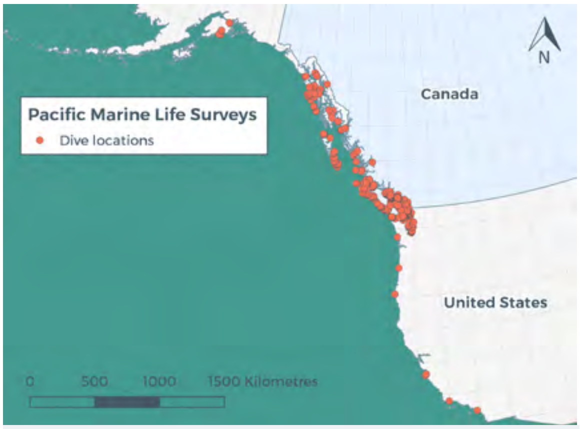


Figure 3. PMLS dive locations.

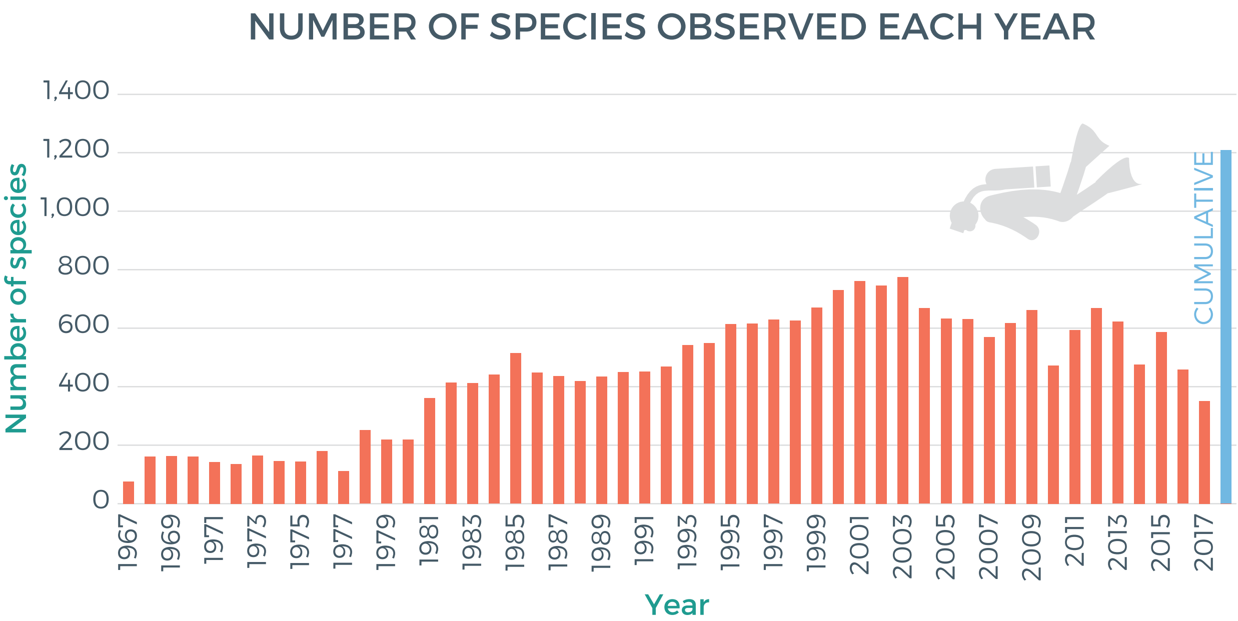


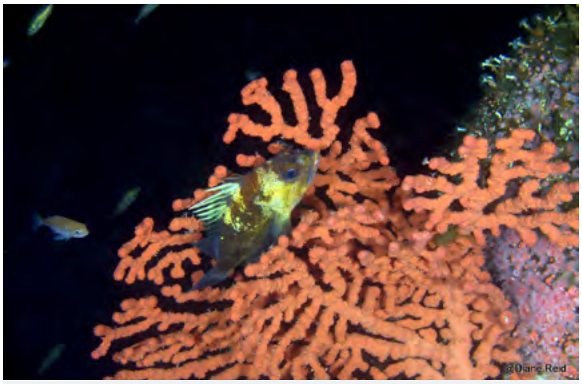
Figure 4. The number of species observed each year varies with the number of dives recorded and with the accumulated experience of the divers. The more experience, the more species identified and recorded. Also, fewer plants were identified in the 1960s and 1970s.

several reasons. The collection is a set of species observations by location with some accompanying habitat descriptions. Species absence from a site at any time cannot be inferred, and abundance estimates are relative. The effort expended to gather observations is not standardized. Each unit of effort is a dive and all dives are not equal due to individual differences in diver skills, including observation and taxonomic identification. Further, the distribution of dives in space and time is not consistent or standardized. The taxonomic expertise of divers increases with experience, such that the number of species identified per year increased for many years, peaking in 2003, and shows variability since then (Figure 4). For a record of biodiversity, the length of the time series and the geographic extents are rare and valuable. According to the PMLS database, biodiversity (within diving depths) among regions of the B.C. coast does differ.[3] The database is well suited to support site-specific explorations, biodiversity comparison among regions, and comparison across time periods.

What is being done?

Development of the database and interface software is ongoing, to make it more flexible and easy to use. Charlie adds new features as required to satisfy new reporting requests, or to make it easy to export results in formats required by other organizations (e.g., iNaturalist). Data collection is continuing, enabling discovery of new trends or changes in species communities that may be linked to environmental changes. Records from the past 50 years can be used to pinpoint areas to be revisited to answer specific research questions.

The structure and function of the database were used as a model for work that started in the Arctic in 2014. Species observations from Arctic research expeditions (an Ocean Wise initiative run by the Vancouver Aquarium Marine Science Centre) are being collected and recorded in a similar database.



Juvenile rockfish with coral. (Photo: Diane Reid)

What can you do?

Individual and Organization Actions:

- Report unusual SCUBA observations along with location data and photos to Donna.Gibbs@ocean.org. Credible observations will be added to the database.
- Study the taxonomy of biodiversity in nearshore marine habitats.

Government Actions and Policy:

- Support citizen science programs that encourage and facilitate learning about the marine environment.
- Encourage university students to study taxonomy.

Footnotes

[1] Marliave, J.B., Gibbs, C.J., Gibbs, D.M., Lamb, A.O. and S.J.F. Young. 2011. Biodiversity Stability of Shallow Marine Benthos in Strait of Georgia, British Columbia, Canada Through Climate Regimes, Overfishing and Ocean Acidification. In: Grillo, O. (Ed.) Biodiversity Loss in a Changing Planet, InTech. DOI: 10.5772/24606. Available from: https://www.intechopen.com/books/biodiversity-loss-in-a-changing-planet/biodiversity-stability-of-shallow-marine-benthos-in-strait-of-georgia-british-columbia-canada-throug Accessed July 6, 2017.

[2] The Marine Biodiversity Project. Accessed February 13, 2018. http://www.vanaqua.org/marine-biodiversity/.

[3] Marliave et al. 2011

Donna diving on the HMCS Annapolis in Howe Sound. (Photo: Diane Reid)

Fishing benefits coastal communities & contributes to sense of place; are these benefits at risk?

AUTHORS
Fiona Beaty and **Karin Bodtker**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Jim McIsaac, Executive Director, T. Buck Suzuki Environmental Foundation

What's happening?

In 2016, British Columbia's seafood sector contributed $415 million to B.C.'s gross domestic product and provided over 10,000 jobs (see our articles on Seafood Production in the Seafood Theme and Employment in the Livelihoods Theme). However, fisheries contribute much more than the economics and jobs imply, especially in coastal communities. For example, in a 2012 assessment of the North and Central Coast's social, economic and cultural sectors, the level of economic and cultural interest that coastal communities showed in commercial fisheries stumped analysts.[1] The magnitude of in-

Photo: Jenn Burt

terest in commercial fisheries dwarfed that for other economic sectors and inspired socio-economists to further investigate community ties to the seafood industry.

The resulting in-depth study, focused in the Pacific North Coast Integrated Management Area (PNCIMA, Figure 1), revealed that commercial fisheries not only support regional economies, but they also increase the social capital – social networks and community integrity – of coastal communities. Culture, intergenerational values, gift and trade, and lifestyle were the top values that fishermen[2] associated with their profession (Figure 2).[3] For example, in this study 20 fishermen reported gifting or trading seafood[4] to over 2,000 people annually, an act that increased the sense of fellowship amongst fishermen, non-fishermen, and friends and families within the PNCIMA communities.[5] Further, commercial fishermen value their occupation beyond the money-making capacity, more as a way of life linked to ecosystem and a strong sense of place. Recent trends have put these benefits and this way of life at risk.

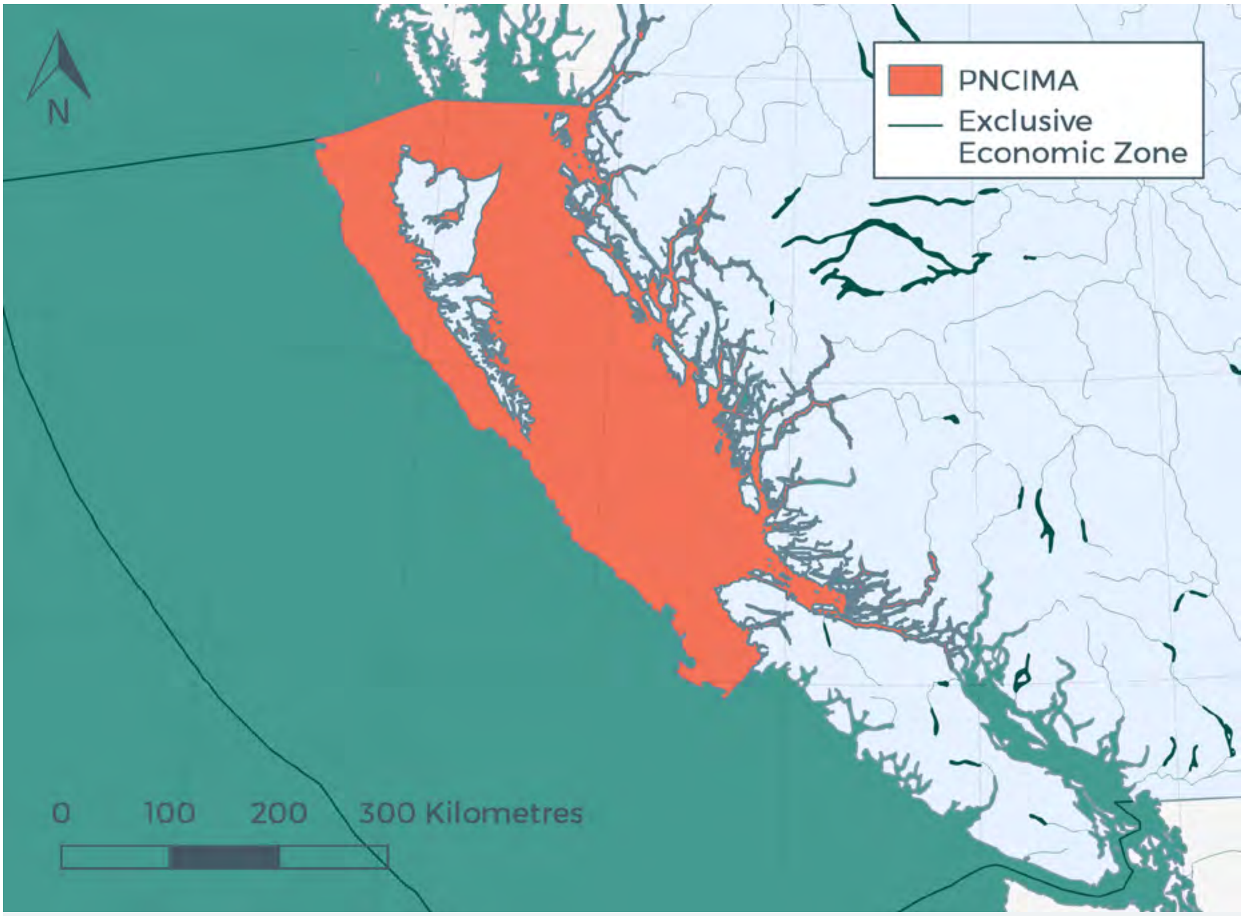


Figure 1. The Pacific North Coast Integrated Management Area (PNCIMA) and Canada's Pacific Exclusive Economic Zone.

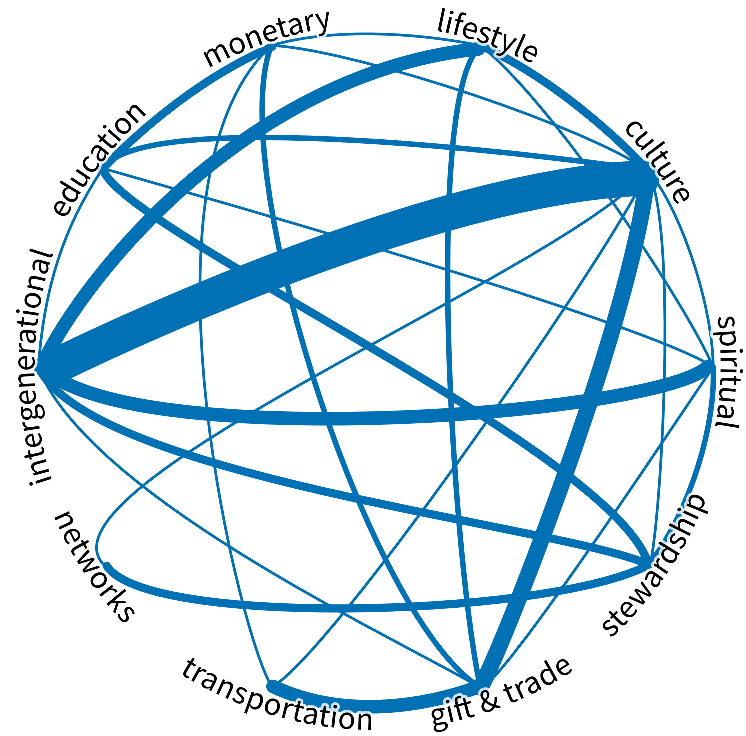


Figure 2: “Intangible” values associated with commercial fisheries in PNCIMA based on interviews with 23 local fishermen. The line width depicts the number of times a link between two values was mentioned, with the most frequently referenced values being identified as culture, intergenerational exchange, gift and trade, and lifestyle. All values remained connected to other value categories, signifying the complex nature of connections that communities have with commercial fisheries. Source: O'Donnell et al 2013.

Why is it important?

Regions with higher social capital, such as coastal communities that sustainably manage wild fisheries, are associated with improved social wellbeing, deeper community trust, long-term obligations between community members, and a higher investment in collective activities.[6] This can lead to a stronger sense of resource management and stewardship, better-informed fisheries management decisions, and more community investment in integrated marine planning.

These community benefits, if not managed for, are at risk. As a result of efforts to improve resource sustainability and net economic benefits, commercial fisheries have contracted over the last three decades. The management tools associated with these efforts, such as private quota trading systems, have had unintended consequences, such as reducing the proportion of benefits returning to coastal communities and to small boat owner-operators.[7]

Is there a particular importance or connection to First Nations?

In B.C., six percent of the population identifies as Aboriginal, but in coastal census subdivisions with populations under 1,000 (i.e., 73 smaller coastal subdivisions), 58 percent of the population identifies as Aboriginal.[8] Stories and legends of B.C.'s coastal First Nations people often encapsulate the pervasive and strong sense of place embedded in their culture. They speak of being part of this coastal ecosystem since time immemorial, as gathering and using marine resources has always been a part of the coastal cultures.

B.C.'s First Nations are spokespeople for fisheries and resource management as it relates to Aboriginal rights and titles.[9] Shellfish harvesting, for example, is a lifestyle and means of subsistence that First Nations groups have employed throughout their history and harvesters often work independently on traditional territories to harvest wild shellfish. However, access to shellfish habitat is being jeopardized as the shellfish aquaculture industry grows and privatization of marine space through tenures increases.[10] The number of clam and oyster tenures granted in B.C. doubled between 1999 and 2005, and again between 2005 and 2015.[11] Many First Nations see the increasing number of private aquaculture tenures as a threat to traditional unrestricted access to natural resources. Marine resource privatization has critical implications for First Nations' traditions, cultural identity, and local values associated with wild fisheries.

Razor clams, North Beach Naikoon, Haida Gwaii (Photo: Sally Taylor, Flickr CC BY NC 2)

What is the current status?

The past three decades have seen significant changes in the management and structure of the commercial fishing industry. A shrinking commercial fishing fleet is one outcome of this restructuring. The total number of registered fishing vessels in the fleet dropped by 64 percent between 1985 and 2015 (Figure 3). The contraction in fleet size occurred almost entirely in the small boat fleet, which has been reduced by 4,144 vessels (Figure 4). With an average crew of 2.5 workers per small boat, a loss of 4,144 registered small fishing vessels means a loss of over 10,000 jobs. Even if only half of those jobs were based in coastal communities, the loss is significant.

Unfortunately, the fleet data from Fisheries and Oceans Canada (DFO) does not include information about where vessels and their owners reside,[12] but most small boat harbours in fishing communities have infrastructure for vessels up to 65 feet.

In addition to downsizing of the fisheries fleet and loss of thousands of harvesting jobs,[13,14] processing plants and canneries have shut down coast wide,[15] access rights to fisheries resources have changed due to private quota trading systems,[16] and aquaculture leases,[17] and many aboriginal and rural fishing communities have become increasingly marginalized.[18,19,20]

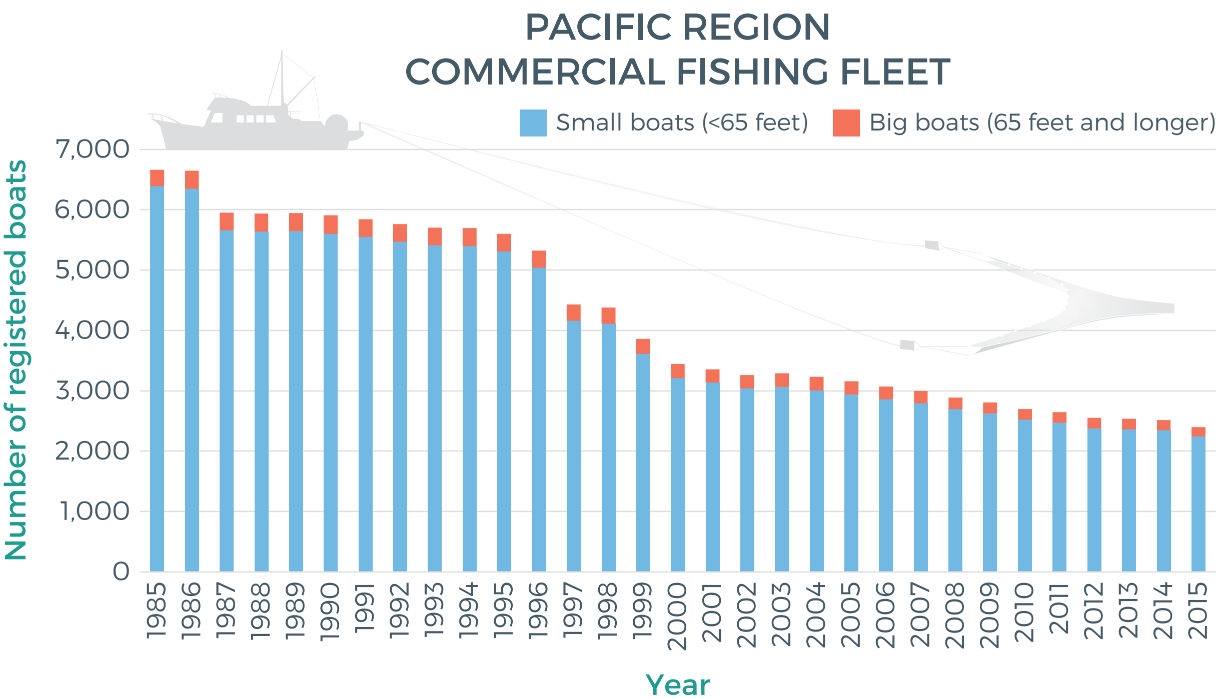


Figure 3. The number of registered vessels in the Pacific Region commercial fishing fleet. Small boats are less than 65 feet, and big are 65 feet in length and larger. Data Source: Fisheries and Oceans Canada, Pacific Region Operations Branch

A recent study claims that the way that fishing quotas have been implemented in Canada's Pacific Region is putting an end to small boat fishermen operating out of coastal communities.[21] The halibut fishery is one example of this. The fishery is characterized by a limited entry licensing regime (meaning each vessel needs to own a license to fish halibut and number of licenses available are limited), a total allowable catch set annually (in the case of halibut this catch limit is set by the International Pacific Halibut Commission through an international treaty between Canada and the United States), and individual transferable quotas (ITQs introduced in 1993 are traded in a private market). Catch shares or quotas are intended to secure access for fishermen, prevent over-competitive races for fish, and bring an element of measurable individual accountability to fishing.[22] All fishermen landing halibut need to own or lease halibut quota. However, market value of halibut quota per pound more than tripled between 1998 and 2015 (Figure 5),[23] essentially putting it out of reach for new entrants to the fishery. In 2017, the going rate was $125 per pound[24] and, as of early 2018, the price has reportedly risen to $135.[25] Owners of quota are not required to be active fishermen – they can lease their quota. Lease prices for halibut quota have increased over the same period,

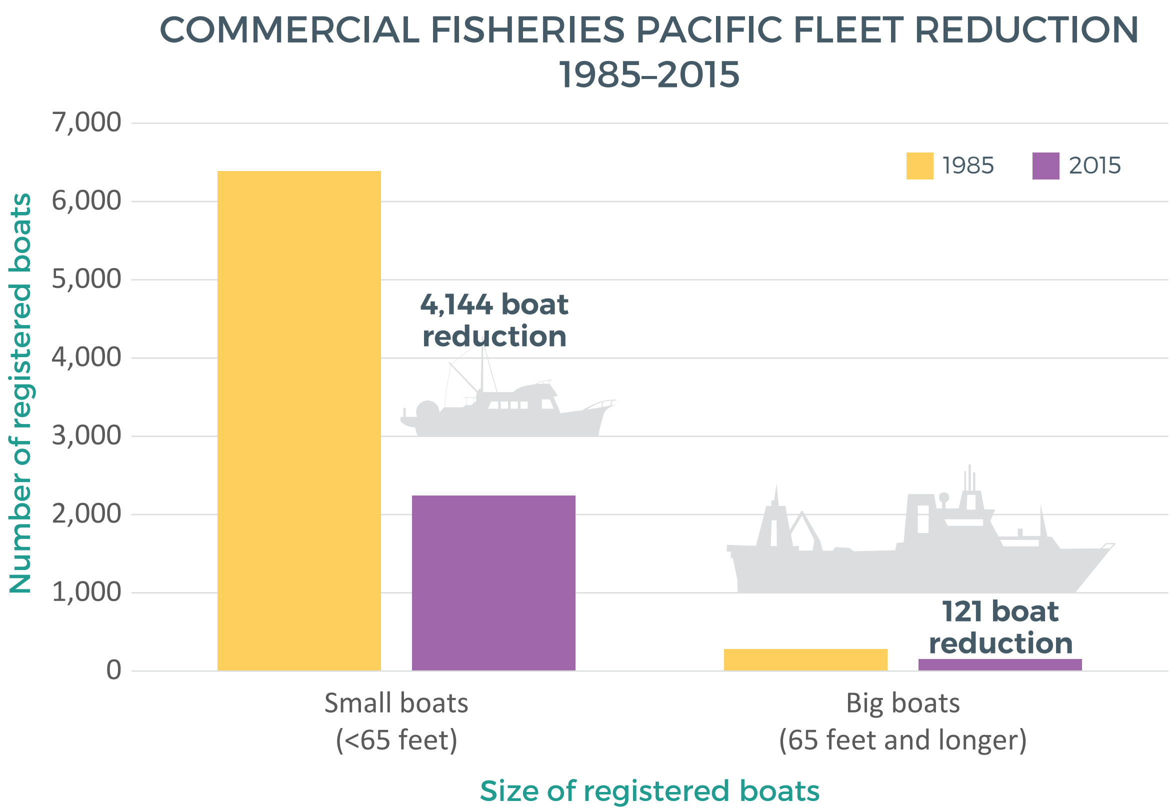


Figure 4. Small boat versus big boat fleet reduction in the Pacific Region between 1985 and 2015. Data Source: Fisheries and Oceans Canada, Pacific Region Operations Branch

but not quite at the same rate.[26] Quota pricing, one small piece of a very complex system, seems to point to unintended social and economic consequences of this quota management regime.

Overall, competition for access to halibut harvest is high among all those involved including between Canada and the United States,[27] and within Canada among First Nations, commercial fisheries, and sport fisheries. This competition will continue to drive the value of halibut quota up, perhaps even more so if total available quota decreases. In light of the competition and market pressures, concerns for the sustainability of halibut fishermen and fisheries are understandable. In September 2009, Canada's Pacific halibut fishery earned Marine Stewardship Council certification for being a sustainable and well-managed fishery. This certification is scheduled to expire in 2020.[28]

The many changes to management and structure of commercial fisheries since the 1980s were driven primarily by economic rationale, with conservation as an afterthought – at least according to the summary, "A Brief History of Fleet Reduction in BC," authored by Dennis Brown.[29] The authors of the Caught up in Catch Shares report argue that catch shares in B.C.'s ITQ system were implemented without clear social objectives, have essentially privatized a public resource, and have reduced the ability of smaller boats and coastal communities to benefit from the industry.[30]

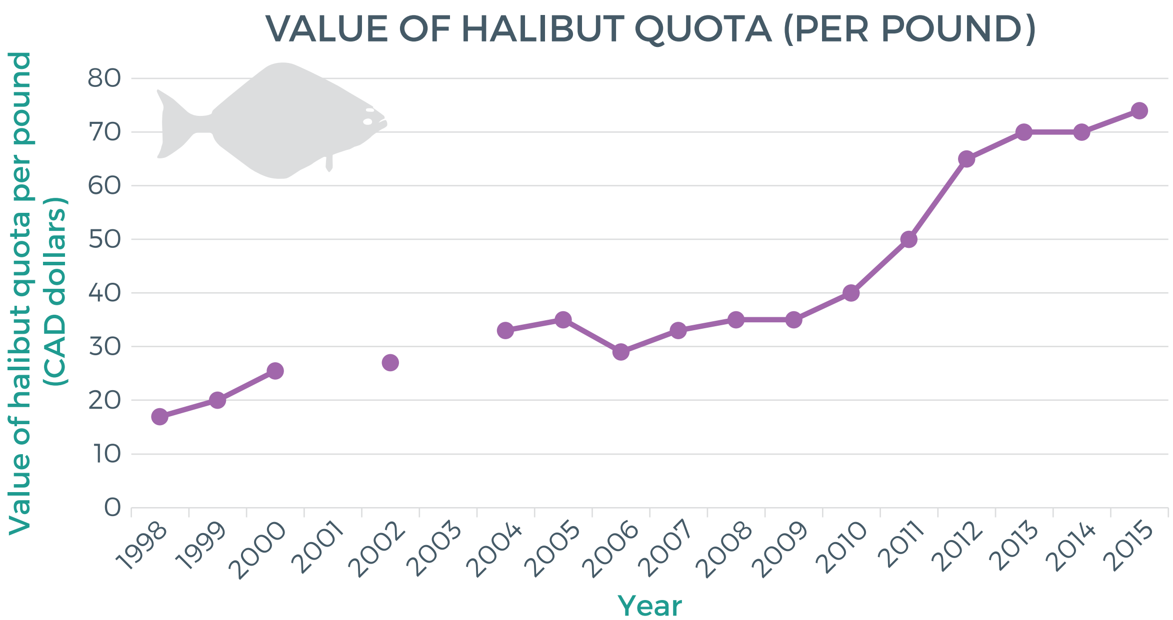


Figure 5. The market value of halibut quota (per pound) from 1998 to 2015 (not adjusted for inflation). Data Source: Analyses of Commercial Fishing Licence, Quota, and Vessel Values, prepared annually for Fisheries and Oceans Canada, Pacific Region.

What is being done?

In B.C., adaptation strategies to the structural changes along the coast use both top-down and bottom-up approaches. One approach that uses both of these strategies is the North Pacific Coast's Marine Plan Partnership (MaPP), which is a marine planning initiative led by 17 First Nations groups and the B.C. Provincial government. This partnership's focus is on sustainable economic development that supports coastal communities, protects the marine environment, and follows an ecosystem-based management framework.[31]

Several initiatives are investigating the impacts of B.C.'s fisheries system and how policies could enable benefits to flow from the resource to fishermen and their communities. In February 2018, Ecotrust Canada hosted a Fisheries for Community gathering to bring together individuals, communities, organizations, harvesters, and First Nations whose livelihoods, economies, food access, cultures, and wellbeing are tied to local fisheries, and who want to work together to ensure fisheries can continue to support them and their communities now, and for future generations. This may be the catalyst to align forces and turn the tide raising common socio-economic objectives for fishermen, coastal communities, and First Nations as a priority for senior governments. A summary of this forum will be available on the Ecotrust Canada website.

The Canadian Council of Professional Fish Harvesters (CCPFH) is completing phase one of a Fisheries Labour Market Information Study nationwide.[32] Based on tax filer data from Statistics Canada, they have found significant nationwide declines in the number of fish processing workers, self-employed fish harvesters, and fish harvesters that earn wages since 2000. They presented information focused on the Pacific Region to the Ecotrust Canada forum mentioned above and will be reporting out more publically.[33]

As part of a much larger project, the Canadian Fisheries Research Network has built a comprehensive fisheries evaluation framework.[34] This multipurpose framework identifies indicators across four broad dimensions – governance, economic, social and ecological – that can be tailored to evaluate specific fisheries. This tool allows managers to openly evaluate trade-offs between competing fisheries objectives across these four dimensions – something not transparent today. Results of this work are in press and expected to be published in 2018.

What can you do?

Individual and Organization Actions:

- Know your fisherman: choose seafood options that support local fishermen and sustainable harvesting.
- Support B.C.'s buy local program: https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/programs/market-development-programs/bc-buy-local-program
- Purchase and eat sustainable seafood. Learn more at:
  - Ocean Wise Seafood Program: http://seafood.ocean.org/
  - Seafood Watch: http://www.seafoodwatch.org/seafood-recommendations/consumer-guides
  - Marine Stewardship Council: https://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/pacific
- Demand improvements to seafood labelling and traceability requirements: SeaChoice, ThisFish
- Participate in citizen science efforts that support oceanic monitoring (e.g., Pacific Salmon Foundation's Salish Sea Marine Survival Project Citizen Science Program[35] and while on the ocean use the OceanSmart app to report interesting ecosystem events).

Government Actions and Policy:

- Undertake an independent review of fisheries licensing policies as they affect harvesters, First Nations and coastal communities in B.C.
- Support integrated ocean management by providing resources and engaging coastal communities, First Nations and stakeholders in decision-making.
- Support investment in research for fisheries, sustainable aquaculture techniques and institutions.
- Support comprehensive ocean socio-ecosystem monitoring, including environmental conditions to facilitate HAB detection and response.

Resources

Fisheries and Ocean Canada, Pacific Halibut
http://www.dfo-mpo.gc.ca/fm-gp/sustainable-durable/fisheries-peches/halibut-fletan-eng.htm

A History of Pacific Fisheries Policy [pre-confederation to 1993] by Douglas M. Swenerton
http://www.dfo-mpo.gc.ca/Library/165966.pdf

Footnotes

[1] Robinson Consulting and Associates Ltd. 2012. Socio-economic and cultural overview and assessment report for the Pacific North Coast Integrated Management Area. Submitted to Fisheries and Oceans Canada. Available at http://www.pncima.org/media/documents/secoa/secoa-final-edit-oct-29-13.pdf See also Pacific North Coast Integrated Management Area Initiative: Sub-Regional Advisory Forums Summary Report. 2011. Accessed March 13, 2018. Available at http://www.pncima.org/media/documents/pncima-publications/sraf-spring-2011-summary-report-reformatted.pdf

[2] "Fishermen" is the term voted on in 1996 by the women (the men abstained) in the United Fishermen and Allied Workers Union (UFAWU). They decided that this term would encompass both men and women working in the fishing industry.

[3] O'Donnell, K., Hesselgrave, T., Mackdonald, E., McIsaac, J., Nobles, D., Sutcliffe, T., Fernandes, D., and B. Reid-Kuecks. 2013. Understanding values in Canada's north Pacific: capturing values from commercial fisheries. T Buck Suzuki Environmental Foundation and Ecotrust Canada.

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[5] O'Donnell et al. 2013.

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[10] Joyce, A. L., Satterfield, T. A. 2010. Shellfish aquaculture and First Nations' sovereignty: the quest for sustainable development in contested sea space. Natural Resources Forum. 34: 106-123.

[11] Joyce and Satterfield 2010.

[12] Transport Canada Vessel Registration System does include this information. Accessing and analyzing these data was beyond the scope of this article.

[13] Robertson et al. 2015.

[14] Stocks 2016.

[15] The Canfisco cannery in Prince Rupert stopped canning salmon as recently as 2015. https://globalnews.ca/news/2336619/prince-ruperts-largest-cannery-closing-500-jobs-in-jeopardy/

[16] Pinkerton, E. 2012. Alternatives to ITQs in equity-efficiency-effectiveness trade-offs: How the lay-up system spread effort in the BC halibut fishery. Marine Policy, 42: 5-13.

[17] Joyce and Satterfield 2010.

[18] O'Donnell et al. 2013.

[19] Robertson et al. 2015.

[20] Stocks, A. 2016. The state of coastal communities in British Columbia. T. Buck Suzuki Environmental Foundation. Accessed July 17, 2017. http://www.bucksuzuki.org/images/uploads/docs/StateofCoastalCommunities_WEB.pdf

[21] Robertson et al. 2015.

[22] Robertson et al. 2015.

[23] Nelson, S. 2004-2015. Analyses of Commercial Fishing Licence, Quota, and Vessel Values, prepared annually for Fisheries and Oceans Canada, Pacific Region. Accessed March 2, 2018. Available through the federal science library at http://science-libraries.canada.ca/eng/home/

[24] A March 2018 article in the Globe and Mail quotes 2018 halibut quota prices at $125 per pound. Koreski, J. "Seeking an elusive, expensive catch: quotas" published March 2, 2018. The Globe and Mail. Accessed March 11, 2018. https://www.theglobeandmail.com/news/british-columbia/seeking-an-elusive-expensive-catchquotas/article38196750/

[25] McIsaac, J., Executive Director, T. Buck Suzuki Environmental Foundation. Personal communication via phone call, February 27, 2018.

[26] Nelson 2004-2015.

[27] https://www.nationalfisherman.com/alaska/us-canada-disagree-distribution-declining-halibut-catch/

[28] Marine Stewardship Council. 2018. Canada Pacific Halibut (British Columbia). Accessed March 2, 2018. https://fisheries.msc.org/en/fisheries/canada-pacific-halibut-british-columbia/

[29] Appendix 3, Robertson et al. 2015.

[30] Robertson et al. 2015.

[31] Marine Plan Partnership (MaPP). 2017. Retrieved from http://mappocean.org/

[32] http://www.fishharvesterspecheurs.ca/programs-initiatives/labour-market-information-study-1

[33] McIsaac, J., Executive Director, T. Buck Suzuki Environmental Foundation. Personal communication via phone call, February 27, 2018.

[34] Canadian Fisheries Research Network. 2014. Students collaborate in development of Comprehensive Fisheries Evaluation Framework. Accessed March 13, 2018. http://www.cfrn-rcrp.ca/article183

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Income disparity and wellbeing in B.C.'s coastal regions

AUTHORS
Karin Bodtker and **Raissa Philibert**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
No Technical Review

What's happening?

Income disparity in some of B.C.'s coastal regions is greater than the B.C. average, which is greater than Canada's overall score (Figure 1).[1] Income disparity is a significant indicator of social wellbeing and is commonly known as the wealth gap between the rich and the poor. In this article, we consider two metrics of income disparity. Both metrics agree that among B.C. coastal census divisions, Comox Valley demonstrates the least income disparity and the Central Coast has the highest disparity score. Depending on the metric, Greater Vancouver, Mount Waddington, and Skeena-Queen Charlotte areas also score relatively high in disparity, while Strathcona, Cowichan Valley and Alberni-Clayoquot areas exhibit lower disparity scores.

Photo: Dan Blondal

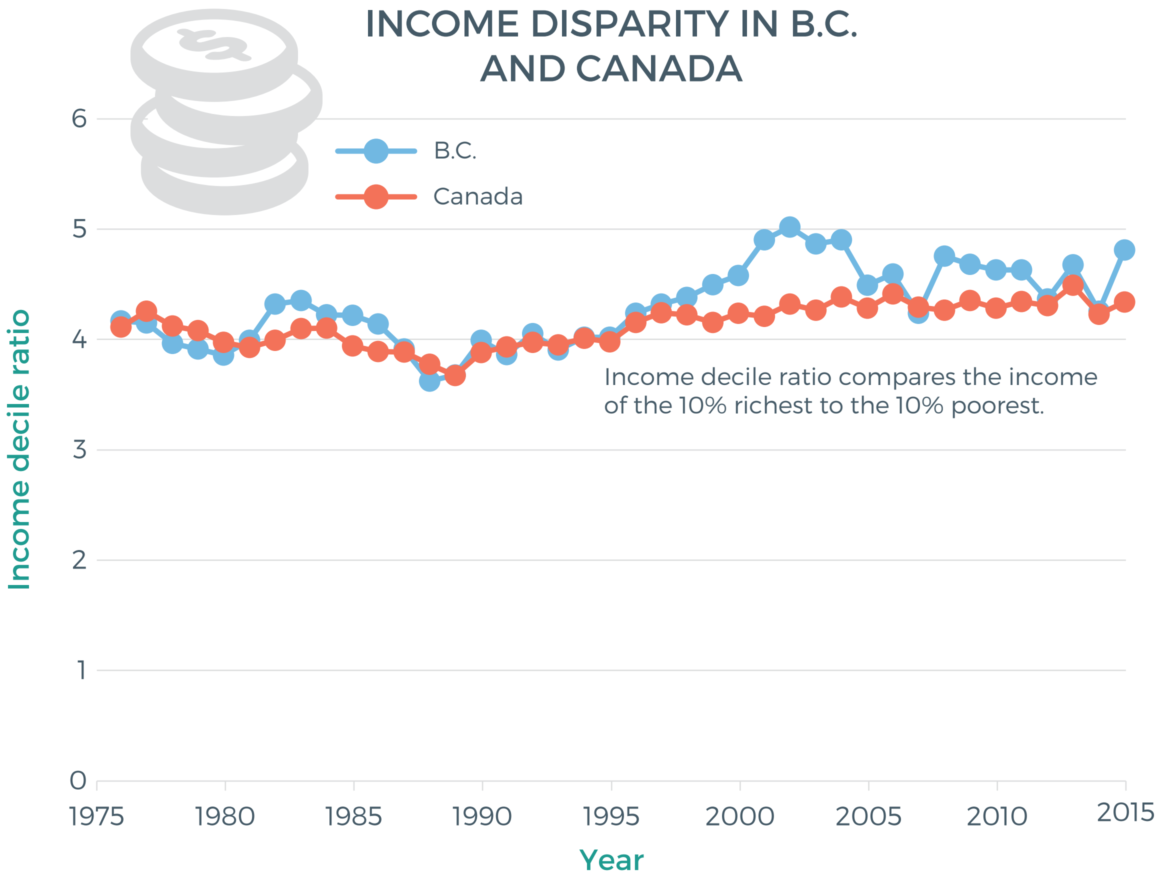
The **Canadian Index of Wellbeing** defines wellbeing as a state of **comfort, health, or happiness** that reflects:

- COMMUNITY VITALITY
- DEMOCRATIC ENGAGEMENT
- EDUCATION
- ENVIRONMENT
- HEALTHY POPULATIONS
- LEISURE & CULTURE
- LIVING STANDARDS
- TIME USE

Why is it important?

Standard of living is one of eight categories of wellbeing identified by a Canadian network of academics and documented in the Canadian Index of Wellbeing (CIW).[2] A 2016 CIW report[3] concluded that the gap between national economic growth and overall wellbeing is widening. Since the recession in 2008, Canada's economy has recovered and grown by 8.1 percent, as measured by growth in Gross Domestic Product (GDP). However, when overall wellbeing was calculated using a metric that included standard of living and seven other aspects of human wellbeing, the results showed a mere 1.1 percent gain in overall wellbeing over the same time period. In short, not all citizens are benefitting from the growth in GDP. In fact, across Canada, scores for several components of the wellbeing index have declined.

Income disparity is one indicator that illustrates the growing gap between economic growth and general wellbeing. The gap between Canadians in the top income brackets and those at the bottom has widened. According to the Conference Board of Canada, income inequality increased over the 20 years following a low in 1989 and has leveled out since.[4] After-tax income



In 2015 the 10% richest in B.C. earned 4.8x the income of the 10% poorest.

Figure 1. Income disparity (decile ratio) in Canada and B.C. from 1976 to 2015. Higher values mean greater disparity. Data source: Income Statistics Division, Statistics Canada.

data from Statistics Canada show that inequality scores for B.C. have been consistently higher than inequality scores for Canada as a whole since 1998 (Figure 1). A look further back in time suggests a pattern of higher inequality at the beginning of the 20th century, falling rates through the 1970s, and rising inequality since then, but only for certain countries including the U.S., U.K., and Canada.[5] Inequality in continental Europe and Japan has not risen to the same extent since the 1980s.

Income inequality matters because societies with greater disparity are shown to have worse health and wellbeing outcomes.[6,7] Further, these negative outcomes are not restricted to the poor. They are felt by those at both the bottom and top of the socioeconomic ladder, meaning everyone suffers in unbalanced societies. Currently, scientists are studying potential causal relationships and looking for evidence that once a certain threshold of inequality is crossed, impacts to health and wellbeing become evident.[8]

Is there a particular importance or connection to First Nations?

