TSLEIL-WAUTUTH
THE PEOPLE OF THE INLET

BURRARD INLET ACTION PLAN

A science-based, First Nations-led initiative to improve the health of the Burrard Inlet ecosystem by 2025

Submitted by:

KERR WOOD LEIDAL
consulting engineers

TSLEIL-WAUTUTH NATION

Children of TAKaya – Wolf Clan

BURRARD INDIAN BAND

Message from Chief Maureen Thomas:

The Tsleil-Waututh people have lived along the shores of Burrard Inlet since time out of mind. The name Tsleil-Waututh means *People of the Inlet* in our *hən̓q̓əmin̓əm̓* language. Our ancestors, who numbered in the many thousands, maintained villages around Burrard Inlet and intensively used all of the natural resources there, especially marine and intertidal resources.

Tsleil-Waututh, like our Musqueam and Squamish relatives, has a long-held legal obligation to steward the water, land, air, and resources in Burrard Inlet. This stewardship responsibility includes restoring conditions that provide the environmental, cultural, spiritual, and economic foundation for our communities to thrive.

To that end, Tsleil-Waututh asked Kerr Wood Leidal Associates Ltd. (KWL) to develop a *Burrard Inlet Action Plan* as a way to map out how best to improve environmental conditions in Burrard Inlet.

The plan was built on a foundation of information collected during interviews with numerous experts, scientists, and resource managers around Burrard Inlet. It was further improved after incorporation of the comments provided at the first Burrard Inlet Science Symposium on May 19, 2016. I would like to extend my sincere gratitude for your participation in developing this plan.

We envision this plan as a key guidance document for a science-based, First Nations-led initiative to improve the health and integrity of Burrard Inlet.

The leads at Tsleil-Waututh for the plan are John Konovsky and Bridget Doyle. John can be contacted at 604-353-2106 or jkonovsky@twnation.ca. Bridget can be contacted at 778-838-2795 or bdoyle@twnation.ca.

Sincerely,

Chief Maureen Thomas

3075 Takaya Drive North Vancouver, B.C. V7H 3A8 Tel: 604-929-3454 Fax: 604-929-4714

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Acknowledgements

The *Burrard Inlet Action Plan* was developed by Kerr Wood Leidal Associates Ltd. (KWL) on behalf of the Tsleil-Waututh Nation (TWN). This document relied on collaboration between the TWN, KWL, and the willingness of numerous experts and resource managers to share their time and expertise providing relevant and up-to-date information. The authors are grateful for their contributions and would like to thank and acknowledge them.

Guidance and support for the *Burrard Inlet Action Plan* was provided by John Konovsky and Bridget Doyle of the TWN. Patrick Lilley and Peter deKoning were the primary authors of the plan. Laurel Morgan provided valuable comments and feedback which helped to improve the plan. KWL staff Mike Harvard and Shayna Scott provided administrative support to the overall project.

Tsleil-Waututh's traditional knowledge was provided by Mike George and Ernest (Iggy) George of the TWN.

The following individuals provided their knowledge, expertise, and information on Burrard Inlet through an interview process conducted to assist with development of this report:

Matt Foy	Fisheries and Oceans Canada
Sandie Hollick-Kenyon	Fisheries and Oceans Canada
Colin Levings	Fisheries and Oceans Canada (emeritus)
Doug Hay	Fisheries and Oceans Canada (emeritus)
Tom Therriault	Fisheries and Oceans Canada
Janice Boyd	Environment Canada
Liz Freyman	BC Ministry of Environment
Diane Sutherland	BC Ministry of Environment
Deb Epps	BC Ministry of Environment
Chris Harley	University of British Columbia
Leah Bendell	Simon Fraser University
John Clague	Simon Fraser University
Ken Ashley	Rivers Institute, British Columbia Institute of Technology
Peter Ross	Coastal Ocean Research Institute, Vancouver Aquarium
Rob Butler	Pacific Wildlife Foundation
Nikki Wright	SeaChange Marine Conservation Society
Ramona de Graaf	BC Shore Spawners Alliance
Michelle Gaudry	Georgia Strait Alliance
John Matsen	Squamish River Streamkeepers
Ian Collings	Teranis Consulting
Hugh McConnell	Consensus Infrastructure Solutions (formerly with GVRD)
Robyn Worcester	Urban Ecology Consulting (formerly with Stanley Park Ecology Society)

Executive Summary

The *Burrard Inlet Action Plan* ("Action Plan") is a founding guidance document for a new science-based, First Nations-led initiative to improve the health of Burrard Inlet by 2025. The purpose of the Action Plan is to:

- Summarize available scientific knowledge about Burrard Inlet and assess status and trends in the ecosystem for key topics of interest;
- Identify priority issues that continue to contribute to degradation or limit recovery;
- Identify important knowledge gaps and research needs;
- Foster development of a shared vision for environmental stewardship; and
- Identify strategic near-term actions that could be taken to improve the health and integrity of Burrard Inlet by 2025.

The *Burrard Inlet Action Plan* is not meant to be a regulatory document nor does it establish regulatory requirements. The Action Plan is a leadership and coordinating document meant to identify priorities and help focus the region around a shared, strategic environmental stewardship agenda for Burrard Inlet. The Plan is a "living document" that will be updated and adapted over time in response to monitoring results and new information. While its initial focus is on marine waters, eventually a more comprehensive review will be necessary that incorporates both the marine waters and all contributing uplands.

Status and Trends in the Burrard Inlet Ecosystem

An assessment of status and trends in the Burrard Inlet ecosystem based on existing scientific information and traditional knowledge had the following key findings:

- Long-term changes in physical water quality parameters, such as water temperature, salinity, dissolved oxygen, and pH are of concern. The extent to which changes observed to date are natural or human-caused is largely unknown. Climate change is expected to further impact physical water quality, with a wide variety of potential ecological impacts.
- Polluted water and contaminated sediments are broadly impacting environmental quality, affecting key species and food webs, and limiting human uses of Burrard Inlet. Primary contaminants of concern include pathogens, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and legacy persistent organic pollutants such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs). Levels of many contaminants still regularly exceed water quality objectives.
- Potential sources of contamination are diverse and not well characterized for most pollutants. Major sources of pollution include authorized industrial discharges, the Lions Gate Wastewater Treatment Plant, occasional combined sewer overflows and sanitary sewer overflows, urban and industrial stormwater runoff, contaminated sites, on-site sewage disposal, and spills of oil, fuel, and other hazardous substances.
- Over 93% of the historic extent of estuaries in Burrard Inlet has been lost due to development. Localized losses of other nearshore habitats such as eelgrass beds, kelp forests, and productive beaches have also been observed, although these declines and their causes are not well-documented.
- Approximately half of Burrard Inlet's shorelines have been altered and 53 km of natural shoreline has been lost. Shoreline alteration is highest in the Inner Harbour (90%) and lowest in Indian Arm (exact percentage not known). Shoreline alteration and hardening has had negative impacts on nearshore habitats and key species, and impacted circulation and sediment transport.

- Salmon, forage fish, shellfish, birds, and marine mammal populations have all declined from historic levels. While recovery in some salmon and bird species has been observed, other species are still declining. Commonly identified threats include loss of habitat and prey species, human disturbance, pollution, and climate change.
- Shoreline hardening, construction of overwater structures, and dredging appears to have changed circulation and sediment transport patterns and rates of deposition and erosion in some parts of Burrard Inlet (e.g., Central Harbour). Climate change is predicted to change yearly flow patterns in the Fraser River, with potentially significant impacts on circulation patterns and sediment transport into Burrard Inlet.
- Thirty-seven invasive non-native species have been identified in Burrard Inlet and its marine riparian area. Little is known about many of the marine species and their potential impacts.
- Climate change is predicted to raise sea level and change annual river discharge patterns, particularly for the Fraser River. Both could have significant detrimental impacts on Burrard Inlet.
- Emerging issues of concern in Burrard Inlet include newer contaminants (such as emerging persistent organic pollutants, pharmaceuticals and personal care products, and endocrine-disrupting chemicals), microplastics, and underwater noise pollution.

Another important finding of the status and trends assessment was that, in general, there is insufficient, up-to-date data to inform strategic environmental stewardship planning. Furthermore, existing research and monitoring efforts are not coordinated and information is not widely shared. Priority knowledge gaps and research needs that were identified include:

- Collecting up-to-date, high resolution data on physical water quality parameters;
- Identifying the locations of contamination hotspots;
- Improving mapping of important nearshore habitat types;
- Improving knowledge about forage fish populations and juvenile salmon migration routes and survival;
- Understanding the locations, sources, and potential effects of emerging pollutants; and
- Potential impacts of climate change on key species and habitats and large-scale physical processes.

What Does a Healthy Burrard Inlet Look Like?

Concerned about declining environmental quality within the marine waters of their territory, the Tsleil-Waututh Nation envisions a productive, resilient, and diverse Burrard Inlet ecosystem where:

- Healthy, wild marine foods can be harvested safely and sustainably;
- Water and sediment is safe and clean for cultural, spiritual, ceremonial, and recreational activities;
- Important habitats are plentiful, productive, and connected; and
- High levels of biodiversity and healthy populations of key species are viable and will continue to persist in the long term.

Near-term priorities for Tsleil-Waututh include re-opening Indian Arm to traditional shellfish harvesting, ensuring safe, clean water in the Central Harbour and elsewhere in Burrard Inlet for cultural and spiritual practices, and enhancing key estuaries.

Recovery Goals, Strategies, and Actions

Based on the findings of the status and trends assessment and the Tsleil-Waututh's vision of a healthy Burrard Inlet, five broad goals have been identified as critical to recovering the Burrard Inlet ecosystem:

Goal A: Improve water quality and reduce contamination;

Goal B: Protect and enhance fish and wildlife habitat;

Goal C: Protect and recover key species populations and food webs;

Goal D: Protect and restore supporting biophysical processes/ecological integrity; and

Goal E: Identify and track emerging issues.

To begin to work towards achieving these goals, 16 strategies and 66 actions have been identified which will contribute most significantly to ecosystem recovery in Burrard Inlet in the next 5 to 10 years.

Goal A: Improve water quality and reduce contamination	
Strategy A-1: Review and update water quality objectives for Burrard Inlet	
A-1.1	Initiate a Burrard Inlet Water Quality Monitoring Working Group.
A-1.2	Collate and share existing water and sediment quality and contamination information for Burrard Inlet.
A-1.3	Review and update the 1990 provisional Water Quality Objectives for Burrard Inlet.
Strategy A-2: Harmonize and improve water quality and pollution monitoring and reporting	
A-2.1	Develop standardized water and sediment quality sampling and laboratory methods to ensure consistency in future data collected among the various monitoring programs.
A-2.2	Advocate for increased and standardized compliance monitoring for authorized industrial discharges.
A-2.3	Support development and implementation of a new environmental quality monitoring program focussed on nearshore habitats to complement existing monitoring programs.
A-2.4	Expand water quality and flow monitoring for rivers, creeks, and stormwater outfalls entering Burrard Inlet.
A-2.5	Install a network of scientific instruments to continuously monitor physical water quality in Burrard Inlet in conjunction with Oceans Network Canada.
A-2.6	Coordinate monitoring with new efforts like the Vancouver Aquarium's *PollutionTracker* and Environment Canada's Cumulative Effects Monitoring Initiative.
A-2.7	Establish reporting format and report on the consolidated results of water quality and contamination monitoring.
Strategy A-3: Review, characterize, and prioritize sources of pollution	
A-3.1	Update the existing point source discharge inventory for Burrard Inlet to include new outfalls and point sources of pollution every five years.
A-3.2	Review monitoring, reporting, and oversight of authorized industrial discharges.
A-3.3	Characterize pollutant loadings from stormwater and other non-point sources of pollution to Burrard Inlet.
A-3.4	Conduct a review of information in the provincial Contaminated Sites Registry and federal Contaminated Sites Inventory on contaminated sites in close proximity to Burrard Inlet.
A-3.5	Update inventory and review status of on-site sewage disposal systems in Indian Arm in coordination with Vancouver Coastal Health.
A-3.6	Develop a water quality model and decision-support tool for Burrard Inlet for one or more pollutants of concern based on limiting pollutant loads to levels that allow achievement of water quality objectives.

Goal A: Improve water quality and reduce contamination	
Strategy A-4: Reduce levels of pollution from existing sources	
A-4.1	Actively participate in Metro Vancouver's liquid waste and air quality management planning initiatives for Burrard Inlet.
A-4.2	Develop an industry-specific eco-certification program to encourage adoption of best management practices for reducing non-point source pollution.
A-4.3	Develop a targeted, region-wide social marketing campaign focused on pollution prevention from specific industries and households.
A-4.4	Work with local governments to designate and keep Burrard Inlet as a no-discharge zone for boats.
A-4.5	Assess pump-out facilities and other discharge alternatives for recreational vessels in Burrard Inlet.
A-4.6	Advocate for phasing out the use of copper in automotive brake pads and shoes to reduce contamination in stormwater runoff from roads.
A-4.7	Advocate for adoption of provincial or federal laws and approaches to identify, reduce use of, or phase out and properly dispose of toxic materials, particularly those that persist or bioaccumulate in the marine environment.
Strategy A-5: Limit impacts from future discharges, new development, and spills	
A-5.1	Advocate for a regional requirement that new authorized industrial discharges consider projects in the context of cumulative effects to Burrard Inlet from all forms of development.
A-5.2	Advocate for municipal, regional, or provincial development standards that protect watershed health and the health of receiving environments such as Burrard Inlet.
A-5.3	Continue to improve spill prevention and response planning and execution for oil, fuel, and other types of hazardous spills in Burrard Inlet.

Goal B: Protect and enhance fish and wildlife habitat	
Strategy B-1: Map and monitor priority habitat types	
B-1.1	Update existing shoreline habitat inventories and classifications every five years to look at the amount habitat lost/gained over time.
B-1.2	Conduct more detailed mapping and assessment of trends in the extent and condition of important nearshore habitats, such as estuaries, salt marshes, tidal mudflats, eelgrass meadows, kelp beds, and productive beaches.
B-1.3	Map potential forage fish spawning habitat and develop a habitat suitability model for different species.
B-1.4	Conduct an analysis of the state of habitat compensation sites to assess function and quantify amount of productive habitat gained/lost over time.
Strategy B-2: Identify, prioritize, and protect high priority habitats	
B-2.1	Develop and regularly update a "top ten list" of the highest priority sites for protection.
B-2.2	Advocate for protection of identified high priority sites through acquisition, designation, or changes in management.
Strategy B-3: Identify and prioritize high priority sites for habitat restoration	
B-3.1	Develop a "top ten list" of the highest priority sites for habitat restoration and enhancement.
B-3.2	Continue to support the Burrard Inlet Estuary Restoration Pilot Program.
B-3.3	Conduct a pilot project to develop a comprehensive conservation strategy for one of the large, high priority nearshore habitat complexes in Burrard Inlet.
B-3.4	Support the development of guidance in best management practices for restoration techniques likely to be used in Burrard Inlet.

Goal B: Protect and enhance fish and wildlife habitat	
Strategy B-4: Reduce or manage threats to habitat	
B-4.1	Develop pilot projects, case studies, and best management practices for shoreline softening to encourage their wider use within Burrard Inlet.
B-4.2	Advocate for phasing out the use of new treated-wood pilings and other treated structures in freshwater and marine waters within the Burrard Inlet catchment.
B-4.3	Cover treated-wood pilings in areas of high density and where leaching may occur into vulnerable habitats.
B-4.4	Direct new shoreline development and outfalls away from vulnerable habitats.
B-4.5	Advocate for a policy of no net increase in shoreline hardening associated with shoreline development.

Goal C: Protect and recover key species populations and food webs	
Strategy C-1: Assess and monitor priority species populations	
C-1.1	Collate and develop a common database for salmon escapement data for Burrard Inlet rivers and creeks.
C-1.2	Further study the migration routes and survival of juvenile salmon in Burrard Inlet as they leave local rivers and creeks.
C-1.3	Conduct a study to assess use of Burrard Inlet by out-migrating juvenile salmon from the Fraser River.
C-1.4	Conduct a baseline study of forage fish use and develop a long-term forage fish stock assessment and monitoring program.
C-1.5	Expand regular bivalve surveys to other priority sites within Burrard Inlet and investigate the nature and extent of transition from native to invasive non-native species.
C-1.6	Continue to study how finfish and shellfish will be influenced by continued acidification of marine waters and potential ways to mitigate those impacts.
C-1.7	Participate in ongoing monthly bird surveys by Bird Studies Canada and Pacific Wildlife Foundation.
C-1.8	Collaborate with marine mammal monitoring through the B.C. Cetacean Sightings Network and other databases.
C-1.9	Develop and maintain a spatial database of occurrences for all priority species found in Burrard Inlet, including fish, birds, marine mammals, and marine invertebrates.
Strategy C-2: Manage unique threats to key species not covered by broader ecosystem-based approaches	
C-2.1	Identify and manage the sources of contamination to priority shellfish beds, and the possible role climate change may play in the frequency of harmful algal blooms.
C-2.2	Collect or collate information on harvest levels for commercially or recreationally harvested species and evaluate to assess whether levels are sustainable.
C-2.3	Work with the Vancouver Fraser Port Authority to mitigate the impacts of overwater structures and artificial lighting at night on fish species.