We did not look at First Nation communities in particular.

Photo: Kim Wright

What is the current status?

We looked at two common metrics of income disparity:

- **An income decile ratio**, or the ratio of the income of the 10 percent richest to that of the 10 percent poorest (Figure 2),[9] and
- **The Gini coefficient**,[10] a statistical measure of inequality (Figure 3).[11]

Income ratios are the most basic inequality measures and are widely used because they are easy to understand, but they are vulnerable to extreme values and outliers.[12] Income decile ratio, which in our case compares the adjusted household income of the top 10 percent to that of the bottom 10 percent of households, in coastal B.C. ranges from 4.14 to 6.68 (Figure 2). For example, the top 10 percent in the Central Coast division earn 6.7 times as much as the bottom 10 percent in that region. Higher values indicate greater income inequality and may imply lower overall wellbeing. Strathcona, Powell River and Comox Valley census divisions have the lowest disparity among coastal divisions.

The Gini coefficient can be used to measure any form of uneven distribution, and is the most widely used single measure of inequality.[13] Values range from zero, where all people have equal income, to one, where one person has all the income. Therefore, higher values indicate greater inequality. The coefficient allows direct comparison of two populations' income distribution, regardless of their size, but very different income distributions can have the same Gini coefficient.[14] For example, a population with incomes skewed to the low end could have the same Gini score as a population with incomes skewed to the high end.

The Central Coast and Greater Vancouver have the highest Gini coefficients of the B.C. coastal census divisions (Figure 3). Researchers have found that not only are negative health outcomes related to income inequality despite individual income level,[15] but also that association between negative outcomes and income inequality is stronger above a threshold of 0.3[16] for the Gini coefficient.[17]

The conference board of Canada ranks Canada 13th out of 16 peer countries (using Gini scores, after taxes and transfers).[18] The United States experiences the greatest income inequality, while countries like Denmark, Finland, and Norway show the lowest rates. Within Canada, B.C., Alberta, and Ontario have the highest income inequality.[19]

Interpreting either of these metrics has limitations and caveats. In any region, the relative size of urban versus rural populations will contribute to the inequality metric – incomes are generally lower in rural areas – as will the relative proportion of the population receiving income from sources such as self-employment, investments, or income assistance. These factors can be broken out and studied in more detail to inform policy to address the increasing gap between the rich and the poor.

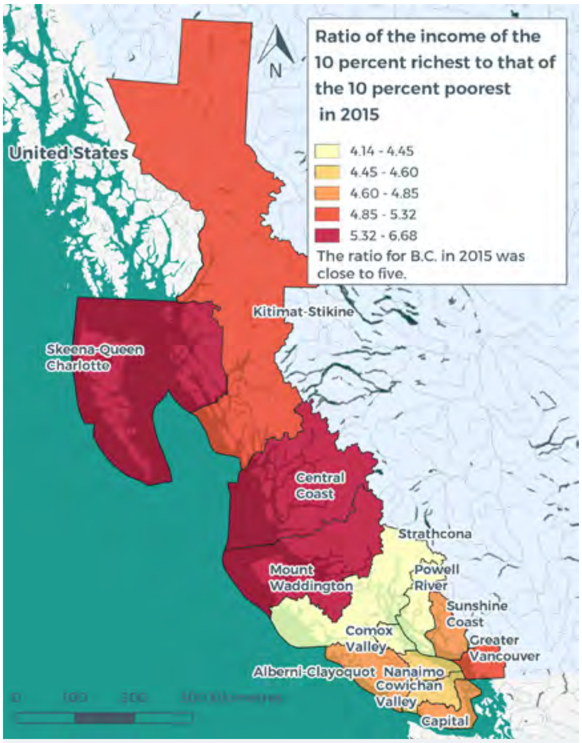


Figure 2. Income decile ratio for B.C. coastal census subdivisions. Higher values mean greater income inequality. Data Source: Statistics Canada

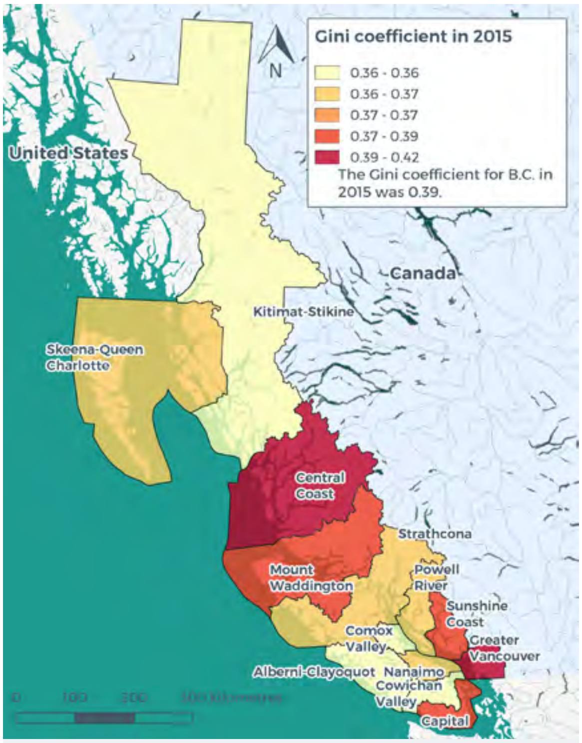


Figure 3. Gini coefficient for B.C. coastal census divisions. Gini values range between zero and one, with higher values indicating greater disparity. Data Source: census mapper

What is being done?

Statistics Canada through the Canadian census program tracks the distribution of income across Canada. This provides regular and comprehensive data, with a short gap in 2011 when the federal government replaced the long form census with a National Household Survey. The data collected in 2011 do not compare well statistically with census data before or since. Suppression of census data does occur occasionally, for reasons of confidentiality and accuracy. Statistics are not released for areas with small populations (less than 40 households), nor for areas with a response rate of less than 50 percent, as the risk of inaccuracy is high.[20]

Tracking of disparity metrics, such as the Gini coefficient or the decile ratio, is done at the international scale by organizations that also research and develop policy recommendations, such as the Organisation for Economic Co-operation and Development (OECD) and the World Bank.[21] Within Canada, think tanks like the Fraser Institute and the Broadbent Institute publish analyses and opinion pieces with opposing political perspectives.

The British Columbia government, in a September 2017 budget update, announced several tax measures that may begin to restore fairness and reduce income inequality in the Province.[22]

What can you do?

Individual and Organization Actions:

- Be aware of income inequality issues in your community and support government policy and action to address change and imbalance.

Government Actions and Policy:

- Provide a universal basic income as part of social assistance to reduce income inequality.
- Further extend health and social benefits to low and modest income Canadians, to reduce income inequality.[23]
- Mitigate the inequality impact of technological progress by improving the general skills level across all geographies through broader access to high-quality education and training programs.
- Remove obstacles to women's participation in the labour force.
- Work to reduce and minimize tax evasion.
- Convene a Fair Tax Commission to review the entire provincial tax system.[24]

Resources

Statistics Canada, 2016 Census topic: Income
http://www12.statcan.gc.ca/census-recensement/index-eng.cfm

Report from BC Statistics – Mind the Gap: Income Inequality Growing, 2012
http://www.bcstats.gov.bc.ca/Files/3af25093-fc87-48f7-b6bd-5e951af09c9b/MindtheGapIncomeInequalityGrowing.pdf

An interactive map of Gini Coefficients based on Canada Census 2017
https://censusmapper.ca/maps/840#7/49.404/-124.360

Our World in Data: Income Inequality
https://ourworldindata.org/income-inequality/

OECD on Income Inequality
https://data.oecd.org/inequality/income-inequality.htm

Broadbent Institute
http://www.broadbentinstitute.ca/income_inequality and http://www.broadbentinstitute.ca/towards_a_more_equal_canada

Fraser Institute
https://www.fraserinstitute.org/studies/towards-a-better-understanding-of-income-inequality-in-canada

Canadian Index of Wellbeing
https://uwaterloo.ca/canadian-index-wellbeing/what-we-do/domains-and-indicators/gini-coefficient-income-gap

Report from City of Vancouver including information on Income Inequality
http://vancouver.ca/files/cov/factsheet5-making-ends-meet.PDF

Footnotes

[1] Data from Statistics Canada. Table 206-0032 - Upper income limit, income share and average of adjusted market, total and after-tax income by income decile, Canada and provinces, annual. (accessed: December 07, 2017)

[2] Canadian Index of Wellbeing. 2017. Accessed Dec. 7, 2017. https://uwaterloo.ca/canadian-index-wellbeing

[3] Canadian Index of Wellbeing. 2016. How are Canadians Really Doing? The 2016 CIW National Report. Waterloo, ON: Canadian Index of Wellbeing and University of Waterloo. Accessed Dec. 7, 2017. https://uwaterloo.ca/canadian-index-wellbeing/sites/ca.canadian-index-wellbeing/files/uploads/files/c011676-nationalreport-ciw_final-s.pdf

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[9] The map presents the ratio of after-tax adjusted household income decile limits of the ninth decile and the first decile. Data provided by Statistics Canada, Nov. 22, 2017, Eric Olson, Chief, Housing and Census Income, Income Statistics Division.

[10] Developed by and named after an Italian statistician, Corrado Gini, in 1912.

[11] Data retrieved from CensusMapper, "After Tax Household Income Gini Coefficient," accessed November 15, 2017. https://censusmapper.ca/maps/840#5/55.727/-122.981 (CensusMapper uses data from Canada Census 2016.)

[12] United Nations. 2015. Inequality measurement. Development Issues No 2. UN Department of Economic and Social Affairs. 2p. Accessed Dec. 6, 2017.Available at: http://www.un.org/en/development/desa/policy/wess/wess_dev_issues/dsp_policy_02.pdf

[13] Chapter 6. Inequality Measures, p.101-119. In Haughton, J. and S.R. Khandker. 2009. Handbook on Poverty and Inequality. The World Bank, Washington, D.C. 446pp. http://siteresources.worldbank.org/INTPA/Resources/429966-1259774805724/Poverty_Inequality_Handbook_Ch06.pdf

[14] United Nations 2015.

[15] Kennedy, B.P., Kawachi, I., Glass, R., and D. Prothrow-Stith. 1998. Income distribution, socioeconomic status, and self rated health in the United States: multilevel analysis. BMJ 1998; 317 doi: https://doi.org/10.1136/bmj.317.7163.917

[16] The Gini coefficient value in the threshold study resulted from standardization of several metrics of income inequality and may not be not directly comparable to the Gini values that we report for B.C. and coastal regions.

[17] Kondo, N., Sembajwe, G., Kawachi, I., van Dam, R.M., Subramanian, S.V., and Z. Yamagata. 2009. Income inequality, mortality, and self rated health: meta-analysis of multilevel studies. BMJ 2009; 339 doi: https://doi.org/10.1136/bmj.b4471

[18] Conference Board of Canada. 2017.

[19] Conference Board of Canada. 2017.

[20] Statistics Canada, "Guide to the Census of Population, 2016. Chapter 11 – Dissemination," Statistics Canada Catalogue No.98-304-X2016001, February 8, 2017, http://www12.statcan.gc.ca/census-recensement/2016/ref/98-304/chap11-eng.cfm and Statistics Canada. 2017. 2016 Census - Geographic Areas Not Released. Dec. 11, 2017. Available at http://www12.statcan.gc.ca/census-recensement/2016/ref/sup/index-eng.cfm

[21] For example, OECD. 2015. Growth and income inequality: trends and policy implications, OECD Economics Department Policy Notes, No. 26, Accessed Dec. 7, 2017. http://www.oecd.org/eco/labour/Growth-and-income-inequality-trends-and-policy-implications.pdf

[22] Government of BC. 2017. Budget 2017 September Update. Accessed Dec 7, 2017. http://bcbudget.gov.bc.ca/2017_Sept_Update/default.htm

[23] Canadian Index of Wellbeing 2016, pg. 68.

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Coastal Development and Livelihoods

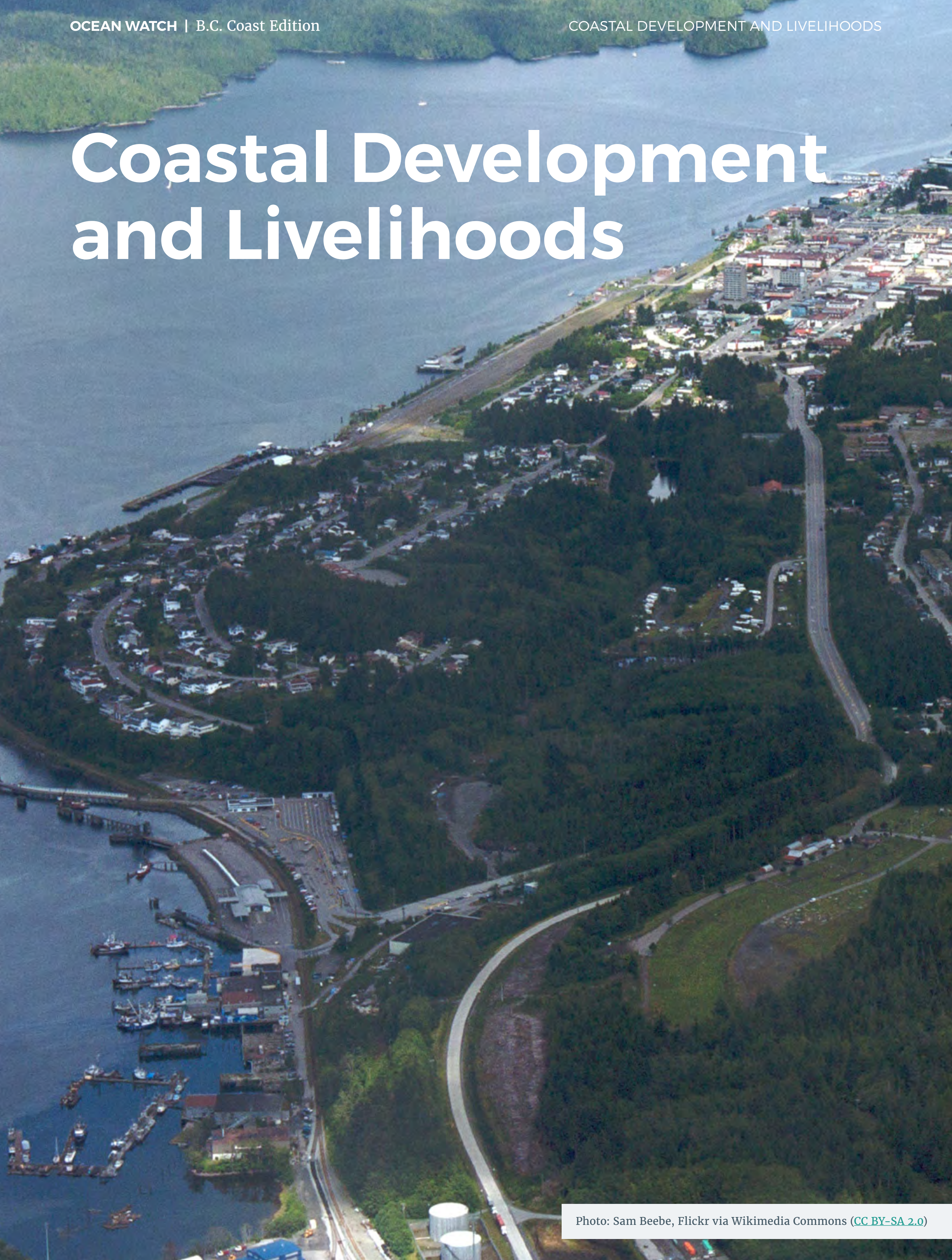


Photo: Sam Beebe, Flickr via Wikimedia Commons (CC BY-SA 2.0)

Summary

B.C.'s coastal communities are often caught in a balancing act between economic prosperity and environmental stewardship. As more people flock to B.C.'s coast, development in housing stock, infrastructure and industry is increasing pressure on the natural world. Yet the impacts are not all negative. The economic boost from development is bringing much-need income to coastal communities – many of which have lower median incomes and higher unemployment than the provincial average – and improving economic outlooks and overall wellbeing.

Industries like fishing and seafood production, central to life on the coast, are also in the midst of massive change, with the number of jobs available in decline as commercial fisheries shrink to comply with sustainability targets. But easing pressure on the environment does not necessarily lead to economic hardship. Sustainably managed wild fisheries can provide a source of high-quality, stable employment, while jobs related to sport fishing continue to increase.

However, far from land, human development is affecting life under the water's surface, as underwater noise from ship traffic, industrial activity and recreation increases in intensity. The noise from human activity can spread far and wide underwater, affecting the breeding, communication, and migration patterns of whales, dolphins and other marine animals. As more research is being done on the impact of underwater noise, policies and strategies are starting to emerge to lessen the sonic impact of human activity – and help us live in harmony with the natural world.

Coastal Development & Livelihoods Snapshot Assessment

Population & Major Projects

B.C.'s growing population is increasing development pressure along B.C.'s coastline, particularly in the province's more densely populated south. This growth is highlighting the need for a cohesive system of tracking the cumulative effects of development – both positive and negative – in coastal communities.

CAUTION

Income & Employment

With few exceptions, incomes in coastal B.C. are lower than the provincial average, while the percentage of low-income residents and unemployment is higher. These indicators suggest large parts of coastal B.C. may be struggling economically, leading to possible negative effects on health and wellbeing.

CRITICAL

Underwater Noise

Underwater noise from shipping, construction, recreation and shoreline development has been doubling in intensity every decade since the 1950s. This is having a marked impact on whales and other marine life as noise from ship traffic, recreation and industry impedes their ability to hunt, communicate, rest and breed.

CRITICAL

Seafood Industry Jobs

Jobs related to seafood production have been on the decline in coastal communities since 1984, but these numbers don't tell the entire story. Fewer registered fishing vessels and licences are associated with commercial fisheries today, but benefits such as greater diversity in catch, improved sustainability, and increasing opportunities for stable employment have emerged in exchange.

CAUTION

Coastal development: patterns of population growth, major projects, and coastal tenures

AUTHORS
Raissa Philibert and **Karin Bodtker**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
This article had no technical reviewers.

What's happening?

In British Columbia, development on land is expected to have some impact on the marine environment.[1] Coastal development is often driven by or related to population growth. The population of coastal B.C. has been growing at a rate of up to nine percent per year in some areas, especially in larger municipalities, and has been decreasing in some rural areas (Figure 1).[2] Based on a B.C. inventory of major development projects, commercial and residential projects (underway and proposed) are concentrated in areas of high population density, while industrial projects (generally with higher costs) are currently concentrated on the North Coast. Potential impacts on the marine environment will vary with development type and local environment sensitivity.

Photo: a.dombrowski, Flickr via Wikimedia Commons ().

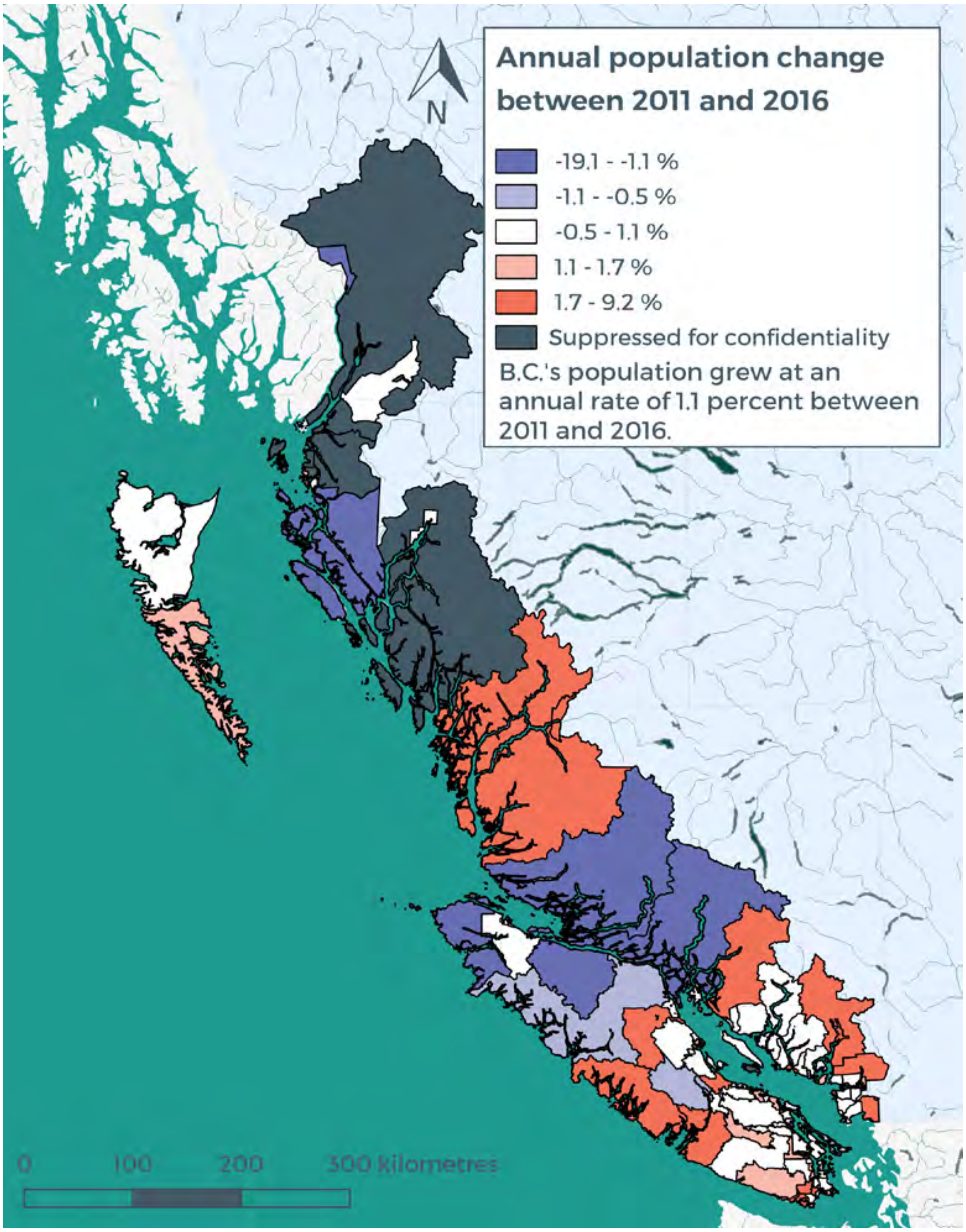


Figure 1: Annual population change (percent) between 2011 and 2016, mapped by census subdivision. Source: Statistics Canada.

Why is it important?

Coastal development generally involves some human-made structure(s) near the coast and sometimes includes modification of the shoreline. Development can be industrial, commercial, community-focused, or residential. At any scale, coastal development is important to plan for because it comes with benefits and with environmental impacts.

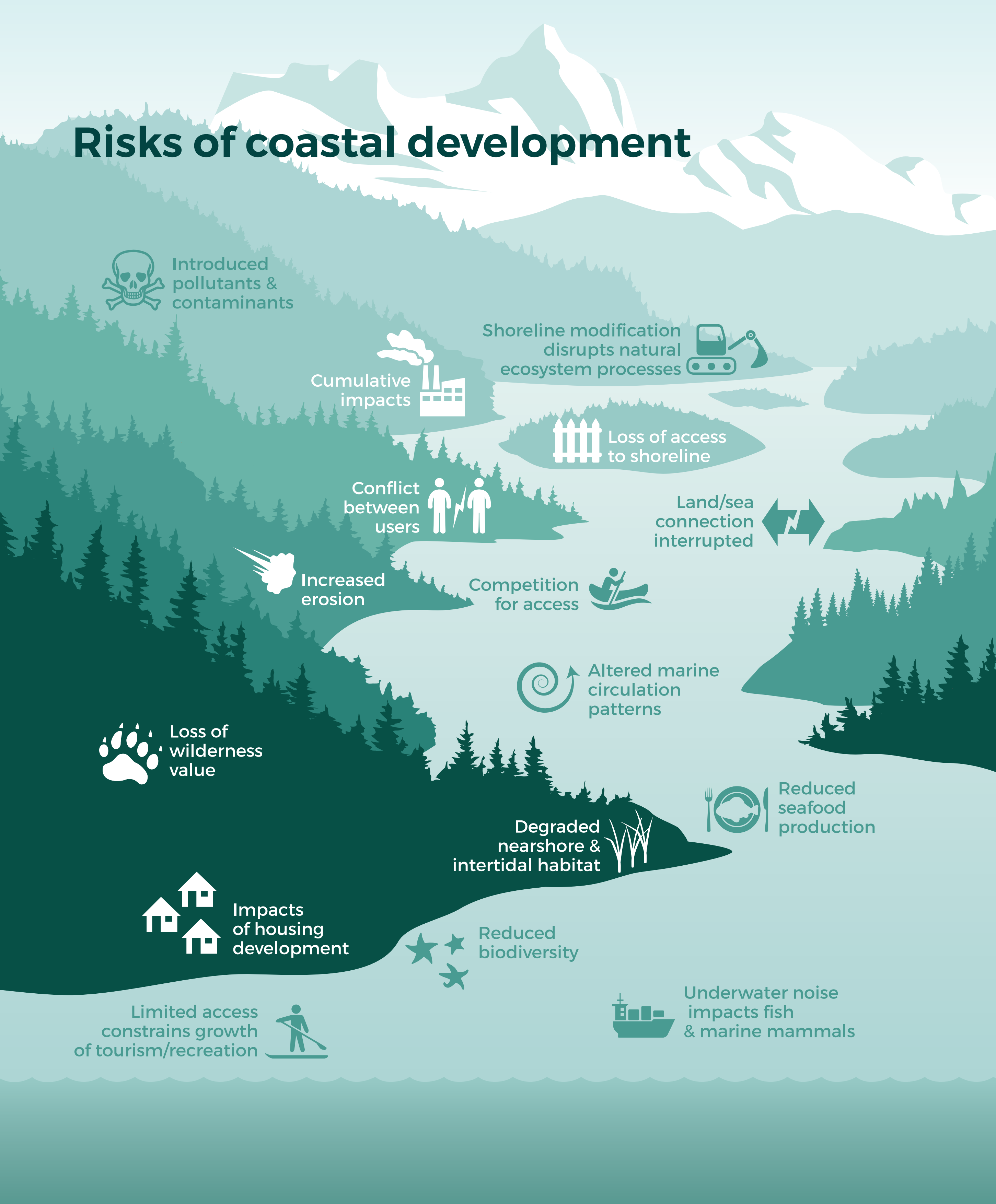
The benefits of coastal development range from economic to social and cultural, and can result in new jobs, greater community wealth, and improved access to the waterfront. New development often funds research, environmental studies, and community improvements such as infrastructure adaptations for expected sea level rise and increased public transit.

On the other hand, development along the shoreline interrupts the natural ecosystems' land-sea connection and can alter marine circulation patterns, shade eelgrass beds, reduce biodiversity, increase erosion, degrade nearshore and intertidal habitat, reduce coastal seafood production, and introduce pollution and contaminants. Social and economic costs of coastline development include potential loss of property value due to flooding or sea level rise, and loss of wilderness value and access to the marine environment as more shoreline becomes developed. To complicate the tallying of benefits and impacts, some development is actually redevelopment, which may lead to remediating environmental impacts through land-use change. For example in Howe Sound, a former chemical plant at the Squamish waterfront was converted to residential use and required remediation prior to redevelopment.

Is there a particular importance or connection to First Nations?

Access to marine resources and coastal spaces is essential for the wellbeing of First Nations communities in B.C. Increasing coastal development, intensifying activity and competition for space and resources can put First Nations' access at risk. A recent study[3] reviews how resource access and spatial access affect the wellbeing of coastal communities, including First Nations, and identifies factors that support or undermine access. The paper goes further to propose research priorities and recommend actions.[4]

Risks of coastal development



What is the current status?

Population growth and population density indices are used by governments to determine services and infrastructure needs. The population in British Columbia increased by 1.1 percent annually between 2011 and 2016. While most of coastal B.C. is sparsely populated with less two persons per square kilometre, the Vancouver census subdivision hosts 5,493 people per square kilometre (Figure 2).[5] Furthermore, populations in urban areas are increasing faster (up to nine percent per year between 2011 and 2016) than populations in rural areas. It follows that more residential development is expected in areas of rapid growth. In Northern B.C., the population decreased since 2011, except in Haida Gwaii and the Central Coast (Figure 1).

One way of investigating current and proposed development in coastal areas of B.C. is through B.C.'s Major Project Inventory (MPI).[6] The inventory, compiled by the B.C. government, lists construction projects with an estimated capital cost of $15 million (CAD) or greater ($20 million or greater within the Lower Mainland–Vancouver area). These projects are classified as commercial, industrial, infrastructure, institutional, or residential projects. In November 2017, 679 out of 974 projects (70 percent) listed in the MPI were located within the coastal development regions (Figure 3).[7,8] Included are proposed projects, projects underway and recently completed projects. The MPI does not, however, estimate the likelihood of proposed projects proceeding. According to the Business Council of British Columbia, many of the proposed projects in the MPI have been cancelled.[9]

In the south of B.C. where the population is growing, residential and commercial projects are more numerous than in the province's north. For instance, 374 residential, institutional, and commercial projects listed in the MPI are located in the Mainland/Southwest and 105 in Vancouver Island/Coast regions but only five in the North Coast region (Figure 3). In contrast, industrial development projects, which are not necessarily driven by population growth and often require higher investments, are more numerous in the North Coast region. Twenty-six out of the 56 projects listed in the MPI for the North Coast region are proposed industrial projects with a total capital cost of $201 billion. This represents a significant proportion of the estimated total of $351 billion[10] for all of the projects (proposed, completed and underway) located within the three coastal development regions. Even though several oil and gas projects were cancelled in the third quarter of 2017 (and are not shown in Figure 3), this sector still represents about half of the proposed projects in the North Coast.[11]

Shoreline development can be quantified by studying foreshore land use according to Land Act Tenures. These are Crown land dispositions issued for specific purposes and periods of time under an agreement between an individual or company and the provincial government. Approximately 29 percent of the B.C. coastline is "tenured" and a further five percent was subject to a tenure application as of January 2018 (Figure 4).[12] The permitted purpose of tenures varies and not all have a negative impact or result in man-made

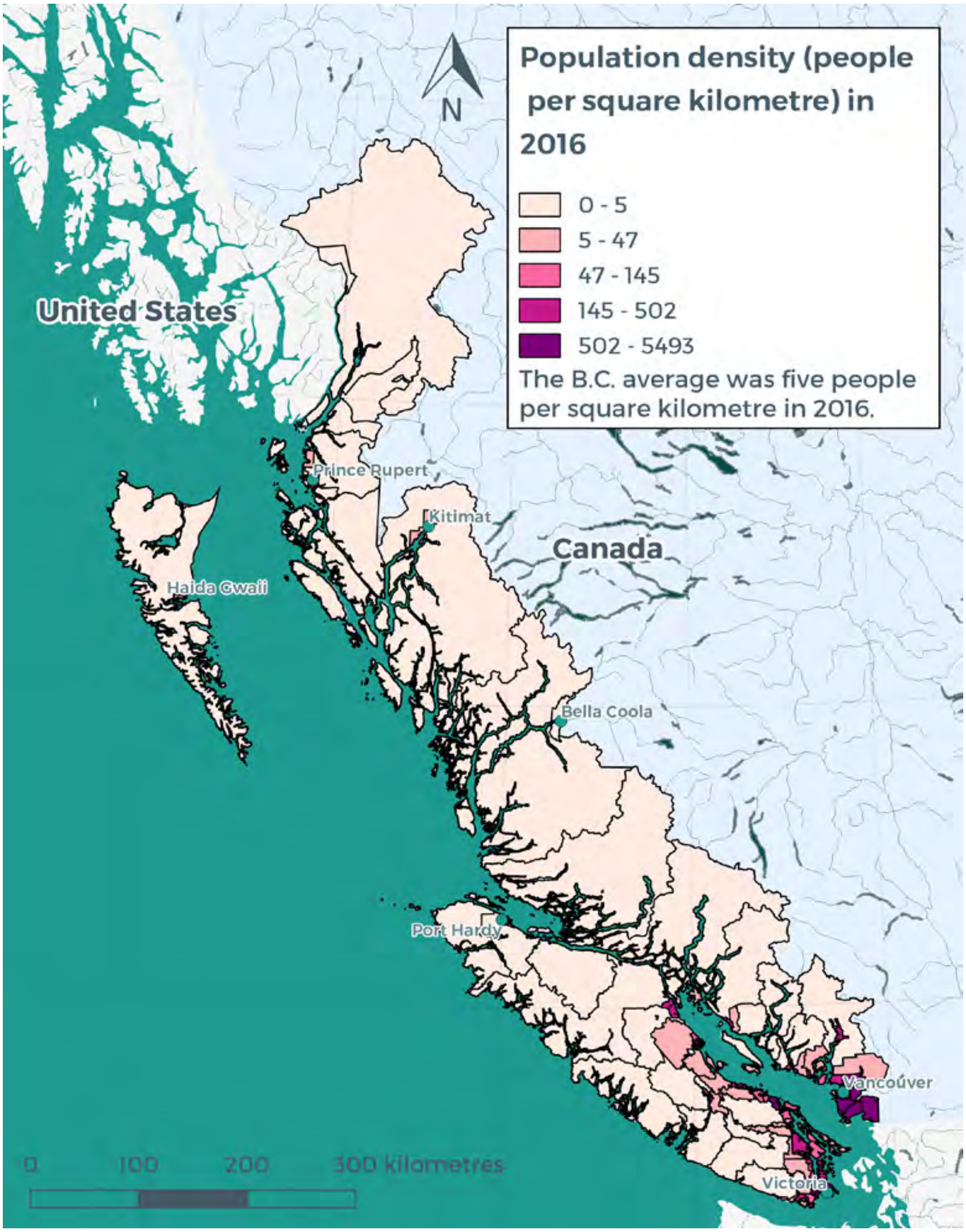


Figure 2: Population density in 2016, mapped by census subdivision. Source: Statistics Canada.

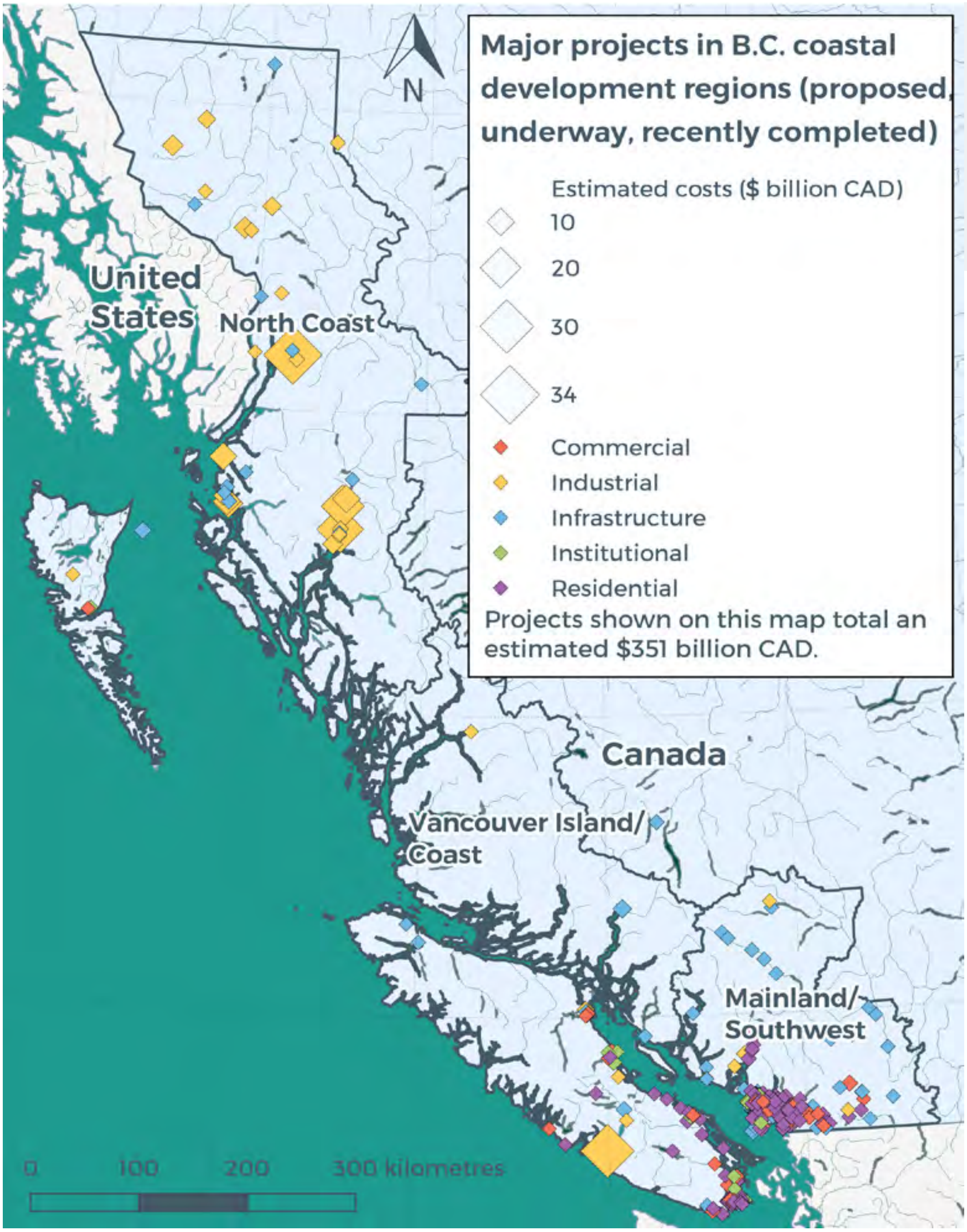


Figure 3: Major projects within coastal development regions as of November 2017. Source: British Columbia Major Projects Inventory.

structures on the shoreline – quite the opposite in the case of tenures for protection and reserves (covering almost 16 percent of B.C.'s shoreline). Currently 5.3 percent of the coastline is tenured for commercial and industrial use, while 3.6 percent is residential (Table 1). From the bird's-eye view that Figure 4 affords, patterns reveal themselves. Clusters of commercial and industrial tenures occur on the North Coast, the west coast of Vancouver Island, and along the shores and inlets of Johnstone Strait; protection and reserve tenures are concentrated in the Central Coast; and residential tenures are prevalent along the southeast shores of Vancouver Island. Understanding these patterns can help to predict and understand the different types of impacts to the marine environment in different regions, including where protection seems to be concentrated.

TABLE 1. COASTAL TENURES AND APPLICATIONS (JANUARY 2018); PURPOSE AND PERCENT OF SHORELINE COVERED IN BRITISH COLUMBIA.

TENURE PURPOSE	EXISTING TENURES (% SHORELINE COVERED)	TENURE APPLICATIONS (% SHORELINE COVERED)
Protection and reserves	15.7	0.6
Commercial and industrial	5.3	3.6
Residential	3.6	0
Commercial recreation	0.5	0.2
First Nations	0.3	0.1
Moorages	0.2	0
Other	3.1	0.3
Total	28.7	4.8

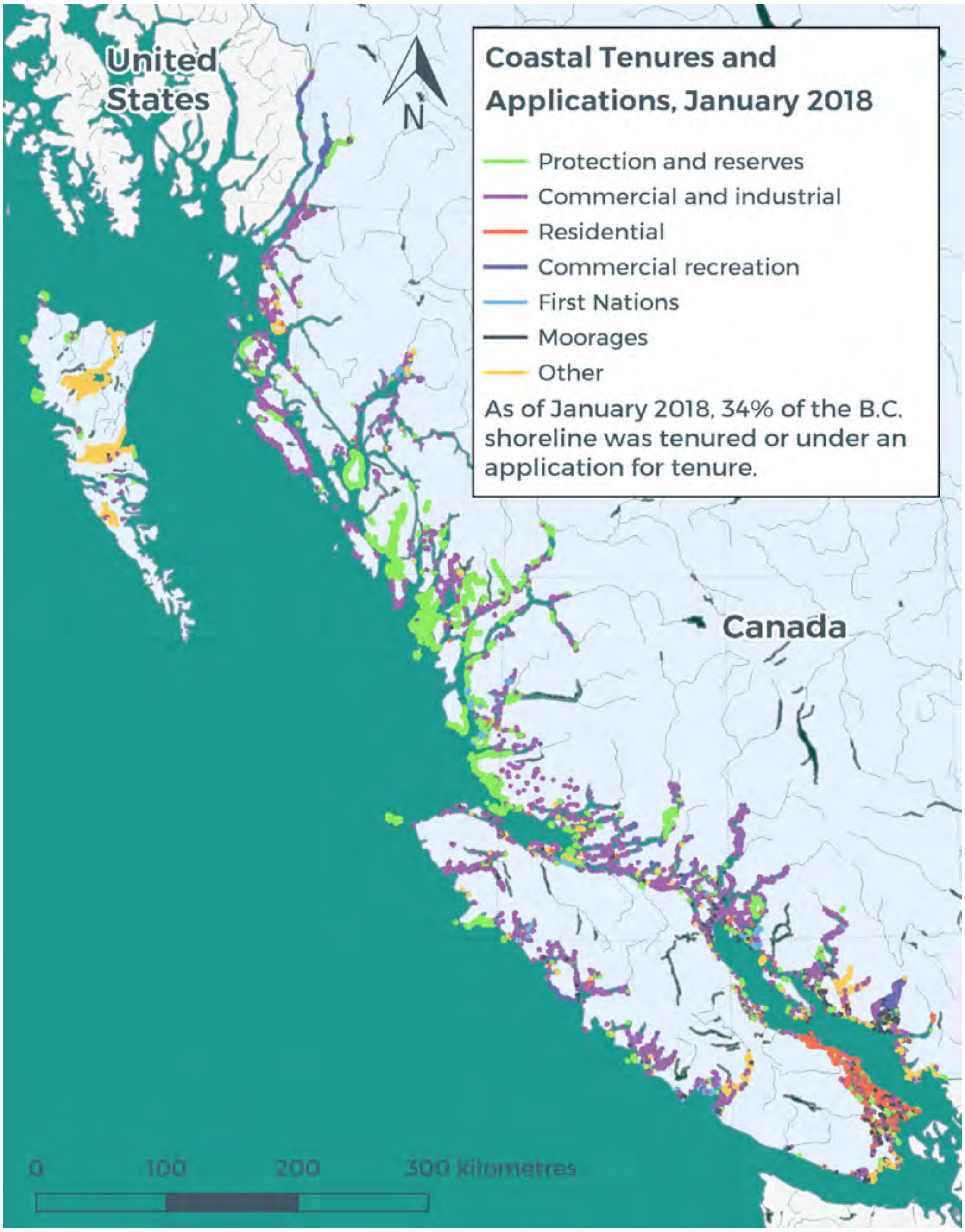


Figure 4: Location and purpose of shoreline tenures in B.C. as of January 2018. Source: GeoBC, Tantalis – Crown Tenures

What is being done?

There is no single level of government that is responsible for overseeing and approving coastal development in B.C.[13] Residential and commercial building permits are issued by local governments, which include municipalities, regional districts, and First Nations governments. The provincial government co-ordinates review and approval of industrial development projects. First Nations are integral to all of these decision-making processes through participation in a comprehensive referral process. First Nations are often involved in direct consultation with project proponents. These processes consider the cumulative effects of multiple proposals in a cursory way, but there is a need for more comprehensive planning and analyses to consider mounting development pressure. B.C. has completed a few assessments of cumulative effects[14] in terrestrial ecosystems and recently approved an interim framework for assessing and managing cumulative effects. This interim framework provides guidance regarding existing legislation and programs that can help to evaluate cumulative effects but does not introduce any new regulatory requirements and does not mention marine ecosystems or identify any values in the marine realm. In 2018, consultations with First Nations and other stakeholders will continue as part of a structured evaluation of the interim policy and required revisions will be made before finalizing the policy.

With projected rises in sea level, coastal communities in B.C. are likely to become vulnerable to flooding. Stakeholders, including the provincial government, recognize the need to plan and implement measures to mitigate for such climate change impacts.[15] For example, the foreshore in the District of West Vancouver has been leased from the province by the District.[16] This allows the District of West Vancouver to manage its shoreline and, through a Shoreline Protection Plan, naturalize and protect coastal habitats and waterfront infrastructure.

What can you do?

Individual and Organization Actions:

- Individuals, developers and industry can follow, promote, develop, discuss and share best practices (e.g., Green Marine certification – green-marine.org, GreenShores approaches for shoreline development – islandstrust.bc.ca/islands/island-ecosystems/caring-for-my-shoreline/greenshores-approach).
- Collate and make available pre-proposal data from environmental and social research.

Government Actions and Policy:

- Prioritize studies to further understand the effect of shoreline development on marine circulation patterns, shading, biodiversity, erosion, habitat degradation, seafood production, pollution and contaminants.
- Develop and promote an inventory of best practices for developers and update it regularly.
- Apply new and proven methods to assess development projects. For example, innovative tools to provide decision support for complex planning problems are becoming more available and more accepted. Taking ecosystem service values into account when evaluating the trade-offs of proposed development is one way to proceed.[17]
- Add marine values to the B.C. cumulative effects framework.
- Collate and make available pre-proposal data from environmental and social research.
- Support jurisdictions that want to work together to develop comprehensive land and marine use plans co-operatively.
- 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.

Resources

The Development of Major Projects within the Natural Resource Sector: An Overview of British Columbia's Regulatory Process
https://www2.gov.bc.ca/gov/content/industry/natural-resource-use/natural-resource-major-projects

An explanation of the coastal jurisdictions in B.C. from West Coast Environmental Law
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Guides for the protection of shorelines from the Capital Regional District
https://www.crd.bc.ca/education/our-environment/concerns/how-can-i-help/protect-shorelines-streamsides

from the Islands Trust
http://www.islandstrust.bc.ca/how-do-i/care-for-my-shoreline/

Learn more about B.C.'s Land Tenures Branch and Crown Land Procedures
https://www2.gov.bc.ca/gov/content/industry/natural-resource-use/land-use/crown-land/crown-land-procedures?keyword=crown&keyword=tenures

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Income and labour in B.C.'s coastal regions

AUTHORS
Raissa Philibert and **Karin Bodtker**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Kevin Milligan, Professor of Economics, University of British Columbia

What's happening?

Livelihoods, income and employment are important aspects of economic wellbeing. While household income and employment do not provide a full picture of how livelihoods are related to health and overall wellbeing, they are nevertheless useful to evaluate the relative economic wellbeing of a region.

Among the coastal regions of B.C., the highest income census divisions, as measured by median household income (Figure 1)[1] are Greater Vancouver and Kitimat-Stikine. These two areas have median household incomes that are as high or higher than the B.C. average. All other coastal areas have median household incomes that are below the provincial average. Furthermore, most coastal divisions have a higher prevalence of low-income households, lower rates of participation in the labour force, and higher unemployment rates than the B.C. average for each of these indicators.

Photo: Karin Bodtker

Why is it important?

Assessing the health of coastal communities and regions involves many factors, but economic wellbeing in terms of livelihoods certainly plays a role. Economic wellbeing means having enough resources to face life's challenges.[2] Obvious factors include income and employment[3] (see also our discussion of income disparity in the Wellbeing theme). The relationship between happiness and income and unemployment has been the subject of many studies. Given their importance, these factors have been included in several indices of wellbeing such as the Canadian Index of Wellbeing[4] or the OECD Better Life index,[5] alongside other equally important indicators. It is important to remember that economics are just part of the overall picture.

At an individual level, people with higher incomes report higher levels of life satisfaction.[6] A sufficient income allows for a family or household to meet their basic needs such as food, shelter and clothing. Higher income also helps to provide better access to education, extended health care as well as leisure activities. On the other hand, lower incomes may lead to a number of obstacles to wellbeing including social exclusion and marginalization.[7]

The links between employment and wellbeing seem clear cut. In Canadian as well as European studies, people who are employed report being happier than unemployed people, even if they are receiving the same income through other sources.[8] Employment often provides a sense of purpose as well as a source of income. Similarly, high rates of unemployment are associated with a number of negative impacts in addition to a loss of income. For example, a Canada-wide study has found that communities with higher unemployment rates have poorer health and higher mortality rates.[9] Unemployment has repercussions for the economy and society as a whole, even for those who are employed.[10,11] In general, the unemployed in these studies and as defined by Statistics Canada are those who are actively looking for work. Those who are not working by choice are categorized by Statistics Canada as "not in the labour force" rather than unemployed.

Is there a particular importance or connection to First Nations?

Although the majority of the population in some of the coastal areas we report on is Indigenous, we did not differentiate Indigenous peoples or look at First Nation communities in particular.

What is the current status?

The median after-tax household income, representative of the resources available to a household, is less than the provincial average in all coastal census divisions, except two (Figure 1). People living in the same household and sharing resources are better off than those living on their own.[12] The median after-tax household income in 2015 for B.C. overall was $61,280 and ranged from $45,824 to $63,365 in the coastal regions (Figure 1). The median after-tax household income in B.C overall increased by one percent per year between 2005 and 2015.[13] Even in coastal areas with low employment, there has been no decrease in median household income between 2005 and 2015.

The prevalence of low-income status, based on a Statistics Canada indicator,[14] is higher than the provincial rate in most coastal regions (Figure 2). In 2015, if the income available per individual in a household was less than $22,133, all members of that household had a "low-income" status. About five million Canadians or 14.2 percent of the population lived on a low income in 2015.[15] B.C. had the fourth highest prevalence

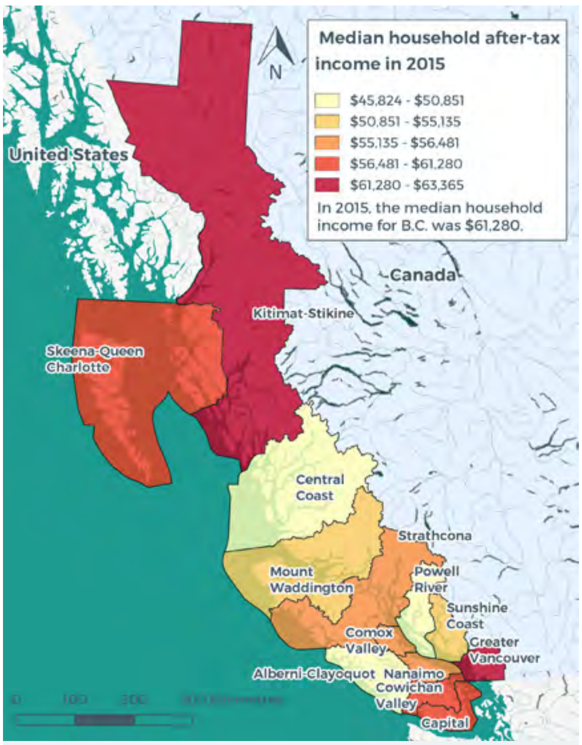

Figure 1: Median after-tax household income in 2015 for B.C. coastal census divisions. Data source: Statistics Canada

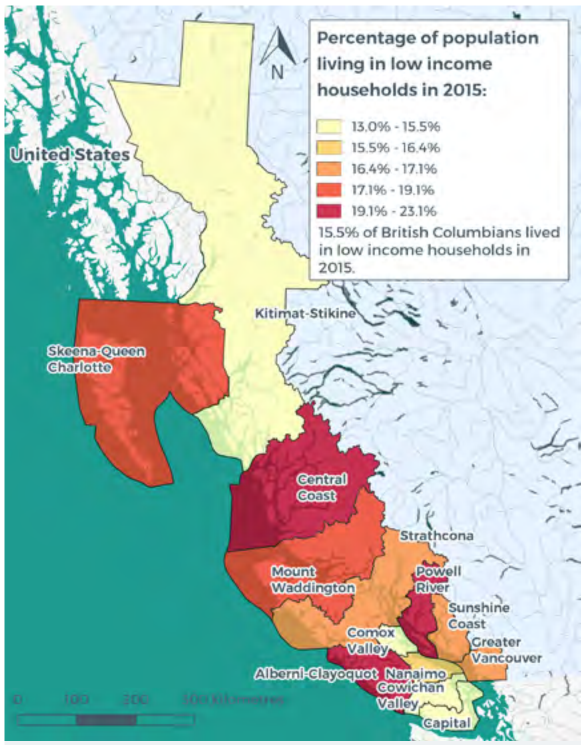

Figure 2: Percentage of population who lived in low-income households in B.C. coastal census divisions. Data source: Statistics Canada.

of low-income households among Canadian provinces, with 15.5 percent of its population considered low income. Coastal areas with a high prevalence of low income also reported a low median income (Figures 1 and 2).[16] In the Central Coast, which had the lowest median after-tax household income in 2015, 23 percent of the population lived in low-income households.

The unemployment rate (the unemployed portion of the labour force, or those who are actively seeking work) in B.C. (6.5 percent) was lower than that of Canada (7 percent) and was the lowest among the provinces. However, even with significant differences in unemployment rates among B.C. coastal areas, all but two census divisions recorded higher unemployment than the B.C. average (Figure 3).[17] Along the coast, there was a clear north-south pattern, with much higher employment rates in the North than in the South.

High median income is paired with low unemployment in the Greater Vancouver area. In fact, the Greater Vancouver and Capital census divisions, where the major population centres in B.C. are located, both had high rates of participation in the labour force (Figure 4),[18] low rates of unemployment (Figure 3), high-

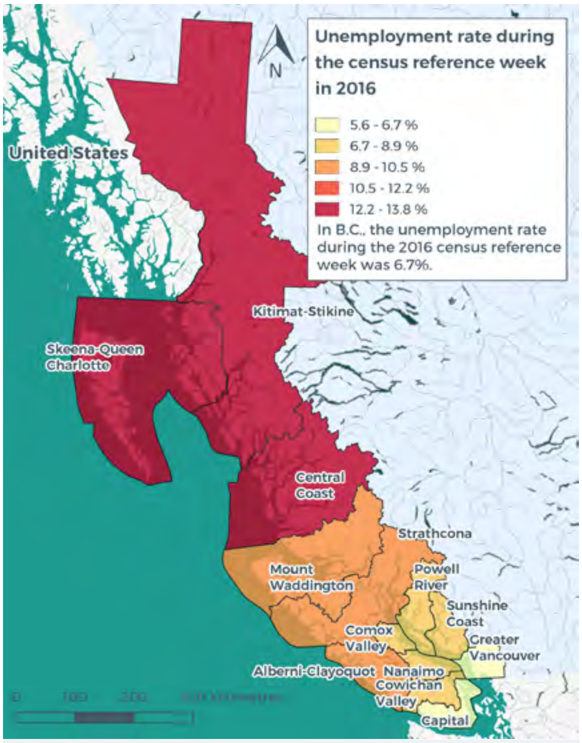

Figure 3: Unemployment rates for B.C. coastal census divisions during the week of Sunday, May 1 to Saturday, May 7, 2016. Data source: Statistics Canada

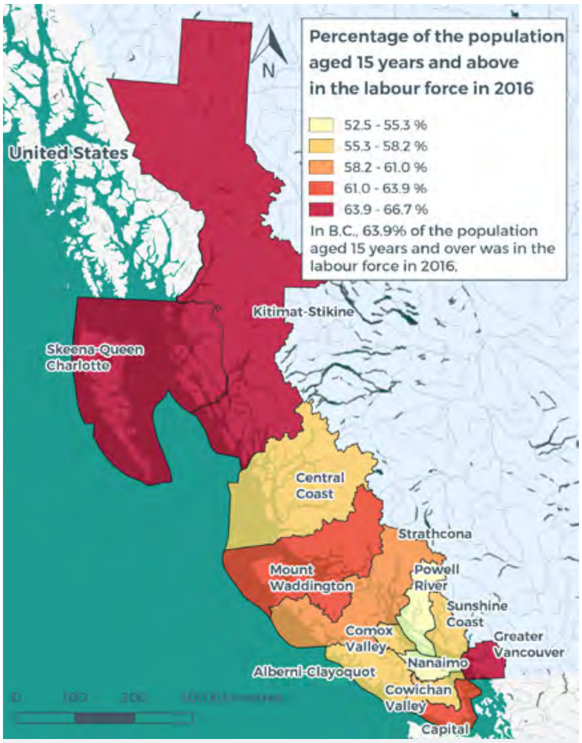

Figure 4: Labour force participation rates (i.e., percentage of the population aged 15 years and above who were either working or looking for work) during the census reference week. Data source: Statistics Canada

er median household incomes (Figure 1), and low to medium prevalence of low-income (Figure 2).

The mismatch in Kitimat-Stikine, where high median household income ($62,936) was reported despite a high rate of unemployment (13.8 percent), could be due to income being based on 2015 data, whereas unemployment was specific to the week of Sunday, May 1 to Saturday, May 7, 2016.[19] Significant job losses occurred in oil-dependent regions such as northern B.C. in 2015 and 2016 as oil prices declined in 2015.[20] Unemployed people who may have lost their jobs before the census reference week would still report a high income for the previous year and would be considered part of the labour force, explaining the high participation rate of 64.4% in Kitimat-Stikine (Figure 4). Similar patterns were seen in other parts of Canada that are dependent on an oil economy.

What is being done?

Statistics Canada through the Census of Canada tracks the distribution of income across the country. This provides regular and comprehensive data, with a short gap in 2011 when the federal government replaced the long form census with a National Household Survey. The data collected in 2011 do not compare well statistically with census data before or since. Suppression of census data does occur occasionally, for reasons of confidentiality and accuracy. Statistics are not released for areas with small populations (less than 40 households), or for areas with a response rate of less than 50 percent.

Statistics Canada also conducts monthly labour market surveys collecting information about the unemployment and participation rates per industry and occupation. The labour market survey provides employment data for Canada, the provinces, and territories, as well as economic regions.[21] Data from the labour market surveys are also combined with the annual Canadian Income Survey (CIS). The CIS includes information on sources of income, household expenses (such as housing and childcare), and individual and household characteristics.

Work BC summarizes the labour market statistics from Statistics Canada to produce monthly highlights as well as labour market profiles highlighting employment statistics for B.C. and for economic regions. This includes information about employment per industry, although there is no clear differentiation of marine-related industries. Work BC also reports on the types of jobs and skills that will be in demand in B.C. between 2017 and 2027 in the B.C. Labour Market Outlook report.[22]

Both the federal government and the B.C. government are developing poverty-reduction strategies,[23] which include a consultation component to obtain feedback from citizens.

What can you do?

Individual and Organization Actions:

- Be aware of unemployment and income inequality issues in your community and support government policy and action to address change and imbalance.

Government Actions and Policy:

- Provide a universal basic income as part of social assistance to reduce income inequality.[24]
- Further extend health and social benefits to low and modest income Canadians, to reduce the impacts of low income.
- Improve the general skills level across all geographies through broader access to high-quality education and training programs.
- Remove obstacles to women's participation in the labour force.

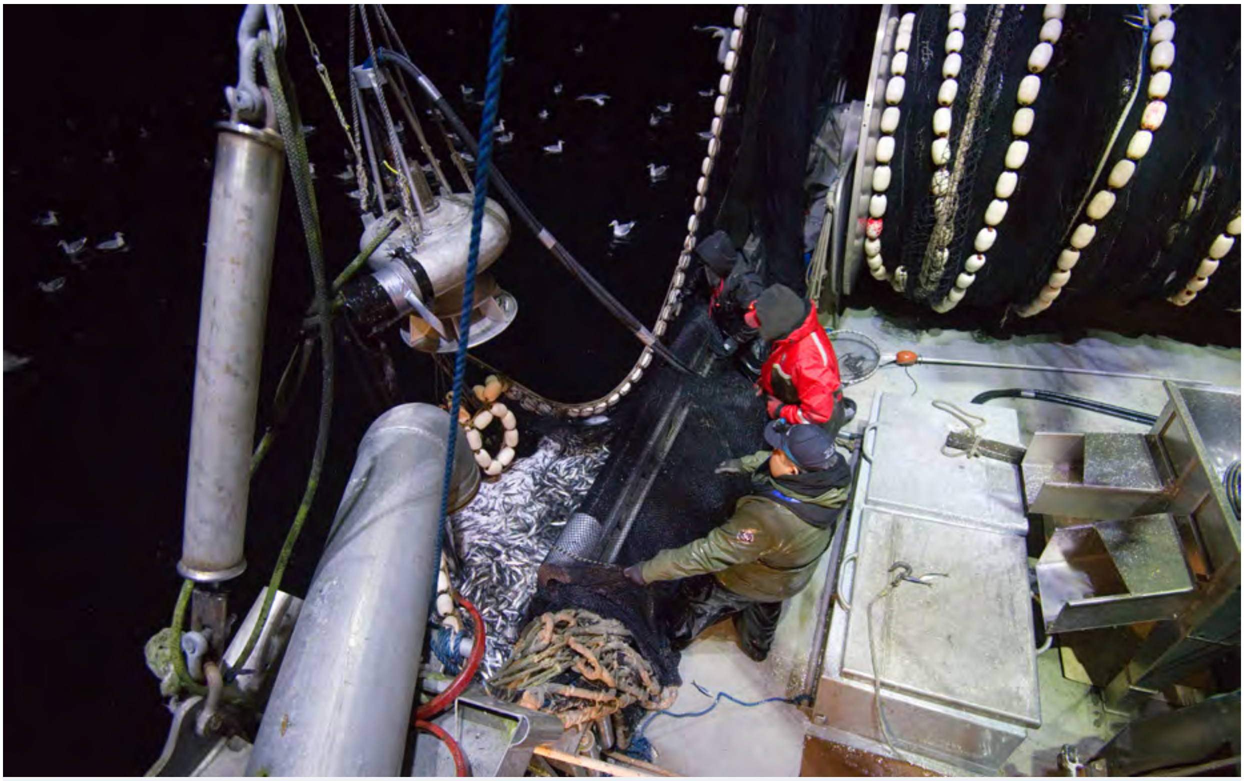

Photo: Ocean Wise

Resources

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Underwater noise interferes with marine animal communication

AUTHOR
Kathy Heise, Research Associate, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Harald Yurk, Bioacoustician/Biophysical Scientist, Fisheries and Oceans Canada

What is happening?

Underwater noise, primarily associated with increases in commercial shipping, has been doubling in intensity each decade in the open waters of the eastern North Pacific[1] since the 1950s – a three-decibel (dB)[2] increase every 10 years. Research suggests that this increase in noise is not all due to commercial shipping in deep water, but that additional contributions come from nearshore vessel traffic and other anthropogenic activities such as marine construction and small vessel traffic.[3] Overall, human activities in and near

Humpback whales and large vessels often share the same marine space. (Photo: Karina Dracott)

SPECTROGRAMS OF UNDERWATER SOUNDS

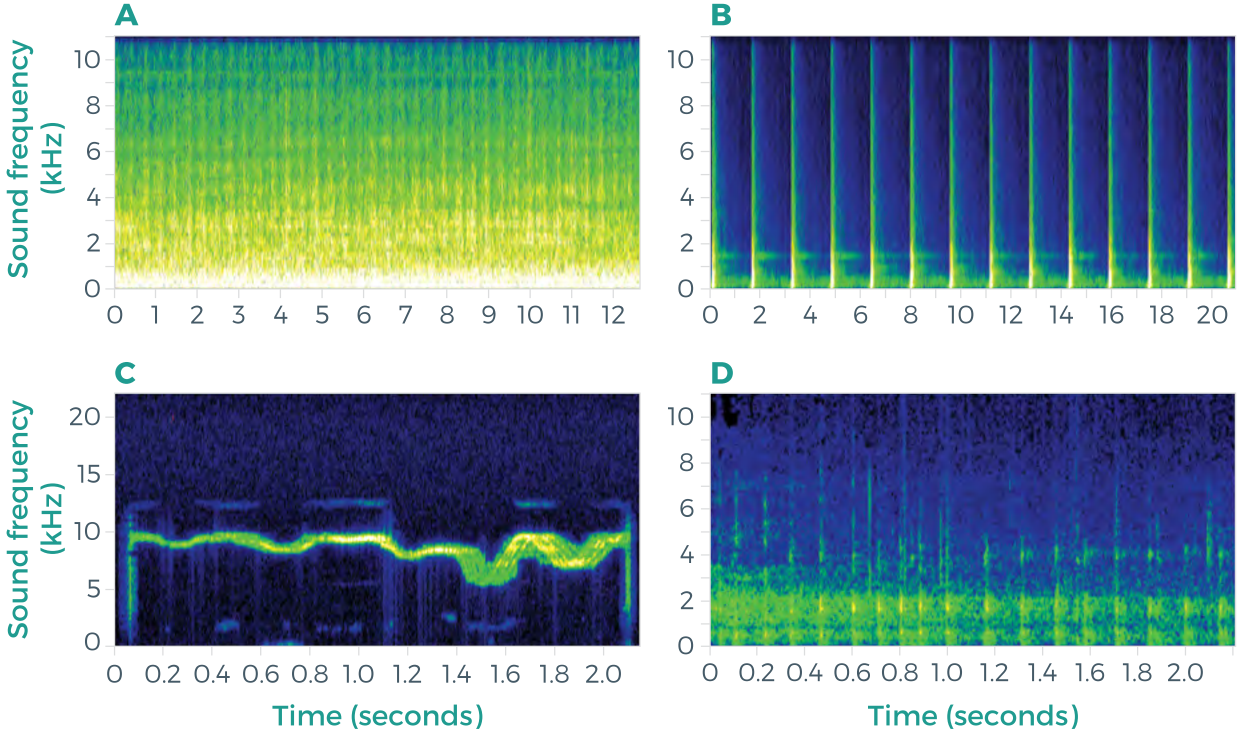


Figure 1. Spectrogram of underwater sounds. A: Continuous (always on) sound from a ship at a distance of 850 meters. Noise from vessels actually extends up to over 100 kHz depending on the vessel type. (Sound clip of freighter in online article.) B: Pile driving, which is an impulsive (on/off) sound of high-energy. This illustration shows 14 pulses (representing the underwater sound produced when the hammer strikes the pile to drive it into the ground) over 21 seconds. (Sound clip of pile driving in online article). C: A killer whale whistle, which is a narrowband sound, extending over a very limited range of frequencies. This depicted sound centers around nine kHz most of the time but ranges from six to 10 kHz along the entire signal. (Sound clip of killer whale whistle in online article.) D: Killer whale echolocation, which can range from very low frequencies (less than one kHz) to over 100 kHz. The display shows the recorded frequencies of the sounds between 0 and 11 kHz (Y-axis). The time (X-axis) shows three seconds of vertical lines, which represent echolocation signals. (Sound clip of echolocation in online article.)

the water are a growing concern as these activities appear to change the soundscape everywhere in the marine environment and these changes are affecting marine animals negatively.

What is sound and what is noise? The answer depends on who is listening. Essentially, a sound is an acoustic signal when it is important to the listener, but becomes noise when it interferes with the reception or transmission of a sound. For example, to an acoustician, someone who studies the properties of sound, listening for the underwater sounds of earthquakes, whales make noise; but to a whale listening for the call of another whale, ships and earthquakes make noise. The use of sound is the main form of transmitting and receiving information for most marine animals, but unfortunately, human-caused underwater noise has been increasing at an astonishing rate, interfering with the ability of marine animals to listen for predators, successfully find prey, communicate with each other, maintain contact, and navigate.

When we describe sounds, we consider the frequency, loudness, and the time period over which they occur. The following diagrams, called spectrograms, illustrate underwater sounds by depicting the frequency on the vertical axis, the duration on the horizontal axis and the loudness through colouration (blue to green to yellow represent increasing loudness). The spectrograms shown include the continuous sound of a nearby ship (Figure 1A), the repetitive and impulsive noise of pile driving (Figure 1B), the narrowband sound of a killer whale whistle (Figure 1C), and the echolocation signals of a resident killer whale (Figure 1D).

Low frequency sounds (under 100 Hz) associated with commercial shipping or seismic explorations (air guns) can travel hundreds if not thousands of kilometres underwater. Due to the large number of ships traversing all ocean basins at any given time, the noise pollution created by ships travels far and wide with little loss of energy, particularly in deep ocean channels (Figure 2).

How far can low frequency sound travel in the ocean?

Figure 2. Low frequency sound can travel for hundreds or even thousands of kilometres, especially when travelling in deep ocean channels.[4] These channels occur as a result of changes in water temperature (surface water changes with outside temperature while deeper water maintains more constant temperatures), differences in salinity, and increased pressure with depth, which compresses water molecules. The red arrows show the transmission distance of a tone that was broadcast at less than 100 Hz.

Why is it important?

Underwater noise has emerged as a conservation concern globally, as it is a threat to a number of declining marine mammal populations, and also has impacts on fish and invertebrates (e.g., shellfish). Even zooplankton are affected by activities such as seismic surveying, during which air-gun blasts can kill these small and often microscopic animals at distances of up to 1.2 kilometres away from the source.[5,6,7]

Data gathered before and after 9/11 illustrated the unseen costs of underwater noise on an endangered population of North Atlantic right whales. Researchers had been collecting fecal samples from this population well in advance of 9/11 for stress hormone analysis. For three days following the events of 9/11 airspaces were silenced and shipping traffic was significantly reduced (resulting in a reduction of underwater noise by six dB) in the Bay of Fundy. Stress hormone levels in North Atlantic right whales were measurably and significantly lower during this time. Once air and ship traffic resumed to normal, stress hormone concentrations returned to pre 9/11 levels.[8]

We also know that increased underwater noise interferes with the echolocation and communication of whales, a phenomenon known as acoustic masking.[9]

Killer whales venturing into noisy waters. (Photo: Ocean Wise)

Figure 3 illustrates how the distance at which killer whales can detect their prey is reduced by underwater noise: R represents the distance which killer whales under quiet conditions can detect prey through echolocation, r1 is the distance under current ambient conditions which killer whales can detect prey, and r2 is the detection distance that is predicted to occur if noise levels increase in future as a result of increased commercial shipping. As killer whales dive to chase their prey into deeper and darker water, their ability to use vision to follow prey declines, which is why they rely on acoustic cues – echolocation signals – to find and capture their prey. Acoustic masking is one of the most obvious impacts of underwater noise on marine mammals, and Figure 4 shows how this overlaps with the echolocation and communication signals of killer whales.[10]

Research suggests that killer whales increase the amplitude of their calls in noisy environments but this comes with an increase in energetic cost of sound production[11] and may increase their stress levels, and/or affect their activity budgets. If the noise levels are high enough and sustained over long periods, the ability of the whales to communicate could be completely impaired.

Underwater noise and its potential impacts on marine life vary among vessel types because they emit very different sound pressure levels (which are called sound

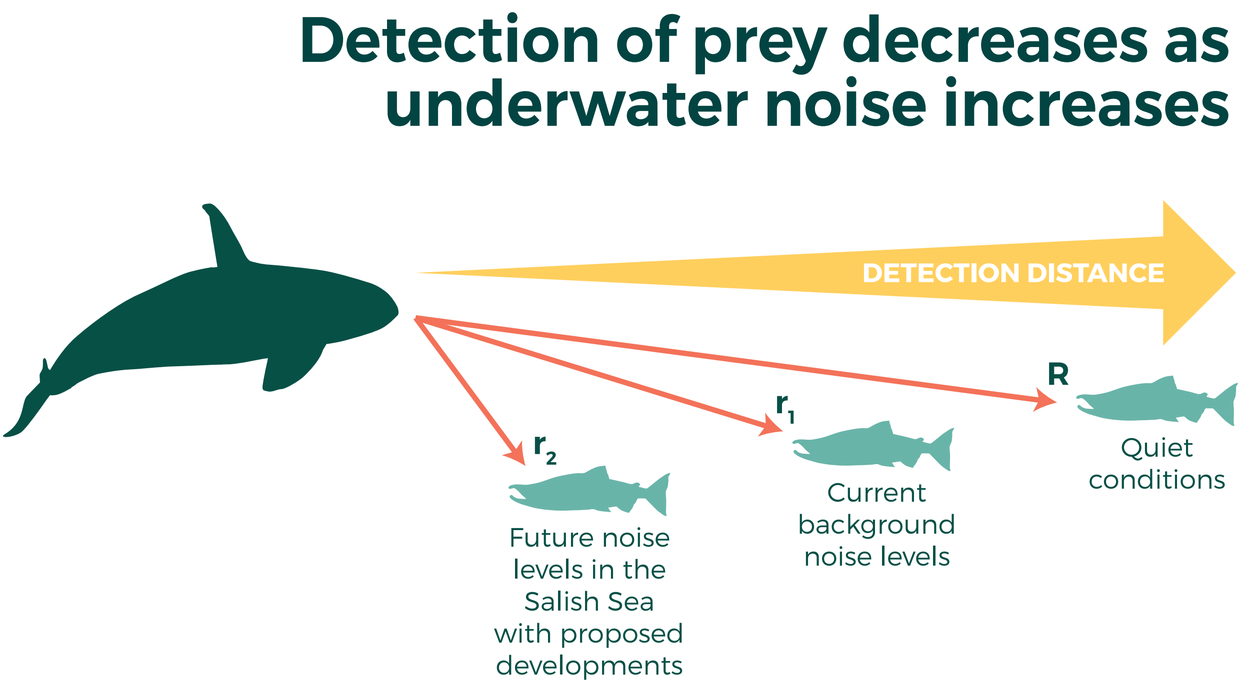


Figure 3. The hypothetical reduction in detection distance of prey for killer whales using echolocation under increasing underwater noise levels. R represents the detection distance under quiet conditions, r1 represents the detection distance under current background noise levels, and r2 represents the detection distance that is predicted to occur if noise levels increase in future as a result of increased commercial shipping.

ACOUSTIC MASKING OF WHALE CALLS BY A SHIP

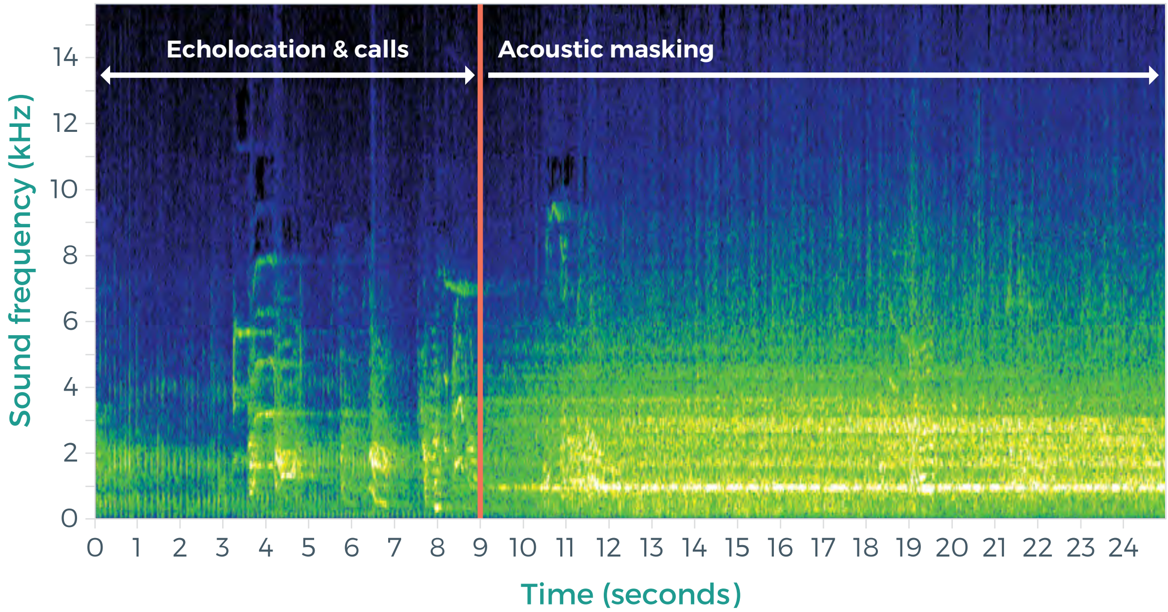


Figure 4. Spectrogram illustrating an example of acoustic masking, recorded by Orcalab on Hanson Island in Johnstone Strait. During the first nine seconds, the calls and echolocation signals of a fish-eating northern resident killer whale pod are clearly visible. Approximately nine seconds into the recording a large ship comes out from behind an island, masking the sounds of the whales. Whale calls can no longer be distinguished (heard or seen in the spectrogram), which means it is likely that the whales can no longer hear calls from each other as well, especially at greater distances. At 19 seconds into the recording there is a very loud killer whale vocalization, which can be heard above the ship noise. (Sound clip of acoustic masking in online article)

source levels, or sound amplitudes, or simply, loudness) at different frequencies (Figure 5). Generally, tankers and especially container ships, produce much more noise in lower frequencies (less than 250 Hz) than most other vessels (Figure 5). Container ships also have much higher sound levels across all frequencies, but container ships also travel much faster than most other commercial vessels. Sound source levels of small pleasure craft also vary greatly with speed and some can emit much higher noise levels in higher frequencies than shown in Figure 5 when they travel quickly. Low frequency noise, however, travels further underwater than higher frequency noise. This means that large commercial vessels drown out the noise of smaller vessels in lower frequencies when travelling in the same area. At higher frequencies (especially above 10,000 Hz) noise from smaller vessels can be louder than that from large ships depending on how fast the small vessel is travelling. This is important for smaller whales and dolphins that usually hear those higher frequencies better than large whales. Because all vessels do still have high sound levels at frequencies above 10,000 to 20,000 Hz – which is in the range where killer whales' hearing starts to become most sensitive – vessel noise is loud enough to mask not only large whale signals but also signals of smaller whales such as killer whale communication and echolocation.

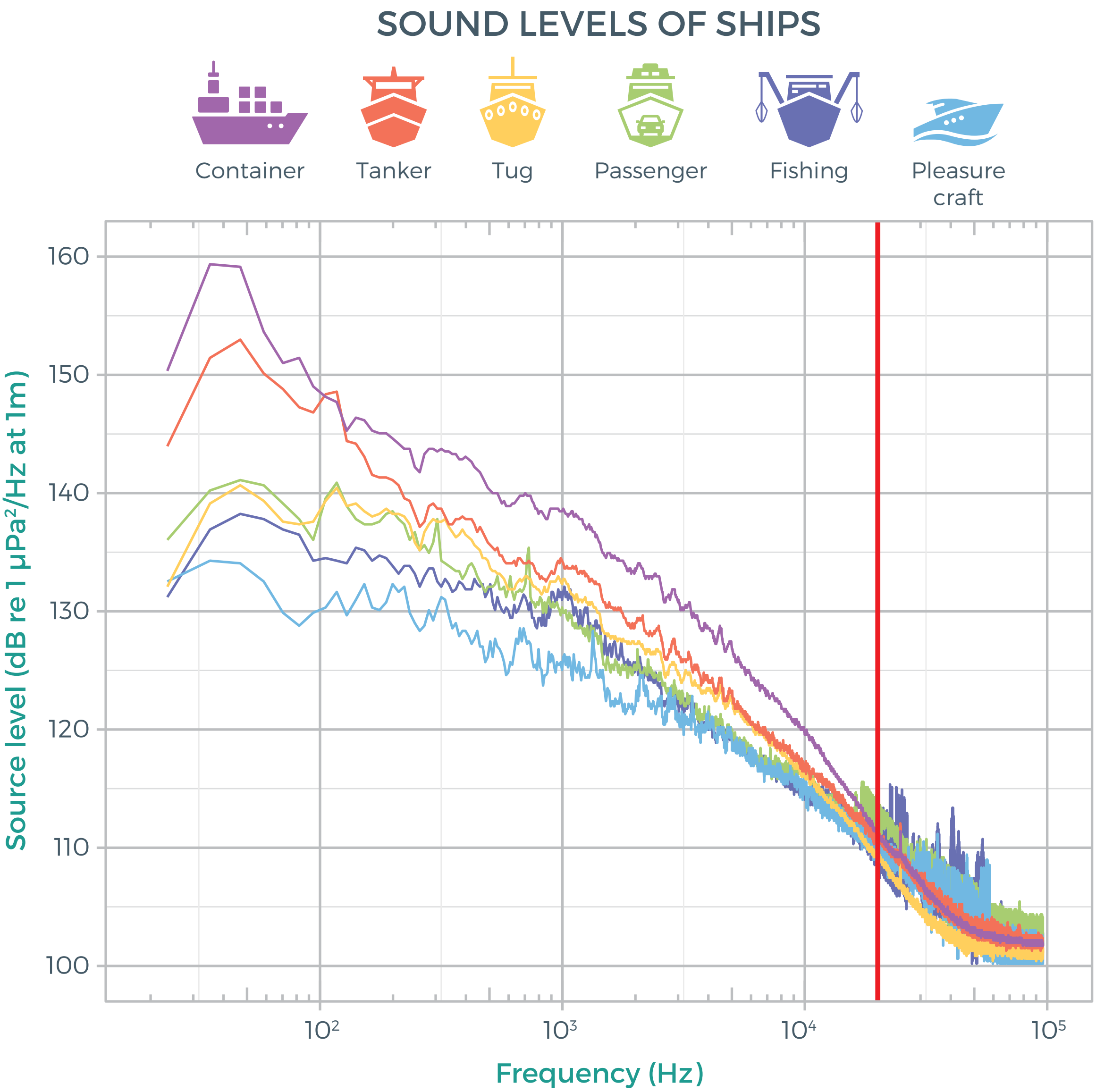


Figure 5. Median source sound levels of ships for a range of vessel classes (see legend). Each vessel generates noise over a range of frequencies (x-axis) and the sound pressure (loudness) (y-axis) of the noise is greater at lower frequencies. (The frequency range audible to humans is roughly 20 to 20,000 Hz for children, while most adults do not hear well above 15,000 Hz. The red vertical line indicates 20,000 Hz.) Source: Veirs et al. 2016.

Is there a connection to First Nations?

TEACHING RELATED BY RAY HARRIS, SHULQWILUM-CHEMANIUS FIRST NATION

"I remember being on a canoe with my grandpa. When a few black fish came close to us Grandpa lifted up the oars and drifted as the whales came closer. He said when you get close enough to see and hear the whales you have to be quiet. That's the teaching he had passed on to him and that's the teaching I pass on to my children and grandchildren. Being quiet and respectful of the whales is the way we are taught. Of all things they need quiet."

What is the current status?

From 1972 to 1999, the number of ships increased globally from 57,000 to 87,000 and their total cargo carrying capacity (gross tonnage) has increased from 268 million tons to 543 million tons. Increases in carrying capacity and newer faster ships could explain the observed increase in underwater noise, as bigger ships are generally noisier and faster ships are generally noisier.[12] However, it is not that simple because on average newer vessels are quieter than older ones due to improvements made to ship design to reduce fuel consumption.[13] Removing the loudest, and often oldest, vessels from the fleet could reverse or slow the trend in increasing underwater noise.

The recession in 2008 and 2009 took its toll, but at the beginning of 2014, the world's commercial fleet consisted of 89,464 vessels, with a total tonnage of 1.75 billion deadweight tons (dwt).[14] From 2010 to 2030, the total tonnage and number of vessels is projected to increase for all major ship types between 1.8 and three times (this includes bulk carriers, containerships and liquefied natural gas vessels). The increases in tanker capacities are expected to be less than other ships – 1.7 to 1.8 times greater.[15]

Underwater noise levels are being monitored at a number of locations on the B.C. coast (Table 1), as well as in the nearby waters in northern Washington State, part of the home range of the endangered southern resident killer whale (SRKW). The Canadian Department of Fisheries and Oceans (DFO) also has a number of hydrophones deployed that focus on detecting fin, humpback and killer whales. In the future, these may be useful for monitoring underwater noise.

TABLE 1. NON-GOVERNMENT ORGANISATIONS IN B.C. WITH UNDERWATER HYDROPHONES, AND APPROXIMATE LOCATIONS.