Goal D: Protect and restore supporting biophysical processes/ecological integrity	
Strategy D-1: Build our understanding of how Burrard Inlet functions as an interconnected system	
D-1.1	Improve knowledge of circulation patterns, sediment transport, and climate change-related impacts to circulation in Burrard Inlet.
D-1.2	Study impacts of shoreline hardening on erosion, deposition, and drift cell function.
Strategy D-2: Address threats to ecological integrity	
D-2.1	Support the BC Spartina Working Group's existing *Spartina* surveillance and control measures in Central Harbour and Port Moody Arm.
D-2.2	Develop an early detection rapid response program for high priority future invasive non-native species within Burrard Inlet.
D-2.3	Review existing ballast water management procedures to understand the potential risks of species introductions into Burrard Inlet.
Strategy D-3: Restore ecological integrity over time	
D-3.1	Seek to reduce or modify the influence of shoreline or overwater structures which have altered sediment transport and circulation patterns.

Goal E: Identify and track emerging issues	
Strategy E-1: Identify, characterize, and track emerging issues	
E-1.1	Conduct a review of emerging pollutants based on land use and industry types present in Burrard Inlet.
E-1.2	Advocate for continued study and information sharing on contaminants of emerging concern and microplastics in sewage treatment effluent and at sewer outfalls, and advocate for adoption of treatment technologies that remove contaminants of emerging concern.
E-1.3	Conduct a baseline study of marine debris and microplastics in Burrard Inlet to characterize extent of problem, specific sources, and effects on fish, wildlife, and the marine environment.
E-1.4	Support research on the effects of underwater noise on marine mammals in Burrard Inlet.
Strategy E-2: Take a proactive approach to managing emerging issues	
E-2.1	Promote proper disposal of pharmaceuticals and other contaminants of emerging concern.
E-2.2	Work with the Vancouver Fraser Port Authority, local municipalities, boating groups, and other stakeholder groups to reduce the amount of marine debris in Burrard Inlet.
E-2.3	Advocate for controls on the manufacture and sale of products containing microplastics as part of broader national and international efforts.

Monitoring and Adaptive Management

Monitoring the implementation of the actions that make up the Action Plan is an important part of ensuring its success. Developing a broader monitoring plan for Burrard Inlet should not seek to replace existing monitoring efforts but to better integrate and coordinate these efforts, streamline approaches, fill information gaps, and improve the availability of monitoring results and their use in the performance monitoring and adaptive management processes. Performance indicators and targets should also be developed from which progress can be measured and reported on. Thirteen potential performance indicators and targets are provided.

Potential Performance Indicators and Targets	
Indicator	**Related Performance Targets – By 2025**
Marine Water Quality	• All BC Ministry of Environment water quality monitoring sites attain provincial water quality guidelines.
Recreational Water Quality	• All monitored beaches meet the BC Ministry of Environment water quality guidelines for recreational water quality.
Marine Sediment Quality	• All sediment quality monitoring sites achieve Canadian Council of Ministers of the Environment (CCME) sediment quality guidelines for metals, PCBs, and PAHs.
Contaminants in Fish and Mammals	• Bioaccumulative contaminants (PCBs, PDBEs) measured in English sole are below threshold levels. • In response to PAHs and endocrine-disrupting contaminants, English sole in Burrard Inlet exhibit no PAH-related liver disease or toxics-related reproductive impairment. • Contaminant concentrations (metals, PAHs) measured in mussels are trending downward. • Bioaccumulative contaminants (PCBs, PBDEs) measured in harbour seals are trending downward.
Shellfish Beds	• At least 10 hectares of shellfish beds are open to limited harvesting at least 80% of the year. (Shellfish harvesting has been closed in Burrard Inlet since 1972.)
Estuaries	• An increase of 50 hectares in estuarine habitat basin-wide and an increase in at least 25% habitat area in each of five different estuaries.
Eelgrass	• *No target set at this time – baseline needed.*
Shoreline	• Total amount of shoreline hardening removed is greater than the total amount of new shoreline hardening (total metres removed > total metres added).
Salmon	• Stable or increasing trends in salmon returns to Capilano, Seymour, and Indian rivers relative to baseline period.
Herring/Surf Smelt	• *No target set at this time – baseline needed.*
Birds	• Stable or increasing trend in four key species relative to baseline period – Western Grebe, Barrow's Goldeneye, Surf Scoter, and Great Blue Heron.
Marine Mammals	• Increased number of key species of marine mammal sightings relative to baseline period.
Invasive Non-native Species	• Number of occurrences of *Spartina patens* in Burrard Inlet salt marshes has been reduced by 50% and the total coverage has been reduced by 75%. • By 2025, no new aquatic invasive non-native species have established.

Suggested reporting tools include implementation progress reports (every two years), ecological health report cards (every two years), and an online project atlas.

Implementation

To begin implementing the Action Plan, the following six strategic priorities are recommended as an initial focus of efforts:

Priority 1: Update Water Quality Objectives for Burrard Inlet

The current water quality objectives for Burrard Inlet were created in 1990 by BC Ministry of Environment as provisional objectives. They were developed to protect aquatic life, wildlife, and human recreation from pollution in the inlet. Water quality objectives define what can be considered clean, safe, or within the range of natural conditions. They represent important thresholds which can be used as triggers for remedial action and against which progress in environmental management can be assessed.

Updating the water quality objectives for Burrard Inlet would provide an initial focus for which to share and combine existing data, and begin to prioritize issues and solutions. Undertaking this task will require formation of a working group representing diverse interests. It is hoped that this initiative would lay the groundwork for further efforts and coordination to reduce or abate the sources of pollution.

Priority 2: Install Scientific Instruments to Monitor Water Quality in Burrard Inlet

High-resolution water quality data is essential for strategic environmental stewardship planning for the inlet. Lack of up-to-date data, particularly with respect to physical water quality, was identified as an important knowledge gap. At this time, scientific instruments that continuously monitor physical water quality are deployed in the Strait of Georgia and elsewhere in the Salish Sea, but not in Burrard Inlet. A priority should be placed on installing permanent instrument arrays at one or more key locations in the inlet to provide important water quality data.

Priority 3: Characterize and Reduce Pollution from Stormwater Runoff – Pilot Project on TWN Reserve

Stormwater runoff is likely the largest source of pollution to Burrard Inlet, but is one of the most challenging to manage. It is best addressed on a catchment-by-catchment basis consistent with the region's Integrated Stormwater Management Planning initiatives. Major pollutants of concern in urban stormwater typically include pathogens, metals, and PAHs.

Since the TWN Reserve in North Vancouver (Burrard I.R. #3) is one important location for cultural, spiritual, and ceremonial activities, characterizing and reducing pollutants in stormwater in streams originating upland, running through the reserve, and flowing into Burrard Inlet is recommended as a potential initial pilot project. This would involve bringing cutting-edge strategies, practices, and technologies to measure and improve stormwater quality, within the context of also addressing quantity-related impacts of stormwater to creeks and streams. The lessons learned through this pilot project could then be applied in other catchments around the inlet.

Priority 4: Map Nearshore Habitats and Forage Fish Spawning Beaches

The loss of habitat in Burrard Inlet has been identified as a primary driver of declines in key species of finfish, shellfish, birds, marine mammals, and many other species. Nearshore habitats, in particular small estuaries, eelgrass meadows, kelp beds, and productive beaches, have been extensively lost to urban, industrial, and port development. In addition, forage fish are an extremely important component of the food web in Burrard Inlet. They are the essential link between plankton and larger predators including fish, birds, and mammals. However, there is limited information on the locations of these habitat types within Burrard Inlet.

Efforts should be undertaken to map the locations of important nearshore habitats and forage fish spawning beaches and fill these two very important knowledge gaps for strategic environmental stewardship planning.

Priority 5: Conserve Critical Nearshore Habitat Complexes – Pilot Project at Maplewood Flats

As identified in Priority 4, the loss of nearshore habitat is a primary driver of environmental degradation and species declines. Development of a pilot project focused on reducing threats and improving environmental conditions at one of the larger, centrally-located nearshore habitat complexes should be a priority action.

Maplewood Flats is one of the largest intertidal habitat complexes as yet unaddressed in Burrard Inlet. The area has cultural, spiritual, and ceremonial significance for TWN members. It is also home to Wild Bird Trust of British Columbia, a non-governmental organization. A pilot project there can improve conditions by addressing numerous environmental issues including creosote piles, sediment contamination, substrate embeddedness, wood waste, depleted bivalve populations, and invasive species. It can also include restoration of another small estuary at the mouth of McCartney Creek.

Priority 6: Recover Shellfish Beds – Pilot Project in Indian Arm

Being able to once again safely harvest traditional wild foods, particularly bivalves, in Burrard Inlet is deeply important to the TWN. Its achievement will represent an important milestone in the environmental recovery of Burrard Inlet.

Shellfish health begins upland with controlling the sources of pollution, particularly pathogens. Significant progress on this issue has been achieved in Indian Arm. On October 26, 2015, the Canadian Shellfish Sanitation Program opened a small beach in Indian Arm for ceremonial harvest of bivalves. Additional investigation and correction of any sources of pollution in Indian Arm will ensure that progress to date is sustained and expanded. The lessons learned through this pilot project can be applied at other locations around the inlet.

Other Implementation Priorities

Other implementation priorities include continual improvement in spill prevention and response and phasing out the use of treated-wood pilings and other treated structures. Priority research questions include the effects and mitigation of acidification in marine waters, the sources and effects of marine debris and microplastics, underwater noise effects on marine mammals, and identifying the preferred migration routes for juvenile salmon through Burrard Inlet.

To build capacity and renew collaborative action on a shared strategic stewardship agenda for Burrard Inlet, the following additional measures are also recommended: developing informal partnerships to implement specific actions, forming of a scientific advisory panel, and developing a formal partnership model for Burrard Inlet stewardship between the Musqueam, Squamish, and Tsleil-Waututh Nations.

Introduction

Burrard Inlet is a saltwater body located in the heart of the metropolitan Vancouver region. Fed by mountain streams and strong tidal currents, the inlet provides valuable habitat for birds, fish, and wildlife. The inlet's productivity and abundance also made it a destination for successive waves of human settlement. Today, over two million lower mainland residents, along with visitors from across the world, depend on the inlet's economy and enjoy the recreational and scenic opportunities it offers.

The Tsleil-Waututh people have used, occupied, and governed Burrard Inlet and its surrounding catchment according to Coast Salish protocol for thousands of years. However, over the last 150 years, urban, industrial, and port development, pollution, and resource exploitation around the inlet have impaired its health and reduced the opportunity for Tsleil-Waututh and other local First Nations to utilize the waters and beaches of Burrard Inlet for traditional food harvesting and other cultural practices. Continued population growth, increased commercial activities, and proposed new infrastructure development will put further stress on this unique ecosystem over the coming decades.

In 1991, the Burrard Inlet Environmental Action Program (BIEAP) was initiated to coordinate and implement actions to begin to restore the health of the inlet. BIEAP partners included five government agencies: Environment Canada, Fisheries and Oceans Canada, BC Ministry of Environment, Lands, and Parks (now BC Ministry of Environment), the Vancouver Port Corporation (now the Vancouver Fraser Port Authority), and the Greater Vancouver Regional District (now Metro Vancouver). BIEAP's work was supported by municipalities and First Nations. In its 22 years of existence, BIEAP undertook many important initiatives and had some significant achievements. However, evolving mandates of the partner agencies, legislative changes, and a perceived reduction in the benefits from the interagency program led to the closure of BIEAP in March 2013.

Although progress has been made, many environmental issues persist, knowledge gaps remain, and some key actions have not yet been taken or are progressing slowly. Outcomes important to TWN have not yet been achieved, including reopening the inlet to shellfish harvesting, recovery of salmon populations, and the rebuilding of forage fish populations within the inlet. Continued resources must be put toward recovery actions in Burrard Inlet if progress is to continue. TWN believes that a science-based, coordinated approach to ecosystem recovery continues to be necessary to address priority issues and that by working with other First Nations, government agencies, and other groups, further progress can be achieved.

TWN has and continues to raise the profile of marine environmental quality issues and the need for greater emphasis on environmental stewardship in Burrard Inlet. As part of this leadership role, TWN commissioned the development of this *Burrard Inlet Action Plan*, a founding guidance document for a new science-based, First Nations-led initiative to improve the health of Burrard Inlet by 2025.

The purpose of the *Burrard Inlet Action Plan* is to:

- Summarize available scientific knowledge about Burrard Inlet and assess status and trends in the ecosystem for key topics of interest;
- Identify priority issues that continue to contribute to degradation or limit recovery;
- Identify important knowledge gaps and research needs;
- Foster development of a shared vision for environmental stewardship; and
- Identify strategic near-term actions that could be taken to improve the health and integrity of Burrard Inlet by 2025.

Development of the plan included a review of existing information and interviews with traditional knowledge holders, key experts, and resource managers to help identify important sources of data and information, critical knowledge gaps, and priority actions.

The *Burrard Inlet Action Plan* is organized into six sections:

- Section 1, Planning Context, provides an overview of the geographical and physical setting of the Burrard Inlet ecosystem, human uses, pressures, and describes several cross-cutting issues that provide important context to the plan.
- Section 2, Status and Trends in the Burrard Inlet Ecosystem, summarizes the current state of science and knowledge and assesses progress on environmental management in Burrard Inlet across five interrelated themes:
  - Water quality and contamination;
  - Fish and wildlife habitat;
  - Key species populations and food webs;
  - Biophysical processes/ecological integrity; and
  - Emerging issues.
- Section 3, What Does A Healthy Burrard Inlet Look Like?, presents TWN's vision for a healthy Burrard Inlet, near-term priorities, recovery goals, and several guiding principles for Burrard Inlet recovery.
- Section 4, Goals, Strategies, and Actions, presents 16 strategies and 65 near-term actions under five broad goals recommended to fill key knowledge gaps and to further recover the Burrard Inlet ecosystem over the next 5 to 10 years.
- Section 5, Monitoring and Adaptive Management, reviews existing monitoring initiatives, recommends potential performance measures and targets, and suggests a path towards a more integrated, coordinated monitoring program for Burrard Inlet.
- Section 6, Implementation, provides additional recommendations with respect to strategic priorities, leadership and collaboration, and funding for coordinated environmental action.

The *Burrard Inlet Action Plan* is not meant to be a regulatory document nor does it establish regulatory requirements. The Plan is a leadership and coordinating document meant to identify priorities and help focus the region around a shared, strategic environmental stewardship agenda for Burrard Inlet. The Plan is a "living document" that will be updated and adapted over time in response to monitoring results and new information. While its initial focus is on marine waters, eventually a more comprehensive review will be necessary that incorporates both the marine waters and all contributing uplands.

A healthy Burrard Inlet is important to TWN, other First Nations, to their partners, and to all citizens of the region. Similarly, First Nations, all levels of governments, industry, businesses, non-governmental organizations, volunteer stewardship groups, and the general public all have a role to play in protecting and restoring Burrard Inlet. This Plan will assist in initiating a new coordinated, integrated, and outcome-oriented action program for recovering the Burrard Inlet ecosystem.

1. Planning Context

1.1 Burrard Inlet – Physical Setting

Geographic Context

Burrard Inlet is part of the Salish Sea, a transboundary, estuarine ecosystem that encompasses the coastal waters and watersheds of the Strait of Georgia, the Strait of Juan de Fuca, and Puget Sound in southwestern BC and northwestern Washington. Named for the Coast Salish First Nations who have lived around the sea for over 10,000 years, the Salish Sea is one of the largest, most biologically rich inland marine ecosystems in the world. The area supports approximately 172 bird species, 37 mammal species (Gaydos and Pearson, 2011), 247 species of fish (SeaDoc Society, 2015) including all seven species of Pacific salmon[1], and populations of almost 120 threatened and endangered species, such as Southern Resident Orcas (*Orcinus orca*) (Gaydos and Zier, 2014). The Salish Sea is the primary rearing area for salmon that migrate out of many of BC and Washington's coastal rivers, including the Fraser River.

Of the seven million people that live within the drainage basin of the Salish Sea, 1.1 million live in the municipalities that border Burrard Inlet. This includes seven municipalities: the City of Vancouver, City of Burnaby, City of Port Moody, Village of Belcarra, District of North Vancouver, City of North Vancouver, and District of West Vancouver.

Physiography

Burrard Inlet is unique among inlets of coastal British Columbia. The inlet is heavily influenced by freshwater inputs from the Fraser River, lacks a sill at the seaward edge, and has six distinct basins, several of which are fairly shallow (Thompson, 1981). Burrard Inlet is also surrounded in part not by mountains but by relatively flat lands, a fact that made it highly suitable for human settlement and development as a major harbour on the West Coast of Canada. Only at its most inland portion in Indian Arm is the inlet a true fjord (Thompson, 1981).

From its outer boundary connecting Point Atkinson to Point Grey, Burrard Inlet covers 11,300 ha and stretches from the Strait of Georgia back 30 km to the head of Indian Arm. The total length of shoreline is approximately 190 km (BIEAP, 2011; Haggerty, 2001; Stantec, 2009). The inlet can be naturally divided into six basins with distinctive attributes: the Outer Harbour (including English Bay), False Creek, Inner Harbour, Central Harbour, Port Moody Arm, and Indian Arm (BIEAP, 2011) (Figure 2-1).

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[1] Fisheries and Oceans Canada recognizes seven species of Pacific salmon in British Columbia: Chinook (*Oncorhynchus tshawytscha*), sockeye (*Oncorhynchus nerka*), coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*), pink (*Oncorhynchus gorbuscha*), steelhead (*Oncorhynchus mykiss*), and cutthroat trout (*Oncorhynchus clarki*). The latter two species were formerly in the genus *Salmo* and classified as trout but scientists have concluded they are more like Pacific salmon and have reclassified them to the genus *Oncorhynchus*.

Catchment Area

The catchment area for Burrard Inlet covers 98,000 ha (BIEAP, 2011). Land cover ranges from subalpine meadows to dense mature forest to extensive industrial and urban areas. With the exception of upper Indian Arm, development is common throughout and generally concentrated near the inlet's shoreline.

Approximately 112 streams feed into Burrard Inlet (Balanced Environmental Services, 2010), 17 of which are known to have salmon (Haggerty, 2001). An additional 40 streams have been lost due to development (DFO, 1995). The Capilano, Seymour, and Indian Rivers are the most significant sources of freshwater, as well as the water from the Upper Coquitlam River watershed via the Buntzen Lake diversion from the Coquitlam Reservoir (Haggerty, 2001). Capilano and Seymour are regulated rivers, with inline reservoirs that provide Metro Vancouver's water supply. The Indian River is unregulated. Other important streams include Lynn Creek, Mosquito Creek, Mackay Creek, and McCartney Creek on the North Shore, as well as Noons Creek, Schoolhouse Creek, and Mossom Creek near Port Moody (Haggerty, 2001).

Influence of Freshwater

Burrard Inlet is considered estuarine due to the influence of freshwater inputs (Davidson, 1979). Relatively fresh water flows toward the mouth of the inlet, overlying saltier water underneath coming from the Strait of Georgia (Haggerty, 2001). In addition to the 112 streams that flow into the inlet, the Fraser River exerts enormous influence on circulation patterns, physical and chemical attributes, and ecological processes. During spring freshet, which peaks in May and June, the Fraser River supplies the Outer Harbour with large volumes of brackish water, lowering salinities, increasing turbidity and lowering light levels, depositing sediments, and reducing primary production (Levings *et al*., 2004; Stockner and Cliff, 1979; Stone *et al.*, 2013). Furthermore, the Fraser River supplies many juvenile salmonids that extensively utilize the nearshore areas of Burrard Inlet (MacDonald and Chang, 1993).

Currents and Tides

Currents and tides play important roles in circulation patterns of water and sediments, the mixing of water and flushing of the inlet, as well as creating and nourishing important habitat in both deep water and intertidal areas. The Inner and Central Harbours get flushed as tides move in and out of the inlet (Li and Hodgins, 2004). Daily tides range an average of 3.1 m, and the maximum tide range is 4.9 m (BIEAP, 2011; Levings *et al*. 2004). Currents can reach 11 km/hr through First and Second Narrows (BIEAP, 2011). After the water moves through each Narrows, it slows down and forms eddies as it moves east into the Inner and Central Harbours. In the Inner Harbour, an eddy moves clockwise to the south and counter-clockwise to the north. In the Central Harbour, two clockwise eddies form to the south and a counter-clockwise eddy forms to the north by Maplewood Flats. These eddies reverse direction as the water moves out (Haggerty, 2001). Marine foragers, such as seabirds and marine mammals, are attracted to these areas of natural upwelling created by the eddies (Stone *et al.*, 2013).

Temperature

Water temperatures in the inlet are influenced by many factors: temperatures in the Strait of Georgia, tides, runoff, winds and water from the Fraser River. A thermocline exists in much of the inlet, where 5 m of warmer, fresher water sits on top of colder, more saline water. Water temperatures can reach 20°C in the shallow waters of the Outer Harbour and Port Moody Arm, but temperatures drop 5–10°C below the thermocline. Temperatures reach a maximum of 15°C in the Inner and Central Harbour basins. Winter temperatures drop to 6–8°C (Haggerty, 2001).

Salinity

Salinity is strongly influenced by the Fraser River, with salinities varying greatly at the surface, while being more consistent at depth. Plumes of low salinity water from the Fraser River can penetrate past First Narrows into the Inner Harbour. In deep water, salinity is 29–30%. At the southwest of the Outer Harbour, surface salinity can be 10% and becomes approximately 20% as you reach the North Shore (Levings *et al*., 2004). As the waters are mixed through First Narrows, salinities become more consistent. Summer salinity ranges from 18–20%; winter salinities are 20–26% (Haggerty, 2001). Peak freshwater inputs in the inlet coincide with spring freshet from the Fraser River (May and June); high winter rainfall in local rivers increases freshwater inputs. In Indian Arm, salinities reach their lowest, approximately 10%, about midway between head of Indian Arm and its entrance to the Central Harbour, and reach about 15% at the entrance (Thompson, 1981).

Dissolved Oxygen

Studies in the 1960s and 1970s found dissolved oxygen (DO) levels in Burrard Inlet were well above the levels that would impair marine organisms (5–10 mg/L) in the Inner Harbour, and even DO levels at the bottom of Port Moody Arm were 6 mg/L (Levings *et al.*, 2004). However, more recent monitoring since the early 1990s has shown dissolved oxygen (DO) levels in Burrard Inlet are frequently low (< 6.5 mg/L) at lower depths (Bull and Freyman, 2013). While DO levels near the surface are generally not thought to be a problem, they are of some concern at depth. In the deep water of Indian Arm, DO levels can drop to less than 1 mg/L (Levings *et al*., 2004). Though low DO levels in Indian Arm are thought to be naturally occurring, in much of the inlet, it is not clear to what degree low DO levels have been exacerbated by human causes (Bull and Freyman, 2013). Trends in DO levels are also not well-known.

The Basins

Burrard Inlet is comprised of six major basins which vary in their physiographic conditions (Figure 1-1; Figure 1-2):

Outer Harbour (5600 ha)

The Outer Harbour is the westernmost basin, bounded by First Narrows to the east, and to the west by a line connecting Point Atkinson in West Vancouver and Point Grey at the west end of the University Endowment Lands. The eastern end of the Outer Harbour is also known as English Bay. The Outer Harbour is 45 m deep on average, and is approximately 100 m deep at its mouth (Haggerty, 2001). There has been little industrial development in the Outer Harbour, but much of the shoreline has been hardened with seawalls and filled for residential development. In the southwest, there are extensive sand and mudflats, which act as a nursery ground for flatfish (MacDonald and Chang, 1993). Much of the southern shoreline is beach, and historically, the eastern beaches in English Bay were augmented with sand placements. Beaches in West Vancouver are mostly cobble and gravel, though some were augmented with sand in the past as well (BIEAP, 2011). Beaches in Point Grey and in West Vancouver are important spawning grounds for forage fish (R. de Graaf, pers. comm.).

False Creek (77 ha)

False Creek is a small and shallow arm (4–8 m deep) connected to the southeast corner of the Outer Harbour (BIEAP, 2011). It is the most built-up of the basins, with no natural shoreline or riparian area remaining, though recent developments have included habitat creation projects. The surrounding area is highly urbanized and developed. Historically, numerous streams flowed through salt marshes and tidal flats into False Creek, creating a rich ecosystem that supported clams, oysters, crabs, mussels, and many fish species (FCWS, 2007). However, the marshes and tidal flats were filled to create industrial land in the early 1900s.

Inner Harbour (1540 ha)

The Inner Harbour stretches 8.8 km from First Narrows in the west to Second Narrows in the east. An 18 m deep sill at First Narrows and a 14.5 m deep sill at Second Narrows separate the Inner Harbour from the Outer Harbour and Central Harbour, respectively (BIEAP, 2011). Depths in the Inner Harbour average 21 m and reach 66 m at its deepest point. It is well-circulated and flushed regularly by the tides and currents between the Narrows. This basin is also one of the most industrialized, with over 80% of the shoreline altered (Stantec, 2009). The Inner Harbour is home to significant port activity, with container and bulk terminals, as well as roads and rail lines connecting the harbour to regional and continental transportation networks. Three (3) major streams flow into the Inner Harbour: Mackay Creek, Mosquito Creek, and Lynn Creek.

Central Harbour (890 ha)

The Central Harbour is 7.8 km long and is bounded by Second Narrows to the west and Port Moody Arm and Indian Arm to the east. Like the Inner Harbour, it is tidally mixed and well-flushed. Depths range from 17–65 m (BIEAP, 2011). The shoreline of the Central Harbour is less developed than the Inner Harbour, with mostly natural or semi-natural armoured shoreline (riprap) (Stantec, 2009).

Maplewood Conservation Area and its associated tidal mudflats, commonly known as Maplewood Flats, are an important protected habitat area in the northwest corner of the Central Harbour. According to Tsleil-Waututh community members, Maplewood Flats was once home to significant eelgrass and kelp beds. Erosion of the shoreline is a concern in the Central Harbour (Stantec, 2009). The Seymour River and Lynn Creek once shared a significant estuary and delta which extended out into Burrard Inlet at what is now Second Narrows. Maplewood Flats, including the McCartney Creek estuary, is a remnant of the east end of this large delta.

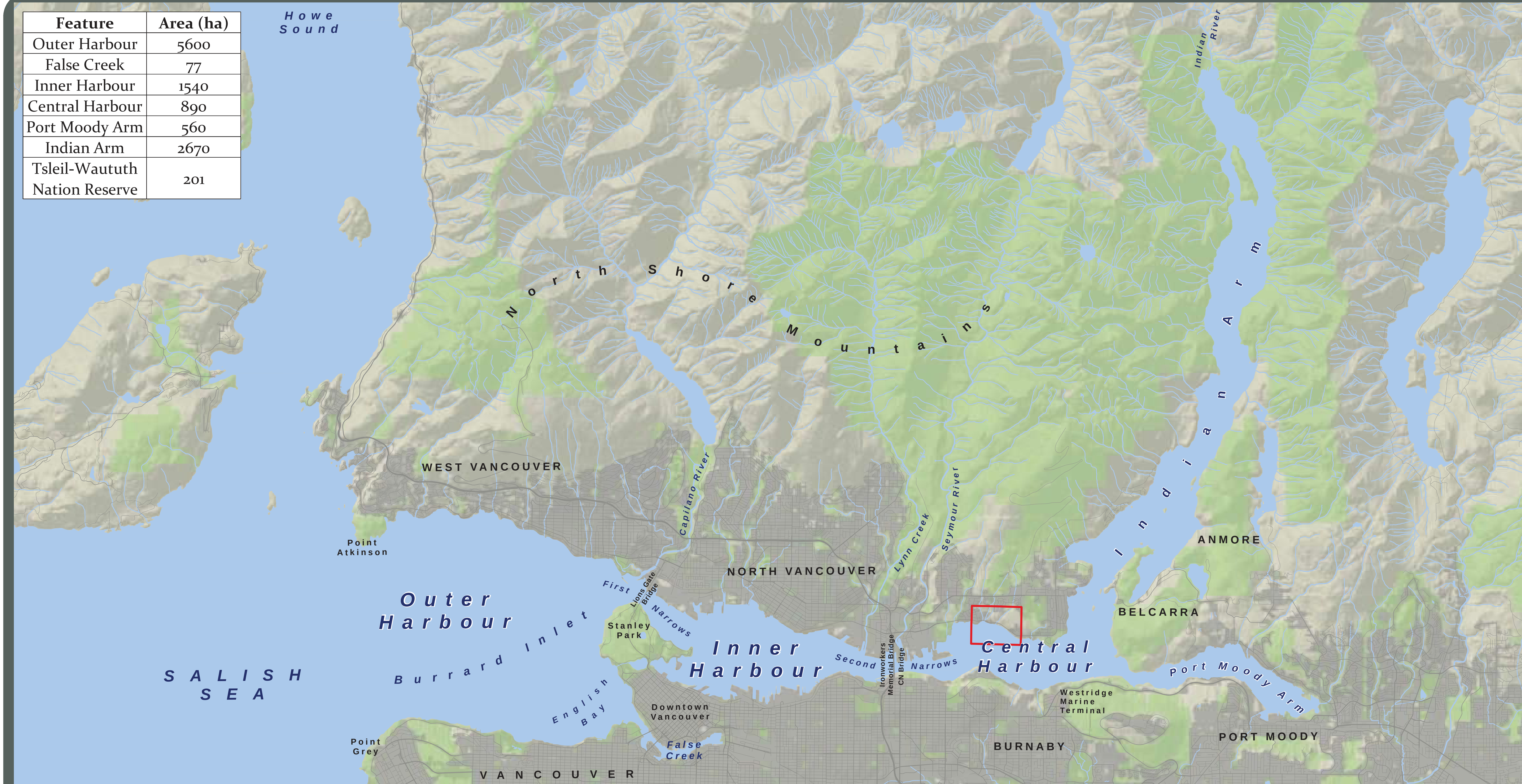
Port Moody Arm (560 ha)

Port Moody Arm is a shallow (10 m deep on average) water body at the eastern end of Burrard Inlet. It is slow-circulating with minimal freshwater inputs (BIEAP, 2011). The stable water column, high temperatures, and high nutrient levels make it the most biologically productive basin in the inlet, containing the highest levels of phytoplankton and plant growth (Stockner and Cliff, 1979). Port Moody Arm has important ecological value due to the low levels of altered shoreline, intact riparian areas, and high-value tidal flats in the eastern end. Ten main tributaries flow into Port Moody Arm and support chum, coho, and Chinook salmon. Port Moody Arm at Reed Point also hosts a population of giant pink sea stars (Village of Belcarra, 2014). Industrial development, including saw mills, oil refineries, and shipping terminals, was prevalent from the early 1900s along the shores of Port Moody Arm, impacting its ecological health. As the amount of industry has disappeared from the arm, ecological health has been improving (City of Port Moody, 2011). Shoreline erosion is also a concern in this basin (Stantec, 2009).

Indian Arm (6900 ha)

Indian Arm is the largest of the six basins and a true coastal fjord. It is characterized by deep water (mean depth of 120 m and a maximum depth of 218 m) and bounded by steep-sided mountains. Located at the northeast end of Burrard Inlet, Indian Arm is separated from the Central Harbour by a 27 m deep sill at the entrance (BIEAP, 2011). Freshwater from the Indian River moves across the surface of the inlet towards the Central Harbour, although water exchange is limited. Full replacement of water in Indian Arm can take 7–10 years (BIEAP, 2002a). Indian Arm is the most pristine of the basins in Burrard Inlet, with limited pollution issues. It is the least productive basin in the inlet (Stockner and Cliff, 1979), with cold, clear waters. Dissolved oxygen is low in deep waters (<1 mg/L) but this might be a natural occurrence (Levings *et al*., 2004). Much of the Indian Arm shoreline remains undeveloped and the surrounding land is forested and part of Say Nuth Khaw Yum Provincial Park. There are also two rockfish conservation areas in Indian Arm. Say Nuth Khaw Yum Provincial Park is collaboratively managed by the Tsleil-Waututh Nation and BC Parks.

Feature	Area (ha)
Outer Harbour	5600
False Creek	77
Inner Harbour	1540
Central Harbour	890
Port Moody Arm	560
Indian Arm	2670
Tsleil-Waututh Nation Reserve	201



Tsleil-Waututh Nation
Burrard Inlet Action Plan

Figure 1-1: Burrard Inlet Sub-Basins

Legend

- Developed Area
- Parks and Protected Areas
- Tsleil-Waututh Nation Reserve

Map Scale: 1:60,000
Projection: UTM, NAD 83, Zone 10
0 1.25 2.5 5 Kilometers

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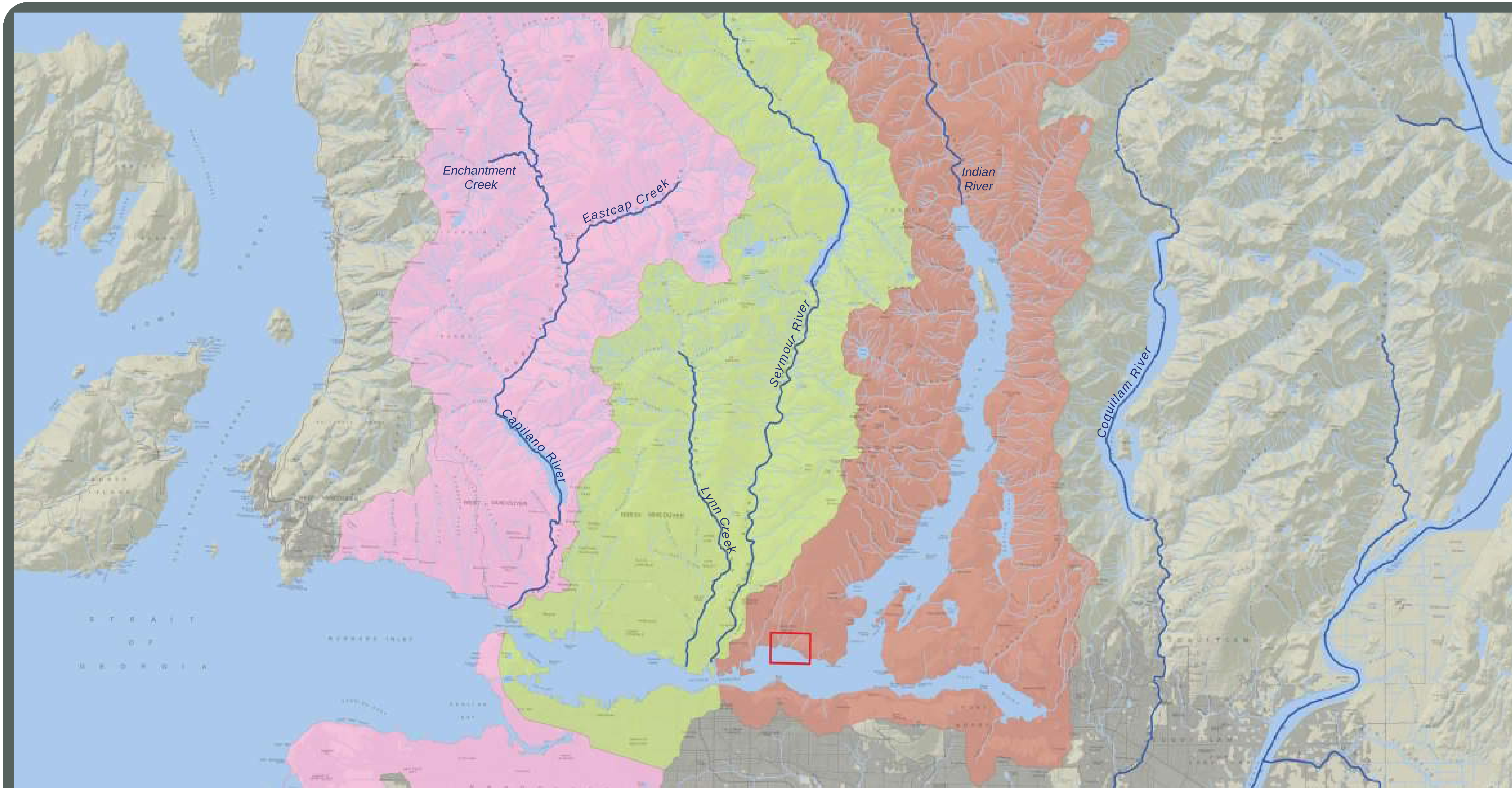