NETWORK	APPROXIMATE LOCATION OF HYDROPHONES	WEBSITE
Port of Prince Rupert	Entrance to Prince Rupert Harbour	http://www.rupertport.com/port-authority/sustainability/marine-mammals
Cetacealab	Central BC Coast	Forwhales.org
Pacific Wild's Great Bear Sea Hydrophone Network	Central BC Coast	http://pacificwild.org/initiatives/ocean/great-bear-sea-hydrophone-network
Orcalab	Vicinity of Johnstone Strait	Orcalab.org
Saturna Island Marine Research and Education Society	Saturna Island and vicinity	http://saturnamarineresearch.ca/
Ocean Networks Canada	West Coast Vancouver Island and Strait of Georgia (Figure 6)	http://www.oceannetworks.ca/observatories/pacific
Vancouver Fraser Port Authority	Inner Waters of the Salish Sea	https://www.portvancouver.com/environment/water-land-wildlife/marine-mammals/echo-program/
Salish Sea Hydrophone Network	Juan de Fuca Strait and northern Washington State waters	http://www.orcasound.net/listen/

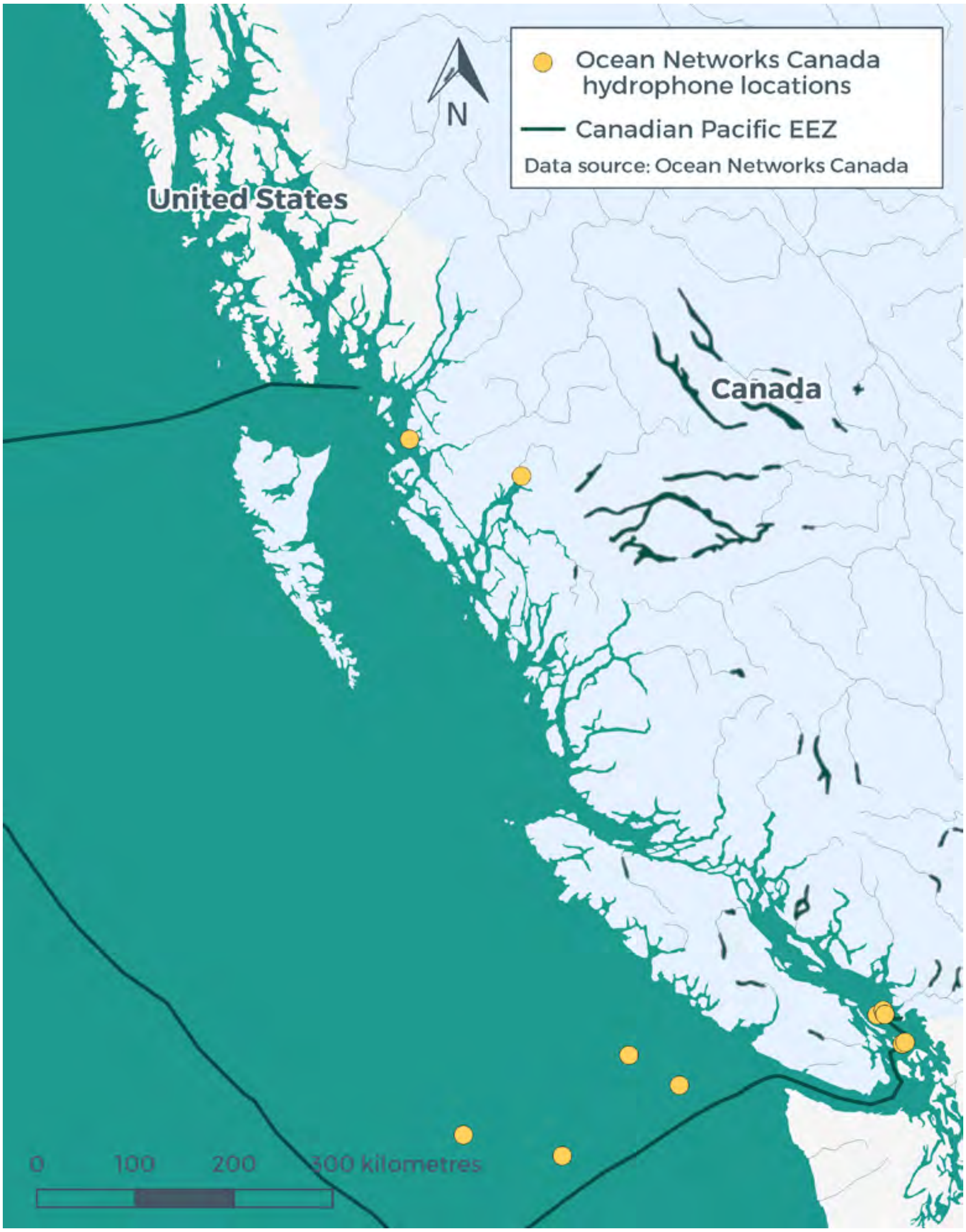


Figure 6. Ocean Networks Canada hydrophone locations. Source: Ocean Networks Canada

What is being done?

At a time when marine life must respond to the growing impacts of climate change and increasing ocean acidification, underwater noise is one more stressor that needs to be managed. Fortunately, there are known ways to reduce underwater noise. For example, the navy has known for decades how to make vessels quieter and commercial shipping can adopt many of these same technologies. Transport Canada with help from Fisheries and Oceans Canada (DFO) is also moving towards management of underwater noise through spatial and temporal restrictions on vessel traffic, and DFO is developing better guidelines for the use of air guns during seismic surveys.[16]

There are a number of initiatives that are addressing underwater noise on the B.C. coast. These include:

- Green Marine: An international program that has developed performance indicators on underwater noise as part of its green certification program. www.green-marine.org
- Vancouver Fraser Port Authority and JASCO Applied Sciences are working together through the ECHO program to monitor underwater noise of individual vessels and report these levels to vessel owners, incentivizing quieter vessels by reducing their port fees, and conducting vessel slow down trials to determine if slower vessels are quieter than faster ones. Information can be accessed at https://www.portvancouver.com/environment/water-land-wildlife/marine-mammals/echo-program
- The Port of Prince Rupert is monitoring underwater noise and incentivizing quieter vessels access to the port. More information available at http://www.rupertport.com/port-authority/sustainability/marine-mammals
- Fisheries and Oceans Canada and Transport Canada have sponsored two recent workshops on underwater noise. One workshop focused on underwater noise metrics[17] and the second on underwater noise mitigation.[18] These will help to shape future policy decisions.

What can you do?

Individual and Organization Actions:

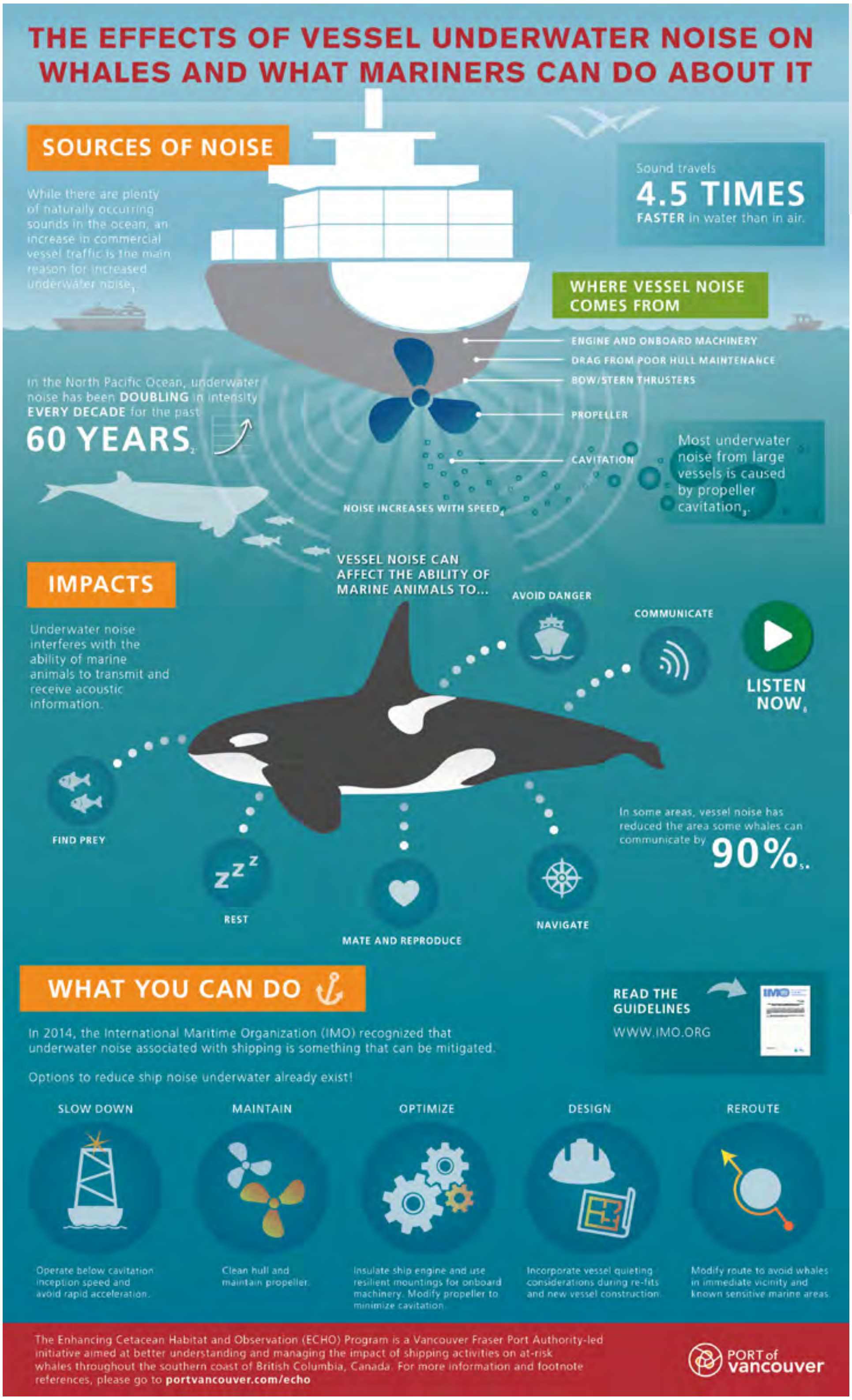
As an individual boater or a member of the shipping industry, you can:

- Slow down to reduce noise.
- Clean your hull and maintain your propeller.
- Insulate your engine and use resilient mountings for onboard machinery.
- Incorporate vessel quieting considerations during re-fits (e.g., modify your propeller to minimize cavitation).
- Modify your route to avoid whales.
- Shut off your sounders, especially when in the vicinity of whales and only when it is safe to do so, as this will quieten noise levels at higher frequencies.
- As a member of the shipping industry, you should be familiar with and follow the 2014 International Maritime Organization guidelines on underwater noise (www.imo.org).

Government Actions and Policy:

Both Transport Canada and DFO are moving towards adopting policies aimed at regulating underwater noise generated from shipping, recognizing that increased noise levels impact marine life. Future recommendations to increase the foraging and communication efficiency of southern resident killer whales (SRKW), as well as other marine life include:

- Develop marine environmental water quality objectives based on all sources of underwater noise.
- Incorporate the cumulative impacts of multiple projects on the underwater soundscape in environmental assessment processes.
- Expand the critical habitat for SRKW to include waters off the southwest area of Vancouver Island and Swiftsure Bank.
- Harmonize whale-watching regulations that are consistent with those in U.S. waters, and maintain and improve the capacity for enforcement of these regulations.
- Establish trans-boundary collaborations that focus on management actions to quantify and reduce underwater noise associated with vessel traffic, particularly in SRKW critical habitat.
- Implement temporal and spatial vessel regulations and/or guidelines to quiet the acoustic habitat of SRKW. These may include vessel speed and/or routing restrictions, no-go periods for large ships (e.g., midnight to 4 a.m.) and the use of convoys.
- Support incentive programs and regulations that reduce the acoustic footprints of vessels that regularly travel in the critical habitat of species at risk.
- Identify and create acoustic refuge areas for SRKW.
- Apply D-tags on northern resident killer whales to better understand killer whale behavior, especially foraging at night.



Effects of underwater noise on whales and what mariners can do to mitigate these impacts. Illustration courtesy of the Vancouver Fraser Port Authority.

Resources

The International Maritime Organization's guidelines for quietening vessel noise is available at https://www.nrdc.org/sites/default/files/wat_14050501a.pdf

Green Marine's performance indicators on under water noise: https://www.green-marine.org/program

Achieving Quieter Oceans by Shipping Noise (AQUO) are working on assessing and mitigating the impacts of maritime transport on the marine environment: http://www.aquo.eu

European Union marine strategy framework directive sets targets for maximum underwater sound exposure levels for 2020: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-11/index_en.htm

WWF Canada organized two workshops on underwater noise issues in British Columbia, the first describing existing conditions in the northeast Pacific (Ocean Noise in Canada's Pacific) and a second to generate management solutions (Finding Management Solutions in Canada's Pacific). Available at: http://www.wwf.ca/newsroom/reports/oceans/

Footnotes

[1] Andrew, R.K., B.M. Howe, and J.A. Mercer. 2002. Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustical Research Letters Online: DOI 10.1121/1.1461915

[2] A decibel is a relative unit of measure that quantifies sound on a logarithmic scale. Decibels in water are not equivalent to decibels measuring sound in air, because water and air have different densities and therefore different reference pressures for the decibel scale.

[3] Chapman and Price 2011. Low frequency deep ocean ambient noise trend in the North Pacific. Journal of Acoustical Society of America 129, EL 161. https://doi.org/10.1121/1.3567084

[4] Munk, W.H., Spindel, R.G, Baggeroer, A., and Birdsall, T.G. 1994. The Heard Island feasibility test. Journal of the Acoustical Society of America 96 (4): 2330-2342.

[5] Tollefson, J. 2017. Air guns blasts kill plankton. Nature 546: 586-587.

[6] Slabbekoorn H, Bouton N, van Opzeeland I, Coers A, ten Cate C, Popper A.N. (2010) A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology and Evolution 25:419–427.

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[9] Blue, fin, and sei whales are particularly impacted as their low frequency sounds overlap with the predominant frequencies of shipping noise.

[10] Heise, K.A., Barrett-Lennard, L.G., Chapman, N.R., Dakin, D.T., Erbe, C., Hannay, D.E., Merchant, N.D., Pilkington, J.S., Thornton, S.J., Tollit, D.J., Vagle, S., Veirs, V.R., Vergara, V., Wood, J.D., Wright, B.M., Yurk, H. 2017. Proposed metrics for the management of underwater noise for southern resident killer whales. Coastal Ocean Report Series (2), Ocean Wise, Vancouver, 30pp. DOI: 10.25317/CORI20172.

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[12] Hildebrand, J. 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series 395: 5-20.

[13] Gassman, M,m L. Kindberg, S.M Wiggins, and J. A. Hildebrand. 2017. Underwater noise comparison of pre- and post-retrofitted MAERSK G-Class container vessels. Scripps Institution of Oceanography, University of California. MPL TM-616

[14] Deadweight tons (dwt) describes a vessel's cargo-carrying capacity in weight; 1 DWT is approximately 1018 kilograms. Gross tonnage (GT) describes a vessel's cargo carrying capacity by volume; 1 GT is approximately 2.83 cubic meters.

[15] Lloyd's Register, QinetiQ and University of Strathclyde, Glasgow. 2013. Global Marine Trends. Accessed on Sept. 15, 2019 at: http://www.futurenautics.com/wp-content/uploads/2013/10/GlobalMarineTrends2030Report.pdf

[16] DFO. 2010. Guidance related to the efficacy of measures used to regulate potential impacts of seismic sound on marine mammals. Canadian Science Advisory Secretariat, Science Advisory Report 2010/043. 13 pp. Available at http://www.dfo-mpo.gc.ca/Library/341565.pdf

[17] Heise et al. 2017. As per footnote 8.

[18] DFO. 2017. Evaluation of the scientific evidence to inform the probability of effectiveness of mitigation measures in reducing shipping-related noise levels received by southern resident killer whales. CSAS Advisory Report 2017/041. http://publications.gc.ca/collections/collection_2017/mpo-dfo/Fs70-6-2017-041-eng.pdf

Employment in B.C.'s marine fisheries and aquaculture declining

AUTHORS
Fiona Beaty and **Karin Bodtker**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Jim McIsaac, Executive Director, T Buck Suzuki Environmental Foundation

What's happening?

British Columbia's seafood industries provide thousands of full-time and part-time jobs each year. In 2011, industries including the capture fishery, aquaculture, seafood processing and saltwater sport fishing employed about 10,100 British Columbians, 46 percent of whom worked in establishments associated with the saltwater sport fishing industry. The total for 2011 is the lowest value reported since 1984 (Figure 1).[1] Unfortunately, employment data for all four industries combined for more recent years are unavailable.

Not surprisingly, the number of commercial fishing licenses and fishing vessels involved in the commercial fishery are both on the decline as well. Data are available through 2015 for these indicators.

Photo: Jenn Burt.

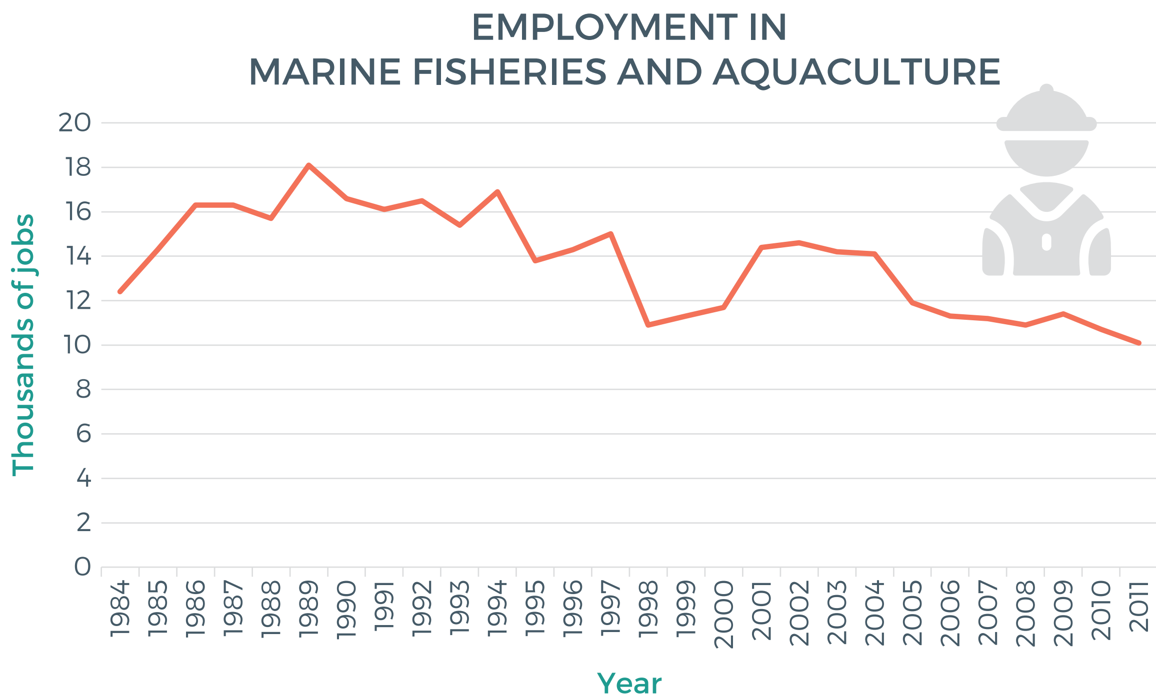


Figure 1. Total employment in seafood-related industries including the capture fishery, aquaculture, seafood processing and saltwater sport fishing. Source: BC Stats and Statistics Canada

Why is it important?

Coastal communities and First Nations depend significantly upon seafood-related industries for their livelihood, employment, diet, and identity. Employment numbers reported here include seasonal and part-time jobs, but do not take into account the economic and cultural ripples that direct employment has on other businesses, community structures, and industries. Sector summary reports assembled by the province include economic multipliers that estimate the total impact of the sector on B.C.'s economy and tangential employment. For example, based on 2008 data, every $1-million increase in seafood-sector output supports about 3.5 additional jobs in industries that supply goods and services to the sector and those supported by the spending of seafood industry employees.[2]

What these reports do not examine is the seafood-related industries' impact on social wellbeing, culture, or the environment. A recent in-depth, non-government study reported that wild capture commercial fisheries contribute significantly to the social capital, wellbeing, and resilience of coastal communities.[3] Overwhelmingly, participants in the study felt that employment in the commercial fishing industry led

Photo: Jenn Burt.

to intangible benefits including a lifestyle that connected people to each other, to their communities and to the physical environment they occupy. The actual employment is just one part of the overall benefit.[4] Shrinking employment opportunities in the fishing industry can therefore have consequences that go beyond livelihoods. It can also be difficult to fill opportunities that do emerge, as working conditions are tough and the work is physical and requires employees to be away from home.

That being said, in order to provide a steady and ongoing source of jobs, fisheries, and seafood production more broadly, needs to be ecologically sustainable. The relationship between seafood production, employment, and long-term sustainable harvesting is not a simple one – especially as technology increases efficiency in harvesting, processing, and aquaculture. Our seafood production article (in the Seafood theme) reports that overall seafood production (wild-caught and aquaculture combined) and exports have increased since 2000, despite changes in the management and structure of B.C.'s commercial fisheries that were driven in part by conservation concerns. At the same time, overall employment in seafood-related industries has declined.

Is there a particular importance or connection to First Nations?

Going back millennia, First Nations have used seafood, in particular Pacific salmon and shellfish, as a source of food, trade, culture, and spiritual sustenance. First Nations also participate in the activities and economies related to commercial fisheries, aquaculture, seafood processing, and saltwater sport fishing. We located data relevant to First Nations for the commercial fishing industry only.

Data from Fisheries and Oceans Canada (DFO) reports that the number of commercial fishing licences issued to First Nations has fluctuated between about 1,000 and 1,300 since 1985. However, the number has climbed in the last decade from 1,050 in 2007 to over 1,300 in 2015 (Figure 2).[5] Licences issued to First Nations fall under different categories, including communal – which allow for the harvest of fish for food, social or ceremonial (FSC) purposes and related activities[6] – reduced fee,[7] and licences issued to the Northern Native Fishing Corporation (NNFC). Over the same period, the total number of commercial fishing licences issued rose to a peak in 1989 and has been falling since then. As a result, First Nations are holding an increasing percentage of the total licences issued (Figure 2). Recent changes can be partially attributed to the Allocated Transfer Program of the Pacific Integrated Commercial Fisheries Initiative launched in 2007 by DFO.[8,9] The number of licences may be a proxy for fishing activity but is not directly related to First Nations employment in the industry, nor to economic benefit from fishing. For example, licences can be leased to non-First Nations, some reduced fee licenses are held in control agreements by non-native enterprises, and value by species varies considerably from year-to-year.[10]

What is the current status?

The number of jobs fluctuates greatly in any industry that relies on natural resource production. Examination of labour survey data estimating employment in four industries related to seafood production confirms this volatility (Figure 3).[11] Since 1984, the capture fishery is the only industry to see a significant decline in the number of jobs, although a smaller overall decrease is evident in seafood processing jobs. The number of aquaculture jobs, stable compared to the other industries, doubled between 1984 and 2005 to reach 2,100 jobs and has subsequently dropped to 1,100 in 2015. Employment in the saltwater sport fishing industry is perhaps the anomaly, as it increased by about 30 percent between 2000 and 2011 (Figure 3).

The Labour Force Survey, which provides the data used to track employment for three of the four industries reported here, is a monthly survey that uses the North American Industry Classification System (NAICS). Capture fishery employment figures were adjusted

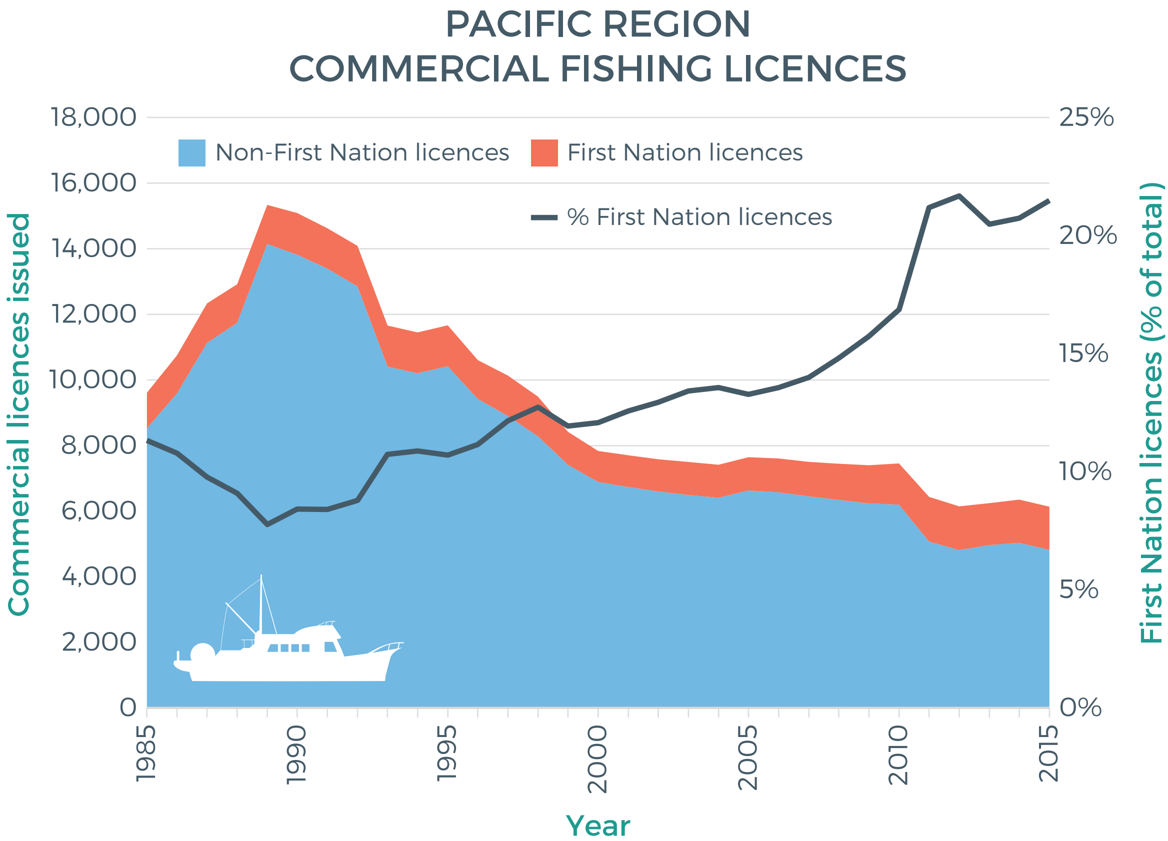


Figure 2. The number of First Nations' (FN) and non-FN commercial fishing licences issued in the Pacific Region. FN licences include communal, reduced fee, and licences issued to the Northern Native Fishing Corporation (NNFC). Source: Fisheries and Oceans Canada, Pacific Region Operations Branch.

by BC Stats from a class that includes fishing, hunting and trapping. Aquaculture employment comprises establishments primarily engaged in farm-raising aquatic animals and plants. Seafood processing includes seafood product preparation and packaging (even shipboard processing). Sport fishing is not a defined industry in the NAICS,[13] so data to inform the saltwater sport fishing industry are based on tourism employment figures from the survey of Employment, Earnings and Hours,[14] which means these numbers are generous compared to the other three industries.

The size and structure of B.C.'s commercial fisheries has diminished since the 1980s, as evidenced by decline in employment (Figure 3), licences, and registered fishing vessels (Figure 4).[15] The number of jobs in the capture industry has decreased by 67 percent since its peak in 1989, while the total number of commercial fishing licences has fallen by 75 percent and commercial vessels by 64 percent. These changes have been linked to significant shifts in coastal communities in B.C.[16] (See also the Seafood Production article in the Seafood theme and our article on fishing as it relates to sense of place and wellbeing.)

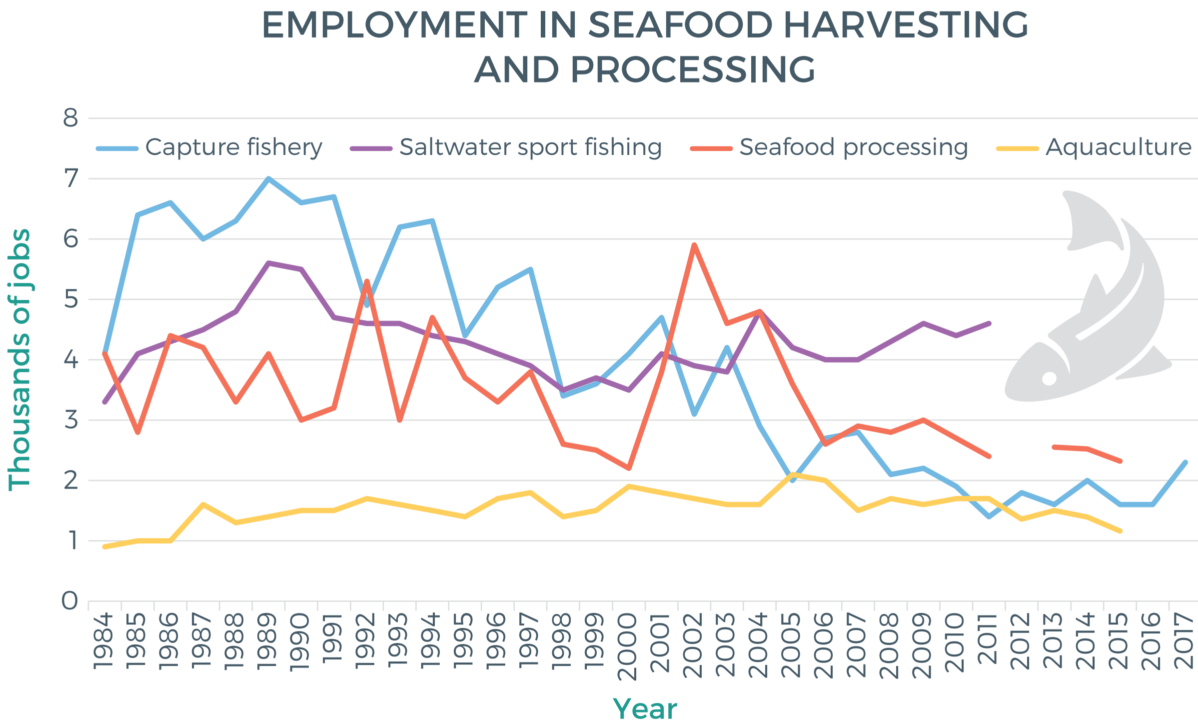


Figure 3. Annual employment estimates for the seafood harvesting and processing sector since 1984. Sources: BC Stats and Statistics Canada. (Seafood processing data for 2013-2015 are estimated.[12] The saltwater sport fishing industry numbers are based on tourism employment figures from the survey of Employment, Earnings and Hours, which differs in method from the Labour Force Survey.)

These changes may look dire when reported in isolation; however, they are due to efforts to rationalize B.C.'s commercial fisheries and increase the returns on investment on one hand, and to improve sustainability and increase the number of year-round jobs on the other hand. Competitive-style fishing of the 1980s (i.e., when the fishery season was only open until the total allowable catch was caught, – sometimes only a few hours, days, weeks or months – resulting in competitive and dangerous harvesting practices) is not an easily managed harvesting strategy today, given the need to protect small stocks and improve monitoring of fishing activities. In addition, while salmon and herring fisheries once made up the majority of B.C.'s wild-caught species, the industry has diversified significantly over the past decades, with crab, prawns, sablefish, halibut, geoduck, groundfish, and shellfish comprising a higher proportion.[17]

The coming decades will demonstrate whether the seafood harvesting and processing industries can continue to provide secure livelihoods, while improving sustainability, keeping up with environmental and technological changes and meeting a growing human demand for seafood.

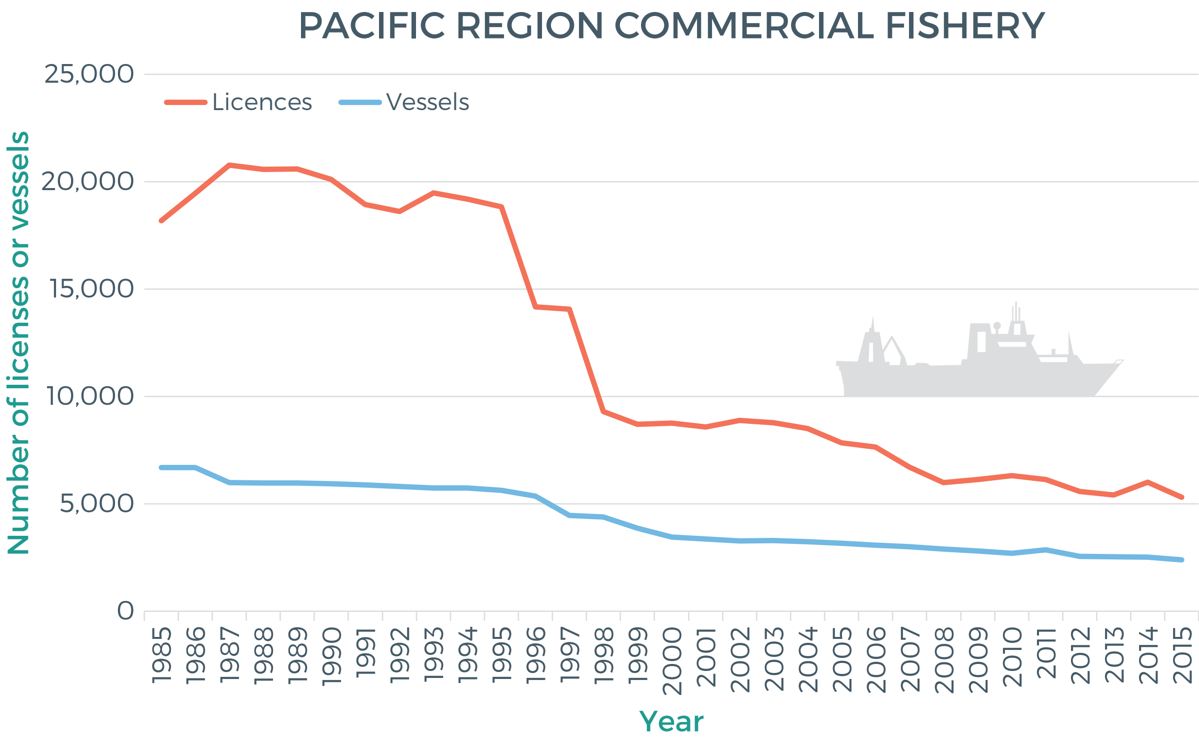


Figure 4. The number of commercial fishing licenses valid for each year and the number of registered commercial fishing vessels in the Pacific Region. Vessels include all size classes from less than 10 metres (35 feet) to larger than 38 metres (125 feet). Source: Fisheries and Oceans Canada, Pacific Region Operations Branch.

What is being done?

There are myriad formal and informal community-based fisheries management strategies emerging along B.C.'s coast. One such strategy is a formal license bank, which aims to serve small-boat fleets, rural fishermen, and support sustainable harvest techniques by collectively managing licences and quotas (i.e., the amount of harvest allowed for a particular licence) using fair-trade prices. Many Indigenous communities as well as non-Indigenous groups, such as the Pacific Coast Fishermen's Conservation Company based out of Ucluelet,[18] have adopted this approach. In addition to formal license banks, informal community initiatives are increasingly emerging along the coast as fishermen create alliances of trading networks in order to coordinate the fisheries market in a co-operative manner.

What can you do?

Individual and Organization Actions:

- Choose seafood options that support local fishermen and sustainable harvesting.
- Support B.C.'s buy local program: https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/programs/market-development-programs/bc-buy-local-program
- Purchase and eat sustainable seafood. Learn more at:
    - Ocean Wise Seafood Program: http://seafood.ocean.org/
    - Seafood Watch: http://www.seafoodwatch.org/seafood-recommendations/consumer-guides
    - Marine Stewardship Council: https://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/pacific
- Demand improvements to seafood labelling and traceability requirements: SeaChoice, ThisFish
- Participate in citizen science efforts that support oceanic monitoring (e.g., Pacific Salmon Foundation's Salish Sea Marine Survival Project Citizen Science Program[19] and while on the ocean use the OceanSmart app to report interesting ecosystem events).

Government Actions and Policy:

- Support management strategies that allow more fishermen to actively participate in decision-making.
- Support investment in research for fisheries, sustainable aquaculture techniques and institutions.

Resources

First Nations Fisheries Council
http://www.fnfisheriescouncil.ca/

Footnotes

[1] Data Sources: Labour Force Survey and Survey of Employment, Earnings and Hours as reported in: BC Stats. 2007. British Columbia's Fisheries and Aquaculture Sector. Prepared for the BC Ministry of Environment. 108 pp. Accessed January 23, 2018. http://www.eaa-europe.org/files/bc-fisheries-aquaculture-sector-2007_7927.pdf; BC Stats. 2013. British Columbia's Fisheries and Aquaculture Sector, 2012 Edition. Prepared for the Department of Fisheries and Oceans Canada. 98 pp. Accessed January 23, 2018. https://www2.gov.bc.ca/gov/content/data/statistics/business-industry-trade/industry/fisheries-aquaculture; FastFacts 2015. Accessed January 23, 2018. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/statistics/industry-and-sector-profiles; Fisheries and Oceans Canada. 2017a. Fisheries and the Canadian Economy. Accessed January 23, 2018. http://www.dfo-mpo.gc.ca/stats/cfs-spc/tab/cfs-spc-tab2-eng.htm; Statistics Canada. Table 282-0008 - Labour Force Survey estimates (LFS). Accessed January 11, 2018.

[2] In economic terms, these multipliers are known as indirect and induced effects. E.g., see BC Stats 2013.

[3] O'Donnell, K., Hesselgrave, T., Mackdonald, E., McIsaac, J., Nobles, D., Sutcliffe, T., Fernandes, D., and B. Reid-Kuecks. 2013. Understanding Values in Canada's North Pacific: Capturing Values From Commercial Fisheries. T Buck Suzuki Foundation and Ecotrust Canada.

[4] O'Donnell et al. 2013

[5] Fisheries and Oceans Canada. 2017b. Pacific Region Licences. Data sourced from tables in "number of commercial fishing licences issued, by species." Accessed February 2, 2018. http://www.dfo-mpo.gc.ca/stats/commercial/licences-permis/licences-permis-pac-eng.htm

[6] Fisheries and Oceans Canada. 2013. Communal Fishing Licences. Accessed February 2, 2018. http://www.pac.dfo-mpo.gc.ca/abor-autoc/licences-permis-eng.html

[7] Prior to 2003, these were called "Indian" licences. See data tables, Fisheries and Oceans Canada, 2017b, Pacific Region Licences.

[8] Fisheries and Oceans Canada. 2017c. Pacific Integrated Commercial Fisheries Initiative. Accessed February 2, 2018. http://www.pac.dfo-mpo.gc.ca/fm-gp/picfi-ipcip/index-eng.html

[9] First Nations Fisheries Council. 2016. *First Nations participation in commercial fisheries: opportunities and challenges for CFEs*. FNFC Annual Assembly. Retrieved from: http://www.fnfisheriescouncil.ca/wp-content/uploads/2015/09/11-N.Philcox-FN-Commercial-Fishing-Enterprises.pdf.

[10] First Nations Fisheries Council 2016.

[11] Data Source: Labour Force Survey and Survey of Employment, Earnings and Hours. (See footnote 1 for details).

[12] Fisheries and Oceans Canada 2017a.

[13] Province of British Columbia. About the Labour Force Survey. Accessed February 2, 2018. https://www2.gov.bc.ca/gov/content/data/

Photo: Jenn Burt

Project, Citizen Science Program. Retrieved from http://marinesurvivalproject.com/research_activity/list/citizen-science-program/.

Stewardship and Governance

Photo: Dale Simonson, Flickr CC BY-SA 2.0

Summary

After decades of centralized, top-down governance, Canada is in the midst of a paradigm shift in its approach to environmental stewardship and conservation. New collaborative decision-making structures are now stemming from the bottom up, and recognizing the historical role Indigenous people have played in protecting and managing land, water, and resources.

Several co-governance agreements are now in the works between the federal and provincial governments and First Nations, drawing upon their expertise as environmental stewards. Through these partnerships, B.C. is poised to revolutionize how it handles marine conservation with the aim of establishing a jointly governed network of marine protected areas (MPAs) in the Northern Shelf bioregion. The agreement could see the first Indigenous-governed MPAs emerge on our coast, putting the future of marine ecosystems in the hands of those who are most invested in their health.

At the same time, the federal government continues to work toward its goal of protecting 10 percent of Canada's coastline by 2020. Several new areas for marine conservation have recently been established or proposed, including vital habitat for fragile and rare glass sponges, globally distinct seabirds, and hydrothermal vents. Despite this progress, however, MPAs still exist in a complicated web of competing objectives and jurisdiction, underscoring the need for cohesive oversight to ensure protected areas truly ensure aquatic ecosystems are preserved for generations to come.

Stewardship and Governance Snapshot Assessment

Marine Protected Areas

Several new marine refuges and marine protected areas in British Columbia have been established or proposed as part of Canada's goal to conserve 10 percent of its coast by 2020. However, comprehensive oversight is still needed to ensure various marine protection areas function as a cohesive network.

HEALTHY CAUTION

Evolution in Governance

Once strictly top-down, a more collaborative approach to conservation is beginning to emerge in B.C.'s coastal regions. Indigenous peoples are increasingly being recognized for their role in stewardship and the governance of conservation efforts on land and sea.

HEALTHY

Marine Protected Areas

AUTHOR
Carrie Robb, MSc, GIS ADP, Aquatic Science Biologist

REVIEWER
Chris McDougall, MSc, Marine Spatial Planner

What's happening?