Tsleil-Waututh Nation

Burrard Inlet Action Plan

Figure 1-2: Burrard Inlet Drainage Catchments with Major Rivers and Creeks

Legend

- Outer Harbour Catchment
- Inner Harbour Catchment
- Central Harbour, Port Moody Arm, and Indian Arm Catchment
- Major Creeks and Rivers
- Tsleil-Waututh Nation Reserve

Map Scale: 1:75,000

Projection: UTM, NAD 83, Zone 10

0 1.5 3 6 Kilometers

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Ecological Significance

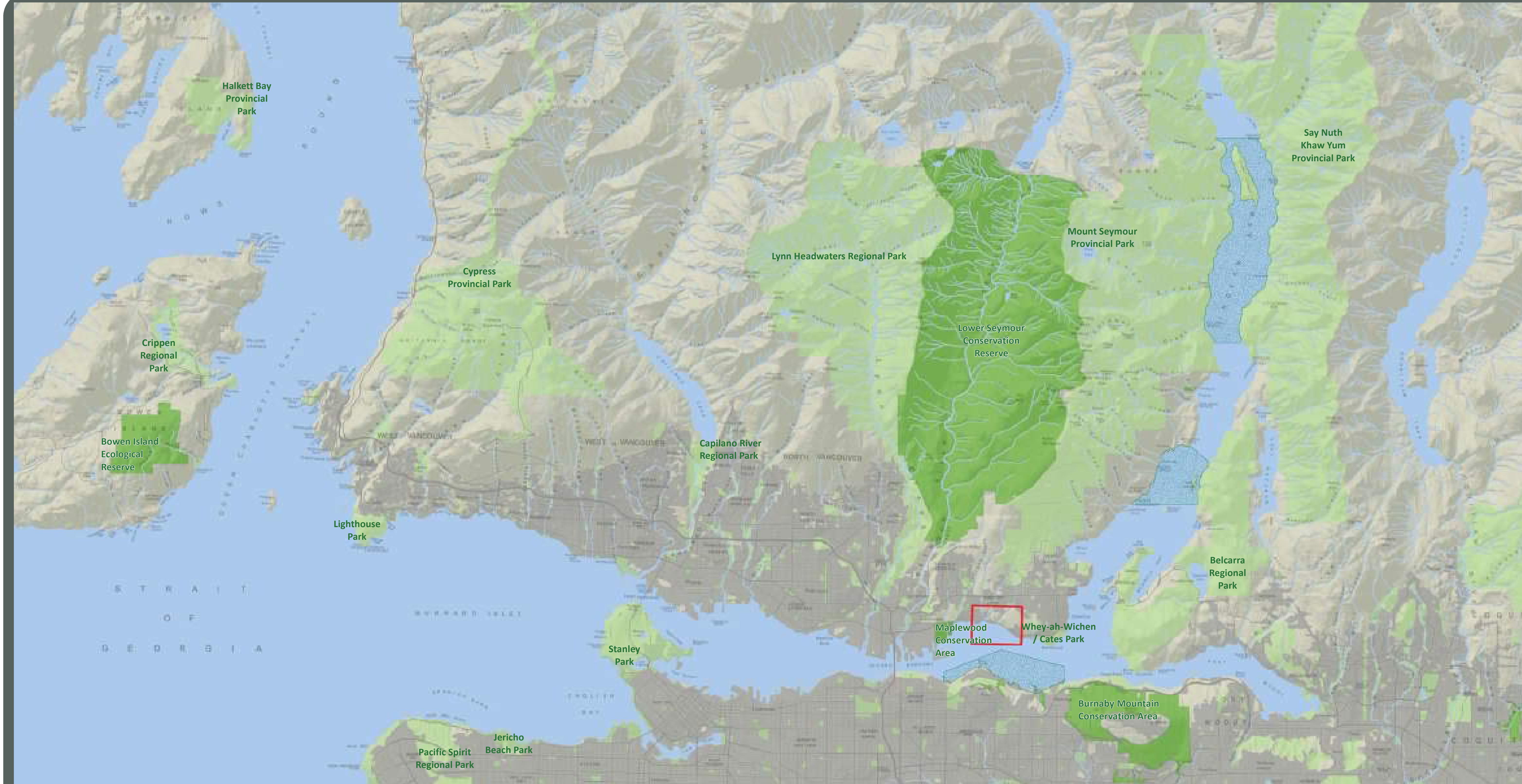
Despite high levels of development and human activity, Burrard Inlet is still rich in biodiversity and functions as a significant component of the broader Salish Sea ecosystem:

- The inlet and its catchment is home to over 1,200 species including mammals, birds, fish, reptiles, amphibians, tunicates, arthropods, molluscs, vascular and non-vascular plants, marine algae and sea grasses, fungi, and plankton (Stone *et al.*, 2013).
- Seventy-five species of fish have been identified, including all of the flatfish species found in the northeast Pacific Ocean (City of Port Moody, 2011; Haggerty, 2001; Levings *et al.,* 2004).
- All seven species of North American Pacific salmon utilize Burrard Inlet's rivers and creeks for spawning. Salmon use the entire inlet in the early stages of their life cycle and during migration (Levings *et al*., 2004).
- Fifty-three of the 172 bird species that inhabit the Salish Sea ecosystem are known to use Burrard Inlet during all or a portion of the life cycle, including murrelets, grebes, sea ducks, herons, loons, coots, alcids, plovers, Black Oystercatchers (*Haematopus bachmani*), kingfishers, goldeneyes, Pigeon Guillemots (*Cepphus columba*), Bald Eagles (*Haliaeetus leucocephalus*) and Osprey (*Pandion haliaetus*) (Gaydos and Pearson, 2011; Stone *et al.,* 2013). Burrard Inlet is internationally-recognized as an Important Bird Area (IBA) and supports globally-significant populations of three species, Western Grebe (*Aechmophorus occidentalis*), Barrow's Goldeneye (*Bucephala islandica*), and Surf Scoter (*Melanitta perspicillata*), and nationally-significant population of one species, Great Blue Heron (*Ardea herodias*) (BSC, 2015).
- Sightings of orcas (*Orcinus orca*), grey whales (*Eschrichtius robustus*), harbour porpoises (*Phocoena phocoena*), and other smaller cetaceans are infrequently but consistently reported from Burrard Inlet (BCCSN, 2015). More common resident marine mammals include river otters (*Lontra canadensis*) and harbour seals (*Phoca vitulina richardsii*).

Parks and Protected Areas

The largest protected area in and around Burrard Inlet is Say Nuth Khaw Yum Provincial Park, which encompasses much of the shoreline of central and north Indian Arm. Other large parks include Belcarra Regional Park, Jericho, Locarno, and Spanish Banks Beach Parks, Pacific Spirit Regional Park, Stanley Park, Whey-ah-Wichen (Cates Park), Lighthouse Park, Barnet Marine Park, and Maplewood Conservation Area. Across the catchment areas of Burrard Inlet, approximately 66% of the land is currently protected, although a high proportion is in the North Shore Mountains or around Indian Arm (Jacques Whitford AXYS, 2008).

Currently, the only marine protected areas are three rockfish conservation areas, one along the south side of the Central Harbour, and two within Indian Arm (Twin Islands and Croker Island).



Tsleil-Waututh Nation

Burrard Inlet Action Plan

Figure 1-3: Major Parks and Protected Areas in Burrard Inlet

Legend

- Conservation Area or Ecological Reserve
- Park (Local, Regional, Provincial, National)
- Developed Area
- Rockfish Conservation Zone
- Tsleil-Waututh Nation Reserve

Map Scale: 1:60,000
Projection: UTM, NAD 83, Zone 10
0 1.25 2.5 5 Kilometers

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1.2 Tsleil-Waututh Land and Resource Use in Burrard Inlet

The Tsleil-Waututh people are Coast Salish, sharing customs and interests with other First Nations and tribes around the Salish Sea. According to Coast Salish concepts of land tenure and territoriality, the water, land, air, and resources of Tsleil-Waututh territory are their birthright. They have a profound obligation to both their ancestors and future generations to protect and care for the water, land, air, and resources and to fulfill their stewardship obligations and responsibilities.

The Tsleil-Waututh are the "People of the Inlet". They have occupied, governed, and acted as stewards of their territory since time immemorial. Tsleil-Waututh ancestors did so at contact (AD 1792) and at the time of the British Crown's assertion of sovereignty (AD 1846), and they continue to do so today.

Prior to contact, many Tsleil-Waututh villages existed in eastern Burrard Inlet. Several thousand Tsleil-Waututh people occupied these sites. The villages were strategically located in defensible and typically sheltered locations where rich intertidal resources were found.

All of Burrard Inlet was within easy daily travel distance of Tsleil-Waututh village sites. Most distant were the Indian River, at the head of Indian Arm, and the beaches west of what is now Stanley Park. Tsleil-Waututh people could travel anywhere in Burrard Inlet within two hours from their villages, and they did so to meet their daily needs. Even reaching the Fraser River from the south shore of Burrard Inlet took less than two hours' walking time.

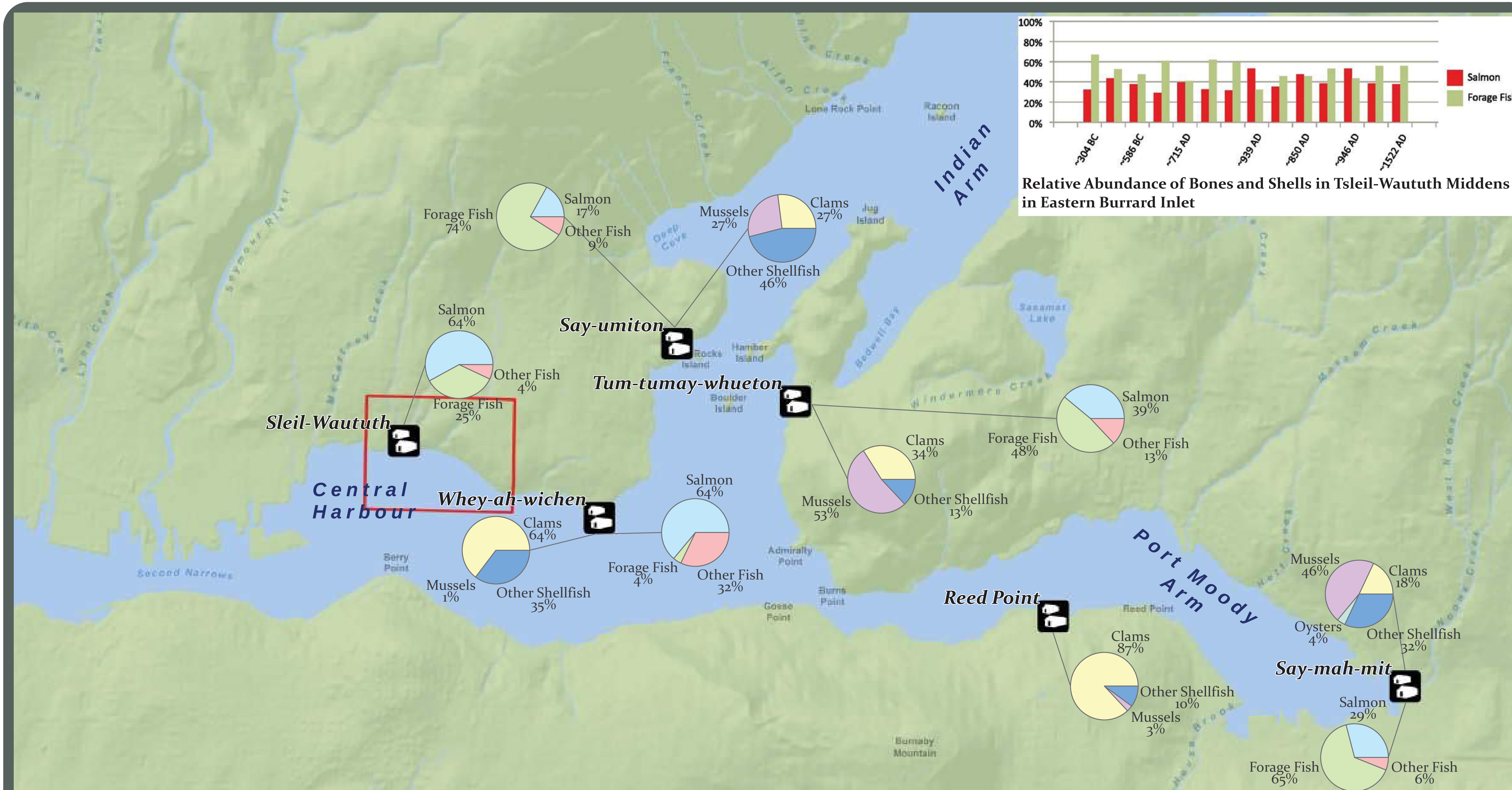
Tsleil-Waututh used sophisticated technology for mass harvesting and storing abundant marine foods. They maintained a series of resource harvest camps and followed a seasonal round of travel and activity. Their ancestors took full advantage of all aspects of the natural environment. Their seasonal round extended beyond Burrard Inlet to include other areas.

Tsleil-Waututh's subsistence economy was based on access to and use of natural resources as staple foods for both the living community and their ancestors. It included trade with other Coast or Interior Salish communities. It was strongly oriented toward marine resources, especially salmon, herring, clams, and birds. It also included extensive use of land and river environments for harvesting a wide range of animals, plants, and technological resources. The Tsleil-Waututh used all environments of their territory and beyond, from mountaintops to the open sea.

As part of their stewardship responsibilities, the Tsleil-Waututh Nation is actively implementing laws, policies, and actions that aim to ensure a healthy and prosperous future for their people, water, land, air, and resources. They use their stories, traditions, and knowledge to understand how cumulative effects of development have affected their environmental and cultural values.

The archaeological record confirms elements of resource harvest spoken of in their oral history. The record spans more than 2,500 years, from approximately 750 BC to around AD 1850. It shows that for physical nourishment prior to contact, Coast Salish people, including Tsleil-Waututh, obtained 90% or more of their protein from marine species (Chisholm *et al.*, 1983).

Tsleil-Waututh protein sources can be identified from the rich array of discarded bones and shells found in the shell middens excavated around eastern Burrard Inlet (see Morin, 2015; Pierson, 2011; Stantec, 2011; Lepofsky *et al*., 2007; Trost, 2005; Ham and Yip, 1992; Charlton, 1974; Williams, 1974). Finfish such as salmon and various species of forage fish were all abundant in Burrard Inlet. While salmon are a well-recognized food source, forage fish, in particular herring but also to some extent surf smelt, sardine, sand lance, eulachon, and anchovy, were a more important food source at some places and times. Shells from bivalve shellfish species such as clams and mussels, and bones from mammals and birds, including marine species such as seals, are also present in the archaeological record. These resources provided the protein necessary to feed the Tsleil-Waututh people.