November 2017 Update

by Karin Bodtker, Coastal Ocean Research Institute, an Ocean Wise initiative

On October 28, 2017, the Government of Canada announced a new set of "marine refuges" that bring Canada past a domestic target to protect five percent of marine and coastal areas by 2017.[1] Two of these refuges are in the Pacific Region – a new Offshore Pacific Seamounts and Vents Closure,[2] and existing Strait of Georgia and Howe Sound Glass Sponge Reef closures[3] – and both are fishing closures rather than designated protected areas with management plans. This marks the first time fishing closures are counted toward marine protection targets by Canada's federal government.

[1] https://www.canada.ca/en/fisheries-oceans/news/2017/10/canada_reaches_important5marineconservationmilestone.html

[2] http://www.dfo-mpo.gc.ca/oceans/oeabcm-amcepz/refuges/offshore-hauturiere-eng.html

[3] http://www.dfo-mpo.gc.ca/oceans/oeabcm-amcepz/refuges/georgia-georgie-eng.html

Approximately one percent of Canada's oceans are currently protected within marine protected areas (MPAs). However, work is underway to increase the protection we afford our oceans through national and international commitments to develop MPAs and other effective area-based conservation measures (OEABCMs) by 2020 that conserve 10 percent of Canada's marine and coastal areas.[1,2] Nationally, conservation targets will be reached by advancing work on areas proposed as future MPAs, designating large MPAs in offshore areas, establishing new MPAs in areas under pressure from human activities, advancing OEABCMs, and updating the Oceans Act to facilitate MPA designation without sacrificing science and consultation.

On the British Columbia coast, Fisheries and Oceans Canada (DFO) has recently created a new MPA to safeguard reefs of ancient and fragile glass sponges,[3] and an MPA is being finalized to protect the foraging habitats of globally distinct seabird colonies.[4] Research is also underway on a new, large offshore Area of Interest that would conserve unique hydrothermal vent and seamount ecosystems.[5] Within the Northern Shelf Bioregion, the Government of Canada, Province of British Columbia, and 17 First Nations have formed a unique collaboration to develop a network of MPAs.[6] Together, these initiatives are poised to greatly enhance the protection of B.C.'s marine species and habitats (Figure 1).

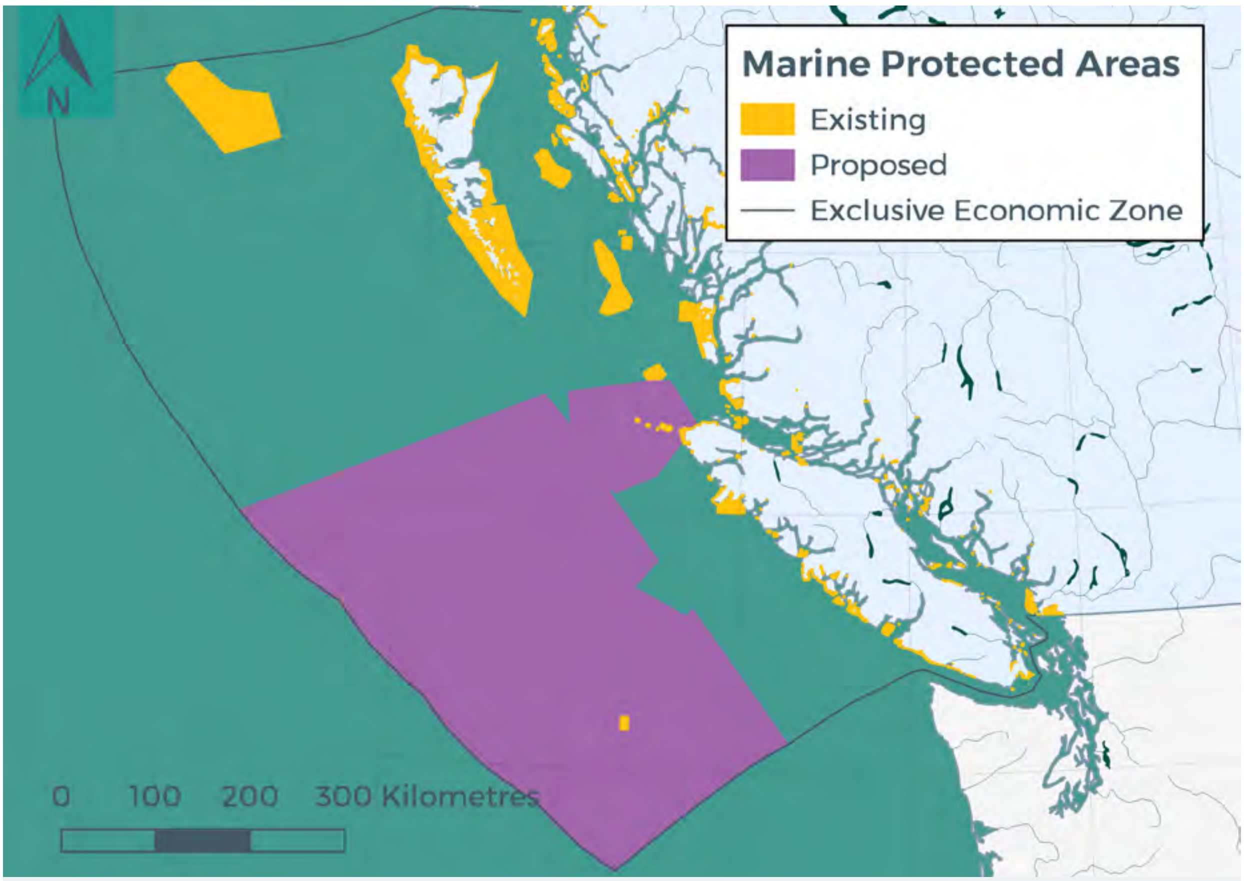


Figure 1. The marine areas of existing and proposed MPAs in the Pacific Ocean of Canada (October 2017).

Why is it important?

MPAs are areas of the ocean where human activities are regulated or restricted to ensure the long-term conservation of marine biodiversity and associated economic and cultural values. MPAs are designed to protect the habitats, ecosystems, and processes upon which marine species rely. Science shows that the benefits of MPAs are enhanced when protected systematically as part of a cohesive network.[7,8] When MPAs function as a unit they can better represent, replicate, and connect important marine features and populations.[9] They may also be more efficient in areas where larger MPAs are difficult to implement. For example, MPA networks can facilitate the movement of seabirds by protecting disparate sites important for breeding, foraging, and over-wintering.

Tufted puffins in their breeding and nesting habitat on Triangle Island (one of the Scott Islands). (Photo: Karin Bodtker)

Is there a particular importance or connection to First Nations?

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

What is the current status?

MPAs have protected portions of the B.C. coast since the creation of Strathcona Park on Vancouver Island in 1911. Over the ensuing century, small MPAs were added on a site-by-site basis as areas of conservation importance were identified, and the total amount of marine area protected increased slowly (Figure 2). In recent years, larger MPAs have been created and the spatial extents of marine protection have increased markedly. With the establishment of the Hecate Strait and Queen Charlotte Sound Glass Sponge Reefs MPA in 2017, just under four percent of the Pacific Ocean of Canada is now within an MPA. Because these sites have been developed and designated independently, they do not necessarily function as a network.

The establishment of MPAs does not ensure the continued conservation of biodiversity on the B.C. coast. B.C.'s MPAs exist in a complicated space, with multiple jurisdictions involved in managing different marine areas, resources, and activities. As such, MPAs are created using a variety of tools, follow a diversity of objectives, restrict and/or continue to allow a range of human activities, and do not always live up to their potential.[10] When considering the quality of the protection provided by MPAs, it is important to account for the MPA's stated objectives, the management measures that are in place, and how well each MPA aligns with MPA network criteria.[11]

Smuggler Cove Marine Provincial Park (Photo: Natulive Canada, Wikimedia Commons, CC BY-SA 4.0)

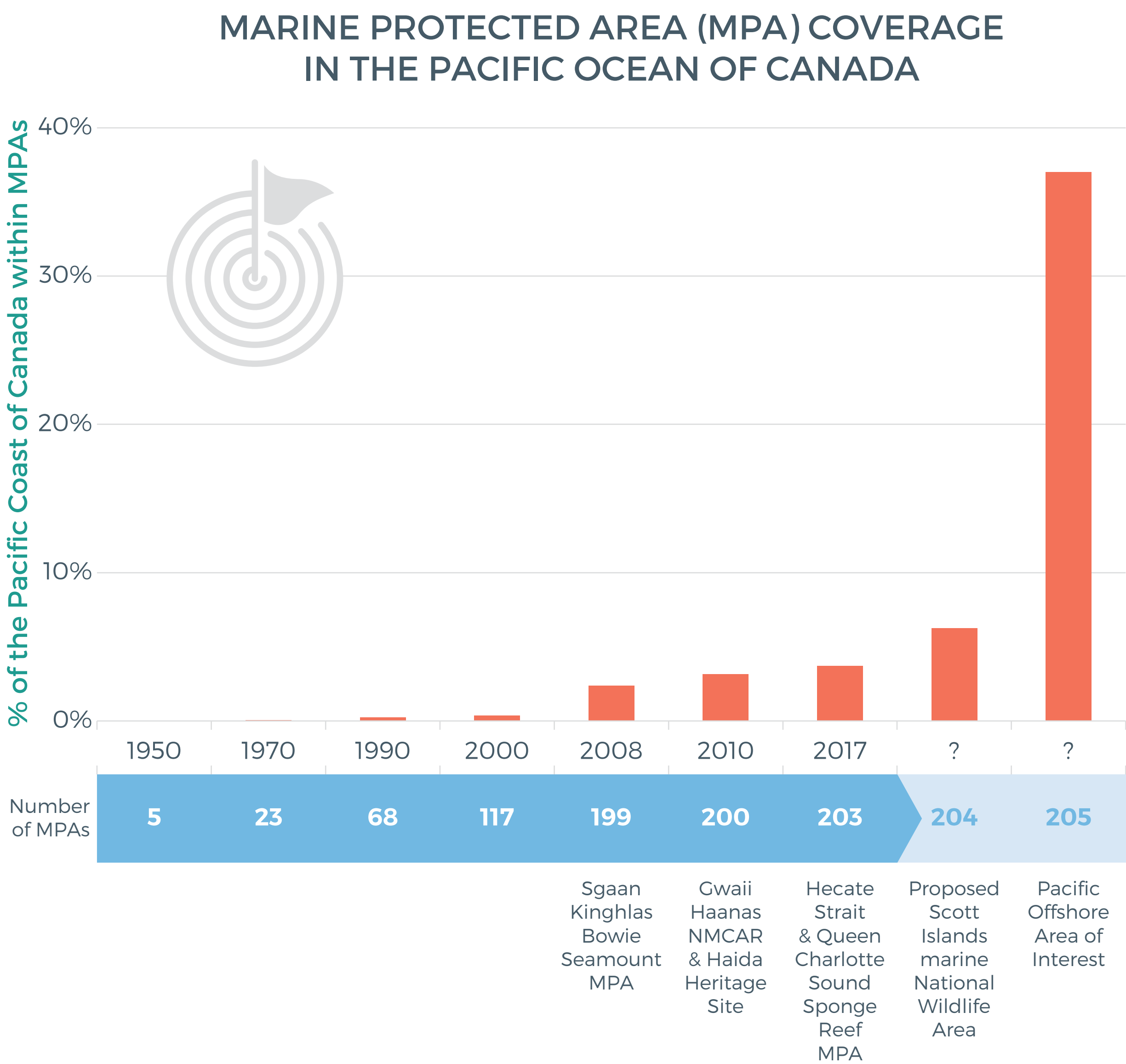


Figure 2. Increasing spatial coverage of MPAs in the Pacific Ocean of Canada over time, with potential future additions.

What is being done?

Fisheries and Oceans Canada is working on a large Area of Interest[12] for an MPA off the west coast of Vancouver Island that would protect hydrothermal vents and seamounts identified as Ecologically and Biologically Significant Areas (EBSAs).[13] Environment and Climate Change Canada is also working to finalize Canada's first marine National Wildlife Area[14] to protect the marine environment around the Scott Islands, which are home to globally significant populations of breeding seabirds.

Within the Northern Shelf Bioregion (NSB), an area of the B.C. coast extending from Bute Inlet north to the Alaska border and west to the edge of the continental shelf (Figure 3), the Government of Canada, Province of B.C., and 17 First Nations are working together on a network of MPAs, in consultation with scientific experts, other governments, and the people who live and work within the NSB. The MPA network planning is based on the goals and principles set out in the Canada-British Columbia Marine Protected Area Network

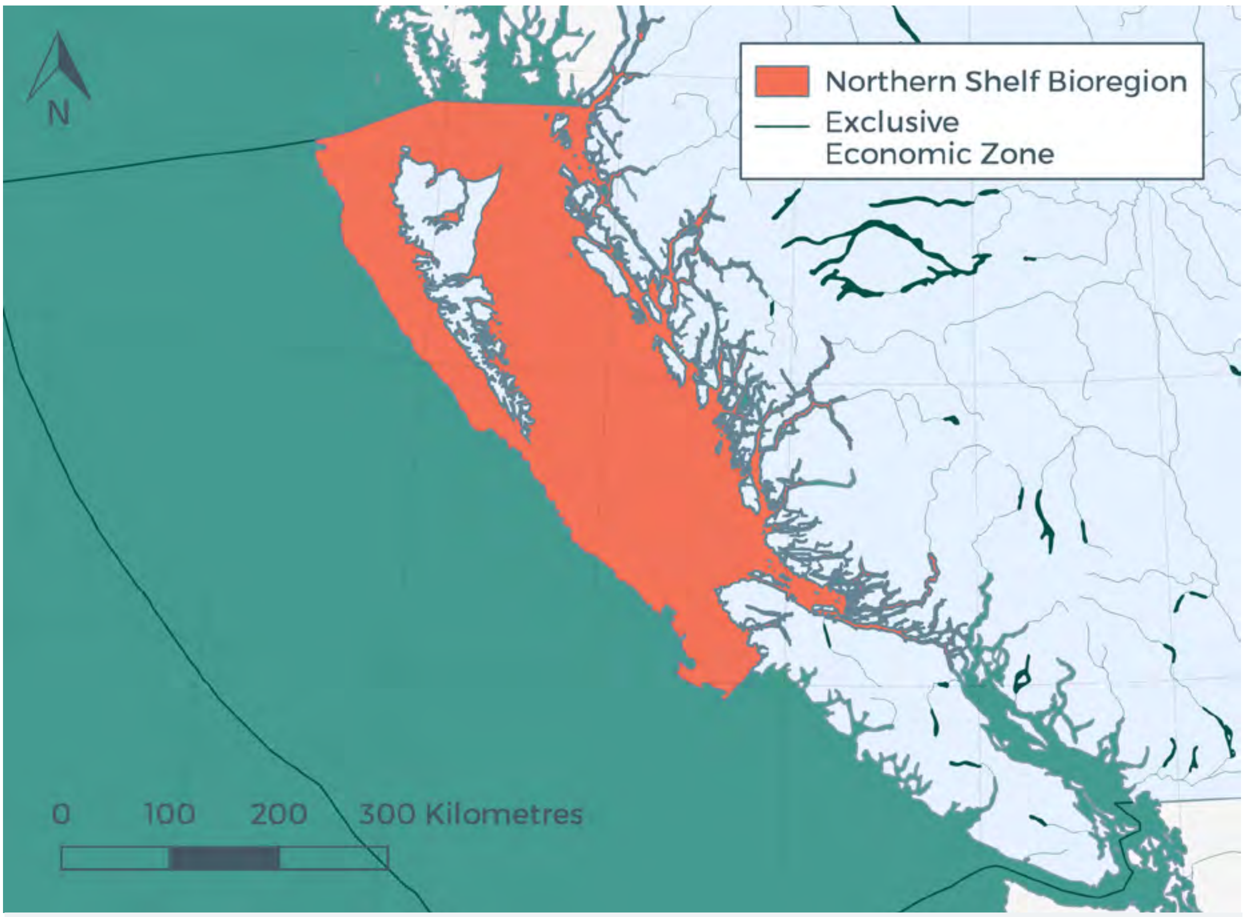
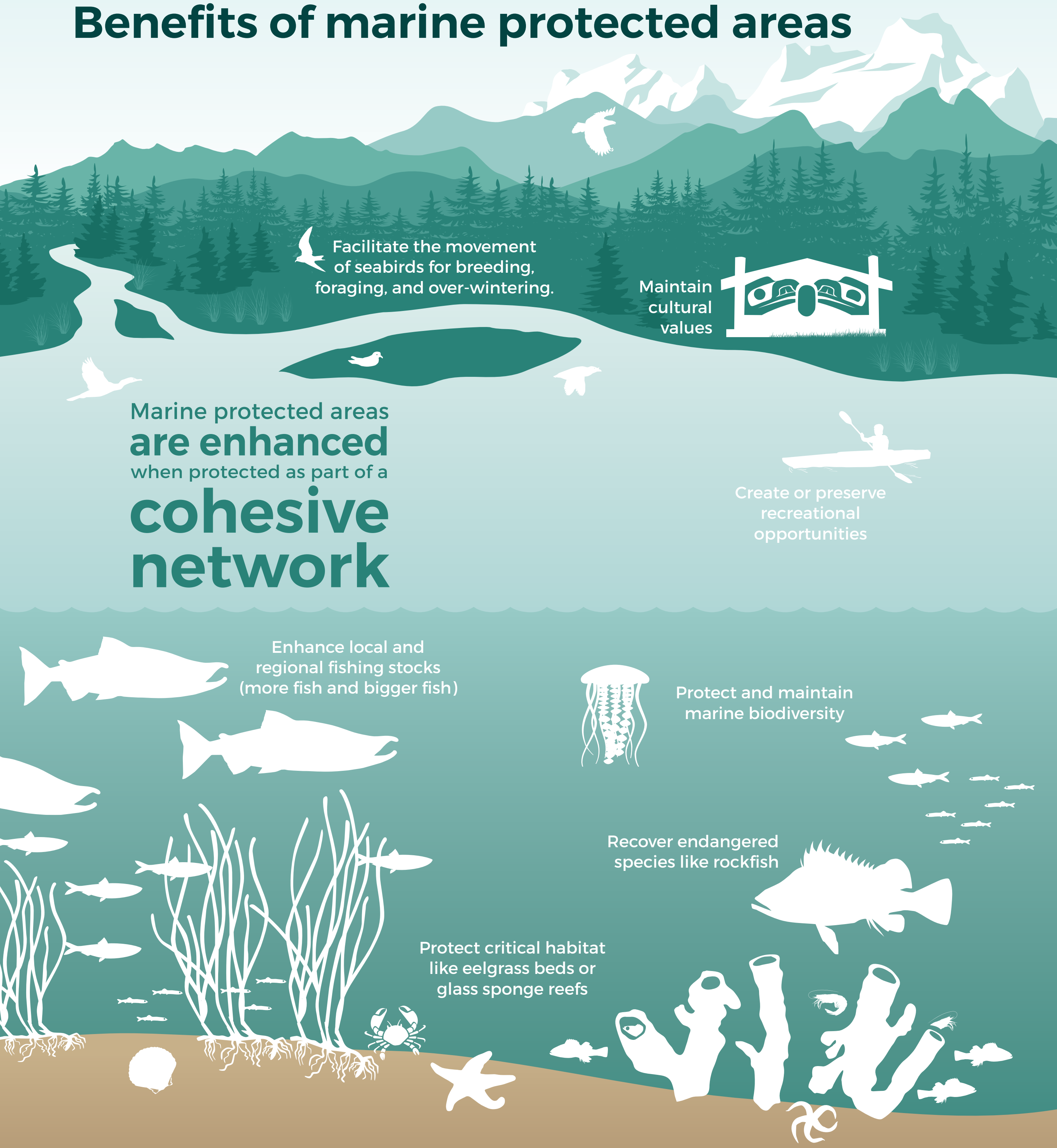


Figure 3. Area within the Pacific Ocean of Canada known as the Northern Shelf Bioregion (NSB) where MPA network planning is underway.

Benefits of marine protected areas



Strategy,[15] with a primary emphasis on the first goal: "to protect and maintain marine biodiversity, ecological representation, and special natural features." As part of this process, the contribution of other existing and proposed MPAs (i.e., Scott Islands marine National Wildlife Area) may be evaluated for their potential inclusion in this network.

Note: This document and the statements within have not been formally reviewed or approved by the organization(s) representing the Government of Canada, the Provincial Government, or First Nations' governments.

What can you do?

Individual and Organization Actions:

- Explore the B.C. coast to discover the incredible diversity of marine ecosystems.
- Participate in MPA network planning. If you live, work, or have an interest in the Northern Shelf Bioregion, visit http://mpanetwork.ca to learn how to be involved.

Government Actions and Policy:

- Finalize the management plans for existing MPAs and collaborate across government agencies to ensure appropriate management actions are taken.
- Begin the process of developing MPA networks within all marine bioregions in Canada's Pacific Ocean.

Resources

MPA network planning in the Northern Shelf Bioregion
http://mpanetwork.ca/bcnorthernshelf/

Proposed Scott Islands marine National Wildlife Area
https://ec.gc.ca/ap-pa/default.asp?lang=En&n=90605DDB-1#__006

Offshore Pacific AOI
http://www.dfo-mpo.gc.ca/oceans/aoi-si/offshore-hauturiere-eng.html

Footnotes

[1] http://pm.gc.ca/eng/minister-fisheries-oceans-and-canadian-coast-guard-mandate-letter

[2] Aichi Target 11 in Convention on Biological Diversity (CBD). 2011. Strategic plan for biodiversity 2011–2020. https://www.cbd.int/doc/meetings/cop/cop-10/information/cop-10-inf-12-rev1-en.pdf.

[3] http://www.gazette.gc.ca/rp-pr/p2/2017/2017-02-22/html/sor-dors15-eng.php

[4] https://ec.gc.ca/ap-pa/default.asp?lang=En&n=90605DDB-1#__006

[5] http://www.dfo-mpo.gc.ca/oceans/aoi-si/offshore-hauturiere-eng.html

[6] http://mpanetwork.ca/bcnorthernshelf/

[7] Gaines, S.D., C. White, M.H. Carr, and S.R. Palumbi. 2010. Designing marine reserve networks for both conservation and fisheries management. Proceedings of the National Academy of Sciences 107: 18286–18293.

[8] Jessen, S., K. Chan, I. Côté, P. Dearden, E. De Santo, M.J. Fortin, F. Guichard et al. 2011. Science-based guidelines for MPAs and MPA networks in Canada. Canadian Parks and Wilderness Society, Vancouver, Canada.

[9] Jessen et al. 2011.

[10] Robb, C.K., K.M. Bodtker, K. Wright, and J. Lash. 2011. Commercial fisheries closures in marine protected areas on Canada's Pacific coast: The exception not the rule. Marine Policy 35: 309–316. doi:10.1016/j.marpol.2010.10.010

[11] Robb, C.K., K.M. Bodtker, and K. Wright. 2015. Marine Protected Areas in the Canadian Pacific: Do They Fulfill Network Criteria? Coastal Management 43(3): 253–269. doi:10.1080/08920753.2015.1030306

[12] http://www.dfo-mpo.gc.ca/oceans/aoi-si/offshore-hauturiere-eng.html

[13] Ban, S., J.M.R. Curtis, C. St. Germain, R.I. Perry, and T.W. Therriault. 2016. Identification of Ecologically and Biologically Significant Areas (EBSAs) in Canada's Offshore Pacific Bioregion. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/034. x + 152 p.

[14] https://ec.gc.ca/ap-pa/default.asp?lang=En&n=90605DDB-1#__006

[15] https://www.for.gov.bc.ca/tasb/slrp/pdf/ENG_BC_MPA_LOWRES.pdf

An evolution in the governance of B.C.'s coastal biodiversity

AUTHOR

Kim Sander Wright, Senior Marine Planning Specialist, David Suzuki Foundation and Global Strategy Advisor on Coastal, Marine and Island Environments for the ICCA Consortium[1]

REVIEWERS

Nathan J. Bennett, PhD, Institute for Resources, Environment and Sustainability, University of British Columbia

Georgia Lloyd-Smith, Staff Lawyer, West Coast Environmental Law

What's happening?

Canadians are in the middle of a paradigm shift when it comes to how we oversee the management of our lands, water and resources. The change is one of governance – that is, who makes the decisions and how we decide what management actions to take. Since time immemorial, Indigenous people have governed what is now known as Canada using their own laws. Now, the Canadian government is beginning to recognize the importance of sharing governance authority with Indigenous people.

Setting of the historic Skedans Village, Gwaii Haanas National Park Reserve and Haida Heritage Site. (Photo: Kim Wright)

Evidence of this governance shift can be found in an October 2016 statement from the Assistant Deputy Minister of Fisheries and Oceans Canada (DFO) Philippe Morel. Speaking about DFO's marine protection measures, he said, "… other measures may also include certain area-based species at risk critical habitat, and they may include some *Indigenous and community conservation*" (emphasis added).[2]

Indigenous and community conservation is a form of conservation in which peoples with collective rights and a historical and custodial relationship with a traditional territory are recognized as the primary decision-makers of where and how conservation should occur within those territories.

There are a number of reasons why Fisheries and Oceans Canada may have made this statement.

1) In Canada, Indigenous peoples have constitutionally protected rights to their traditional territories that can include decision-making rights.[3] These rights arise because Indigenous peoples have governed their territories since long before contact with Europeans. Indigenous peoples also have cultural, linguistic and spiritual connections to these territorial landscapes and seascapes.[4,5] These relationships to the land and sea are built upon thousands of years of interdependence that has created responsibilities for taking care of the natural world. In modern times, one expression of this responsibility to the natural world is in self-identified areas by Indigenous peoples exercising the right and responsibility to collectively self-govern. Such areas of self-governance for conservation purposes are known as ICCAs, which stands for territories and areas conserved by Indigenous peoples and local communities.[6]

2) When it comes to conservation measures, academics and practitioners around the world have increasingly recognized that a rights-based approach, which uses bottom-up processes and is locally governed, can be more effective at achieving long-term conservation outcomes than colonial forms of conservation.[7,8] The use of local rules and customs for governance, monitoring and enforcement, along with local buy-in to the establishment and the outcomes[9] contrasts with colonial conservation structures that use a top-down approach and often divert access and resources away from local populations.[10] Those most familiar with the species and ecological processes, and who have had experience governing their territories for thousands of years, have the most at stake regarding the long-term impacts of their decisions. Taking responsibility for both the terrestrial and marine components of their territories, Indigenous peoples and local communities are often those who are best suited to govern.[11,12]

3) The Government of Canada is actively engaged in expanding marine protection in order to meet Canada's Biodiversity Target 1 of 10 percent marine areas protected or conserved by 2020.[13] The approaching deadline of 2020 has prompted the federal government to question what they can count as "protected areas." (See also the Marine Protected Areas article in this theme.)

Internationally, four governance types for protected areas qualify to be counted against Convention on Biological Diversity (CBD) targets: Governance by

Photo: Kim Wright.

governments (applies to most existing Canadian terrestrial parks and marine protected areas [MPAs]), private governance (e.g., lands owned by the Nature Conservancy), shared governance (government/private or government/Indigenous), and Indigenous and local community governance.[14] In a 2016 Federal report, one terrestrial protected area in the Northwest Territories is recognized as under "Indigenous and local community governance."[15] In addition, several areas have been declared by Indigenous governments as tribal parks[16,17] (discussed below), but whether Indigenous governance of these areas is legally recognized by the Crown in Canada and whether they may be counted toward Canada's biodiversity targets remains unclear. The federal government and many Indigenous governments recognize the lack of protected areas under Indigenous governance and see a potential opportunity.[18]

Why is it important?

The history of the governance of biodiversity conservation and Indigenous peoples in Canada is a troubled one, but the situation is improving. Indigenous peoples have gone from being forcibly evicted from their lands to make way for protected areas[19] to today's co-governance agreements with provincial and federal governments. If the Canadian approach to conservation governance in the future were to be aligned with international standards, such as the United Nations Declaration on the Rights of Indigenous Peoples,[20] it would include appropriate recognition of Indigenous governance of conserved areas in their territories.

What is the current status?

Currently, the federal government is working with 17 First Nations in central and northern B.C. and with the provincial government to craft a tripartite co-governance agreement that will support a jointly established network of MPAs in the Northern Shelf Bioregion.[21] At the same time, the work of the Marine Protected Area Technical Team (MPATT), a joint initiative of Indigenous, federal and provincial governments, is under way to coordinate the network design process. The possibility for some First Nations' governed areas within the MPA network does exist,[22] and, if this occurs, these will be the first recognized Indigenous governed MPAs on our coast.

The Evolution

The following selected milestones do not include all of the legal and political events that have influenced the progression of the rights of Indigenous peoples in Canada, but they do illustrate a summary of the evolution in governance of biodiversity in B.C. (Figure 1). Generally, the evolution consists of an increasing level of Indigenous involvement in governance – from consultation to co-management, and leading toward Indigenous governance.

First Nations and Province complete marine plans, April 2015. (Photo: Province of British Columbia, Flickr, CC BY-NC-ND 2.0)

Consultation

Even after section 35 of the 1982 Constitution was enacted, Indigenous peoples were not necessarily treated differently from stakeholders or special interest groups, such as tourism associations, in a region. In this period of consultation, provincial or federal governments made final decisions, with or without Indigenous input.[27,28] Some Indigenous peoples refused to participate in "consultations" because in their view they had never relinquished their rights to their territories. Therefore, Indigenous peoples were not stakeholders, but governments.[29] In 2004, the Haida decision from the Supreme Court of Canada established a clear duty to consult Indigenous peoples prior to decisions that could impact their constitutionally protected rights.[30]

Following page: Figure 1: Selected Milestones in the evolution of Indigenous governance over territories in B.C.

Evolution of Indigenous governance over territories in B.C. SELECTED MILESTONES

1763

Royal Proclamation: Recognized the rights and title of Indigenous Peoples in Canada to their territories.[23]

1763–1973

The rights and title of Indigenous peoples were not respected for many years as the Crown governed with impunity and sold lands without the consent of the traditional custodians and original occupants.[24]

1973

Calder case[25] recognized Indigenous title to their traditional territory based on occupation. This led to the Nisga'a Treaty, the first modern day treaty that established the legal right to self-governance.

1980

Meares Island Tribal Park created and governed by the Tla-o-qui-aht First Nations.

1982

The Constitution Act: Section 35[26] re-affirms existing aboriginal and treaty rights originally recognized in 1763, marking a turning point for Indigenous peoples in Canada.

1990

Sparrow case: Crown legal case that protected the First Nation's "right to fish" as a Section 35 Constitutional right that was never extinguished by any prior agreements or treaties.

1993

Archipelago Management Board: Government of Canada and the Haida Nation create a management board and agree to disagree about who has sovereignty. First co-management example.

1997

Delgamuukw case: Shows Aboriginal Title is a Section 35 Constitutional right.

2002

BC New Relationship Accord: BC/First Nations government-to-government structures created for working together on decisions about the use of land and resources.

2002–2007

Great Bear Rainforest Agreements: Government-to-government land and resource protocols signed between B.C. and 26 First Nations.

2008

Haa'uukimun Tribal Park created by Tla-o-qui-aht First Nations as a sovereign claim to their traditional territories.

2010

Gwaii Haanas Marine Agreement: Canada's first Indigenous/federal co-governed integrated land/sea management area.

2010

Pacific North Coast Management Area Marine Planning Process (PNCIMA): Tripartite federal/provincial/Indigenous collaborative governance MOU signed for the Great Bear Sea.

2014

Tsilhqot'in case demonstrates the constitutional right and aboriginal title to a traditional territory with title to lands outside a reserve formally recognized for the first time. Implications for marine territories are unknown.

2015–2017

Marine Plan Partnership (MaPP): Provincial/Indigenous collaborative governance, planning, and implementation agreements for the Great Bear Sea.

2016

Great Bear Act: Great Bear Rainforest Agreement is legislated by the Government of B.C., making it enforceable by law.

Co-management

In 1993, the Government of Canada and the Haida Nation created the Archipelago Management Board.[31] Each of the two parties claimed sovereignty to Gwaii Haanas and the surrounding waters, but agreed to set their differences of opinion aside. Their agreement states this and acknowledges a common vision, and agreement to work together to cooperatively manage Gwaii Haanas. The area was first designated by the Haida Nation as a Haida Heritage Site and then jointly with the Government of Canada as a National Park Reserve. The Management Board, made up of equal members of both governments, is Canada's first example of co-management that includes co-governance, where decisions are made by consensus.

The New Relationship Accord between B.C. and First Nations in 2002[32] resulted in new government-to-government structures for working together on decisions about the use of land and resources, although final decision making authority lies with B.C.

The Great Bear Rainforest Co-Management Agreements with 26 First Nations followed,[33] as did co-managed, but not co-governed conservancies, including many that extend into the marine environment, designed to allow for First Nation's use and respect their role as traditional custodians.[34]

Land that had been included in the Pacific Rim National Park Reserve (PRNPR) with little or no consultation was returned to the Tla-o-qui-aht First Nations in 2009 through legislation and negotiated co-management agreements. This represents a step toward acknowledging and remedying past exclusionary decisions, but does not go as far as shared or Indigenous governance.[35]

In 2010, the Gwaii Haanas Agreement36 was extended to include the newly designated Gwaii Haanas National Marine Conservation Area Reserve. The Archipelago Management Board is currently (as of December 2017) developing an updated management plan for the whole area, including this 1,400 square-kilometre marine area.[37]

Between 2010 and 2015, 17 coastal First Nations created marine use plans for their territorial waters and extended co-management agreements with British Columbia to include the marine portions of their territories. The Haida Gwaii Strategic Land Use Agreement and the Kunst'aa guu – Kunst'aayah Reconciliation Protocol[38] was modeled after the consensus based Gwaii Haanas Agreement. The Marine Plan Partnership (MaPP)[39] letter of intent, drawn up between 17 First Nations and the Province of B.C., stipulates consensus-based decisions.[40]

A tripartite co-governance agreement[41] is currently being crafted (as of December 2017) between the same 17 Nations, the Province of B.C. and the federal government to support joint design and establishment of the Northern Shelf Bioregion MPA Network.[42]

Indigenous Governance

In 1980, the Tla-o-qui-aht First Nations created the Meares Island Tribal Park and then, in 2008, the Haa'uukimun Tribal Park, in their traditional territories on the West Coast of Vancouver Island. These parks are assertions of sovereignty over traditional lands. The governance system includes the elected Chief and Council, who hold legal jurisdiction and authority inside reserve lands, and the hereditary chiefs. By combining elected and hereditary governance systems, the Tla-o-qui-aht have expressed their sovereignty claim to include traditional territories as described in their land-use plans. The assumption of responsibility for the land management is an assertion of right and title. However, jurisdictional clarity has not been achieved. The Crown recognizes the duty to consult in the traditional territories, but has not legally recognized the sovereignty of the Tla-o-qui-aht as the decision-makers over territory beyond the reserve lands.[43]

Indigenous governed protected areas, also known as ICCAs, are the next step – areas for conservation purposes identified by Indigenous peoples exercising the right and responsibility to collectively self-govern that are appropriately recognized by Crown governments.

What is being done?

In 2017, Environment and Climate Change Canada (ECCC) created a National Steering Committee and process (called Pathway to Target 1) to help clarify what Indigenous protected areas, ICCAs for example, would look like in a Canadian context.[44] The Steering Committee set up an Indigenous Circle of Experts (ICE) to help inform ECCC on how Indigenous Protected or Conserved Areas (IPCAs) will help Canada meet its terrestrial biodiversity targets.[45] Although marine protection targets are not considered in the pathway process, Fisheries and Oceans Canada (DFO) is participating and may be able to apply forthcoming recommendations in a marine context.

Further, the federal government officially adopted the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)[46] in 2016 and the newly formed government of B.C. gave all ministers a mandate[47] to adopt and implement UNDRIP in September 2017.[48]

In order to redress the legacy of residential schools and advance the process of Canadian reconciliation, the Truth and Reconciliation Commission developed 94 different calls to action.[49]

United Nations Declaration on the Rights of Indigenous Peoples

UNDRIP ON GOVERNANCE:

"Indigenous peoples have the right to participate in decision-making in matters, which would affect their rights, through representatives chosen by themselves in accordance with their own procedures, as well as to maintain and develop their own indigenous decision-making institutions."

UNDRIP ON TERRITORIES:

"Indigenous peoples have the right to the lands, territories and resources which they have traditionally owned, occupied or otherwise used or acquired; and, (2) Indigenous peoples have the right to own, use, develop and control the lands, territories and resources that they possess by reason of traditional ownership or other traditional occupation or use, as well as those which they have otherwise acquired."

UNDRIP ON CONSERVED AREAS:

"Indigenous peoples have the right to the conservation and protection of the environment and the productive capacity of their lands or territories and resources. States shall establish and implement assistance programmes for indigenous peoples for such conservation and protection, without discrimination."

What can you do?

Individual and Organization Actions:

- Become familiar with and implement the Truth and Reconciliation Commission calls to action and UNDRIP[50] in your own workplaces.
- Know which Indigenous peoples' territories your home or workplace is in, and comply with the land and resource use guidance documented in their land and marine use plans.[51]
- Learn about tribal parks or ICCAs in your region, and support Indigenous-led tourism and educational opportunities when available.
- Contact your MLA and hold the B.C. government accountable to their commitment to UNDRIP and the Truth and Reconciliation Commission's calls to action.
- Contact your MP and hold the federal government accountable to their commitment to UNDRIP and the Truth and Reconciliation Commission's calls to action.
- Conservation organizations should use both socially responsible and ecologically effective policies and practices in the conservation of marine areas, as described in the *Appeal for a Code of Conduct*.[52]
- Before supporting government- or conservation organization-led actions concerning resource use or protected areas, confirm that the First Nations, whose territories will be impacted, support the action.

Government Actions and Policy:

- Formally recognize Indigenous rights and title to their lands.
- Recognize the land and marine use plans of B.C.'s Indigenous peoples through the establishment of implementation agreements when requested.
- Establish mechanisms to recognize and support the creation of tribal parks or ICCAs as an "other effective area-based conservation measure" under the Convention on Biological Diversity.
- Establish collaborative decision-making processes and co-management bodies.

Resources

Information on territories and areas conserved by Indigenous peoples and local communities internationally:
iccaconsortium.org

The Indigenous Circle of Experts established by Environment and Climate Change Canada and Parks Canada to provide advice on how Canada can appropriately recognize Indigenous Protected and Conserved Areas:
http://www.conservation2020canada.ca/ice

Governance partners for the Northern Shelf Bioregion Network of Marine Protected Areas process:
http://coastalfirstnations.ca/our-sea/collaborative-governance-and-reconciliation-with-first-nations

Footnotes

[1] ICCA is not a simple acronym. It stands for territories and areas conserved by Indigenous peoples and local communities.

[2] October 4, 2016. Meeting of the Standing Committee on Environment and Sustainable Development transcript: https://www.ourcommons.ca/DocumentViewer/en/42-1/ENVI/meeting-27/minutes

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[13] Canada's Biodiversity Targets: http://biodivcanada.ca/default.asp?lang=En&n=9B5793F6-1

[14] Borrini-Feyerabend, G. et al., 2013, Governance of Protected Areas: From understanding to action. Best Practice Protected Area Guidelines Series No. 20, Gland, Switzerland: IUCN. xvi + 124pp

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[17] Dearden, P., and Bennett, N., 2016, The role of Indigenous peoples in protected areas, in Dearden, P, R. Rollins and M. Needham (eds), Parks and Protected Areas in Canada: Planning and Management, Fourth Edition, Chapter: 12, Oxford, pp.357-390

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[19] Dearden and Bennett 2016.

[20] UNDRIP: https://www.aadnc-aandc.gc.ca/eng/1309374407406/1309374458958

[21] http://coastalfirstnations.ca/our-sea/what-is-a-marine-protected-area/northern-shelf-bioregion-mpa-network/

[22] Meeting of the Standing Committee on Environment and Sustainable Development transcript, October 4th, 2016: https://www.ourcommons.ca/DocumentViewer/en/42-1/ENVI/meeting-27/minutes

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[31] Gwaii Haanas Agreement, http://www.haidanation.ca/wp-content/uploads/2017/03/GwaiiHaanasAgreement.pdf

[32] New Relationship Accord: Province of British Columbia

[33] Agreements with First Nations at https://www.for.gov.bc.ca/tasb/slrp/plan17.html

[34] 2016 Great Bear Rainforest Land Use Objectives Order: https://www.for.gov.bc.ca/TASB/SLRP/lrmp/nanaimo/CLUDI/GBR/Orders/B%20and%20I%20Doc%20final%20draft_Oct%2013.pdf

[35] Murray and King 2012.

[36] Gwaii Haanas Marine Agreement: http://www.haidanation.ca/wp-content/uploads/2017/03/GHMarineAgreement.pdf

[37] Gwaii Haanas Land, Sea, People Plan: https://haidamarineplanning.com/initiatives/gwaii-haanas-land-sea-people-plan/

[38] Kunstaa-guu kunstaayah Agreement: http://www.haidanation.ca/wp-content/uploads/2017/03/Kunstaa-guu_Kunstaayah_Agreement.pdf

[39] Marine Plan Partnership (MaPP): http://coastalfirstnations.ca/our-sea/marine-plan-partnership-for-the-north-pacific-coast-mapp/

[40] Marine Plan Partnership (MaPP) LOI: http://mappocean.org/wp-content/uploads/2013/10/LOI_Completed_Nov_28_2011-signatures-removed.pdf

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[42] Northern Shelf Bioregion MPA network: http://coastalfirstnations.ca/our-sea/what-is-a-marine-protected-area/northern-shelf-bioregion-mpa-network/

[43] Murray and King 2012.

[44] Pathway to Target 1 Process: http://www.conservation2020canada.ca/the-pathway/

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Oceanography and Climate Change

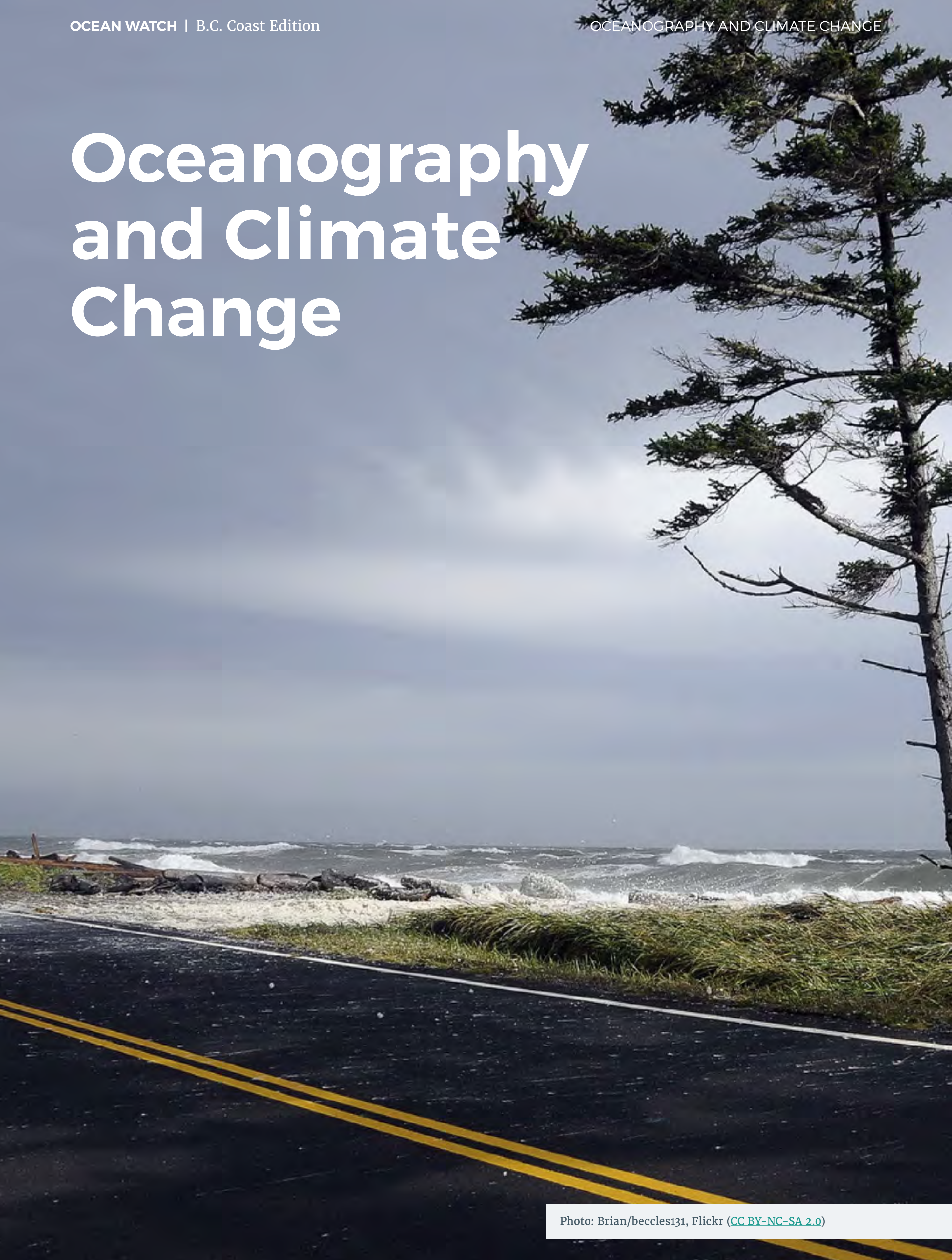


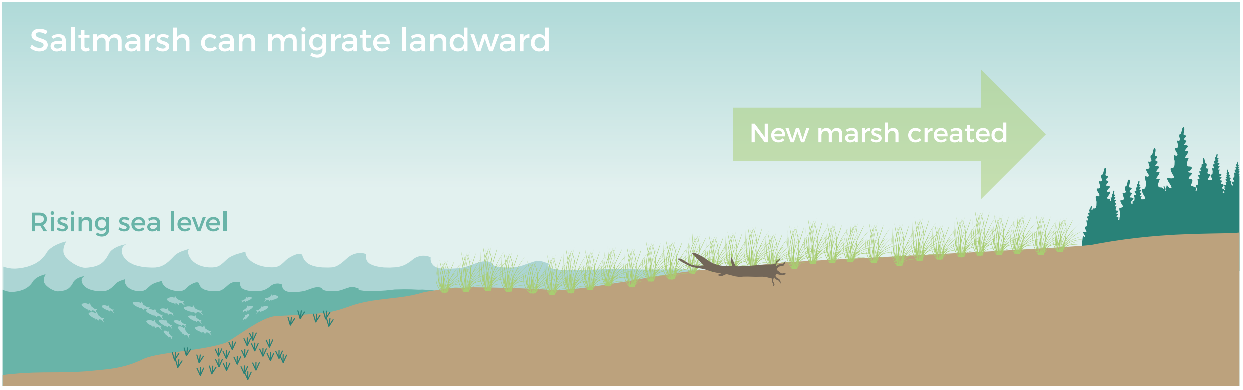
Photo: Brian/beccles131, Flickr (CC BY-NC-SA 2.0)

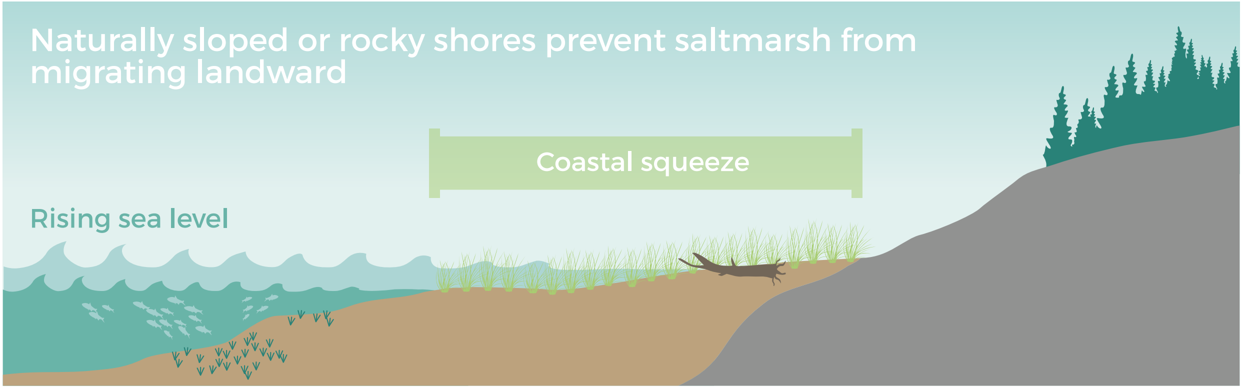
Summary

Climate change is causing the oceans to warm and sea levels to rise throughout the planet, putting coastal communities and aquatic ecosystems at risk. B.C. is no exception. Waters off our coast show a long-term warming trend, with temperatures increasing by approximately 0.1 degrees Celsius per decade since 1981. While the potential effects of warmer temperatures may impact everything from abundance of phytoplankton and other primary food sources to the migration patterns of fish, mammals and birds, the ultimate impact of a warming ocean on aquatic ecosystems is difficult to predict.

One factor arising from warmer ocean temperatures, however, appears to be an increasing rate of rise in sea level. Updated climate models suggest the Antarctic and Greenland ice shelves are melting from the bottom, due to warmer ocean waters, as well as the top. This increase in the melt rate could mean sea levels will rise much faster, and to a greater extent, than originally projected. Sea level rise along Canada's west coast may not be as dramatic as that predicted for the United States, but the new science underscores a need for updated guidelines and adaptation plans to protect B.C.'s coastal communities, people and infrastructure from rising waters and stronger storms as a result of climate change.

Coastal squeeze





Oceanography and Climate Change Snapshot Assessment

Ocean Warming

The world's oceans are warming, including those in B.C. where surface temperatures in recent years have been consistently warmer than the 30-year baseline. More observation and study is needed to track ocean warming and understand its effect on aquatic ecosystems and human settlements.

CRITICAL

Sea Level Rise

New science suggests sea levels may be rising faster, and by a greater amount, than initially predicted, rendering many planning guidelines and adaptation tools in B.C. insufficient. Updates to community plans and policies are needed throughout the coast to protect infrastructure, homes and livelihoods along the coast from the threat of rising waters.

CRITICAL

Ocean warming continues

AUTHORS
Karin Bodtker and **Raissa Philibert**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Peter Chandler, Institute of Ocean Sciences, Fisheries and Oceans Canada

What's happening?

The ocean is on a warming trend. Globally, the surface ocean has been warming at a rate of 0.13 degrees Celsius per decade since 1981,[1] and in 2016, it was warmer than the average temperature for the 20th century by 0.75 degrees Celsius.[2]

Average sea surface temperature off the B.C. coast in 2016 was not quite as warm as the two previous years, but it was 1 degree Celsius warmer than the average temperature between 1981 and 2010 (Figure 1).[3] While annual average sea surface temperatures can vary from year to year, a warming trend, averaging approximately 0.1 degrees Celsius per decade, is evident from satellite data, available since 1981.

Daily observations made at lighthouse stations along the B.C. coast over the previous 80 to 100 years also show long-term warming trends.

Temperature has been measured daily at Entrance Island since 1936. (Photo: Louise Janes, Wikimedia Commons CC BY-SA 4.0)

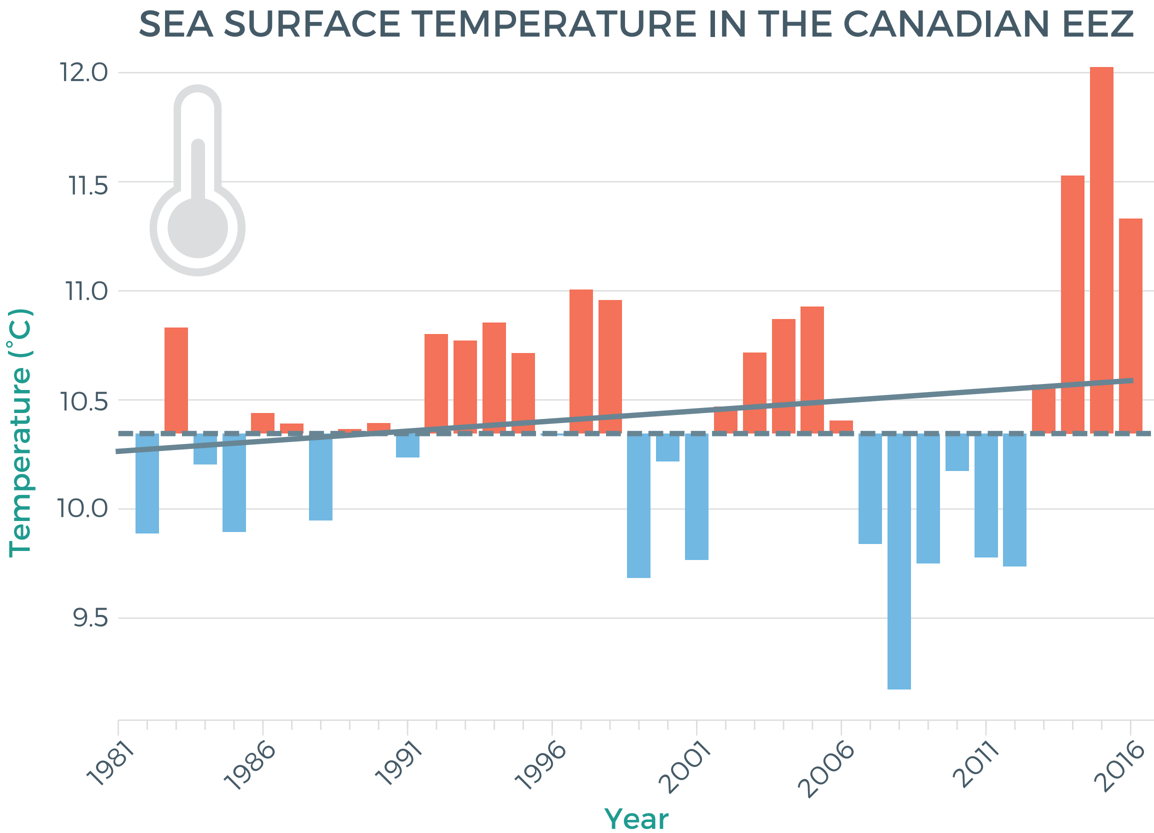


Figure 1. Annual average sea surface temperature in the Canadian Pacific Exclusive Economic Zone (EEZ) based on high resolution satellite data, illustrated as differences from the recent 30-year (1981–2010) average value of 10.3 degrees Celsius (dotted horizontal line). The solid line shows a warming trend of 0.1 degrees Celsius per decade, calculated over the entire time series (1981 to 2016). Source: National Oceanic and Atmospheric Administration (NOAA).

Why is it important?

Ocean temperature, salinity, and chemical properties like pH, a measure of acidity, tell us about the climate of the ocean. Species have long adapted to ocean climates that are typical for the region where they live. Changes to ocean conditions that are outside of the typical range of variability can affect species in many ways. Temperature changes in particular may affect the distribution and abundance, health, and phenology (timing of biologically important processes such as blooms and migration) of marine organisms. These responses are complex and may be influenced by a number of other factors (e.g., time and space scales, species resilience, and addition of other pressures such as changes in predator-prey relationships and human activities).

For example, temperature is one of several factors that determine phytoplankton abundance and community composition. In turn, the abundance, composition and distribution patterns of phytoplankton affect all marine life through the marine food web.[4] When the ocean climate shifts to less productive conditions, the result is less food at the bottom of the food chain. Surface waters, being exposed to the sun, tend to warm faster than deeper waters. They are less dense and act like a cover layer above the colder, nutrient-rich waters, especially if there is little or no wind. When there is a large difference between the temperatures of water at the surface and at depth, more energy is needed to bring the colder waters and the nutrients necessary for phytoplankton growth to the surface.

Changes in the marine ecosystem during unusually warm events can provide some insight into the conditions that may prevail under projected climate change. For example, the increased stratification (separation of warm and cold waters) and reduced mixing of nutrients due to warmer than average temperatures played a role in creating conditions that resulted in lower phytoplankton levels in 2015. Due to the warm events in 2015 and 2016, zooplankton generally found on the south coast were observed much further north than usual.[5] Changes in geographic range have been observed for many terrestrial, freshwater and marine species, including Pacific salmon, sardines, anchovies, and Pacific hake.[6,7] Furthermore, species that have evolved together may not respond to climate change to the same extent and at the same rate, leading to changes in predator-prey relationships and effects on species composition that are difficult to predict.[8,9]

A recent study found that these unusually warm conditions in 2015 compromised the immune system of California sea lion pups, a predator at the top of the food chain, providing more evidence that warmer temperatures have a ripple effect through the food chain.[10] This also shows that marine organisms may become more vulnerable to other stressors due to climate change. Conversely, the presence of other stressors such as pollution or other human disturbances can reduce the ability of the biological communities to adapt to climate change.[11] In B.C., the marine ecosystem in areas such as the Strait of Georgia, which host an abundance of human activity, have been shown to be particularly vulnerable to climate change due to the presence of multiple other pressures.[12]

Finally, warmer ocean temperatures have a direct effect on sea level because the volume of water increases as it warms causing sea levels to rise. Increases in sea level[13] will also amplify the risk of coastal flooding (see Sea Level Rise article).

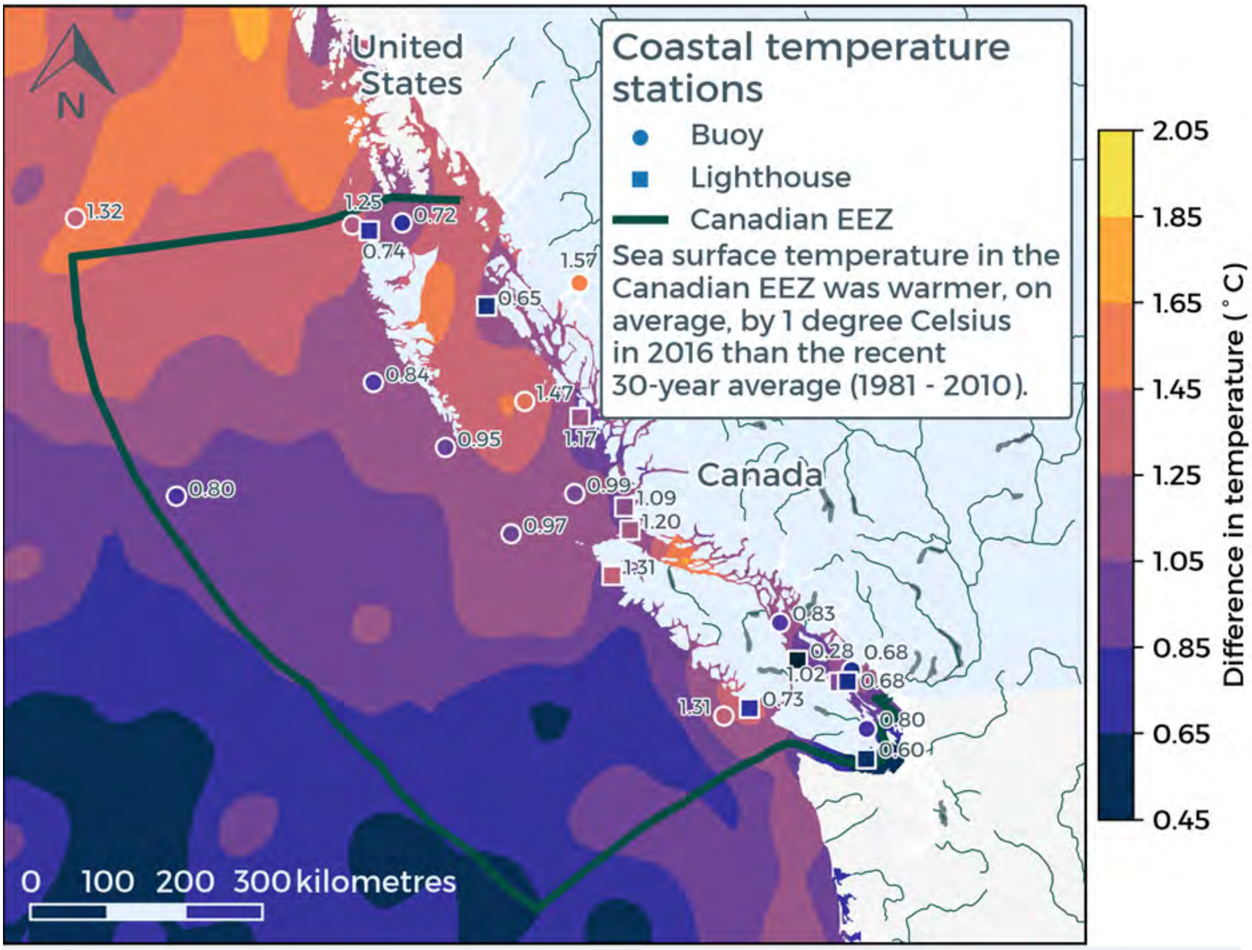


Figure 2. Difference between 2016 average sea surface temperature and a recent 30-year average from 1981 to 2010. All differences are positive meaning temperatures were consistently warmer in 2016. Sources: Sources: NOAA, Fisheries and Oceans Canada (DFO), and Environment and Climate Change Canada (ECCC).

What is the current status?

How warm was 2016 compared to recent history?

If we compare the annual average sea surface temperature in 2016 to the average temperature over a recent 30-year baseline period between 1981 and 2010, we find that temperatures in 2016 were warmer everywhere in the Canadian Pacific Exclusive Economic Zone (EEZ) (Figure 2).[14] The spatial pattern shows differences ranging from about 0.5 to 1.5 degrees Celsius, with the largest differences showing up on Dogfish Banks east of Haida Gwaii, in the middle of Hecate Strait, and in the Broughton archipelago at the north end of Johnstone Strait.

How fast is the ocean warming?

The answer to that question depends on where exactly you take measurements and how far back in time you go to estimate the rate of change. As shown in Figure 1 temperature does not steadily increase year after year but may be above or below average for several years at a time. We looked for statistically significant trends between 1981 and 2016 and found the EEZ to be warming at about 0.1 degrees Celsius per decade (Figure 3). Data from three lighthouse stations and two buoys also showed significant trends with a range in values.

The trend at a buoy (46208) located west of Haida Gwaii shows a cooling trend over time between 1981 and 2016. While this may have been related to La Niña events which led to cooler than average surface waters between 2008 and 2012,[15] it reminds us that the spatial

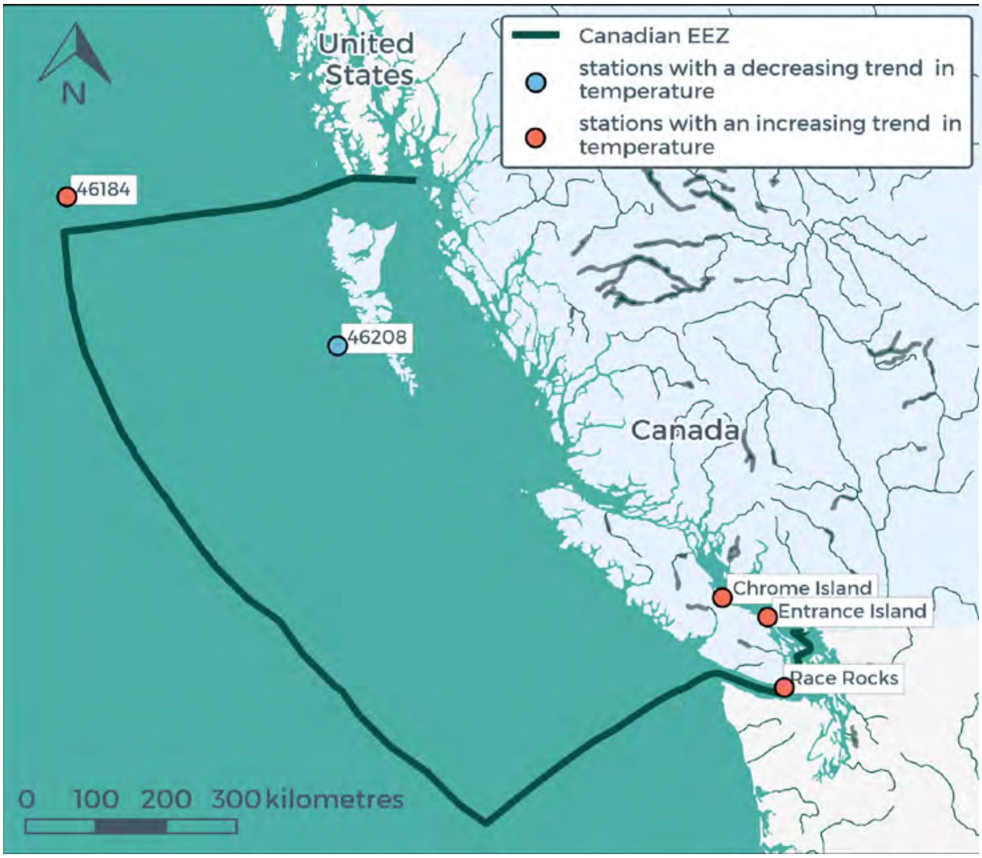
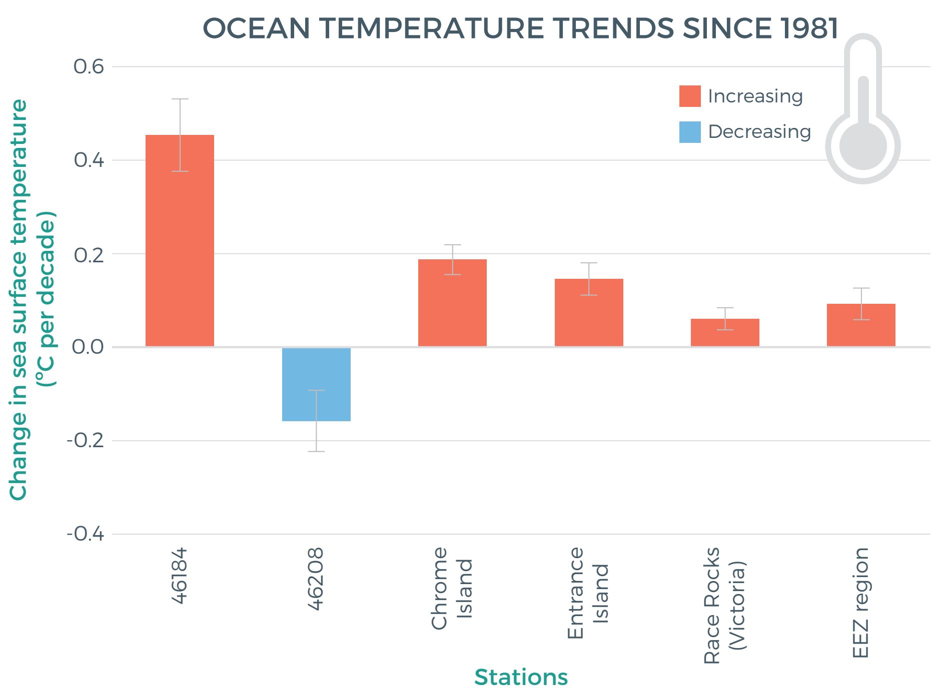


Figure 3. Warming trends from 1981 are statistically significant for the whole EEZ, three lighthouse stations and two buoy locations. Data sources: NOAA, DFO, ECCC.



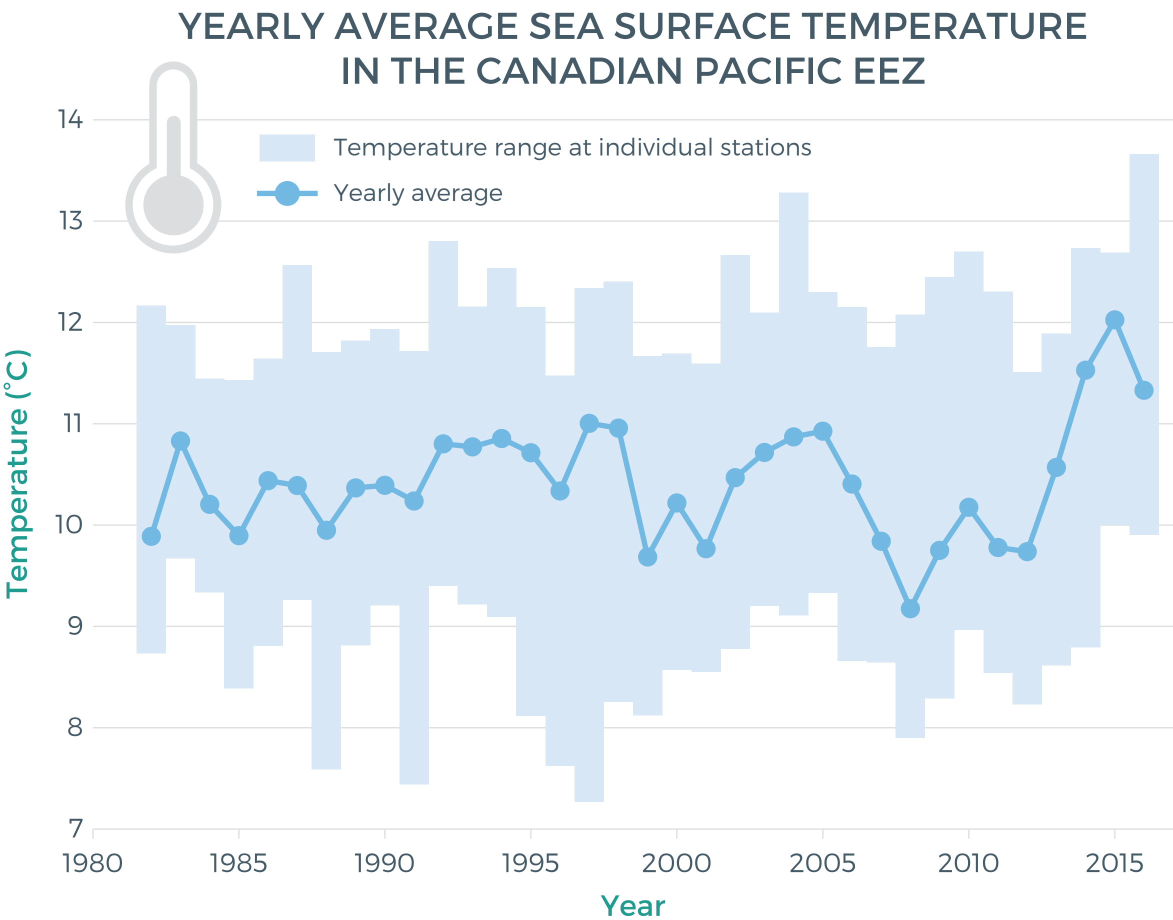


Figure 4. Variability around the average sea surface temperature in the Canadian Pacific EEZ for each year from 1981 to 2016. The points and dark line show the average for the Canadian EEZ from satellite data and the shaded area above and below shows the range of annual averages from measurements at individual light stations and buoys. Data sources: NOAA, DFO and ECCC.

variation in sea surface temperature is considerable. In fact, looking at the time series of annual temperatures back to 1981, we see average values for the EEZ ranging from nine degrees Celsius to about 12 degrees Celsius, and a much larger temperature range (seven degrees Celsius to above 13 degrees Celsius) when we consider values at the individual lighthouses and buoys where data are collected (Figure 4). Trend analysis is also sensitive to the values at the beginning and end of the observation period. For example, if we considered the 30-year interval from 1983 to 2012, the trend in average sea surface temperature across the EEZ would be a decreasing one (Figure 4).

Is the warming evident in one season more than others?

When we examine daily temperatures, especially the differences between 2016 daily values (averaged across the EEZ) and average values for a recent 30-year period (1981-2010), we see that 2016 was warmer than the recent baseline almost every day, except a few days in very early August (Figure 5). Further, it looks like the magnitude of the difference is greatest between January and mid-May. This pattern changes from year to year. Furthermore, warming trends have been observed in one or more seasons at most of the DFO lighthouses in B.C. At stations with warming in more than one season, the rate of warming was similar across seasons. These warmer than normal conditions are more likely due to large-scale oceanic events, such as El Niño rather than one season warming more than others.

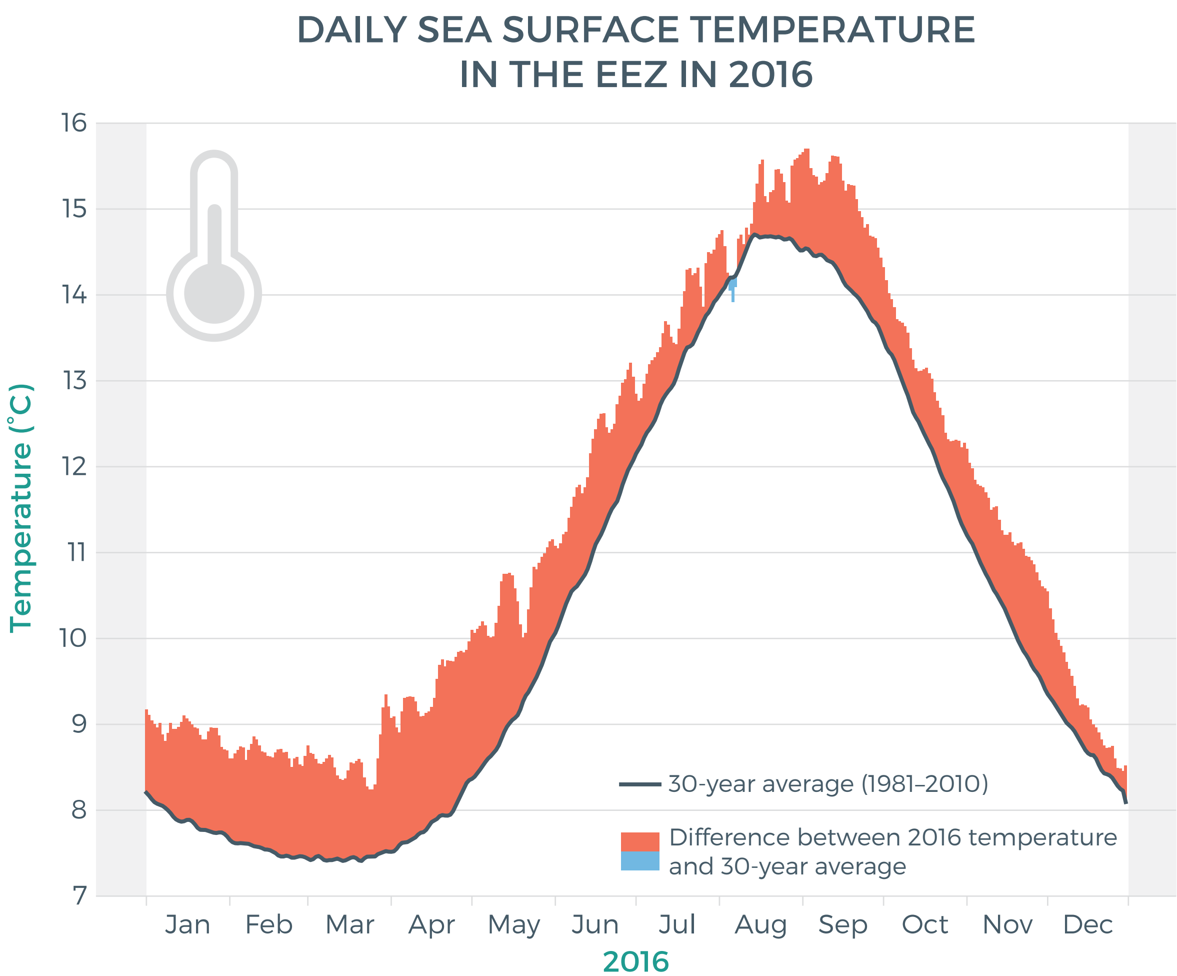


Figure 5. Daily sea surface temperatures illustrated as differences (orange bars) from a recent 30-year average (1981–2010) (solid line), show that daily temperatures in 2016 were consistently warmer than the recent historical average. Source: NOAA satellite data.

What is being done?

Fisheries and Oceans Canada (DFO) has numerous scientists monitoring and reporting on ocean conditions through the State of the Pacific Ocean workshop and report series. They track elements such as physical and biological conditions and select fishery resources for the Canadian Pacific.[16,17] Several DFO monitoring programs have been ongoing for a long time. For example, since 1956, a science vessel has been used to collect physical, chemical and biological data three times a year along Line P, a monitoring line extending about 1,450 kilometres from the west end of Juan de Fuca Strait. DFO has also carried out a similar monitoring program at about 80 stations in the Salish Sea over the past 15 years.[18] Daily observations of sea surface temperatures continue to be made at lighthouse stations along the B.C. coast, some starting over 100 years ago.

Ocean Networks Canada monitors temperature and other physical and chemical properties in real-time to contribute to understanding human-induced changes in the marine ecosystem on the coast of British Columbia.[19] They provide the data along with several visualization tools free of charge for researchers and the public.

After a few big storms in December 2016, divers witnessed a huge influx of Giant fire salps, a deep water species (center of this photo), into shallower waters. (Photo: Peter Mieras, Subvision Productions)

The National Oceanic and Atmospheric Administration (NOAA) in the U.S. provides many online resources and tools. NOAA's National Centers for Environmental Information monitors and assesses the state of the earth's climate in near real time and provides data and information on global and regional climate trends and variability including comparisons to the climate of the past. NOAA also releases a monthly summary of global climate-related occurrences.[20]

Two major groups in Oregon and Washington, the Oregon Climate Change Research Institute at Oregon State University and the Climate Impacts Group at University of Washington, are actively researching climate change in the Pacific Northwest. Among other things, they are looking at impacts on the oceans and coastal communities.

The Pacific Climate Impacts Consortium (PCIC) provides practical information on climate variability and impacts of climate change in our region through tools such as Plan2Adapt and the Regional Analysis Tool.[21] They regularly release science briefs describing modelled projections and their implications for B.C. in non-scientific language.

Most of the countries that are part of the United Nations (including Canada) adopted the Paris Agreement in December 2015. In the agreement, which came into force in November 2016, all countries committed to work to limit global temperature rise.[22]

The Pacific Institute for Climate Solutions (PICS) conducts research on the impacts of climate change and approaches to mitigation and adaption with a focus on B.C. in collaboration with civil society, governments and industry. They provide recommendations to B.C. policy makers as well as educational tools for various audiences.

Both the federal and provincial governments have several initiatives to evaluate and prepare for the impacts of climate change. These include reporting on climate trends and planning for adaptation and mitigation.

What can you do?

Individual and Organization Actions:

- Help prevent climate change by producing fewer greenhouse gasses. Adopt policies and practices within your organization. Recommended actions include driving less, eating less meat and recycling.[23]
- Eat sustainable seafood[24] to foster healthy and resilient fish populations.
- Learn more about climate change and its implications for B.C. from the Pacific Institute for Climate Solutions online courses: Climate Insights 101.[25]

Government Actions and Policy:

- Incorporate latest climate change hazard assessments into emergency response planning.
- Protect any cold water "refugia" within rivers. Strengthen regulations that protect riparian areas along streams to keep warming to a minimum.
- Acknowledge that diversity among salmon populations will be critical in helping salmon populations adapt to future climate conditions and develop policy to maintain the diversity.
- Continue to develop monitoring programs in collaboration with non-governmental agencies to advance the scientific understanding of the marine environment.

Resources

NANOOS: the Northwest Association of Networked Ocean Observing Systems. NANOOS is part of the Integrated Ocean Observing System (IOOS) and provides information and products related to weather and ocean data.
www.nanoos.org/home.php
https://ioos.noaa.gov/

Pacific Climate Impacts Consortium: The Pacific Climate Impacts Consortium (PCIC) is a regional climate service center at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada.
https://www.pacificclimate.org/

Preparing for Climate Change – an implementation guide for local governments in British Columbia.
wcel.org/sites/default/files/WCEL_climate_change_FINAL.pdf

NOAA: National Centers for Environmental Information
https://www.ncdc.noaa.gov/climate-monitoring/

The B.C government provides some information to learn about climate change as well as support and incentives for switching to cleaner energy sources.
climate.gov.bc.ca/home/get-involved/

Footnotes

[1] NOAA National Centers for Environmental Information. 2017. "Climate at a Glance." http://www.ncdc.noaa.gov/cag/.

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Sea level rise is accelerating; the real question is how fast?

AUTHOR
Karin Bodtker, MRM, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWERS
Angela Danyluk, MSc., RPBio, Sustainability Specialist, City of Vancouver
Eric Grossman, PhD, U.S. Geological Survey, Pacific Coastal and Marine Science Center, Santa Cruz, CA

What's happening?

New research by top climate scientists suggests that global sea level rise could accelerate much faster than previously predicted.[1] The lead author in this work is Dr. James Hansen, who in 1981 published research in the journal Science that foresaw human-caused global warming. Hansen, former head of the NASA Goddard Institute for Space Studies in New York City, is renowned for his early (1980s) science-based insistence that global warming trends could be attributed to human causes in addition to natural variation. In 1988, Hansen testified to this effect before a U.S. Congressional committee,[2] a bold move for the time.

Now cutting edge research from Hansen and others is telling us that we could see several meters of sea level rise over the next 50 to 150 years because feedback mechanisms caused by melting ice in Greenland and Antarctica are amplifying and accelerating the melt.[3] Making sense of paleoclimate data (evidence of the earth's past climate going back hundreds to millions of years) is part of what's behind these new models and projections. (Dr. Hansen describes his work in this YouTube video.)

Why is it important?

Why does sea level change?

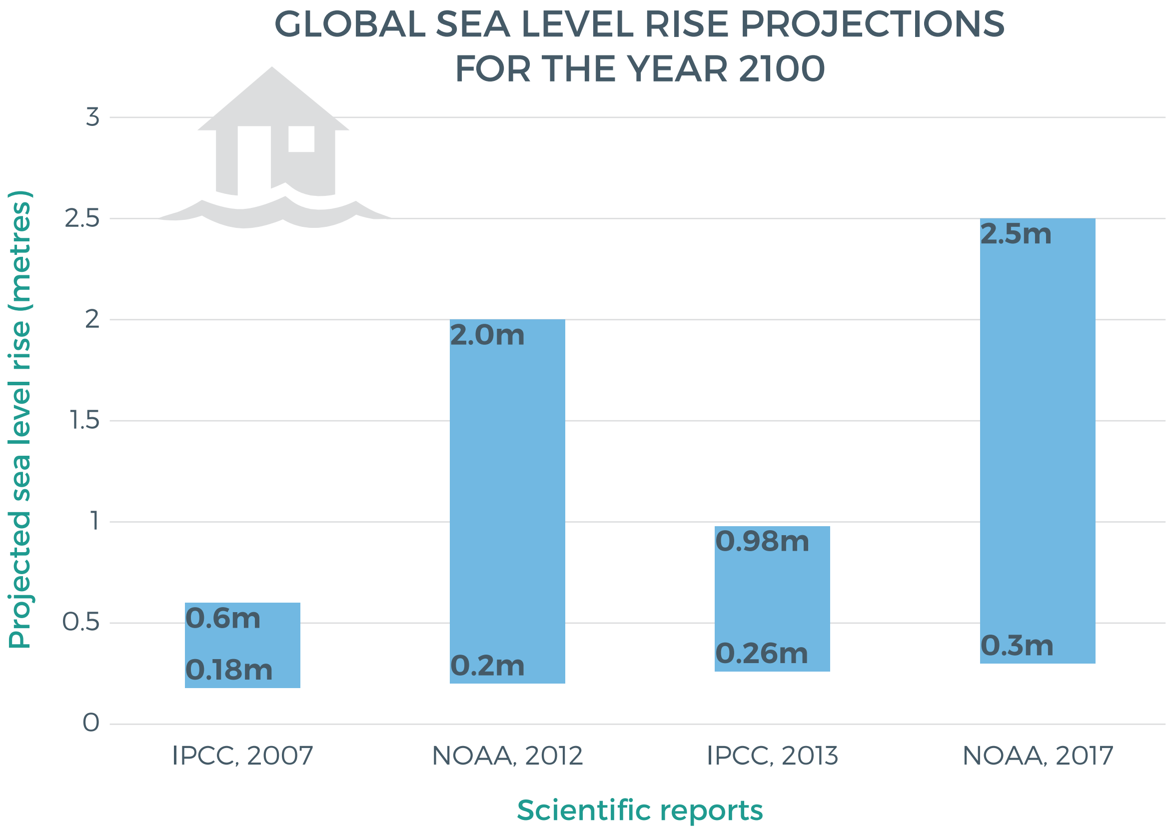
Sea level is rising for several reasons – the principal reason is warming. This phenomenon is called thermal expansion. Warmer water simply takes up more space. A second factor is the addition to ocean water from melting land-based ice. Further, regional variations to global sea level rise also occur in places including British Columbia. Finally, changes in sea level also result from vertical land movement (VLM), at regional to local scales. VLM can be downward (i.e., subsidence) or upward (i.e., uplift) which causes a relative rise or drop in sea levels, respectively.