Tsleil-Waututh Nation

Burrard Inlet Action Plan

Figure 1-4: Relative Abundance of Bones and Shells in Tsleil-Waututh Middens in Eastern Burrard Inlet

Legend

Finfish Bones
- Salmon
- Forage Fish
- Other Fish

Shellfish Shells
- Clams
- Mussels
- Oysters
- Other Shellfish

Tsleil-Waututh Nation Village Site (with Archaeological Information)

Tsleil-Waututh Nation Reserve

Map Scale: 1:20,000
Projection: UTM, NAD 83, Zone 10
0 0.25 0.5 1 Kilometer

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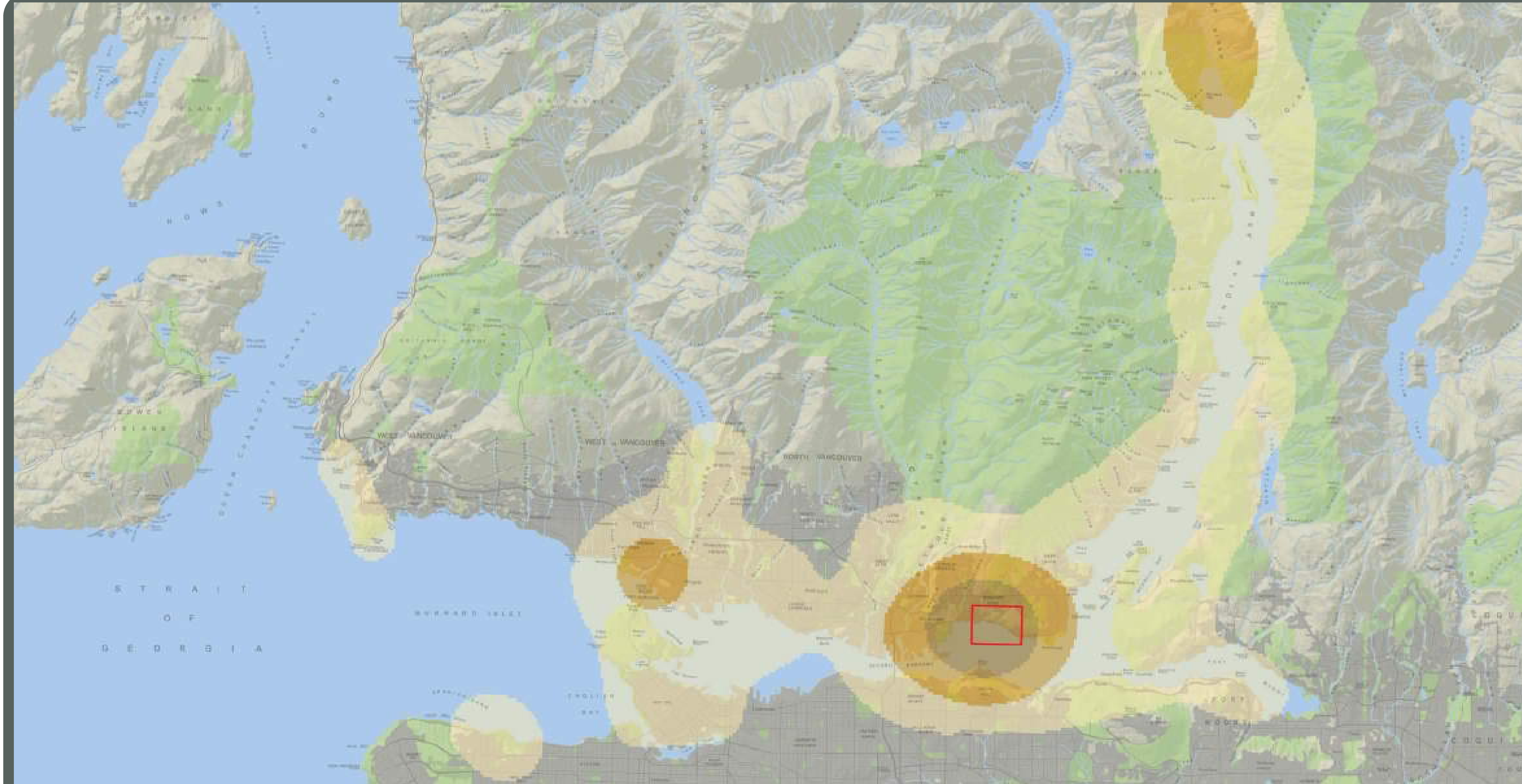

Tsleil-Waututh Nation

Burrard Inlet Action Plan

Figure 1-5: Areas of Concentrated Resource Use in Burrard Inlet

Legend

- Developed Area
- Parks and Protected Areas
- Tsleil-Waututh Nation Reserve

Concentrated Resource Use (Number of Sites/km²)

- Moderate (1 to 18)
- High (18.01 to 68)
- Very High (68 to 140)

Map Scale: 1:60,000

Projection: UTM, NAD 83, Zone 10

0 1.25 2.5 5 Kilometers

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1.3 Other Human Uses of Burrard Inlet

Non-Aboriginal human populations also benefit greatly from some of the important uses supported by the Burrard Inlet ecosystem:

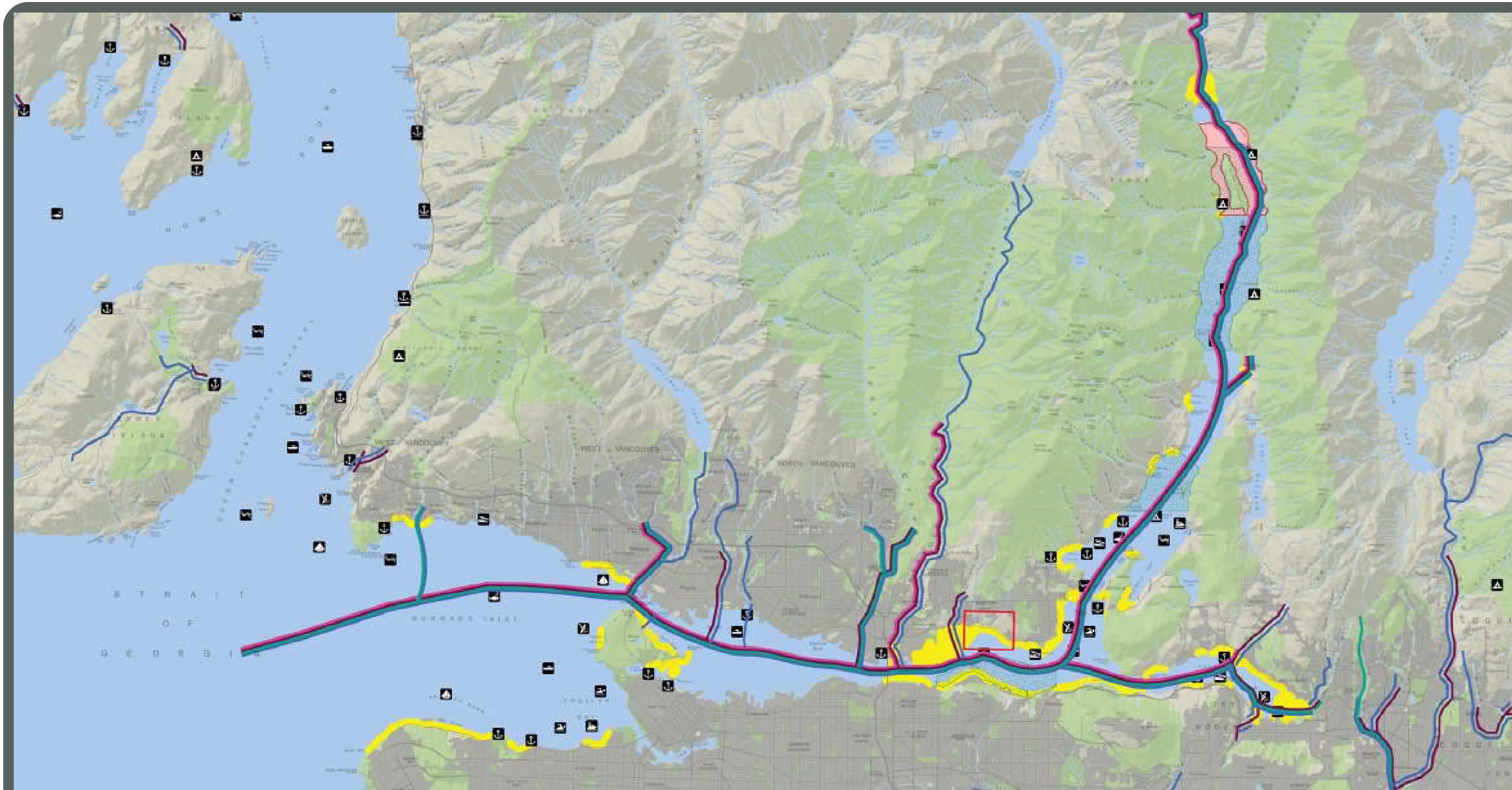
Port Uses and Water-based Transportation: Burrard Inlet is part of Canada's largest port and Vancouver's main harbour. It is a major transportation corridor within the region for a variety of vessels, including container ships, bulk carriers, cruise ships, pleasure crafts, and the SeaBus across Burrard Inlet from the foot of Lonsdale to downtown Vancouver.

Shellfish Harvesting: Non-Aboriginal harvesting of shellfish has historically occurred in Burrard Inlet, including clams, oysters, mussels, scallops, prawns, and crabs. While bivalve (clams, oysters, mussels, scallops) harvesting has been permanently closed in all of Burrard Inlet since 1972 due to contamination concerns, there are active commercial crab and prawn fisheries in Burrard Inlet. Burrard Inlet has supported a commercial fishery for pink shrimp (*Pandalus borealis eous*) for over 50 years (Levings *et al.,* 2004).

Fishing: Although recreational fishing between the Lions Gate Bridge and the Ironworkers Memorial Bridge (also known as the Second Narrows Bridge) is closed year-round, it is open in other areas of the inlet. Areas near the mouth of the Capilano River in the Outer Harbour support a significant recreational salmon fishery. Historically, surf smelt (*Hypomesus pretiosus*) were a managed stock in Burrard Inlet that supported a significant recreational fishery. There are no commercial fisheries for finfish in Burrard Inlet, with the exception of a small shore-based fishery for surf smelt.

Swimming: There are over 20 swimming beaches within Burrard Inlet that are distributed within the Outer Harbour, Central Harbour, and Indian Arm. False Creek, the Inner Harbour, and Port Moody Arm are not considered swimming bodies of water by Vancouver Coastal Health.

Other Forms of Water-based Recreation: Other forms of water-based recreation include pleasure boating, kayaking, and other paddle sports.



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BURRARD INLET ACTION PLAN

FIGURE 1-6: FISHERIES RESOURCES AND RECREATIONAL USE AREAS IN BURRARD INLET

Legend

- Known Shellfish Gathering Site
- Potential Bivalve Harvest Area
- Rockfish Conservation Zone
- Developed Area
- Parks and Protected Areas
- Tsleil-Waututh Nation Reserve

Salmon-Bearing Streams

- Coho
- Chinook
- Chum
- Pink

Recreational Infrastructure

- Boat Launch
- Marina

Recreational Activities

- Camping Site
- Boating
- Canoeing
- Diving
- Fishing
- Jet Skiing
- Kayaking
- Sailing
- Swimming
- Water Skiing

Map Scale: 1:60,000
Projection: UTM, NAD 83, Zone 10
0 1.25 2.5 5 Kilometers

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Sources of spatial data for this map include Tsleil-Waututh Nation, BCMCA, BC Government, Government of Canada, Metro Vancouver, Port Metro Vancouver.

Map produced December 2015 by the Tsleil-Waututh Nation.

1.4 Pressures on Burrard Inlet

Pressures associated with modern-day resource use, industry, and development on Burrard Inlet have increased over time, with impacts to the physical, structural, and ecological components and functions of the Burrard Inlet ecosystem. The most prominent pressures on the Burrard Inlet ecosystem are described below in terms of their contribution to stressed conditions in the ecosystem:

Pollution: Burrard Inlet receives significant amounts of pollution, primarily from development and human activities around the inlet, but potentially from other sources such as long-range atmospheric transport. In the aquatic environment, pollution can reduce habitat quality or function, be toxic to aquatic life, and lead to the loss of beneficial uses such as seafood harvesting and swimming.

A wide range of pollutants are of concern in Burrard Inlet: pathogens, metals, hydrocarbons including polycyclic aromatic hydrocarbons (PAHs), dioxins/furans, persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs), and emerging pollutants, such as pharmaceuticals and microplastics. Pollutants that persist in the environment over time, can bioaccumulate within the foodweb, or are toxic to aquatic life or humans are of most concern.

Sources of pollution include both point and non-point sources, such as:

- Effluent from 35 provincially authorized industrial waste discharges;
- Sewage treatment effluent from the Lions Gate Wastewater Treatment Plant (WWTP);
- Overflows from 8 combined sewer overflow outfalls, and 1 sanitary sewer overflow outfall, and 25 lift station emergency overflow outfalls;
- Runoff from 320 urban and industrial stormwater outfalls;
- Illicit waste discharges (e.g., unauthorized discharges from ships, dumping);
- Leakage from on-site sewage disposal systems (primarily located in Indian Arm);
- Oil, fuel, and other hazardous spills; and
- Deposition of air-borne pollutants, such as metals and nitrogen oxides.

Past industrial activities, such as shipbuilding, wood creosoting, manufacturing, and hazardous materials storage and transport, have left a legacy of contamination in some areas of the inlet. Although some sites have been cleaned up, other sites have not and potential exists for migration or mobilization into the marine environment.

Residential, Commercial, and Industrial Development: As the human population has grown around Burrard Inlet, land has been converted from coastal temperate rainforests to urban landscapes, with associated losses of natural habitat and increases in liquid waste, including wastewater and stormwater runoff. The total population of municipalities around the inlet are expected to grow from 1.1 to 1.7 million people by 2014 (Metro Vancouver, 2009). Although the footprint of land development is unlikely to grow substantially beyond the existing urban development containment boundaries, land use will continue to intensify around the inlet.

Port Activity: The Port of Vancouver is Canada's largest and busiest port and the fourth largest port in North America (Port Metro Vancouver, 2014). As part of Canada's Asia-Pacific Gateway, the port has seen significant growth in the marine transport of imported and exported goods through Burrard Inlet in recent years. In 2014, the port handled approximately 140 million tonnes of cargo and had 3,159 vessel arrivals (Port Metro Vancouver, 2014)[2]. From 1970 to 2010, the total cargo volume handled by the Port of Vancouver more than quadrupled (Port Metro Vancouver, 2015a). Impacts from port development include pollution from authorized discharges, stormwater runoff, spills, loss of nearshore habitat, and disturbance to key species. Shipping also increases air and noise pollution, disturbs species and their habitats, and is a risk for spills and illicit discharges.

Linear Infrastructure Development: Growth in urban, industrial, and port development has led to increases in the number, size, and extent of corridors servicing and traversing Burrard Inlet and its catchment area, including roads, railways, pipelines, powerlines, and other utilities. Some of these developments run adjacent to the inlet's shoreline.

Shoreline Modification: Related to the level of urban, industrial, and port development, much of the Burrard Inlet shoreline has been physically altered from its natural state. Modifications include measures to dissipate wave energy, maintain navigation channels, control shoreline erosion, repair storm damage, protect from flooding, store or accumulate sediment, and promote commercial and recreational activity. Significant Burrard Inlet shoreline changes have occurred related to port development, transportation infrastructure, residential development, and bank protection. Large amounts of natural marine foreshore, nearshore, and estuarine habitat have been lost. A current scarcity of industrial land in the region may lead to increased pressure to expand shoreline-associated development and overwater structures. In addition, rising sea levels and changes to the intensity and frequency of storm events will increase pressure to modify natural shorelines.

Biological Resource Use: Historic logging of the watersheds around Burrard Inlet has had impacts to watershed hydrology, instream habitat conditions, and water quality. Impacts of hunting, fishing, and shellfish harvesting are less well-known. Presently, there is a managed small shore-based commercial surf smelt fishery in Burrard Inlet. There are still active commercial crab and prawn fisheries. It is unclear to what extent, if any, the overexploitation of biological resources may have contributed to declines in mammal, finfish, or shellfish species.

Recreational Activity: Some beaches and bays in Burrard Inlet are used significantly for swimming and boating, as well as recreational fishing, crabbing, and prawning. In 2014, there were an estimated 5,250 recreational boats at moorage within Burrard Inlet (Valiance Maritime Consultants Limited, 2014). Vessels in the area range from small commercial passenger vessels to much smaller power and sail boats, canoes, and kayaks. Recreational boating in Burrard Inlet is very seasonal, with activity rising substantially in July and August. The Central Harbour and Indian Arm are most popular for boating on a regular basis and may potentially see 1,500 boats on the water at one time (Valiance Maritime Consultants Limited, 2014). High levels of use can degrade sensitive habitats, disturb wildlife, and increase the risk of pollution.

Climate Change: In marine ecosystems, increasing atmospheric carbon dioxide and climate change will result in concurrent shifts in temperature, circulation, stratification, nutrient input, oxygen content, and ocean acidification, with potentially wide-ranging impacts to ecosystem structure, diversity, and function. Measures to protect developed areas from sea level rise and increasing runoff will also have their own impacts. Because of the potential huge scope of impacts to the ecosystem, climate change is highlighted and further discussed as one of two cross-cutting issues below.