Sea level is rising now – it's not just in the future. The speed at which this is happening is becoming much better defined given advances in technology and increasingly global coverage of gauges. As governments and scientists develop tools to better measure changes as they occur, models and projections are revised (Figure 1).

As recently as February 2017, the U.S. National Oceanic and Atmospheric Administration (NOAA) increased its projections of global sea level rise,[4] estimating that by the year 2100, global sea levels could rise between 0.35 metres (one foot) and 2.5 metres (8.2 feet). The estimates range because different climate scenarios make different assumptions about what efforts will be made to reduce harmful carbon emissions that cause global warming and rising seas. Just a decade ago, projections for 2100 topped out at 0.6 metres, so the 2017 projection of up to 2.5 metres is a significant change (Figure 1).

WHY HAVE PROJECTIONS INCREASED?

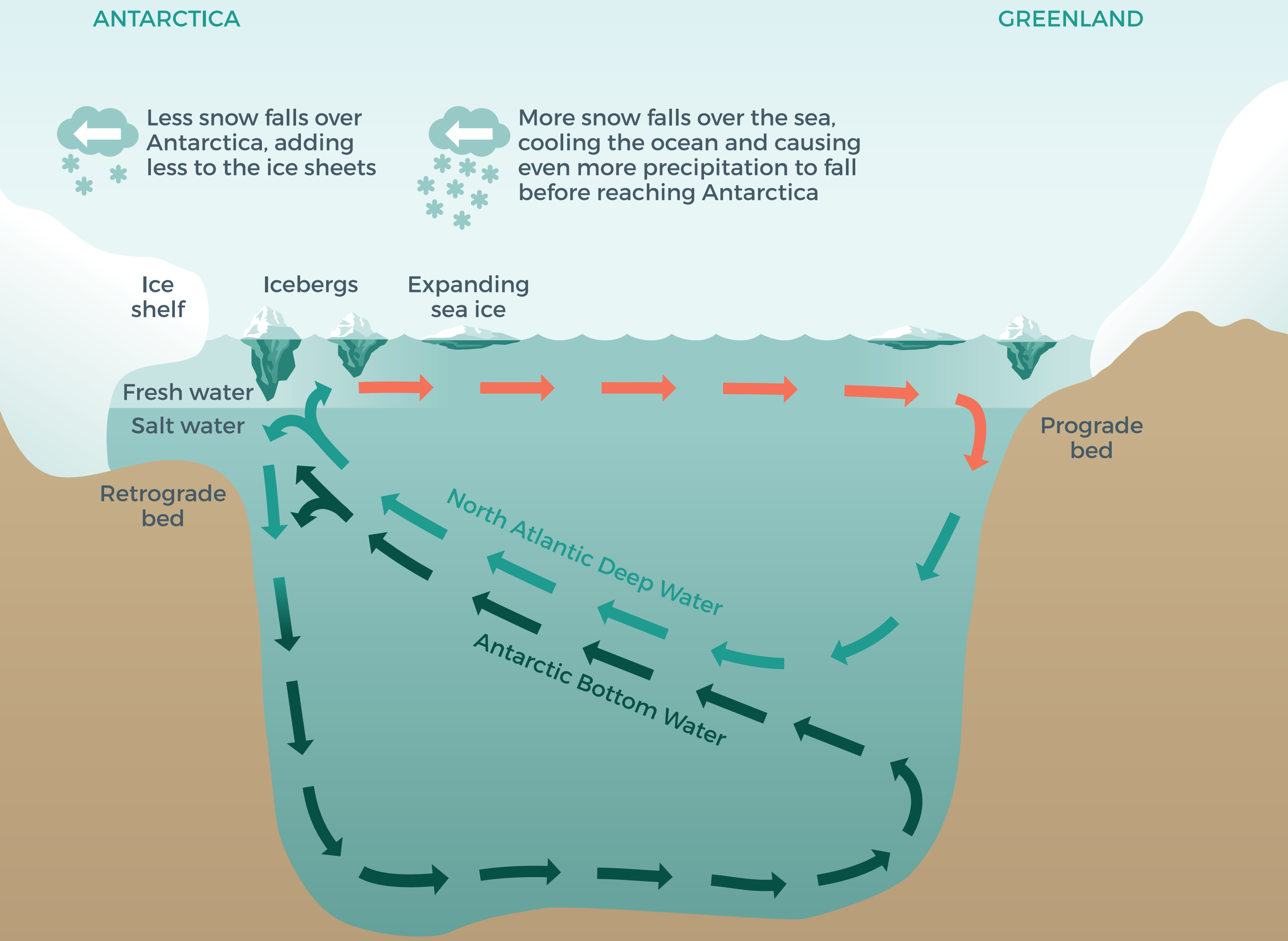
New insights about the Antarctic and Greenland ice shelves[9] suggest they are melting from underneath, where they meet a warming sea, as well as on the surface (Figure 2). Forecasting sea level rise is far from simple and projections have large uncertainties associated with them, but as scientists learn more about the feedback mechanisms, the projected magnitude of sea level rise increases, as does the uncertainty and range of possible values (Figure 1). Hansen and his co-authors hypothesize that the accelerating rate of ice mass loss due to feedback mechanisms is best approximated by doubling the rate of loss every 10, 20, or 40 years. Data collected by satellites are beginning to show such accelerating rates of ice loss and sea level rise (e.g., Figure 3), but satellites have not been collecting accurate data long enough to pinpoint the rate of acceleration.



Projections published since 2012 do take melting ice sheets into account.

Figure 1. Projections of sea level rise vary depending on who publishes them, as they present the scientific consensus of different groups. Both the low end and high end of projections are increasing as scientists learn more about how global climate systems work. Here, estimates of the Intergovernmental Panel on Climate Change (IPCC) and the U.S. National Oceanic and Atmospheric Administration (NOAA) are shown. Projections published in 2012, 2013, and 2017 do take melting ice sheets into account. These projections are anchored in 1980-1999, 1992, 1986-2005, and 2000, respectively. Sources: IPCC 2007[5]; NOAA 2012[6]; IPCC 2013[7]; NOAA 2017[8]

Ice shelf melt feedback mechanisms



Two feedback mechanisms that accelerate ice shelf melt:

1) As fresh water melts, it creates a layer of less dense fresh water sitting on top of heavier salt water (orange arrows). This layering, called stratification, impacts larger ocean circulation, reducing the turnover of Antarctic Bottom Water (darkest green arrows). This traps heat delivered by North Atlantic Deep Water (light green arrows), and increasingly delivers warmer water to the ice shelf edge in Antarctica, which increases melting.

2) The second mechanism depends upon whether precipitation lands on Antarctica as snow, to add to the ice sheets, or if it falls on the area of expanding sea ice prior to reaching landfall. This schematic shows that as the area of floating sea ice expands, due to increased freshwater melting off the ice shelves, it cools the ocean mixed layer and more precipitation falls before it reaches Antarctica adding volume to the ocean rather than the ice shelves.

Figure 2. Source: figure adapted from Hansen et al 2016, Figure 18, CC-BY.

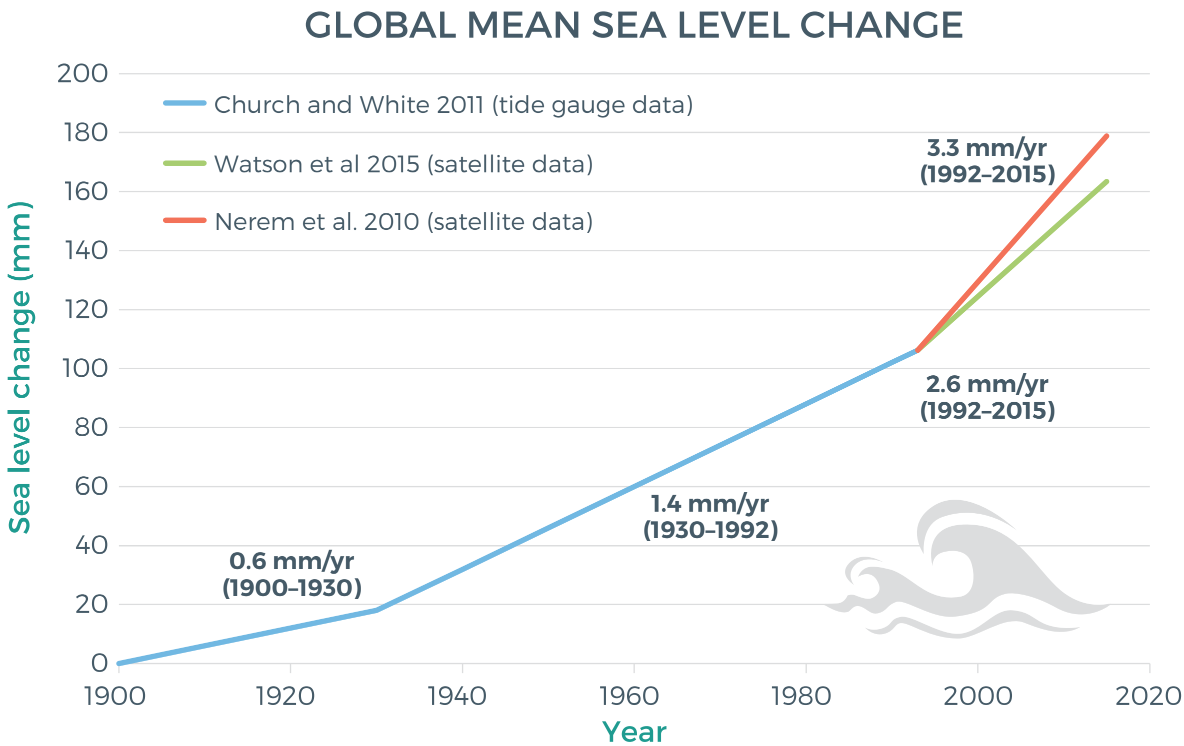


Figure 3. Estimated global sea level change (millimetres) since 1990. Satellite data, available from 1992, suggest that the current rate is as high as 3.3 millimeters per year. Source: adapted from Hansen et al. 2016, Figure 29.

The impacts of rising sea levels range from major changes to our nearshore marine habitats and food webs, to catastrophic flooding that will affect millions of coastal residents globally by late this century.[10] Related predictions include more powerful storms, referred to as "super storms,"[11] which would increase storm surge impacts on shorelines as well as create more hazardous shipping conditions. Ocean modelling work by the United States Geological Survey (USGS) projects an increase in storm frequency and extreme wave heights along the Pacific Coast, primarily north of about 50 degrees North latitude, which means much of B.C. will experience larger coastal storms.[12]

In B.C., coastal erosion will increase (Figure 4) and anticipated loss of wetland habitat would impact salmon, coastal birds, forage fish, and other coastal species. Approximately 80 percent of B.C.'s population resides in coastal communities and many of our commercially traded goods arrive through critical infrastructure (i.e., airports, ports and ferry terminals) that line our shores and are at risk of flooding (Figure 5). The general risks that climate change and rising seas present to different regions of Canada's west coast are summarized in a 2016 report, Canada's Marine Coasts in a Changing Climate, published by the Government of Canada.[13]

Is there a particular importance or connection to First Nations?

Coastal First Nations are especially vulnerable to impacts of sea level rise including flooding and erosion. Harvesting of traditional seafood is often a coastal activity. While specific impacts to nearshore resources are hard to predict, they will very likely affect the availability of traditional food sources, particularly where armoring and steep shorelines limit shore migration and where substrates will be modified (e.g., winnowed or coarsened). In addition, a large number of cultural and archaeological sites sit in coastal areas and at low elevations. The impacts are already being felt, as waters from a high king tide in 2012 covered a unique cultural feature, called the Man Who Fell from Heaven, in Metlakatla Pass on the North Coast and rose alarmingly close to the Elders housing unit there (Figure 6). First Nations and archaeologists continue to identify new cultural sites and make discoveries that document the history of occupation and use of the B.C. coast. The urgency around this work increases as ocean levels rise.

One area of the coast experiencing dramatic change in recent years is the northeast coast of Haida Gwaii where the sandy bluffs are retreating at a rate of up to 12 metres annually (Figure 7).[14]

Figure 4. Signs of erosion along the coastal bluff on Denman Island on Nov. 17, 2012 during a king tide. (Photo: JohnMac2011, Flickr, CC BY-NC 2.0)

Figure 5. Road infrastructure at risk during high king tide plus storm surge, Nov. 24, 2011 in Colwood, near Victoria, B.C. (Photo: Tina Neale, Flickr, CC BY-NC-SA 2.0)

What is the current status?

The Pacific Coast of North America has experienced relatively little sea level change since 1992 compared to some other coastlines around the world, according to satellite altimetry data from NOAA (Figure 8).[15] Tide gauge data for stations with long records at Seattle, San Francisco, and San Diego shows trends that vary over decades due to Pacific Ocean circulation patterns including the Pacific Decadal Oscillation (PDO) and the annual El Niño Southern Oscillation (ENSO).[16] These data show a period of slow sea level rise from 1900 to 1930, then faster rise mid-century between 1930 and 1980, and slow again until about 2005 (see Figure 1 in Bromirski et al 2011). However, follow-up work has identified a recent and significant increase in sea level along the West Coast of North America (i.e., 10 centimetres rise between 2012 and 2016) and suggests that trends for our coast are now closer to the global average of 3.3 millimetres per year when the influence of regional circulation patterns are removed.[17] Further, this faster rate of rise will likely persist in the coming years.[18]

In 2014, Natural Resources Canada published projections of sea level rise for 19 locations along the B.C. coast (Figure 9).[19] These projections are dated and possibly conservative as they were released prior to recent discoveries concerning ice sheet melt, feedback mechanisms, and the recent shift in the Pacific Ocean region.

Figure 6. Left: The Man Who Fell From Heaven is the most important and well-known cultural feature in Metlakatla Pass; it is under approximately three feet of water in this photo taken Dec. 12, 2012. Right: Elders Unit in Metlakatla, B.C. Dec 12, 2012. (Photos: Metlakatla Guardians, Flickr, CC BY-NC-SA 2.0)

Figure 7. Receding bluffs in Naikoon Provincial Park, Northeast Graham Island, Haida Gwaii. (Photo: Christine Rondeau, Flickr, CC BY 2.0)

Natural Resources Canada (NRCan) also developed an index of sensitivity to sea level rise, and scored Canada's coastlines based on the degree to which a coastline may experience physical changes such as flooding, erosion, beach migration, and coastal dune destabilization. In the 2009 analysis, Atlantic Canada and parts of the Beaufort Sea coast were identified as major regions of high sensitivity. Small areas of high sensitivity occur in B.C. (Figure 10). The index is currently being updated. A gap in our knowledge currently exists as to the localized effects of global sea level rise for the B.C. coast, taking into account vertical land motions and recent changes in the regional rates of sea level rise.[22] Research to model and communicate these localized effects, such as the U.S. Geological Survey is undertaking for the U.S. Pacific and Arctic coasts,[23] would be a valued contribution.

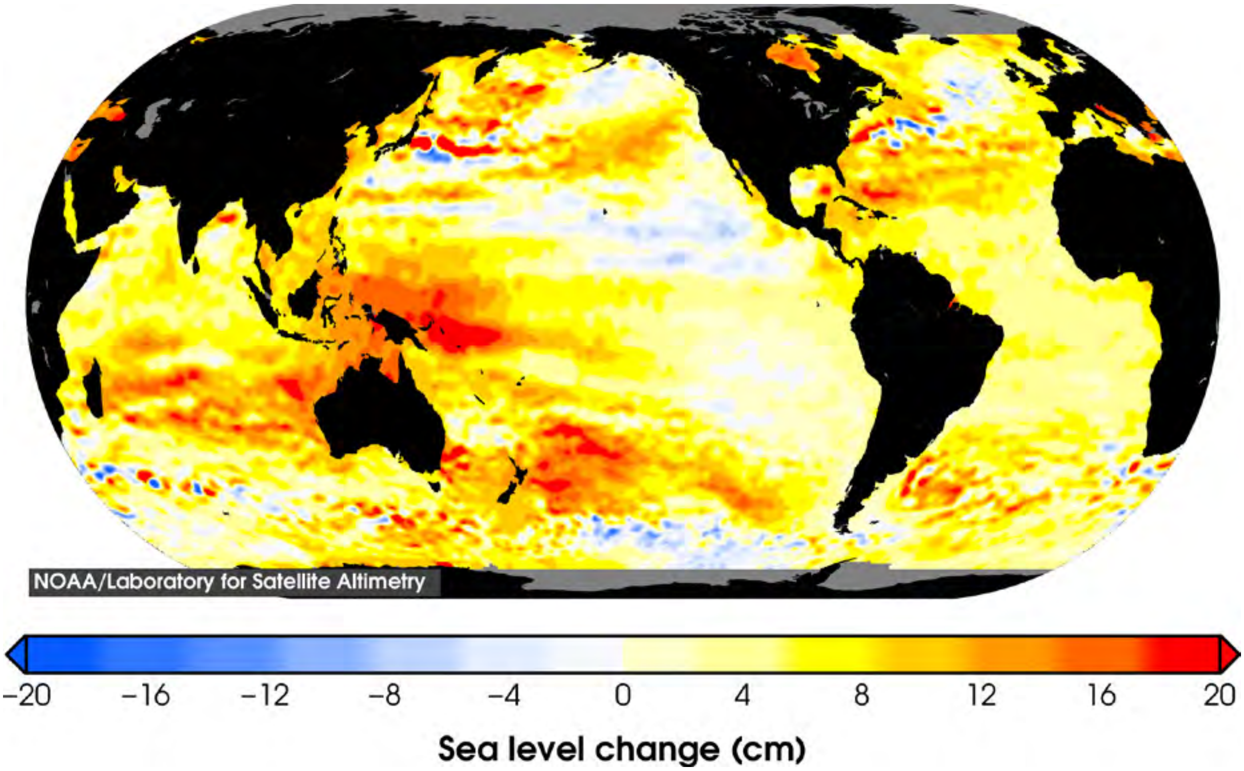


Figure 8. Magnitude of sea level change observed between 1992 and 2016. Source: NOAA's Laboratory for satellite imagery.

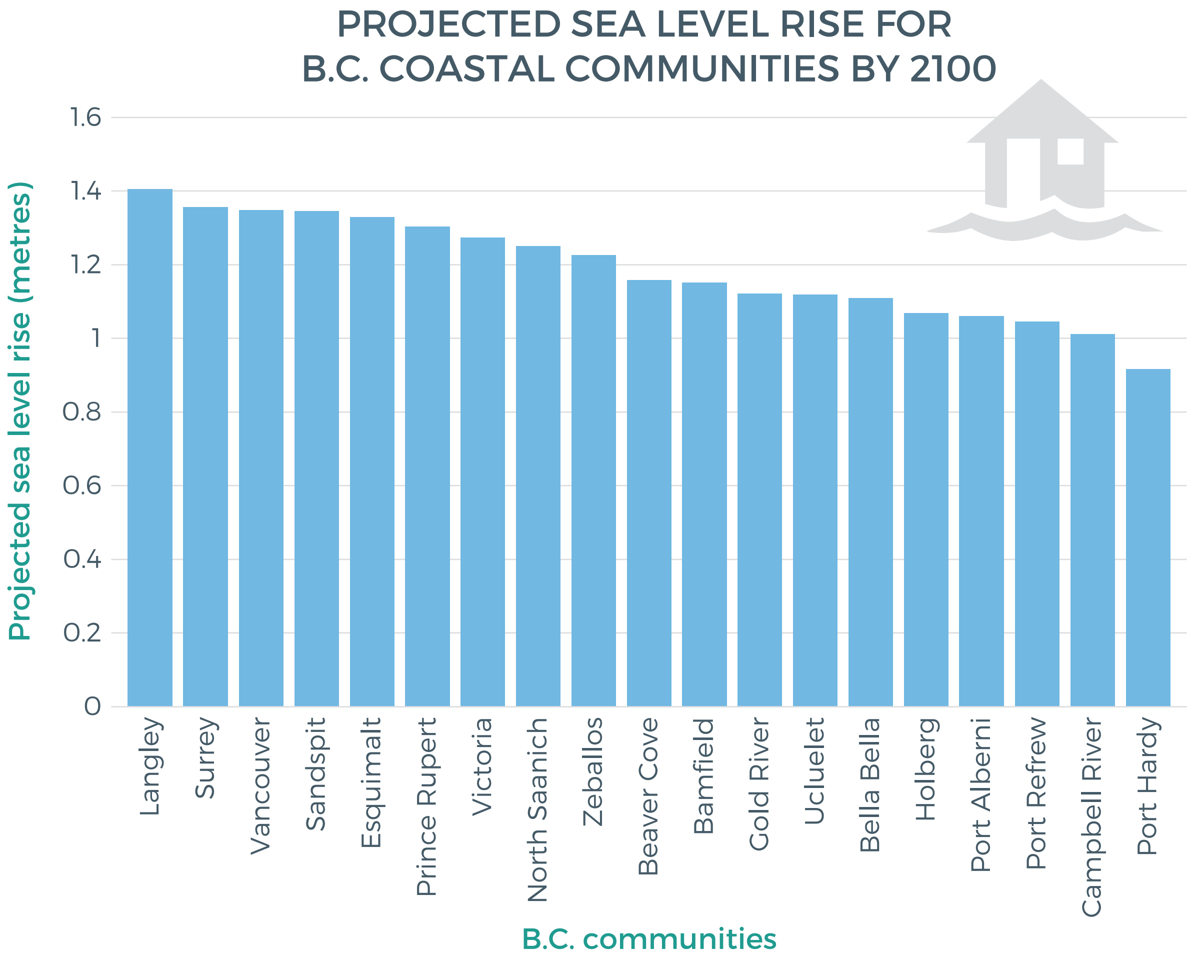


Figure 9. Projected sea level rise by 2100, relative to 1995, for 19 B.C. coastal locations. These projections are based on the IPCC 2013 extreme scenario[20] and GPS observations of vertical land motion, with an added 0.65 metres of global sea level rise anticipated from West Antarctic Ice Sheet loss.[21] Note that NOAA's 2017 projections suggest that these projections, considered extreme in 2014, are now conservative. Source: Natural Resources Canada, 2014.

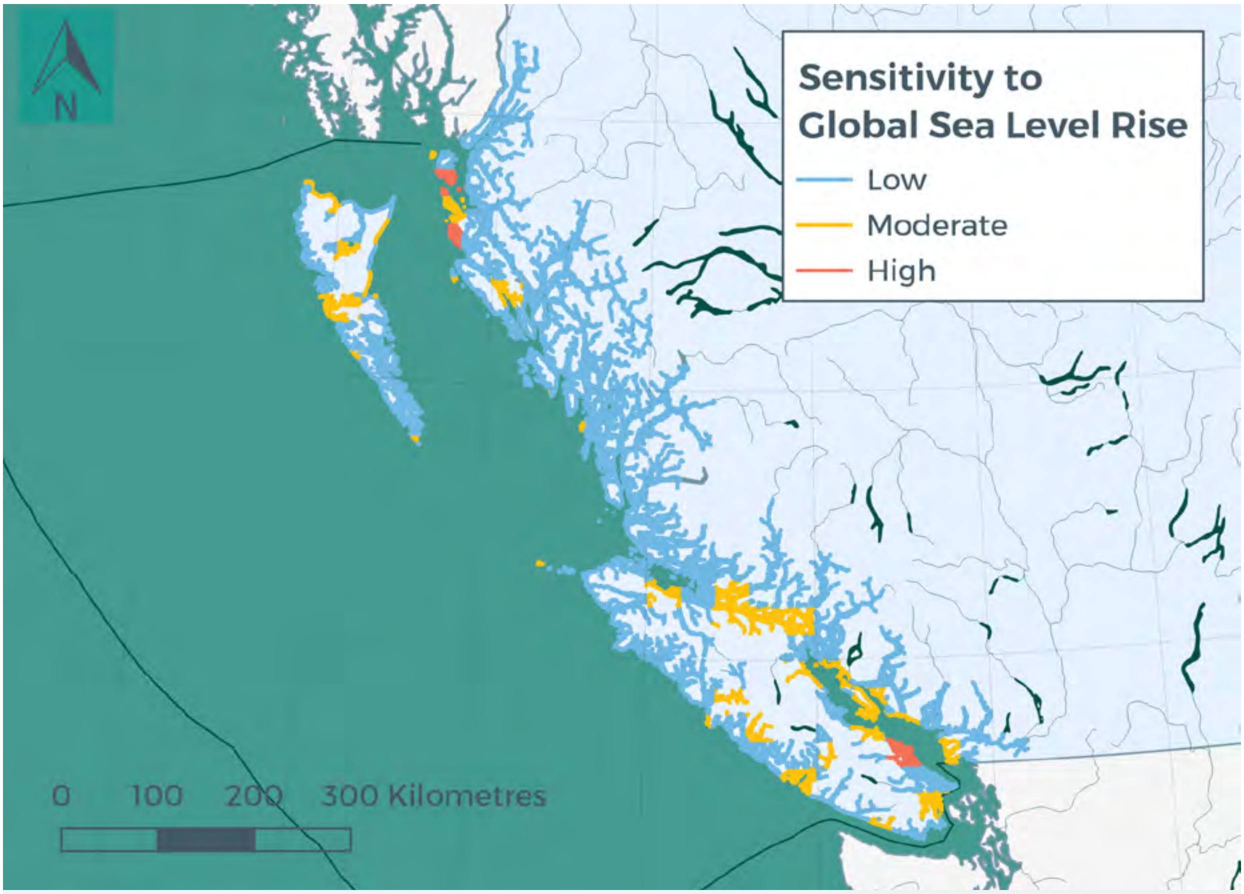


Figure 10. Areas in red were identified as highly sensitive to sea level rise in a 2009 analysis. Source: Natural Resources Canada

What is being done?

B.C. Government policy recommends planning for a 0.5-metre of rise by the year 2050, one metre by 2100 and two metres by 2200 (Figure 11).[24] These guidelines, released in 2011, were based on IPCC 2007 projections and are still in use, although the science is out of date. The 2016 Government of Canada report, Canada's Marine Coasts in a Changing Climate, declared that B.C.'s guidelines fully account for the range of likely (i.e., 66 percent to 100 percent probability) projected sea level change and account for a portion of additional possible rise.[25] New science suggests that may not be enough.

Professional engineers and planners are concerned because city planning timeframes are decades long, and if sea levels are rising faster than B.C. guidelines acknowledge, planning guidelines need to be re-evaluated.

> **"If we plan for a faster rate of sea level rise and it ends up being slower, we'll be okay, but if we plan for the slower rate and sea level rises quickly, we are in trouble."**
>
> **– JOHN READSHAW, P. ENG., COASTAL ENGINEER, SNC LAVALIN[26]**

In a May 2017 blog post, West Coast Environmental Law voiced similar concerns that B.C.'s sea level rise planning guidelines are out of date and lack a precautionary perspective.[27]

Environmental Reporting B.C. reported on a sea level rise indicator in 2016.[28] The report illustrates currently observed sea level change for four B.C. coastal locations with values ranging from -12 cm per century in Tofino to 13 cm per century in Prince Rupert. Projections conveyed in the report are based on the IPCC 2013 global projections, and are outdated.

In an effort to raise awareness and provide tools to build adaptive capacity for Canada's southern coasts, the Province of B.C. published a Sea Level Rise Adaptation Primer in 2013.[29] Adaptation strategies are generally grouped into four categories that aim to protect, accommodate, retreat, or avoid. Adaptation tools discussed in the primer fit into five main categories

GLOBAL SEA LEVEL RISE PROJECTIONS

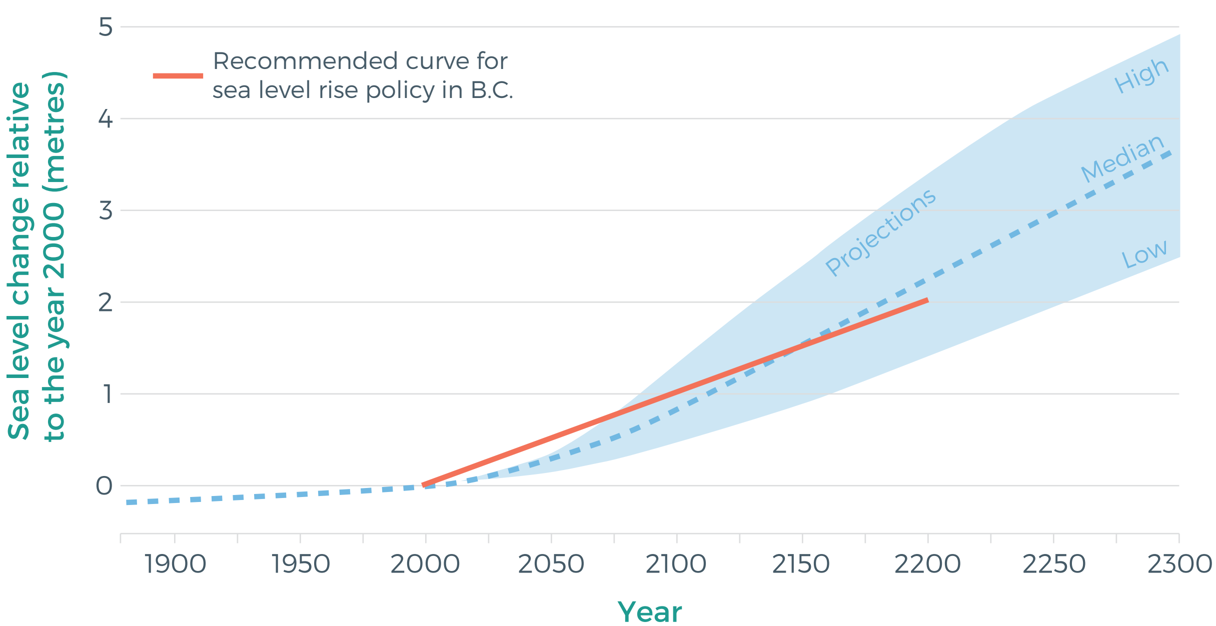


Figure 11. Range of global sea level rise projections (IPCC 2007) and curve adopted for coastal development planning by B.C. government.

including planning tools, regulatory tools, land-use change or restriction tools, structural tools, and non-structural or soft-armouring measures. Following this, a case study undertaken by the B.C. Climate Action Secretariat, partnered with Natural Resources Canada, examined the conditions that led to the successful integration of projected sea level rise science into B.C. government policy.[30]

In 2016, the Federal Government released a Canadian Extreme Water Level Adaptation Tool designed primarily for DFO small craft harbours.[31] The tool provides future water level extremes, based on IPCC 2013 projections with vertical land movement added, along with estimates of wave climate. However, in an important note, planners are directed to the NOAA 2012 high scenario projections,[32] which are more extreme, when considering vertical allowance for critical infrastructure, presumably for an added safety factor.

At local and regional scales, efforts to communicate and develop strategies and policies are common. Governments and associations are providing tools and engaging communities in adaptation planning. Some of these efforts are listed here:

- The Building Adaptive & Resilient Communities (BARC) program offers communities a comprehensive way to respond to the impacts of climate change, develop and implement an adaptation plan, and protect their people, property, and prosperity. Members of the BARC program, which provides online tools and access to staff, currently includes eight B.C. communities that are in different stages of adaptation planning.
  - Members include the Capital Region District, Delta, North Vancouver (City), North Vancouver (District), Surrey, Vancouver, Metro Vancouver, and Victoria.

Figure 12. Breach of the Ladner Dike with a projected 1.2 metres of sea Ievel rise by 2100, plus storm surge, plus high tide. Future high water level of 4.16 metres, Delcan 2011. Source: Delta RAC, CC-BY-NC-ND

- District of West Vancouver has been implementing a Shoreline Protection Plan, a form of adaptation, for several years. Measures taken include enhancing the foreshore and restoring materials lost to erosion over the years.
- Squamish is finalizing its Integrated Flood Hazard Management Plan.
- Both the City of Surrey and the City of Delta are developing coastal flood adaptation strategies, taking advantage of BARC, through Local Governments for Sustainability.
- The Delta-RAC Sea Level Rise Adaptation Visioning Study (Delta-RAC) released in 2012 includes visualizations of the future water levels under various climate scenarios that allow planners and community members to better imagine and evaluate flood adaptation strategies (Figure 12).
- BC Food and Agriculture Climate Action Initiative develops tools and resources to enhance the ability of the B.C. agriculture sector to adapt to climate change. For example, understanding and adapting to anticipated flooding and changes in salinity levels in the Fraser River is essential for the future of food production in Delta.
- City of Vancouver has undertaken a Coastal Flood Risk and Consequence Assessment and has explored a range of high-level adaptation options for flood-prone areas of the city. The city is taking the next steps to prioritize adaptation actions based on water level triggers and vulnerability. The flood construction level in the flood-prone areas was raised by 1 m in 2014 to enhance flood resilience.
- The Fraser Basin Council is active on regional flood mitigation planning and many other issues.

Figure 13. The public outdoor pool in Kitsilano, Vancouver, on a regular day (left) and flooded by the high seas of a king tide in 2012 (right). (Photos: left, Kyle Pearce, Flickr, CC BY-SA 2.0; right, City of Vancouver)

What can you do?

Individual and Organization Actions:

- Inquire about your community's planning for sea level rise. Make sure it is happening, get involved, learn the risks, and voice your opinions.
- Spread the word that sea level rise is happening and we need to acknowledge and plan.
- Support or engage in studies to improve our understanding of how coastal impacts are going to affect ecosystem services people depend upon.
- Reduce your greenhouse gas emissions:
  - Reduce your carbon footprint
  - Insulate your home, check for drafts, lower your thermostat in the winter
  - Consider an electric vehicle, car share, take transit or propel yourself
  - Wash clothing in cool water and hang your clothes to dry
  - For more tips see BC Hydro Power Smart
- Adopt green policies and practices within your organization.
- Raise awareness by continuing to post photos of king tides on social media using KingTidesBC and #KingTides.

Government Actions and Policy:

- Work urgently to eliminate fossil fuel emissions, a major driver of climate change.
- Update federal sea level rise projections more frequently as climate science advances.
- Update provincial policy guidelines more frequently as climate science advances.
- Develop policies to limit development of critical infrastructure in projected flood zones.
- Support or engage in studies to improve our understanding of how coastal impacts are going to affect ecosystem services people depend upon.
- Communicate sea level rise projections and government policies and guidelines to Canadians.
- Begin planning for retreat of key facilities and infrastructure from high flood hazard areas at the end of their service life.

Resources

NASA's earth minute on sea level rise
https://sealevel.nasa.gov/resources/72/nasas-earth-minute-sea-level-rise

Salish Sea Storm Surge Forecast
https://salishsea.eos.ubc.ca/storm-surge/forecast.html

See YaleEnvironment360 for a dated (2013) but balanced discussion on the uncertainties and challenges with predicting sea level rise. "The last time the planet was steadily two degrees C warmer than pre-industrial times, some 120,000 years ago, sea levels were five to 10 meters higher than today. It's likely we'll hit two degrees C of warming by 2100, unless we take extreme measures to mitigate emissions."
http://e360.yale.edu/features/rising_waters_how_fast_and_how_far_will_sea_levels_rise

NOAA Tides and Currents
tidesandcurrents.noaa.gov/

NASA Sea Level Change website
https://sealevel.nasa.gov/

United States Geological Survey:

- **Wave and Wind Projections along United States Coast**
  cmgwindwave.usgsportals.net/

- **Climate Change Impacts to the U.S. Pacific and Arctic Coasts**
  https://walrus.wr.usgs.gov/climate-change/lowNRG.html

- **Puget Sound Coastal Storm Modelling System**
  https://walrus.wr.usgs.gov/coastal_processes/cosmos/puget/index.html

10 things you should know about sea level rise
https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/05/20/10-things-you-should-know-about-sea-level-rise-and-how-bad-it-could-be/?utm_term=.3fa64cc3b9eb

Blog by Deborah Carlson, Staff Counsel at West Coast Environmental Law
https://www.wcel.org/blog/wading-science-sea-level-rise-bc-lags-behind

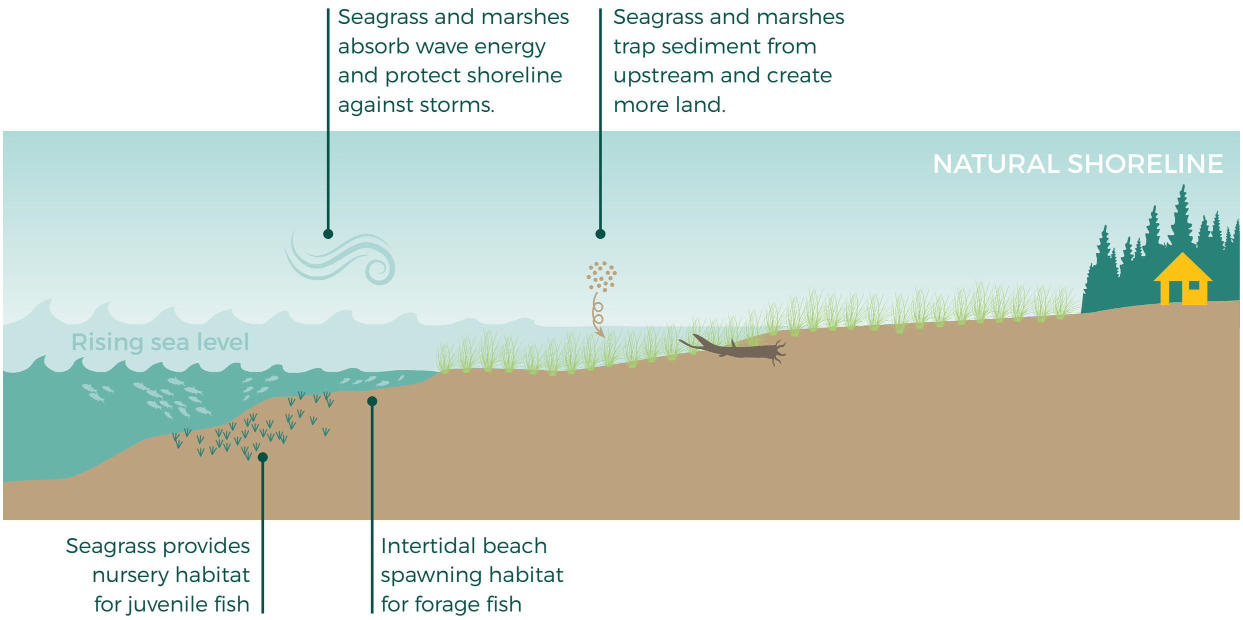
Natural Resources Canada Impact and Adaptation website
http://www.nrcan.gc.ca/environment/impacts-adaptation10761

and related Adaptation Library
http://www.adaptationlibrary.ca/

Natural Resources Canada – Climate and Climate-related Trends and Projections (last updated 2015)
www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2008/10261

Adaptation story from Puget Sound
https://www.eopugetsound.org/magazine/is/slr

Impacts of hard shorelines



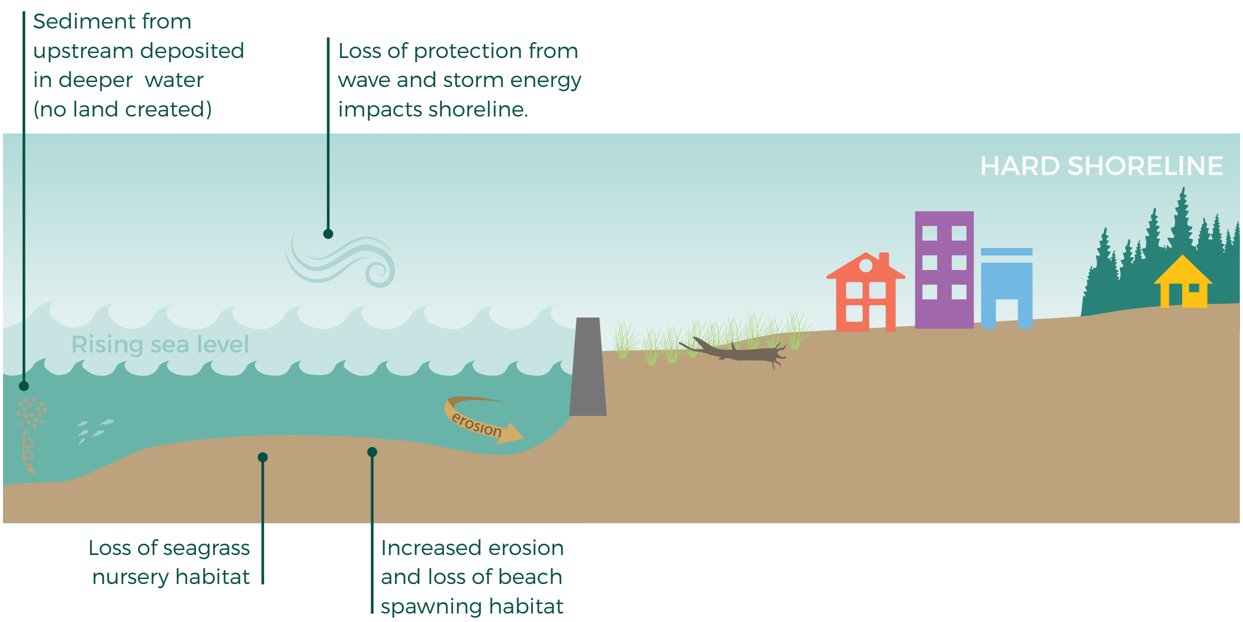


Photo: Mubnii M., Flickr, CC BY-ND 2.0

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[18] Hamlington et al 2016.

[19] James, T.S., Henton, J.A., Leonard, L.J., Darlington, A., Forbes, D.L., and M. Craymer. 2014. Relative Sea-level Projections in Canada and the Adjacent Mainland United States; Geological Survey of Canada, Open File 7737, 72 p. doi:10.4095/295574

[20] RPC8.5, high-emissions, and business-as-usual scenario, Church et al. 2013

[21] James et al. 2014

[22] E.g., Hamlington et al. 2016

[23] For examples, see https://walrus.wr.usgs.gov/climate-change/lowNRG.html

[24] Ausenco Sandwell. 2011. Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Guidelines for Management of Coastal Flood Hazard Land Use, prepared for B.C. Ministry of Environment. 15pp plus appendices. Accessed at http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/coastal_flooded_land_guidelines.pdf

[25] Lemmen et al. 2016.

[26] Readshaw, J., 2017. Discussion on sea level rise. [phone conversation with the author] (Personal communication, 23 June 2017).

[27] https://www.wcel.org/blog/wading-science-sea-level-rise-bc-lags-behind

[28] British Columbia Ministry of Environment. 2016. Indicators of Climate Change for British Columbia 2016 Update. Available at: http://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/reporting/envreportbc/archived-reports/climate-change/climatechangeindicators-13sept2016_final.pdf accessed May 31, 2017.

[29] Sea Level Rise Adaptation Primer prepared for the British Columbia Ministry of Environment, Fall 2013. Available at: http://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/resources/slr-primer.pdf Accessed July 11, 2017

[30] http://www.retooling.ca/_Library/docs/bc_sea_level_rise_en.pdf

[31] http://www.bio.gc.ca/science/data-donnees/can-ewlat/index-en.php

[32] Parris et al. 2012

Seafood

Photo: Ocean Wise

Summary

Overfishing is one of the biggest threats facing the global ocean today, with over 90 percent of the world's fish stocks fully fished or overfished. Yet, in B.C., commercial fisheries and aquaculture contribute hundreds of millions of dollars to the province's economy annually. Further, exports of B.C. seafood products have increased by 10 percent each year for the past few years. Maintaining healthy fish stocks isn't just critical for the health of B.C.'s environment; it is also a central issue for the economic sustainability of these industries. Achieving this balance is no easy task, but progress is being made.

The Ocean Wise Seafood Program has put the issue of sustainable seafood on the radar of consumers, fishers, suppliers, grocers, and restaurateurs throughout Canada. Since its inception in 2005, Ocean Wise has grown from 16 Vancouver partners to more than 700 nationally. It is also the only Canadian partner in the Global Seafood Ratings Alliance, which works to improve the effectiveness of seafood ratings around the world. In 2015, Ocean Wise launched its own assessment program for small-scale Canadian fisheries to promote local sustainable seafood options, and create livelihoods for responsible fishers, particularly in rural and First Nations communities.

Conservation aims have also driven change in Canada's commercial fisheries with the implementation of a sustainable fisheries framework, higher accountability for catch limits, and at-sea and dockside monitoring of groundfish species, bycatch and type of gear used. However, much of B.C.'s seafood sector harvest is due to an increase in aquaculture production – an industry that continues to attract criticism over its impact on ocean health. As the seafood industry continues to put pressure on our oceans – and face new challenges such as the impact of climate change – increased scrutiny, regulation and monitoring of all types of seafood harvest is needed.

Seafood Snapshot Assessment

Sustainable Seafood

Interest in sustainable seafood has grown exponentially since the Vancouver Aquarium established its Ocean Wise Seafood Program in 2005. To date, the program includes more than 700 partners and has recently launched its own monitoring program for small-scale Canadian fisheries.

HEALTHY

Industry Productivity

Seafood production contributes hundreds of millions of dollars to B.C.'s economy each year, with 2016 reaching over $400 million. But while the sector's value continues to grow, balance must be achieved between environmental sustainability and the economic wellbeing of those who work in the industry.

HEALTHY

Sustainable seafood options grow

AUTHOR
Dalal Al-Abdulrazzak, PhD, Ocean Wise Seafood Specialist

REVIEWER
Kurtis Hayne

What's happening?

In 2015, Ocean Wise (http://www.ocean.org/seafood) began conducting assessments of small-scale Canadian fisheries to promote local sustainable seafood options. To date, Nunavut arctic char, Clayoquot Sound gooseneck barnacles, Chedabucto Bay trap-caught shrimp, and British Columbia giant pacific octopus and sea cucumber have all been assessed and recommended as Ocean Wise. Previously Ocean Wise relied strictly on assessments done by others, including Seafood Watch, but this practice limited seafood options from small-scale Canadian fisheries.

Ocean Wise defines sustainable seafood as species that are caught or farmed in a way that ensures the long-term health of the stock as well as the larger marine ecosystem. Ocean Wise aims to educate and empower consumers to make informed seafood choices and works with seafood industry business partners (i.e., fisheries, suppliers, retailers, restaurants, etc.) to meet their commitments to sourcing and selling sustainable seafood. In turn, partners identify these options on their menus or in their display cases with the Ocean Wise symbol. Ocean Wise's classification system is based on two categories: Ocean Wise or Not Recommended. Species are updated or reclassified every 3–5 years with the latest scientific information, and these changes are communicated to Ocean Wise partners.

Photo: Ocean Wise

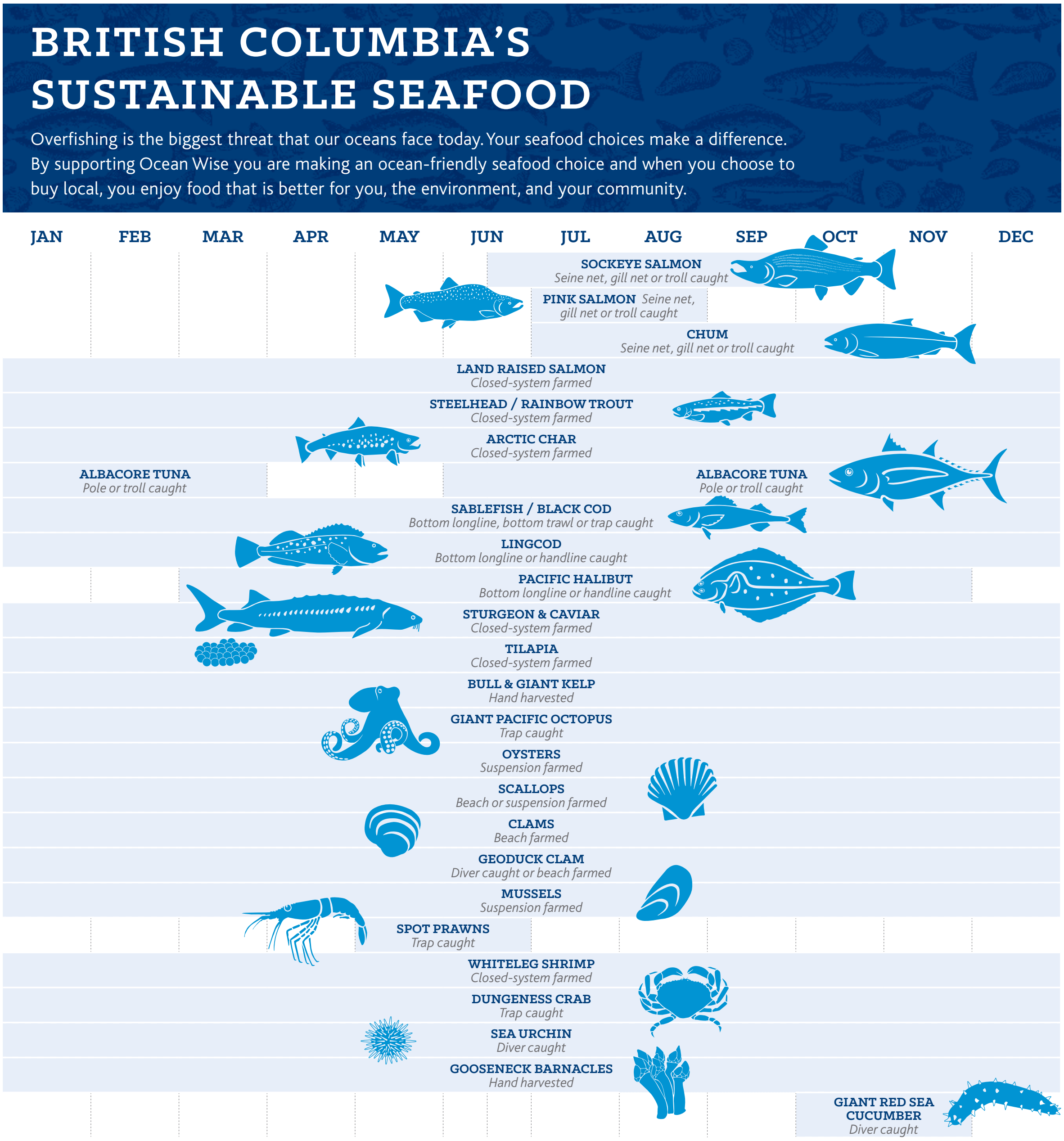
Why is it important?

Overfishing is one of the biggest threats facing the global oceans today. The UN Food and Agriculture Organization (FAO) estimates that 90 percent of the world's fish stocks are fully fished or overfished.[1] In 2014, Canada reported that 34 percent of major fish stocks were considered either critical or cautious,[2] while many other commercially exploited stocks lack the scientific information needed to determine their health.

A rising awareness of overfishing in the late 1990s and early 2000s, saw an increase in sustainable seafood initiatives aimed at creating consumer awareness. The Marine Stewardship Council (MSC) was formed in London, UK in 1996 and is the largest global eco-certification body. MSC certified fisheries meet specific environmental and management standards as well as undergo independent audits for verification in order to carry the eco-label. A similar organization for aquaculture, the Aquaculture Stewardship Council (ASC), was established in 2010.

In North America, many aquariums and non-governmental organizations (NGOs), such as Seafood Watch, took the lead in incorporating consumer-facing seafood recommendation programs into their outreach and education strategies. According to market research done by the Vancouver Aquarium, the most recognized seafood recommendation organization in Canada is the Ocean Wise Seafood Program, which was established in 2005. Unlike the MSC, Ocean Wise is not focused on auditing and certifying fisheries, but rather works largely with consumers, restaurants, and retailers to source and consume products recommended as 'sustainable' based on the rigorous science-based assessments of Seafood Watch and MSC.[3] The exception is the new work of Ocean Wise to assess small-scale Canadian fisheries based on Seafood Watch criteria. (For more information on rankings, certifications, and assessments see the Ocean Wise Standards webpage).[4]

Sustainable seafood choices are available throughout the year in B.C. (Figure 1).



For a complete list of Ocean Wise recommended seafood, visit **ocean.org/seafood**

Figure 1. Annual calendar of sustainable seafood choices in B.C.

Recent study asked why B.C. consumers eat fish

CONTRIBUTED BY
Karin Bodtker, MRM, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWED BY
Dr. Grant Murray, Associate Professor of Marine Policy, Duke University Marine Lab

A recent study (2017) into what matters most to British Columbians when they buy seafood at the supermarket found that taste, smell, and appearance ranked highest among 10 choices (Table 1).[1]

Table 1. Rank order of factors taken into consideration by supermarket shoppers when deciding to purchase seafood.

FACTORS	PERCENT OF RESPONDENTS WHO RANKED THIS #1
Taste, smell, and appearance	34
Farmed versus wild seafood	15.6
Price	12
Health benefits and nutritional value	12
Seafood is local	8
Sustainability of the species	4
Comfortable cooking or preparing seafood	3.4
Health risks such as allergies, mercury, etc.	2
Other	1
Cultural or religious reasons	0

Terms like "local" and "sustainable" were not defined for participants in the study, so people made these choices based on whatever those terms meant to them.

[1] Murray, G., Wolff, K., and M. Patterson. 2017. Why eat fish? Factors influencing seafood consumer choices in British Columbia, Canada. Ocean & Coastal Management 144: 16–22.

Another interesting finding was that shoppers, overall, seem to be consuming seafood less frequently than they did as children (Figure 1). 82 percent of respondents ate seafood at least once a month as a child, while only 67 percent ate seafood with that frequency in the last year. At the other end of the spectrum, 15 percent of consumers never or almost never (i.e., not in the last year) eat seafood, but only six percent of that same group did not eat seafood as a child.

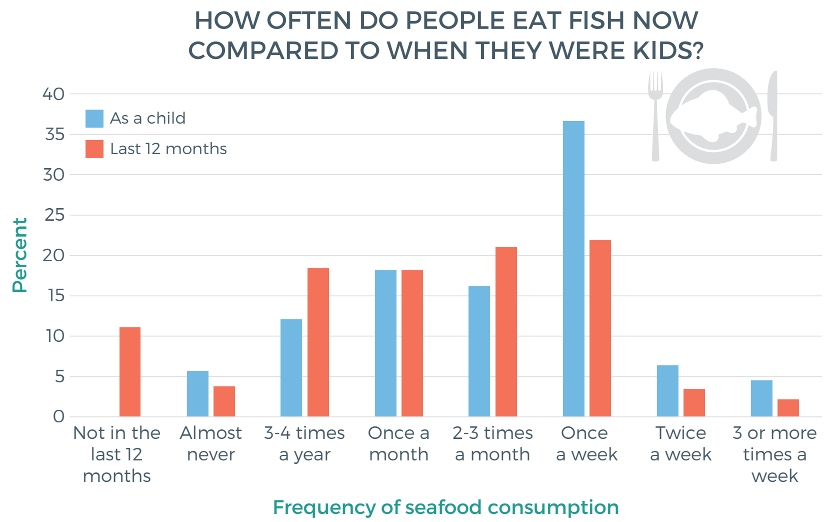


Figure 1. On average, B.C. supermarket shoppers reported consuming seafood less frequently in the last 12 months than they did as children.

Interpretation and generalization of this work is limited for a few reasons:

- Seafood was referred to generically and not by type or species;
- Key terms (e.g., farmed, sustainable, local) were not defined, so each consumer applied their own personal understanding;
- Consumers were surveyed only in grocery stores/supermarkets; and
- Recall of childhood seafood consumption is not perfect.

Is there a particular importance or connection to First Nations?

Within the sustainable seafood movement there is growing interest in ethical fisheries that give fair and equitable access to fisheries.[5] The only gooseneck barnacle (Pollicipes polymerus) fishery in North America occurs off the west coast of Vancouver Island in Clayoquot Sound, near Tofino (Figure 2). This fishery is co-managed by the Canadian Department of Fisheries and Oceans (DFO) and Nuu-chah-nulth First Nations. At present, the fishery is very small with only four groups of 2–3 individuals collecting barnacles from 48 designated harvest rocks. All fishers are members of the Nuu-chah-nulth First Nations and barnacles are gathered entirely by hand. In 2015, Ocean Wise conducted an assessment of this fishery and recommended it as a sustainable option.[6] Hand gathering is highly selective and this harvest method does not cause damage to the surrounding habitat and only causes minimal bycatch of attached mussels and juvenile barnacles.

Figure 2. Hand-picked gooseneck barnacles. (Photo: Ha'oom, T'aaq-wiihak Fisheries)

What is the current status?

Since 2005 Ocean Wise has grown from just 16 local Vancouver restaurant partners to over 700 partners nationally, including suppliers, distributors, and retailers (Figure 3). As consumer demand for sustainable seafood grows, Ocean Wise has likewise expanded to include larger buyers (such as primary producers and suppliers) on the supply chain who are likely to have a bigger market impact. Partners receive up to date sustainability recommendations, access to training and marketing materials, and also benefit from Ocean Wise promotion.

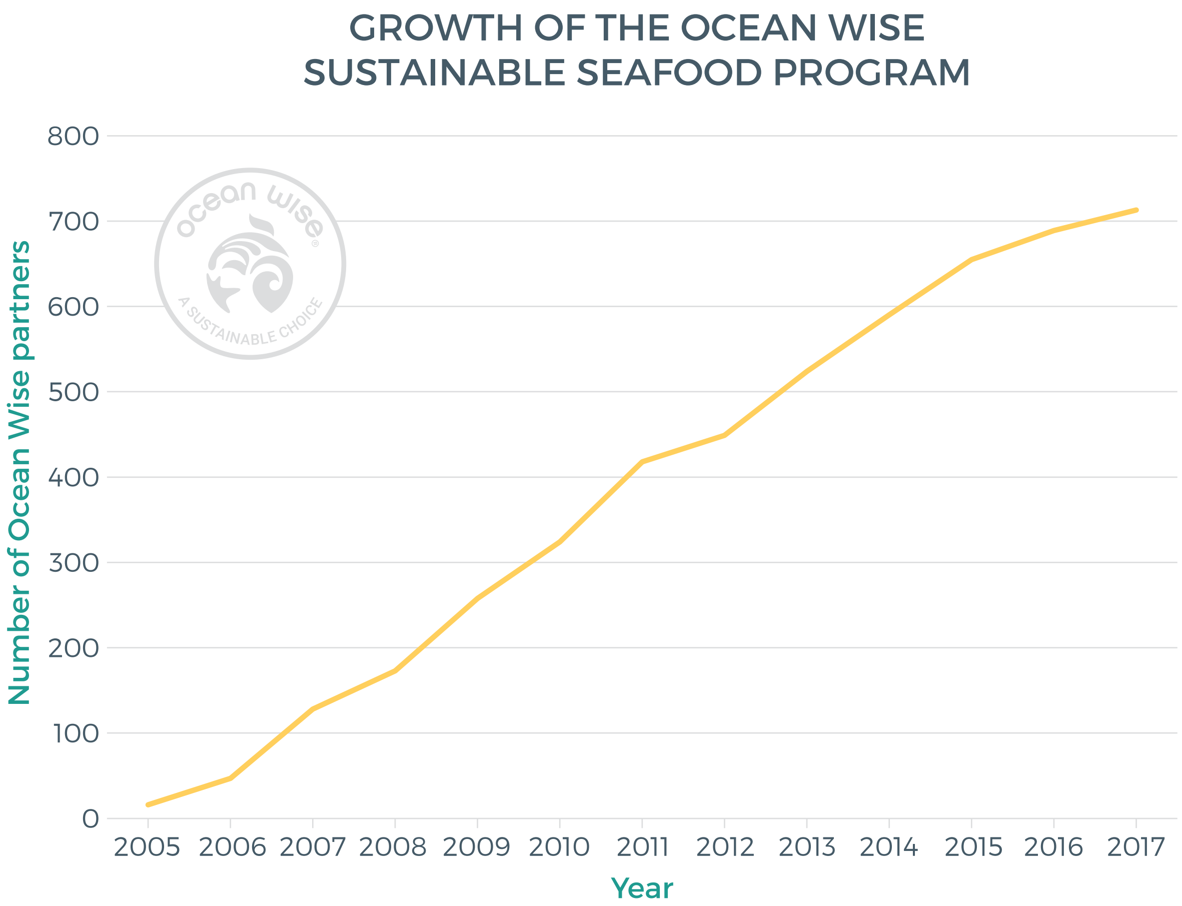


Figure 3. The Ocean Wise sustainable seafood program has shown steady growth since its inception in 2005.

What is being done?

In recognition of a need for better coordination between market-based sustainable seafood initiatives, 16 North American non-profit conservation organizations formed The Conservation Alliance for Seafood Solutions in 2008.[7] A key output of this collaboration was a roadmap with six realistic steps that companies can take to develop and implement a sustainable seafood policy. The original version was updated in 2016 to reflect changes in the sustainable seafood landscape and now includes recommendations to go beyond purely ecological standards and address social issues like human rights and labor exploitation.

As global interest in eco-labels has grown, the Global Seafood Ratings Alliance (GSRA) was formed to improve the effectiveness, efficiency, and influence of seafood ratings organizations around the world. To date, 13 partners from 11 countries (including Ocean Wise as the only Canadian partner) have committed to developing common tools and coordinated action in order to amplify their collective impact.

What can you do?

Individual and Organization Actions:

- Next time you're at the grocery store or a restaurant be sure to ask questions about what species it is, how it was caught or farmed, and where it is from.
- Look for the Ocean Wise symbol when buying seafood to ensure you are making the best choice for our oceans.
- Aim to eat lower on the trophic level – choose smaller forage fish such as sardines and mackerel, or farmed shellfish like clams and mussels, over larger fish such as salmon and halibut.
- Join a Community Supported Fisheries (CSF) such as Skipper Otto to connect with and purchase from local fishermen in your area.

Government Actions and Policy:

- Legislate improved seafood labelling in Canada (e.g., http://labelmyseafood.ca/).
- Allocate more resources to enforce fishery regulations and conduct regular scientific stock assessments of commercially caught species.
- Create more marine protected areas (MPAs) to allow fish stocks to recover.
- Eliminate harmful fishing subsidies of industrial fisheries that lead to overfishing and promote fuel-inefficient technology.

Resources

Skipper Otto Community Supported Fishery (CSF)
http://skipperotto.com/

Ocean Wise
www.ocean.org/seafood

Seafood Watch
www.seafoodwatch.org

Marine Stewardship Council (MSC)
www.msc.org

Ha'oom Nuu-Chan-Nulth Wild Seafood
http://www.haoom.ca/

Aquaculture Stewardship Council (ASC)
http://www.asc-aqua.org/

Sea Choice
http://www.seachoice.org/ and http://labelmyseafood.ca/

Conservation Alliance for Seafood Solutions
http://solutionsforseafood.org/

Global Seafood Ratings Alliance
http://globalseafoodratings.org/

Footnotes

[1] The State of World Fisheries and Aquaculture (FAO, 2016): http://www.fao.org/3/a-i5555e.pdf

[2] Canada's 5th National Report to the Convention on Biological Diversity: https://www.cbd.int/doc/world/ca/ca-nr-05-en.pdf

[3] http://seafood.ocean.org/seafood-guide/how-we-grade/

[4] Ocean Wise Standards webpage: http://seafood.ocean.org/seafood-guide/how-we-grade/

[5] McClenachan, L., Dissanayake, S. T. M. and X. Chen. 2016. Fair trade fish: consumer support for broader seafood sustainability. Fish and Fisheries, 17: 825–838. doi:10.1111/faf.12148

[6] http://www.oceanwise.ca/wp-content/uploads/2016/10/Barnacle-Gooseneck-Leaf-British-Columbia.pdf

[7] http://solutionsforseafood.org/resources/common-vision/

[8] http://globalseafoodratings.org/

B.C.'s seafood sector: total production hits a 20-year high, exports rise steeply

AUTHORS
Fiona Beaty and **Karin Bodtker**, Coastal Ocean Research Institute, an Ocean Wise initiative

REVIEWER
Jim McIsaac, Executive Director, T. Buck Suzuki Environmental Foundation

What's happening?

In 2016, gross domestic product (GDP) from B.C.'s seafood sector reached $415 million, the highest value in the last two decades.[1] This market value includes production from commercial fishing and aquaculture, but not seafood processing. Over the last two decades, real GDP[2] from aquaculture and commercial fisheries combined has fluctuated between $225 million and $400 million (Figure 1).[3]

Spot Prawn Festival 2017 (Photo: Ocean Wise)

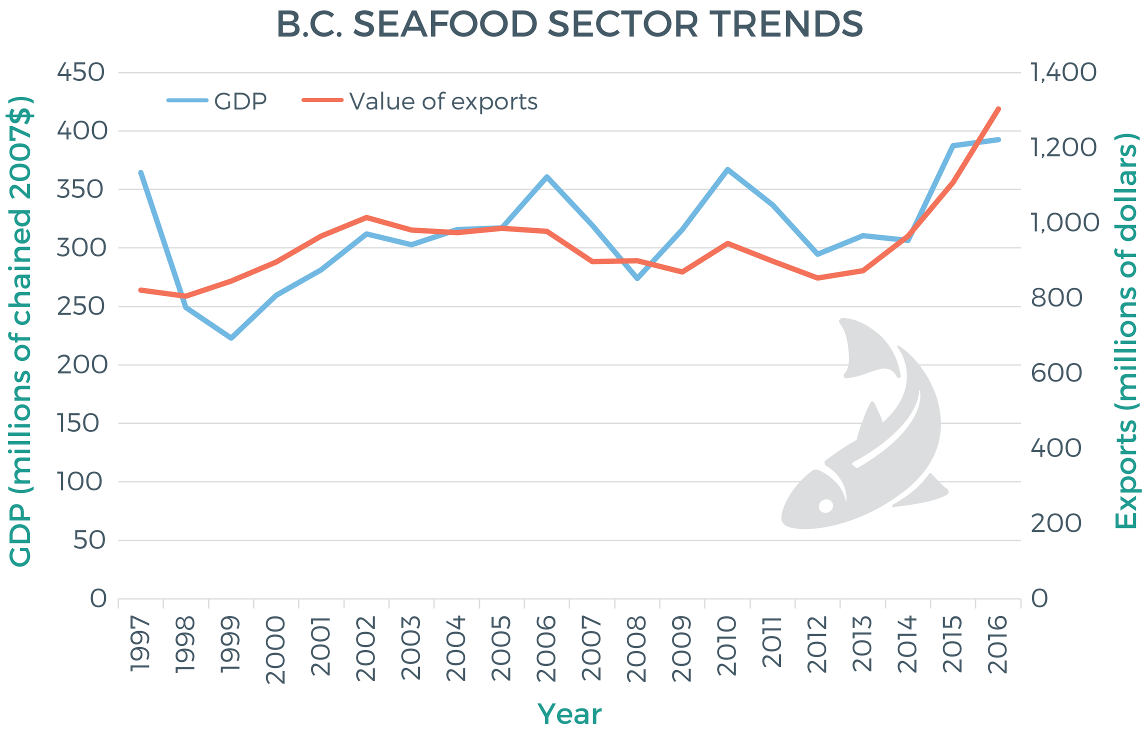


Figure 1. Real GDP for B.C.'s seafood sector is trending up in recent years, as is the value of exported seafood products. Source: Statistics Canada and B.C. Statistics

Photo: Ocean Wise

Further, exports of B.C. seafood products coming from commercial fisheries and aquaculture operations have increased by 10 percent or more for each year between 2013 and 2016.[4] B.C.'s top export, cultured Atlantic salmon, places the province in the top four global producers of this product, behind Chile, Norway, and the United Kingdom.[5] The increasing value of seafood exports reflects a growing demand for B.C. fish products outside of B.C. that will continue to expand as global population expands.

Increasing exports and stable or increasing productivity are positive signs for the seafood sector from an economic perspective. However, positive trends in GDP and the value of exports do not necessarily coincide with improvements in social wellbeing, nor do they reflect changes in the environmental sustainability of the sector. Considering the social, cultural, and environmental perspectives raises questions about whether seafood production is sustainably supporting livelihoods and healthy communities, and whether this level of extraction from the ocean is ecologically sustainable. (See articles in the Sense of Place and Wellbeing theme for discussions on social and community wellbeing. Find indicators of employment in the Coastal Development and Livelihoods theme.) Determining what may be a sustainable production level in ever-changing ecosystems and social systems is the task ahead for the sector, its managers, and consumers alike. Industry has made and continues to make considerable efforts toward ecological sustainability, and consumers are increasingly demanding to know where their seafood comes from, who fishes it, and how sustainably it is fished.

Photo: Ocean Wise

Why is it important?

B.C.'s commercial fishing and aquaculture production contributes hundreds of millions of dollars annually to the province's economy and GDP (Figure 1). GDP is used here as a measure of the sector's size and changes measure growth or shrinkage.[6] However, even in recent years of high production, B.C.'s seafood sector comprises less than 0.2 percent of total provincial GDP. This is down from 0.6 percent in 2005, which reflects a broader shift in economic importance away from resource extraction industries and to service-based industries.[7]

Interpreting the fluctuations in seafood production in the last few decades requires context. Driven primarily by economic and conservation values, changes in the management and structure of B.C.'s commercial fisheries, in particular the groundfish sector, over this time include:

- Mandatory 100 percent electronic or observer monitoring at-sea, and dockside monitoring of groundfish species by all gear types.
- Higher accountability for what and how much is caught.
- The adoption of Individual Transferable Quotas (ITQs).
- Spatial protection including Rockfish Conservation Areas,[8] frozen footprint for bottom trawl gear,[9] and integrated Marine Spatial Planning.[10]
- The implementation of the Sustainable Fisheries Framework (SFF).[11] The SFF includes policies such as the precautionary approach and ecosystem-based management.

The consequences of these changes are reflected in the industry's economic performance as well as other aspects including employment (see Seafood-related Employment article in the Livelihoods theme) and community and social wellbeing (see Fishing benefits coastal communities article in the Sense of Place and Wellbeing theme).

Attention to conservation and environmental impact has also confronted the aquaculture industry, and it suffers criticism on several fronts. Ocean health issues related to finfish aquaculture in particular include habitat conversion and pollution of the marine environment where farms are located, disease and parasites transfer from farmed organisms to wild ones, escape of farmed species threatening wild populations, and a feed regime that depends on wild-forage fish and uses more food energy than it produces.[12] Globally, the salmon aquaculture industry has made steady progress in reducing its reliance on feed originating from wild fish,[13] and the industry in B.C. is taking steps to reduce their environmental impact. Regulation of the industry passed from provincial to federal hands in 2010, which led to new regulations.[14] However, concerns remain that increasing production levels may be unsustainable due in part to environmental impacts.

What is the current status?

While GDP measures economic productivity, harvest is a measure of the biomass removed from the ecosystem. Seafood sector harvest reached 292 tonnes[15] in 2016, the highest value since 2005 (Figure 2).[16] The past three decades of change in the sector are reflected in the balance between aquaculture and wild-caught product. Aquaculture harvest has been increasing, almost without exception, since the 1980s when the salmon farming industry began in earnest, whereas the amount of wild seafood harvest has fluctuated (Figure 2). After considerable volatility for several decades, wild harvests – generally cyclic with larger climate cycles – have remained stable since 2007,[17] with a recent uptick in 2016. Wild-caught fishery dependence upon a resource that varies from year to year helps to explain the greater volatility in harvest levels.

The value of total fish products exported from B.C. has risen steeply in the last three years (Figure 1) to $1.3 billion.[18] These products went to 80 different mar-

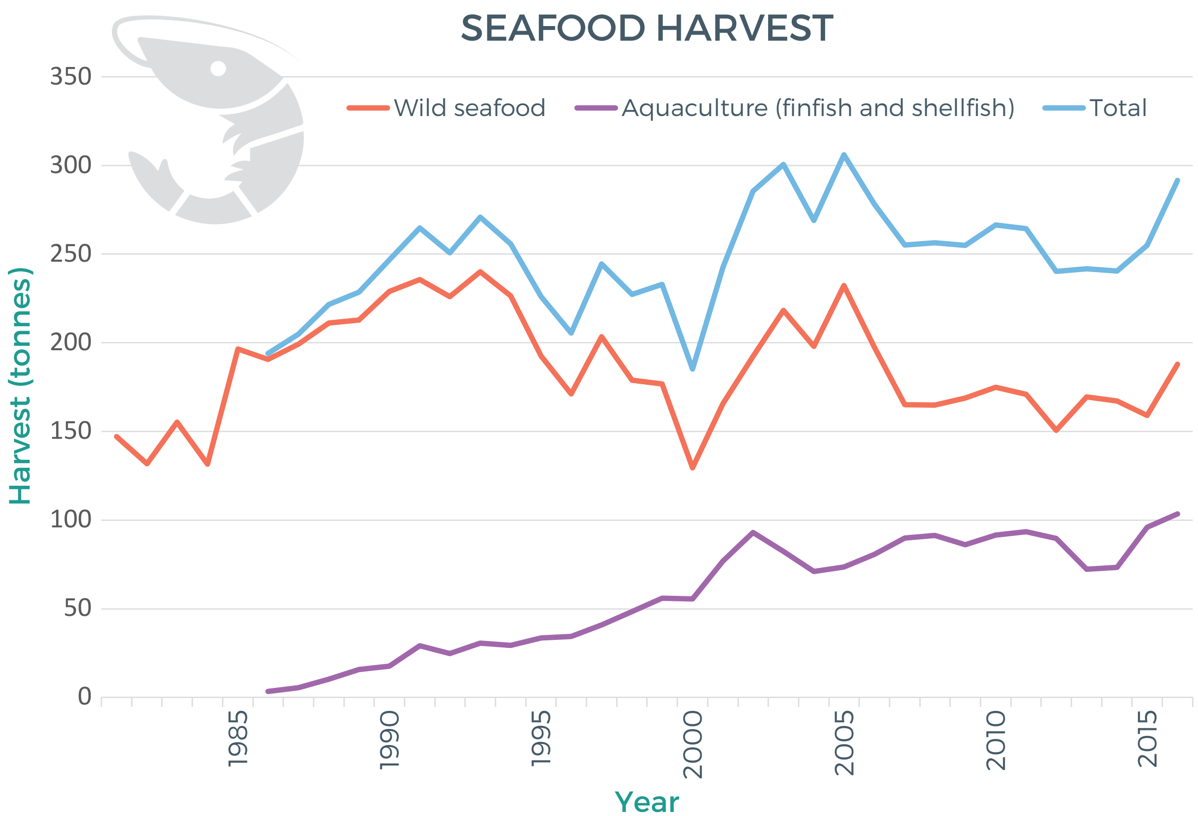


Figure 2. Seafood sector production in terms of harvest (tonnes) of wild and cultured seafood. Sources: Fisheries and Oceans Canada, BC Ministry of Agriculture, and Statistics Canada.

kets, with the biggest buyers being the United States, China, Japan, Ukraine, and Hong Kong.[19] The top five seafood exports were farmed Atlantic salmon, crabs, hake, shrimp and prawns, and herring.

Changing oceanic conditions associated with climate change pose a threat to the sustainability of B.C.'s seafood sector. We are witnessing changes including ocean acidification, increased sea surface temperature, and increased storm intensity and frequency. One example is the warm water "Blob"[20] off the coast from 2013 to 2016, which prompted unpredicted changes in species distribution and abundance. A direct consequence of changing conditions including increased ocean temperature and acidity, for example, is diminished growth rates of salmon[21] and some shellfish.[22] An indirect consequence of climate change is the projected increase in frequencies of harmful algal blooms (HABs) as ocean temperatures warm and storm intensity and frequency rises.[23] HABs make shellfish and farmed species unsafe for human consumption.

What is being done?

Regulating and managing commercial fisheries and aquaculture production, in terms of catch limits and licensed production limits,[24] is largely the purview of the Federal Government. DFO regularly consults with First Nations (see Governance article in Stewardship and Governance theme), industry and other interested sectors through advisory boards (e.g., the Groundfish Integrated Advisory Board). An advisory body for shellfish aquaculture includes First Nations, industry, and conservation representatives. The status of a similar advisory body for finfish aquaculture is unclear.[25] The B.C. government manages coastal aquaculture tenures and licenses marine plant cultivation.

Under the Fish and Seafood Act, the B.C. Ministry of Agriculture tracks reports submitted by all producers of B.C. seafood. These data are analyzed to inform the socioeconomic performance of the sector.[26]

Certification of wild fisheries and aquaculture operations expands every year, and not without controversy. In 2015, B.C. salmon farming companies attained five certifications through the Aquaculture Stewardship Council (ASC), but all certifications required a variance from the agreed upon limits (in the ASC Salmon Standard) for sea lice levels.[27] Also in 2015, the Marine Stewardship Council (MSC) recertified the British Columbia halibut and albacore tuna fisheries as sustainable. B.C. has six species harvested in 14 fisheries holding MSC certification including halibut, hake, albacore tuna, sockeye salmon, pink salmon and chum salmon.[28]

One example of an integrated approach to the management of ocean resources that combines bottom-up and top-down strategies is round table structures that provide the opportunity for various stakeholders to engage with fisheries management. For example, the West Coast of Vancouver Island (WCVI) Round Tables provide the opportunity for stewardship groups, and recreational, commercial, and First Nations fishermen to meet annually with DFO in order to discuss salmon harvest planning, management, and post-season review.[29]

What can you do?

Individual and Organization Actions:

- Know your fisherman: choose seafood options that support local fishermen and sustainable harvesting.
- Support B.C.'s buy local program: https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/programs/market-development-programs/bc-buy-local-program
- Purchase and eat sustainable seafood. Learn more at:
    - Ocean Wise Seafood Program: http://seafood.ocean.org/
    - Seafood Watch: http://www.seafoodwatch.org/seafood-recommendations/consumer-guides
    - Marine Stewardship Council: https://www.msc.org/track-a-fishery/fisheries-in-the-program/certified/pacific
- Demand improvements to seafood labelling and traceability requirements: SeaChoice, ThisFish
- Participate in citizen science efforts that support oceanic monitoring (e.g., Pacific Salmon Foundation's Salish Sea Marine Survival Project Citizen Science Program[30] and while on the ocean use the OceanSmart app to report interesting ecosystem events).

Government Actions and Policy:

- Undertake more frequent stock assessments to ensure annual quotas do not exceed sustainable harvest levels.
- Support investment in research for fisheries, sustainable aquaculture techniques and institutions.
- Support comprehensive monitoring of ocean socio-ecological systems, including environmental conditions to facilitate HAB detection and response.

Resources

Fisheries and Oceans Canada, Fisheries Management
http://www.pac.dfo-mpo.gc.ca/fm-gp/index-eng.html

Consultations
http://www.pac.dfo-mpo.gc.ca/consultation/index-eng.html

Province of BC Agriculture and Seafood Industry and Sector Profiles
https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/statistics/industry-and-sector-profiles

Footnotes

[1] BC Ministry of Agriculture. 2017a. Sector Snapshot 2016: B.C. Seafood. Accessed January 23, 2018. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/statistics/industry-and-sector-profiles/sector-snapshots/bc_seafood_sector_snapshot_2016.pdf

[2] Real GDP takes the inflation out of GDP figures and is used when examining trends in production. For example see: https://geozoneblog.wordpress.com/2013/02/19/gdp-real-gdp-and-chained-2005-dollars/

[3] Data source: Statistics Canada. Table 379-0030 – Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), provinces and territories, annual (dollars)

[4] Province of British Columbia. 2017a. Trade data, Annual B.C. exports. Accessed Dec 19, 2017. https://www2.gov.bc.ca/gov/content/data/statistics/business-industry-trade/trade/trade-data

[5] Province of British Columbia. 2017b. Agriculture and seafood industry and sector profiles. Retrieved from http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/statistics/industry-and-sector-profiles.

[6] Province of British Columbia 2017b

[7] BC Stats. 2007. British Columbia's Fisheries and Aquaculture Sector. Prepared for the BC Ministry of Environment. 108 pp. Accessed January 23, 2018. http://www.eaa-europe.org/files/bc-fisheries-aquaculture-sector-2007_7927.pdf

[8] Fisheries and Oceans Canada. 2017. Rockfish conservation areas. http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/rca-acs/index-eng.html

[9] Wallace, S., Turris, B., Driscoll, J., Bodtker, K., Mose, B., and G. Munro. 2015. Canada's Pacific groundfish trawl habitat agreement: A global first in an ecosystem approach to bottom trawl impacts. Marine Policy. 60: 240-248 DOI: 10.1016/j.marpol.2015.06.028

[10] For example, the PNCIMA Initiative (http://pncima.org/), and Marine Protected Area Network Planning for B.C.'s Northern Shelf (http://mpanetwork.ca/bcnorthernshelf/).

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[12] SeaChoice. 2018. Aquaculture. Accessed February 16, 2018. http://www.seachoice.org/info-centre/aquaculture/

[13] Ytrestøyl, T., Aas, T.S., and T. Åsgård. 2015. Utilisation of feed resources in production of Atlantic salmon (*Salmo salar*) in Norway. Aquaculture 448: 365-374. https://doi.org/10.1016/j.aquaculture.2015.06.023

[14] Fisheries and Oceans Canada (DFO). 2011. Aquaculture in British Columbia. Accessed January 23, 2018. http://www.pac.dfo-mpo.gc.ca/publications/pdfs/aqua_mgmt-gest_aqua-eng.pdf

[15] One tonne equals 2,204.6 pounds

[16] Data sources: Aquaculture 1986-2002 from archived Fisheries and Oceans Canada data accessed at http://www.dfo-mpo.gc.ca/stats/aqua/aqua95-eng.htm; Aquaculture 2003-2016 from BC Ministry of Agriculture Sector data accessed at https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/statistics/industry-and-sector-profiles#Seafood and originating at Statistics Canada; wild seafood 1981-1995 from archived Fisheries and Oceans Canada data accessed at http://www.pac.dfo-mpo.gc.ca/stats/comm/ann/index-eng.html; wild seafood 1996-2007 from archived Fisheries and Oceans Canada preliminary statistics accessed at http://www.pac.dfo-mpo.gc.ca/stats/comm/ann/index-eng.html; wild seafood 2008-2016 from BC Ministry of Agriculture Sector data accessed at https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/statistics/industry-and-sector-profiles#Seafood and originating from DFO.

[17] BC Stats. 2013. British Columbia's Fisheries and Aquaculture Sector, 2012 Edition. Prepared for the Department of Fisheries and Oceans Canada. 98 pp. Accessed January 23, 2018. https://www2.gov.bc.ca/gov/content/data/statistics/business-industry-trade/industry/fisheries-aquaculture

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