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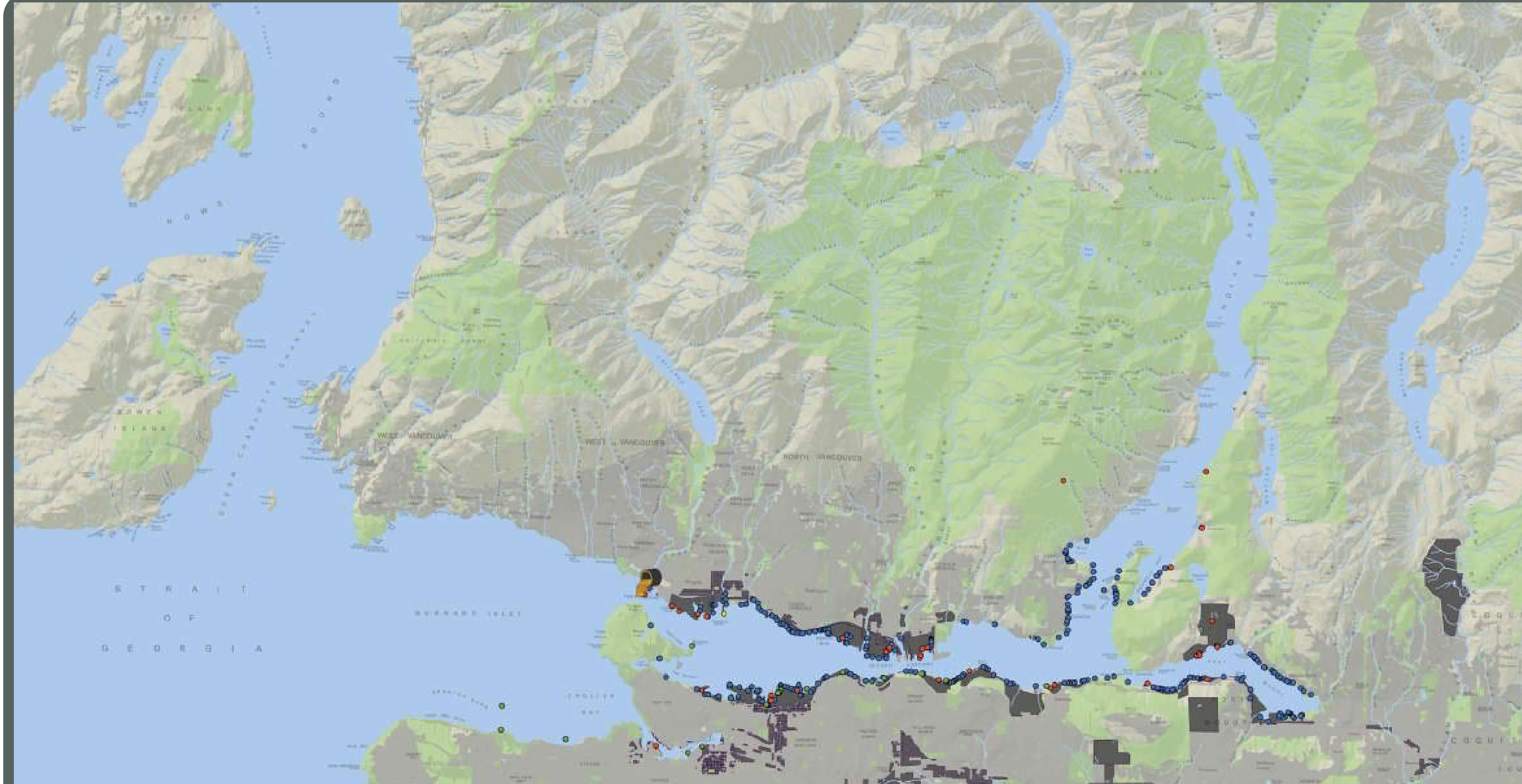
[2] Includes not just Burrard Inlet but also Port of Vancouver facilities on the Fraser River and at Roberts Bank.



Tsleil-Waututh Nation

Burrard Inlet Action Plan

Figure 1-7: Major Industry, Port Facilities, and Outfalls

Legend

- Wastewater Treatment Plant

Outfall

- Authorized Industrial Effluent Outfall
- Combined Sewer Outfall
- Sanitary Sewer Outfall
- Stormwater Outfall

- Industrial and Port Use
- Developed Area
- Parks and Protected Areas
- Tsleil-Waututh Nation Reserve

Map Scale: 1:60,000
Projection: UTM, NAD 83, Zone 10

0 1.25 2.5 5 Kilometers

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1.5 History of Burrard Inlet Environmental Planning and Management Initiatives

Although the Burrard Inlet ecosystem had likely been degraded for some time previously, it was not until the 1980s that the extent of the degradation began to be studied and fully known. In the late 1980s, Environment Canada published a series of studies on the distribution and impact of sediment contamination and the prevalence of pre-cancerous lesions and tumours in bottom fish sampled from Burrard Inlet (Goyette and Boyd, 1989). The studies found that a number of areas were severely impacted. The areas of highest impact examined were found to be in Port Moody Arm, where 75% of English sole tested had precancerous and cancerous lesions in the liver tissues. Other areas of the inlet, such as the north shore of the Inner Harbour from Vancouver Wharves to the Capilano River, and patches along the south shore of the Inner Harbour from Coal Harbour to Vanterm, were identified as having similar impacts, but to a lesser extent.

Mayors of surrounding municipalities called on the Greater Vancouver Regional District to lead an inter-governmental task force aimed at finding actions to address the contamination problems in the Inlet. In 1990, to address the causes of these environmental impacts, an initial draft action plan was developed by the Greater Vancouver Regional District (GVRD, 1990).

To implement the actions initially recommended by the plan, the Burrard Inlet Environmental Action Program (BIEAP) was formed in 1991. Formed initially through a five-year agreement, BIEAP Partners included Environment Canada, Fisheries and Oceans Canada, BC Ministry of Environment, Lands and Parks (now BC Ministry of Environment), the Greater Vancouver Regional District (now Metro Vancouver), and the Vancouver Port Corporation (now the Vancouver Fraser Port Authority). Transport Canada was later added as a Partner because of its significant role in regulating the shipping industry within Canadian waters.

BIEAP was responsible for coordinating implementation of the plan and reporting on actions and progress towards improving the health of the inlet. Over the years, major functions of BIEAP included:

- Coordinated environmental review of new shoreline development projects through the Burrard Environmental Review Committee (BERC);
- Coordination and production of important studies and publications to guide management of Burrard Inlet; and
- Development of key environmental indicators and production of annual reporting.

In 2002, a new environmental management plan for Burrard Inlet was prepared, known as the Consolidated Environmental Management Plan (CEMP), which was later updated in 2011 (BIEAP, 2011). The CEMP laid out goals, objectives, and actions as well as roles and responsibilities with respect to implementation.

Table 1-1: Past Burrard Inlet-wide Environmental Management Plans

Year	Title	Lead Agency
1990	Burrard Inlet Environmental Improvements – Draft Action Plan	GVRD
2002	Consolidated Environmental Management Plan for Burrard Inlet	BIEAP
2011	Consolidated Environmental Management Plan for Burrard Inlet – Updated 2011	BIEAP

Significant BIEAP accomplishments over the years, guided by the various plans, included:

- Improved liquid waste management planning, and long-term measures for curbing and reducing discharges and pollution in wastewater effluent, stormwater, and combined sewer overflows (CSOs);
- Increased public involvement and information;
- Improvements in the quality of certain industrial discharges and adoption of codes of practice to prevent or reduce contaminant releases; and
- Production and hosting of several important Geographic Information System (GIS) tools used for environmental and land use planning, such as detailed habitat mapping of the Burrard Inlet shoreline.

BIEAP was closed on March 31, 2013. Reasons given for the closure at the time included evolving mandates of the partner agencies, legislative changes, and a perceived reduction in the benefits from the interagency program. As a result of the closure, individual government agencies have returned to applying their roles and responsibilities independently through their normal regulatory processes; presently, coordinated strategic planning focussing on the improvement of Burrard Inlet's ecological health is largely absent. BIEAP's resources and publications were distributed among the partner agencies for ongoing use.

Existing Legal and Policy Framework

BIEAP's 2011 Consolidated Environmental Management Plan Update (BIEAP, 2011) provided a good summary of the existing legal and policy framework for environmental management in Burrard Inlet as well as the regulatory roles and responsibilities of the previous partner agencies. Although changes to the federal *Fisheries Act* and the *Canadian Environmental Assessment Act* have occurred since 2011, many of the roles and responsibilities for different aspects of environmental management remain the same. As such, the existing policy framework is not reviewed here.

1.6 Cross-cutting Issues

Cross-cutting issues are issues that affect the multiple aspects of Burrard Inlet's recovery and will have implications that emerge progressively over time. They represent important new context in which recovery will occur, which may impact how other issues are addressed or actions are undertaken. Two cross-cutting issues have been identified at this time: climate change and acidification. More may be added to the plan in the future as information becomes available.

Climate Change

Climate change has the potential to have wide-ranging and far-reaching impacts to both the physical oceanography and ecology of Burrard Inlet. Predicted climate change-related impacts to the physical marine environment include:

- **Sea level rise:** Global sea levels are projected to rise due to thermal expansion of the ocean and melting of ice caps, continental ice sheets, and mountain glaciers (James *et al*., 2014). Regional effects of changes in weather, wind patterns, and ocean currents may contribute to increases in the frequency and intensity of storm surge events. Depending on the climate change scenario used, sea levels in Burrard Inlet are expected to rise anywhere from 20 cm to 1.2 m by 2100 (Bornhold, 2008). A recent projection predicts a mean sea level rise of 63.2 cm (± 31.1 cm) by 2100 (James *et al.*, 2014). Sea level rise will also increase the vulnerability of the Burrard Inlet shoreline to storm surge events, which occur when water is pushed toward the shoreline by the force of the winds during large storm events. Much of the Burrard Inlet shoreline, particularly along Ambleside in West Vancouver, much of the Inner Harbour, and the north shore of the Central Harbour is low lying and undiked (Delcan, 2012). Recommended increases in the flood protection level for areas around Burrard Inlet to adapt to the projected increase range from 1.7 to 5.2 m (Delcan, 2012).
- **Increased water temperatures:** In addition to a general warming of sea surface temperature globally, changes in local flow patterns from rivers will also increase the temperature of the water, as flow patterns become more rain than snow dependent. The timing of freshwater inputs will also change as the highest flows will occur in winter with spring freshet occurring earlier (Johannessen and Macdonald, 2009).
- **Changes in salinity:** With decreasing snowpack in the mountains surrounding Burrard Inlet, increases in salinity are possible (C. Harley, pers. comm.). Increases will be compounded by decreased outflow from the Fraser River. Changes in salinity may alter food webs by favouring certain species over others. For example, whelks and sea stars are more active and increase feeding in more saline waters (C. Harley, pers. comm.). Saltier water and higher temperatures may facilitate the invasion of tunicates and *Sargassum*.
- **Changes in circulation, stratification, and nutrient inputs:** Changes in coastal and interior snow pack and precipitation on both freshwater inputs to Burrard Inlet from local creeks and streams and the timing and size of the Fraser River freshet will also have cascading effects to circulation, stratification, and nutrients in Burrard Inlet. Because of the complexity of these interactions, specific impacts are difficult to predict.

- **Increased occurrences of hypoxia:** Hypoxia is a reduction in the dissolved oxygen content of water. At oxygen levels below 30% saturation, species intolerant of hypoxia (e.g., some fish species) must either migrate to other geographic regions or die. Low oxygen conditions can also be induced by human activities and have similar impacts. Nutrient loading, changes in wind patterns, coastal upwelling, and flow patterns all have the potential to change oxygen levels and increase incidences of hypoxia in coastal BC waters, particularly in areas with confined circulation such as Burrard Inlet.

Expected impacts to marine life from the above changes include shifts in species distributions, changes in community composition and structure, increased occurrence and establishment of invasive species, and a potential loss of indigenous species due to loss of favoured conditions for those species. The above changes may also interact with other stressors to produce multiplicative effects. Predicted climate change impacts for other specific topics of interest are discussed in the status and trends section (Section 2).

Acidification

A portion of the carbon dioxide released into the atmosphere by human activities is taken up by the oceans, altering the basic ocean chemistry, specifically the marine carbonate system. Carbon dioxide dissolves in the surface water and forms carbonic acid which has decreased ocean pH by 0.1 units over the past 200 years. If CO_2 emissions increase as projected by the Intergovernmental Panel on Climate Change, by 2100, the global surface ocean pH will reduce further by 0.3 to 0.5 units (IPCC, 2000).

Although a portion of ocean acidification is due to global carbon dioxide emissions, acidification can also be exacerbated by other regional and local factors. Along the Pacific Northwest coast, coastal upwelling brings offshore water that is rich in carbon dioxide and low in pH up from the deep ocean and onto the continental shelf. Nutrients and organic carbon (such as plants and freshwater algae) in runoff, and local air emissions of carbon dioxide, nitrogen oxides, and sulfur oxides can lead to higher acidification levels locally. Burrard Inlet may be particularly vulnerable to ocean acidification because of regional factors that exacerbate the acidifying effects of global carbon dioxide emissions (Feely *et al.*, 2012). There are indications that pH may already be declining in Burrard Inlet; from 1954–1974, pH typically ranged from 7.8–8.1 but has become lower and more variable since, with a mode of 7.6, ranging from 7.3–7.9 (Marliave *et al.*, 2011).

The most direct biological impacts of lower pH will be to organisms that form calcium carbonate ($CaCO_3$) shells and skeletons, including shellfish species such as clams and oysters. The seawater surrounding calcifying organisms needs to be saturated with carbonate ions to allow shells to form and to protect shells from dissolution (or breakdown into individual ions). The decline in pH will decrease the saturation state of $CaCO_3$. Shell formation disruption accelerates as pH falls below 8.0 (Burton *et al.*, 2012)

In addition to calcifying organisms, ocean acidification has the potential to affect a wide range of organisms in a variety of ways. Acidification may lead to increases in primary productivity in kelps and phytoplankton, but also potentially harmful algal blooms increasing the frequency of paralytic, diarrhetic, or amnesic poisoning of shellfish.

2. Status and Trends in the Burrard Inlet Ecosystem

As part of the Action Plan, a status and trends assessment was undertaken to inform the development of actions to improve the health of Burrard Inlet. The purpose of the status and trends assessment was to:

- Summarize available scientific knowledge about Burrard Inlet and assess status and trends in the ecosystem for key topics of interest;
- Identify priority issues that continue to contribute to degradation or limit recovery; and
- Identify information gaps and research needs.

Over the last 30 years, a variety of research, inventories, and monitoring reports have been published by BIEAP and others to measure, assess, and monitor the type and extent of human impacts to Burrard Inlet. While some of this published information is current, other information is out-of-date. Some topics of interest have also not been well-studied. Therefore, to supplement available published information, 15–20 key scientists and government resource and environmental protection managers were also interviewed to gather more anecdotal information, confirm knowledge gaps, and identify research needs. When appropriate, inferences about likely status and trends in Burrard Inlet were sometimes drawn using information for other similar locations, such as Puget Sound. The input of interviewees was particularly important to develop a more current picture of status and trends for some issues.

The findings of the status and trends assessment are summarized below under five broad themes:

1. Water Quality and Contaminants;
2. Fish and Wildlife Habitat;
3. Key Species Populations and Food Webs;
4. Biophysical Processes/Ecological Integrity; and
5. Emerging Issues.

2.1 Water Quality and Contaminants

Clean water and sediment are foundational building blocks for a healthy marine ecosystem. Contaminants are substances that, when introduced to the environment through human activity, accumulate to levels that would not normally occur and can be toxic to aquatic life or impair habitat function. They can also affect wildlife when present in their diets, such as by impairing reproduction, and can become a further problem when that wildlife is consumed by humans. Contamination is of particular concern for human populations that rely on wild foods as a substantial component of their diet, such as First Nations people.

Water quality and contaminant concerns within the marine environment have been previously identified as one of the most important stressors of the Burrard Inlet ecosystem (e.g., Goyette and Boyd, 1989). While freshwater inputs, tidal flushing, and circulation patterns reduce the accumulation of contaminants to some extent (BIEAP, 2002), it has been known since the 1980s that the levels of some contaminants regularly or periodically exceed federal and provincial water quality guidelines in Burrard Inlet.

While some exceedances may have natural causes, most are the result of pollution discharged into Burrard Inlet from human activities. As a result of the high levels of contamination, shellfish harvesting has been closed since 1972, sublethal impacts to fish and wildlife health have been documented, some fish species are not safe to eat, and local beaches are periodically closed for swimming due to potentially high levels of fecal pollution.

Sources of contaminants to Burrard Inlet are diverse and include authorized industrial discharges, sewage treatment effluent, combined and sanitary sewer overflows (CSOs), stormwater runoff, illicit discharges, and spills. Although local sources are likely to deliver the majority of contaminants to Burrard Inlet, pollutants can also arrive via ocean currents, long-range atmospheric transport and deposition, and even via migratory species that have accumulated contaminants elsewhere and introduce them in the local food web.

Water and sediment quality in Burrard Inlet varies widely by location depending on proximity to known discharges, circulation, stratification, sedimentation, assimilation, and breakdown rates within the marine environment. Contaminant levels present in different types of biota are also influenced by their feeding method, trophic level, and the amount of time spent in Burrard Inlet. Contamination impacts to particular species are dependent on the ability of pollutants to persist in the environment over time, to bioaccumulate in the food web, and their toxicity.

Because water quality and contamination issues in Burrard Inlet are so complex, a complete review is beyond the scope of this report. Therefore, only the status and trends in key water quality parameters and contaminant groups are discussed here: physical water quality, pathogens, trace metals, nutrients, hydrocarbons, legacy persistent organic pollutants, and other industry-specific pollutants. An additional section reviews potential sources of contaminants in terms of their known or likely contributions to different water quality issues as well as measures that have or are currently being undertaken to reduce those sources. Contaminants of emerging concern (CECs) are discussed in the Emerging Issues section (Section 2.5) of the report.

Contaminants also vary in whether they reach their highest concentrations and are of concern in the water column, in sediment, or in biota. Monitoring results are discussed below in terms of the data and the medium where they tend to be measured or most problematic.

2.1.1 Water Quality Objectives for Burrard Inlet

Federal and provincial water quality objectives serve as relevant benchmarks for water quality and contamination in Burrard Inlet. In the absence of more detailed environmental effects monitoring, they can help to screen results to determine whether levels being encountered are likely to be of concern and cause impacts. The *Canadian Council of Ministers of the Environment* (*CCME) Canadian Water Quality Guidelines for the Protection of Aquatic Life*, the *BC Approved Water Quality Guidelines*, and the *BC Interim Sediment Quality Guidelines* represent different available guidelines. Guidelines are typically provided for protection of different water uses. The most relevant guidelines for Burrard Inlet are those for the protection of marine aquatic life, shellfish harvesting, and primary contact recreation as these are the primary uses in the inlet to be protected.

In 1990, BC Ministry of Environment also developed provisional water quality objectives specific to Burrard Inlet, False Creek, as well as three tributary creeks and rivers (Schoolhouse Creek, Lynn Creek, Capilano River) (Nijman, 1990). Site-specific objectives can be more or less restrictive than the general guidelines and are meant to protect the most sensitive designated water use at a specific location with an adequate level of safety. The objectives serve as a guide for issuing permits, licences, and orders by the Ministry of Environment (MOELP, 1986). Summaries of the Burrard Inlet-specific objectives for water, sediment, and contaminants in biota can be found in Appendix A.

Both BC Ministry of Environment and Metro Vancouver, in its 2011 Integrated Liquid Waste and Resource Management Plan (ILWRMP), have identified that the provisional water quality objectives for Burrard Inlet and its tributaries are now 25 years old and need to be updated to reflect new assessment data and changes to the available science on aquatic life and human health impacts.

2.1.2 Physical Water Quality

Physical water quality parameters (also known as physical water properties) include water temperature, dissolved oxygen, conductivity, salinity, pH, turbidity, and total suspended solids (TSS). Physical water quality can influence primary productivity and the metabolic rates of certain organisms. Some species are more sensitive to physical water quality than others, for example, salmon. Physical water quality can also serve as useful proxies for some pollutants, e.g., total suspended solids for metals, or conductivity for chloride concentrations from winter road salting.

Physical water quality in Burrard Inlet is influenced by a wide variety of natural and human factors including regional ocean conditions, coastal upwelling, tidal exchange, the influence of the Fraser River, and freshwater inputs from local creeks and human inputs from outfalls or discharges.

Status and Trends

Due to the significant water depths, freshwater inputs, tidal flushing, and patterns of circulation, physical water quality is generally good in most parts of Burrard Inlet. Sampling in 2009 found pH, turbidity, and suspended solids consistently met objectives (Bull and Freyman, 2013). Turbidity and pH objectives have generally been met since 1990 (Bull and Freyman, 2013).[3] Suspended solids objectives have occasionally not been met between First Narrows and Roche Point, as well as in False Creek and at Locarno Beach between 1991 and 1994 (Sutherland, 2004).

Dissolved oxygen levels at depth are of potential concern. Levels at lower depths have frequently been below the minimum DO objective of 6.5 mg/L. In 2010, 10 of 11 sites sampled did not meet the objective on two or more occasions (Bull and Freyman, 2013). Similar results were obtained in annual sampling from 1990 to 1994, although low levels at that time did not occur every year (Sutherland, 2004). It is not clear whether low dissolved oxygen levels in Burrard Inlet are a natural phenomenon or are due to human causes (Bull and Freyman, 2013).

At this point, it is unclear if salinity patterns in Burrard Inlet are changing in response to climate change.

Threats

Ongoing threats to physical water quality in Burrard Inlet include:

- *Wastewater treatment effluent*: Some components of wastewater treatment effluent have the potential to impact physical water quality, including organic material and suspended solids. As organic material is broken down by aerobic organisms, dissolved oxygen is consumed from the water column. The amount of oxygen consumed is known as the biochemical oxygen demand (BOD). While low dissolved oxygen levels can occur due to natural breakdown processes (e.g., low dissolved oxygen levels in Indian Arm annually due to naturally decaying phytoplankton), additional inputs of organic material can further exacerbate these natural BOD and dissolved oxygen issues.

[3] While objectives for pH have been mostly met, it should be noted that the current site-specific water quality objectives for Burrard Inlet do not incorporate protection of shellfish and bivalve reproduction.

- *Stormwater runoff*: In addition to contaminants, stormwater runoff typically contains significant amounts of sediment which can influence physical water quality. Discharges tend to be rainfall-driven resulting in some dilution of effects.
- *Airborne pollutants*: Acidifying pollution, such as nitrogen and sulphur oxides, can deposit as fallout from smog.
- *Authorized industrial discharges*: There are at least four permits for discharge of high temperature water used for industrial processes into Burrard Inlet. Based on the volumes of water discharged, impacts are expected to be localized (Bull and Freyman, 2013).
- *Climate change*: Climate change has the potential to increase water temperatures and salinity, and decrease pH and dissolved oxygen levels. These changes have the potential for a wide variety of ecological impacts.
- *Flow control*: Flow control structures, including Cleveland Dam (Capilano River) and the Seymour Dam (Seymour River), alter the natural hydrology of major streams entering Burrard Inlet and may impact physical water quality parameters including temperature, dissolved oxygen, and turbidity.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Despite the number of monitoring and research projects that have been conducted in Burrard Inlet, there are still key knowledge gaps. For example:

- Are low levels of dissolved oxygen at depth in Burrard Inlet natural or human-caused?
- What are the long-term trends in physical water quality parameters, including temperature, salinity, and pH? Seawater intakes at three facilities, the DFO Centre for Aquaculture and Environmental Research Laboratory in West Vancouver, the Vancouver Aquarium in Stanley Park, and Environment Canada's Pacific Environmental Science Centre in North Vancouver, have the potential to provide key data.
- Is climate change altering physical water parameters in Burrard Inlet? Climate change is predicted to result in long-term changes to water temperatures and pH and impact freshwater inputs, with impacts to dissolved oxygen and salinity. In light of expected impacts to climate change, it would be advantageous to continuously monitor physical water quality at different locations around Burrard Inlet.

There are a number of projects are currently underway that have the potential to improve physical water quality parameters in Burrard Inlet:

- The Lions Gate WWTP will be upgraded from primary to secondary treatment by 2020. The upgrade is expected to increase removal rates for suspended solids from 50% to 90% and for biochemical oxygen demand from 30–40% to 90% (Metro Vancouver, no date).
- Combined sewer overflows and sanitary sewer overflows to Burrard Inlet are gradually being addressed by ongoing separation of storm and sanitary sewer pipes in Vancouver and Burnaby.
- Municipalities continue to implement stormwater source controls, performance criteria for new developments, and erosion and sediment control bylaws to reduce sediment loading.

2.1.3 Pathogens

Pathogens in water can include bacteria, viruses, protozoan parasites, and other organisms. They are typically introduced to marine waters from wastewater contaminated with human and animal fecal material. The presence of pathogens is a high priority for management in Burrard Inlet because clams, oysters, and other shellfish do not meet guidelines for safe consumption and waters exceed guidelines for recreational uses that involve contact with water (e.g., swimming) on some occasions during the summer months.

Historically, fecal coliform, *Escherichia coli* (*E. coli*), and enterococci are the most commonly used bacteriological indicators of the presence of human and animal fecal material in water. Although most fecal coliforms are not pathogenic themselves, they are used as an indicator of the presence of other bacteria or pathogens that are. *E. coli* and enterococci are increasingly being used as the primary indicators of fecal contamination. *E. coli* is typically used in freshwater while enterococci is used in marine waters. All three bacteria types have approved water quality guidelines for the protection of aquatic life and primary contact recreation (swimming) (Appendix A).

Status and Trends

Objectives for enterococci were generally met in 2002 and 2009, except at sites near First Narrows and in the Inner Harbour (Clark Drive, Coal Harbour, and the Vancouver Wharves) (Bull and Freyman, 2013). Fecal coliform objectives also were met in 2002 and 2009 except at Clark Drive (Bull and Freyman, 2013). The Clark Drive sampling site is located close to the location of an occasional combined sewer overflow (CSO), which may explain elevated levels of these bacteriological indicators (Bull and Freyman, 2013). Historically, fecal coliform objectives were not met most frequently at Brockton Point and Deep Cove Beach (1900–1996), and Barnet Park (2005–2006). Enterococci objectives were not met at Ambleside Park (1991–1992), Cates Park (1990), and Deep Cove (1990–1992) (Sutherland, 2004).

In summer 2008, water quality at 15 of the 19 monitored Burrard Inlet beaches was excellent for swimming, with no closures for elevated coliform levels over the past five years. Deep Cove and Cates Park in North Vancouver, Barnet Marine Park in Burnaby, and Old Orchard Park in Port Moody had periodic closures in 2002, 2005 and 2006. The closures of these four beaches is attributed in part to the lower amount of tidal flushing in these areas (Bull and Freyman, 2013).

In summer 2014, *E. coli* levels in False Creek were 26 times above recommended guidelines for primary contact recreation (swimming) and also above recommended guidelines for secondary contact recreation (boating, kayaking, paddleboarding). Four West Vancouver beaches and Sunset Beach were also closed for swimming due to *E. coli* levels above guidelines for primary contact recreation (Lovgreen, 2015).

Streams entering Burrard Inlet are a source of pathogens. For example, in streams running through the Tsleil-Waututh Reserve (Burrard I.R. #3), fecal coliform concentrations exceed the BC water quality guideline for primary contact recreation regularly (Teranis Consulting, 2011). Fecal coliform sources in this area are considered to most likely be derived from stormwater runoff as well as leakage from sanitary sewers and possibly failing septic tanks.

Potential Sources

Potential sources of pathogens to the marine waters of Burrard Inlet include:

- *Combined and sanitary sewer overflows (CSOs and SSOs)*: In combined sewer systems, stormwater is mixed with wastewater from homes, businesses, and industry in a single pipe. In order to prevent sewers backing up during high rainfall events, overflows are directed out to Burrard Inlet. Sanitary sewers contain wastewater only, and are not designed to carry stormwater, but emergency overflows can occur if there are equipment failures, broken pipes, or power failures, and at times after large rainfall events. CSOs and SSOs are potentially a major but infrequent source of pathogens. As overflows are typically associated with high rainfall events, they generally occur in the fall and winter months, outside of the typical period of the most vulnerable water uses. Impacts are also diluted to some degree by the rainfall volumes.
- *Illicit discharges from boats*: Although boats are not permitted to discharge raw sewage within Burrard Inlet, it is suspected that discharges still occur. They are thought to be one of the primary sources of high *E. coli* levels in False Creek.
- *Stormwater runoff*: Stormwater has been documented to have high levels of pathogens in other jurisdictions and in some Burrard Inlet creeks and streams. A characterization study of urban stormwater from a City of Vancouver catchment on the Fraser River in the 1980s (Swain, 1983) and other studies in the U.S. (US EPA, 1983) have found high fecal coliform levels (e.g., 10,000+ MPN/100 ml) in stormwater, suggesting stormwater is likely to be significant source of pathogens generally. Sources of pathogens in stormwater are thought to include pets, livestock, and wildlife.
- *Sanitary-storm sewer cross-connections*: Occasionally, sanitary sewer pipes are incorrectly connected to the stormwater system during land development. These cross-connections can be a source of pathogens in stormwater. Most municipalities have programs to seek out and rectify cross-connection issues but they are still a potential undocumented source of pathogens.
- *On-site sewage disposal systems*: Indian Arm has approximately 64 outfalls from on-site sewage disposal systems (WorleyParsons Komex and Lorax Environmental, 2006). Most outfalls are from recreational cabins, but there also three yacht clubs.
- *Wastewater effluent*: Pathogens enter Burrard Inlet via discharge from the Lions Gate WWTP.
- *Animal waste*: Feces from dogs and resident Canada Geese (*Branta canadensis*) or other birds may contribute to elevated levels of fecal coliforms, *E. coli*, and other pathogens and parasites in high-use recreational areas.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Research and monitoring efforts on pathogens in Burrard Inlet have provided valuable data, but key information gaps still remain. These include:

- What are the relative contributions of different potential sources of pathogens to Burrard Inlet?
- What are the particular sources of pathogens in stormwater? This is not well-known, which makes measures to reduce pathogen loading in stormwater difficult.
- Which creeks are key suppliers of pathogens to Burrard Inlet? Pathogens in most creeks are not regularly monitored.
- To what extent do failing on-site sewage disposal systems in Indian Arm contribute pathogens? This has only been preliminarily studied.

- To what extent do unknown or illicit discharges contribute to beach closures? There does not appear to be a clear relationship between known sources and closure areas, suggesting unknown or illicit discharges may be a contributing factor to beach closures, or circulation patterns are a significant factor influencing pathogen distribution.
- To what extent will warming waters associated with climate change impact pathogen concentrations? Pathogen contamination issues are expected to increase in the warming waters associated with climate change (L. Bendell, pers. comm.).
- To what extent does intertidal or subtidal sediment provide a reservoir of pathogens for periodic re-suspension in the water column?

Several current projects are addressing pathogen issues in Burrard Inlet:

- Monitoring of bacterial indicators in Burrard Inlet has included both periodic attainment monitoring by BC Ministry of Environment and Metro Vancouver of the ambient waters of Burrard Inlet, as well as weekly beach water quality monitoring from mid-May to the end of September at 19 different Burrard Inlet beaches (Vancouver Coastal Health, 2015).
- Since the early 1970s, Environment Canada, and more recently the Tsleil-Waututh Nation, have also been monitoring the sanitary quality of shellfish as part of the Canadian Shellfish Sanitation Program (CSSP).
- Combined sewer overflows and sanitary sewer overflows to Burrard Inlet have been reduced by ongoing separation of systems in Vancouver and Burnaby.
- Municipalities continue to implement stormwater source controls and performance criteria for new developments which should reduce pathogen levels.
- Bacterial source tracking techniques have been used to try to determine the sources of high levels of contamination in some jurisdictions (e.g., District of North Vancouver) with limited success.

2.1.4 Trace Metals

Heavy metals are distributed among water column and marine sediment. In the water column, they can be in both dissolved form as well as a bound in particles of sediment, which deposit over time. Deposition-mobilization processes play an important role in influencing the exchange of metals between water and sediments (Filgueiras *et al*., 2004).

Certain metals, when present in high enough amounts, can be toxic to aquatic life. For example, copper is highly toxic to fish and other aquatic species in the water column. It interferes with their sense of smell, making them more vulnerable to predators or unable to migrate successfully (Hecht *et al.*, 2007). Young salmon are especially susceptible to the effects of copper. Metals also impact the condition of the benthic environment for organisms that live or feed in bottom substrates, such as shellfish, bottom fish, and lower trophic level invertebrates.

Metals of primary concern include cadmium, copper, lead, mercury, arsenic, and chromium. Mercury is also bioaccumulative, and can accumulate up the food chain. Metals are a primary contaminant of concern in Burrard Inlet because of the high levels of some metals and the wide variety of sources from which they are discharged to the inlet (Tkalin *et al.,* 2001; L.Bendell, pers. comm.).

Status and Trends

Heavy metal contamination in the water column and sediments continues to be of concern in Burrard Inlet. Monitoring of the water column throughout Burrard Inlet conducted in 2009 indicated the most problematic heavy metals to be copper and nickel. Levels of both metals exceeded objectives at most sites and were present at higher levels than identified in 2002 sampling. Copper levels have not significantly improved since the early 1990s; trends in nickel are difficult to assess because of changes in analytical equipment over time (Bull and Freyman, 2013). Objectives for arsenic, barium, cadmium, chromium, lead, and zinc were met at all water column sampling sites in 2009 and appear to have been stable since 2002. This suggests improvement in lead and zinc levels, which exceeded objectives on some occasions in the 1990s (Bull and Freyman, 2013).

Metals in sediments show fewer signs of improvement than in the water column. Cadmium, copper, lead, mercury, and zinc concentrations all exceeded long-term sediment quality objectivesat some sites in 2002 and could have negative effects on aquatic life (Sutherland, 2004). Arsenic, chromium, and nickel all met sediment quality objectives (Sutherland, 2004). Similar results were found in 2005 (Phippen, 2005). Long-term trends in heavy metal concentrations suggest little improvement (Sutherland, 2004); copper, lead, and zinc also exceeded objectives in 1993–1994 (Sutherland 2004), though copper has been declining in surface sediments (Jacques Whitford AXYS, 2008).

Hotspots for sediment contamination are in False Creek, at three sites in the Inner Harbour (Vancouver Wharves, the Clark Drive CSO, and Coal Harbour), and near the Pacific Coast Terminals in Port Moody Arm (Sutherland, 2004). Heavy metal contamination appears to be improving at Vancouver Wharves and IOCO Port Moody, but has not improved at the Clark Drive CSO and in Coal Harbour (Sutherland, 2004). Other hotspots include estuaries where sediments are deposited, including the mouths of Mackay Creek, Mosquito Creek, Lynn Creek, and the Seymour River (L. Bendell, pers. comm.).

Potential Sources

- *Urban and industrial stormwater runoff:* Metals, particularly copper, lead, and zinc are by far the most prevalent contaminants found in urban stormwater (US EPA, 1983). Major sources include vehicle brake pad dust, metal plating and roofing, and vehicle servicing and cleaning.
- *Authorized industrial discharges*: Many of the authorized discharges include specific loadings of metals. For example, a bulk loading facility handling zinc, copper, lead, and nickel east of Second Narrows has potential to add heavy metals to Burrard Inlet (Bull and Freyman, 2013).
- *Shipyards*: Paints and other materials in shipyards can input copper, nickel, and other heavy metals into nearby waterways (L. Bendell, pers. comm.).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Key knowledge gaps exist about the status and trends of heavy metal contamination in Burrard Inlet. These include:

- Where are the hotspots of heavy metal contamination? Although some hotspots have been located (L. Bendell, pers. comm.; Tkalin *et al.*, 2001), extensive sampling throughout Burrard Inlet has not been conducted and sites have not been comprehensively mapped.
- What are the impacts of heavy metal contamination on biota in the upper layer of sediments? Marine biota, such as bivalves, typically live at particular depth profiles in the sediment. Typical sampling of sediments takes a bulk sample, and doesn't analyze the distinct profiles that organisms likely live in.

Specific projects addressing metals were difficult to identify, but progress is being made in some areas. For example:

- Many industrial dischargers have made efforts to better manage through on-site pollution prevention programs. For example, there have been improvements in reducing cargo spillage and stormwater treatment at Pacific Coast Terminals, and they implemented a number of remediation programs since 1985 (TWN, 2005).
- Municipalities continue to try to better manage stormwater and capture pollutants at the source.
- Research into heavy metal contamination in estuarine sediments is ongoing (L. Bendell, pers.comm.).

2.1.5 Nutrients

When excess nitrogen or phosphorus are present on land, they can run off into surface waters, causing a variety of impacts to aquatic ecosystems, including changes in primary productivity, hypoxia, and harmful algal blooms. Inputs of nutrients to surface water can come from many sources including urban, industrial, agricultural, and air-borne sources. The most common sources of nutrient loadings in marine waters include runoff from urban and agricultural land.

Status and Trends

Information about nutrient loading in Burrard Inlet is limited, as no comprehensive study has been completed. Studies in the 1960s and 1970s showed most basins in Burrard Inlet appear to have naturally low levels of nutrients (Levings *et al.*, 2004). Port Moody Arm showed relatively high levels of primary productivity and may have had higher nutrient levels in the past (Stockner and Cliff, 1979). Ammonia levels continued to be below objectives and stable from the 1990s to 2009 (Bull and Freyman, 2013).

Despite the historically low nutrient levels in Burrard Inlet, there is still the potential for concern. Although the high rainfall and lack of significant agriculture make it generally low risk for future widespread nutrient loading issues, it is possible that low levels of nutrient additions could have significant impacts on a traditionally nutrient-poor environment. Furthermore, there is some potential for localized nutrient loading issues associated with urban catchments in areas where extensive fertilizers may be used, such as golf courses.

Potential Sources

Potential sources of nutrients to Burrard Inlet include:

- *Combined and sanitary sewer overflows (CSOs and SSOs)*: CSOs and SSOs are potentially a source of nutrients. Overflows are typically associated with high rainfall events, and raw sewage can enter Burrard Inlet at these times.
- *Stormwater runoff*: Stormwater runoff can gather nitrogen and phosphorus from fertilized yards, agricultural areas, and golf courses.
- *Fraser River and Strait of Georgia*: Nutrient additions to the Fraser River have the potential to infiltrate Burrard Inlet via normal circulation patterns. Concerns about nutrient loading exist throughout the Salish Sea.

- *Wastewater treatment effluent*: Wastewater from the Lions Gate WWTP has the potential to be a significant source of nutrients to the Outer Harbour, although this subbasin is well-flushed compared to the other subbasins of Burrard Inlet.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

A number of projects should reduce nutrient loading over time:

- The Lions Gate Wastewater Treatment Plant is currently being upgraded to a secondary treatment facility.
- Ongoing separation of sanitary and storm sewers in Vancouver and Burnaby will continue to reduce combined sewer overflows to Burrard Inlet.
- Municipalities continue to implement stormwater source controls and performance criteria for new developments which should reduce nutrient levels.

2.1.6 Hydrocarbons

Hydrocarbons are petroleum derivatives and byproducts and are of concern in Burrard Inlet. Typical hydrocarbons sampled in Burrard Inlet include oil and grease, polycyclic aromatic hydrocarbons, and volatile organic compounds.

Oil spills and spills of other petroleum products are a constant threat in Burrard Inlet due to the high levels of industrialization around the inlet and shipping facilities located throughout the inlet. Hydrocarbons from spills can include gasoline, bunker and diesel fuel, crude oil, canola oil, and other sources. Oil has immediate negative consequences on plant and wildlife, and is a source of longer-term contaminants in the inlet as it breaks down over time (Jacques Whitford AXYS, 2008).

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds found in petroleum and petroleum combustion byproducts. They can accumulate in sediments and can be taken up by marine organisms. They have acutely toxic, mutagenic, and carcinogenic properties, and may cause lesions on the internal organs of bottomfish (Goyette and Boyd, 1989).

Volatile organic compounds (VOCs) are organic chemicals that have a low boiling point and tend to evaporate or sublimate from the liquid or solid form of the compound at ambient temperatures. One volatile organic compound of interest is styrene. Styrene can cause tainting of fish tissue and historically was manufactured on the shores of Burrard Inlet. It is no longer monitored (Bull and Freyman, 2013).

Status and Trends

A number of large oil spills have occurred the past two decades: releases of canola oil from a vessel in 1999 and from an onshore handling facility in 2013, a crude oil spill from a ruptured Kinder Morgan pipeline in 2007, and a bunker fuel spill from the bulk grain carrier M/V Marathassa in 2015. Chronic smaller-scale land-based spills and spills from recreational boats are more frequent, but are hard to track (C. Levings, pers. comm.; Jacques Whitford AXYS, 2008). In the mid-1980s, oils, grease, and hydrocarbon concentrations were found to be high in Port Moody Arm and the south shore of the Inner Harbour, likely related to oil refineries and CSOs (Goyette and Boyd, 1989).

Concentrations of PAHs have continued to be a concern in Port Moody Arm, the Inner Harbour, False Creek, and the Outer Harbour. For example, sampling conducted in 2000 showed PAH levels exceeded guidelines to protect aquatic life by factors of 4 to 2500 times in False Creek around Granville Island (Phippen, 2001). Monitoring in 2002 showed values in excess of long-term objectives were widespread, similar to sampling done in 1993, 1994, and 2000 (Sutherland, 2004). Key sites include Granville Island, English Bay near the Vancouver Yacht Club, the Clark Drive CSO, the IOCO transshipment facility, the Petro Canada docks, and Reed Point Marina (Bolton *et al.,* 2003; Phippen, 2001).

Styrene levels were below guidelines in 1993–1994 and no further sampling has been conducted (Bull and Freyman, 2013).

Potential Sources

Potential sources of hydrocarbons to Burrard Inlet include:

- *Stormwater runoff*: During rain events, stormwater collects hydrocarbons that have built up in urban environments on roads and other impervious surfaces. This includes gasoline, lubricants, and oils used in vehicles. These additions represent a chronic input of hydrocarbons to Burrard Inlet.
- *Oil, fuel and other hazardous spills*: Small and large-scale spills are possible from ships (including gasoline, diesel, bunker fuel, and canola oil), handling facilities, refineries, and pipelines around Burrard Inlet. For example, there are a number of petroleum storage and handling facilities, as well as two refineries on the shores of Burrard Inlet (Bull and Freyman, 2013). High levels of commercial and recreational boat traffic increase the risk of small- and large-scale spills.
- *Creosote pilings*: Pilings soaked in creosote used in the building of wharves and piers are an additional source of PAHs in marine environments (TWN, 2005).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Current priority issues and knowledge gaps include:

- Reviewing whether current spill response plans and processes adequately address emerging concerns and have been properly practiced to ensure efficient and effective implementation.
- Comprehensive mapping of sites contaminated with PAHs and other hydrocarbons, to help in remediation planning and predicting impacts on wildlife.
- Collecting adequate baseline information to be able to evaluate effects of future spills.

Though projects specifically addressing hydrocarbons in Burrard Inlet are not common, a number of related projects were identified. For example:

- Improvements in stormwater management techniques in industrial sites around Burrard Inlet, including the use of oil-water separators on site.
- Improvements in stormwater management planning by municipalities that may prevent some water contaminated with hydrocarbons from entering waterways.
- Fish tissue sampling for PAHs conducted approximately once every five years by Metro Vancouver as part of the Burrard Inlet Ambient Monitoring Program.

2.1.7 Legacy Persistent Organic Pollutants

Several persistent organic pollutants (POPs), including polychlorinated biphenyls and the pesticide DDT, are considered legacy contaminants. These are contaminants whose use have been banned or restricted but are still widespread in the environment. Some of these substances have the potential to persist at levels that may impair animal health, particularly the health of long-lived top predators, including orcas, seals, sea lions, and other marine mammals.

Polychlorinated biphenyls (PCBs) are a class of chemical that was used as an insulating material in electric equipment, such as transformers, and also in lubricants and other industrial fluids. Sale of PCBs in Canada was banned in 1977 and release to the environment was banned in 1985. PCBs are toxic to wildlife and are known to bioaccumulate in the tissues of higher animals in higher trophic levels such as seals (Bull and Freyman, 2013). At this time, they are the largest threat to organisms at higher trophic levels, including humans (Peter Ross, pers. comm.).

Polybrominated diphenyl ethers (PBDEs), also known as brominated flame retardants, are a more recent concern. PBDEs are added to household items including clothes, couches, and electronic devices in order to reduce the flammability of these products and prevent fires. They are considered toxic and bioaccumlate in food chains. The manufacture of PBDEs was banned in Canada in 2008, but importing products containing PBDEs is still possible (Government of Canada, 2008).

Other legacy POPs include hexachlorobenzene (HCB), hexachlorocyclohexane (HCH), toxaphene, chlordane, and dioxins and furans. Dioxins and furans are extremely toxic; they typically are enter the environment via municipal waste incinerators, metal smelting, pulp and paper mills, diesel engines, and sewage sludge (Vancouver Aquarium, 2015).

Status and Trends

Two Burrard Inlet sites (Port Moody Arm and the Inner Harbour) had second and third highest total PCB concentrations in sediments of 41 sites sampled in Strait of Georgia. The Port Moody Arm site was above CCME sediment quality guidelines but below probable effect levels (Grant *et al*., 2011). While PCBs occur generally at low levels throughout the inlet (Goyette and Boyd, 1989), sites in False Creek, the Inner Harbour, and Port Moody Arm have accumulated high concentrations in sediments. Sites with high levels of PCBs include Coal Harbour, near the Clark Drive CSO, and in Port Moody Arm near Pacific Coast Terminals. Sampling in 2002 showed Coal Harbour had five times the current sediment quality objective, and concentrations at Pacific Coast Terminals were seven times the objective (Sutherland, 2004). In 2004, False Creek and the Inner Harbour still had concentrations of PCBs above water quality objectives (Jacques Whitford AXYS, 2008). Though not above objectives, PCB concentrations in Indian Arm were higher than expected, and were found to be at levels similar to moderately contaminated sites in Puget Sound (Bolton *et al*., 2003).

Concentrations of DDT in Burrard Inlet follow an increasing trend from west to east, and are highest in Indian Arm and Port Moody Arm (Bolton *et al.*, 2003). However, at these sites, levels are such that there is still a low risk of adverse effects on marine animals (Bolton *et al.,* 2003).

PBDEs have not been consistently monitored so not enough information is available to assess trends. Studies conducted in the Strait of Georgia suggest high levels of PBDEs in the Vancouver area (Vancouver Aquarium, 2015). PBDEs are believed to be accumulating quickly in natural environments, doubling every five years (Government of Canada, 2011).

No sampling of dioxins and furans in Burrard Inlet was identified.

Potential Sources

Many POPs have had regulations banning their manufacture or use (e.g., PCBs and PDBEs), but due to their use in many products, products containing them are still in use and can end up in waterways and waterbodies. Some sources include:

- *Stormwater runoff*: As PCBs and PBDEs are or were commonly found in industrial and household items, these compounds are able to enter stormwater as these items break down. They can then enter stormwater systems and end up in Burrard Inlet.
- *Landfill leachate*: Similar to above, improperly disposed of items can enter landfills that potentially can leach out POPs into the surrounding environment.
- *Dredging*: Dredging activities in Burrard Inlet related to shipping and transportation have the potential to re-circulate trapped POPs in contaminated sediments and allow them to re-enter marine ecosystems and food webs.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

POPs are currently being studied by the Vancouver Aquarium's Ocean Pollution Research Program. Research is focussed on how POPs impact marine mammals and accumulate in natural systems in the Strait of Georgia. A number of POPs are regulated by the federal government, including PCBs and PBDEs.

Despite this research, basic information on POPs in Burrard Inlet is generally lacking. For example:

- What is the prevalence of PBDEs in Burrard Inlet and what is the long-term impact on wildlife?
- What are the sources of POPs in Burrard Inlet and how can they be managed at the source?

2.1.8 Industry-specific Contaminants

Industry-specific contaminants are contaminants of concern that originate from specific industries or industrial processes but are not in widespread use or have widespread sources. Examples of industry-specific contaminants of potential concern in Burrard Inlet include tributyltin (TBT), a variety of organics, cyanide, and sulphide. TBT is a highly toxic ingredient used in anti-fouling paint on ship hulls until it was banned in Canada in 2003. It bioaccumulates in marine mammals and humans around the world, and is associated with negative impacts on marine invertebrates including snails and shellfish, including the possible extirpation of neogastropods (sea snails) from Burrard Inlet (Horiguchi *et al.* 2003; Vancouver Aquarium, 2015). As of March 1, 2009, two tributyltin pesticide active ingredients were registered under the federal *Pest Control Products Act* (PCPA) and are found in six end-use products (Environment Canada, 2009). Phenols and chlorophenols are organic compounds that can also taint fish tissue; phenol once was manufactured on the shores of Burrard Inlet. Historically cyanide and sulphide were potential contaminants related to industrial activity in Burrard Inlet and are toxic to marine wildlife.

Status and Trends

Limited data exists for TBT levels in Burrard Inlet. Monitoring conducted from 1991–1994 showed objectives were not met in the Inner Harbour, Outer Harbour, and False Creek, while objectives were met in Coal Harbour (Bull and Freyman, 2013). Monitoring data does not exist in other basins. Monitoring was stopped after 1994 due to the ban on tributyltin use in anti-fouling paints, the main source of TBT. Tissue samples from collected from shellfish in 1999 showed persistent TBT contamination in Burrard Inlet (Horiguchi *et al.* 2003). This was attributed to either continued release of TBT from vessels over 25 m long, or contamination of sediments.

In 1994, cyanide and chlorophenol objectives were met throughout the inlet, while sulphide results were not clear (MOELP, 1996). Cyanide and sulphide were last monitored in 1994 (Bull and Freyman, 2013). Sulphides in sediment may still be an issue (Bull and Freyman, 2013). Phenols in the water column did not meet objectives from 1991–1994 but are no longer discharged from any regulated facilities and so are no longer monitored (Bull and Freyman, 2013).

Potential Sources

The sources of industry-specific contaminants are easier to identify than other pollutants. Some sources are:

- *Shipyards, marinas, and boat hulls*: Anti-fouling paints that have peeled and flaked off, or spilled during maintenance of boats, can lead to TBT entering the water.
- *Refineries and petroleum handling facilities*: Phenols are of concern from refineries and other petroleum-related industry discharges.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Much of the monitoring for industry-specific pollutants in Burrard Inlet ceased in 1994. It is not known what the current levels of these pollutants are in Burrard Inlet and if these pollutants have declined over time or continue to persist.

There are no known projects currently underway dealing with industry-specific contaminants. Industrial discharges are regulated by BC Ministry of Environment.

2.1.9 Summary of Pollution Sources

Pollutants enter Burrard Inlet from a wide variety of industrial, municipal, and commercial activities, as well as urban runoff and groundwater sources. These include both point and non-point sources of pollution. Despite the difficulty in tracking pollutants and determining sources in many cases, the following key sources of contaminants have been identified around Burrard Inlet.

Authorized Industrial Discharges

BC Ministry of Environment authorizes effluent discharges from specific types of industries under the provincial *Environmental Management Act* (EMA). Examples of discharges typically authorized include industrial process water, cooling water, effluent from sewage treatment plants, or industrial stormwater (Balanced Environmental Services, 2010). These discharges can contain a variety of pollutants, including heavy metals, phenols, hydrocarbons, and endocrine-disrupting chemicals (Bull and Freyman, 2013).

In 2010, there were 23 authorizations for effluent discharges into Burrard Inlet (Balanced Environmental Services, 2010). Seven of the 23 authorizations include multiple discharges for a total of 35 authorized discharges (Balanced Environmental Services, 2010).

Lions Gate Wastewater Treatment Plant

The Lions Gate Wastewater Treatment Plant (WWTP) is located on the north side of Burrard Inlet at First Narrows and provides primary sewage treatment for the three North Shore municipalities. The plant discharges effluent into Burrard Inlet west of the Lions Gate Bridge. Effluent can be a source of total suspended solids, nutrients, metals, oil and grease (Bull and Freyman, 2013).

Constructed in 1961, the plant initially served the District of West Vancouver and served all three North Shore communities by 1964. Prior to the Lions Gate WWTP, untreated sewage was discharged directly into Burrard Inlet.

Current federal regulations require all primary treatment plants be upgraded to secondary treatment. Under Metro Vancouver's ILWRMP, a new Lions Gate WWTP incorporating secondary treatment will be operational by December 31, 2020. The new plant will be located near the foot of Pemberton Avenue in North Vancouver.

Combined Sewer Overflows (CSOs) and Sanitary Sewer Overflows (SSOs)

Combined sewer overflows (CSOs) are a combination of sanitary sewer and storm water discharges that occur when combined sewers reach their capacity to convey both sanitary and storm flows during peak rainfall events. Sanitary sewer overflows (SSO) are overflows from the sanitary sewer system. CSOs and SSOs are sources of heavy metals, nutrients, hydrocarbons, and pathogens (Bull and Freyman, 2013; Sutherland, 2004).

As of 2010, there continued to be 18 combined sewer overflow outfalls and one sanitary sewer overflow outfall to Burrard Inlet (Balanced Environmental Services, 2010). There were also an additional 25 lift station emergency overflow outfalls.

Urban and Industrial Stormwater Runoff

In Puget Sound, Washington State Department of Ecology studies have identified that the largest source of contaminants is not from regulated, point source discharges (e.g., industrial discharges), but polluted stormwater runoff (non-point sources). Polluted stormwater runoff is also likely the leading pollution threat to Burrard Inlet.

In 2010, there were 320 municipal stormwater outfalls mapped entering Burrard Inlet (Balanced Environmental Services, 2010). In addition, 112 small streams also discharge into Burrard Inlet, carrying both natural and urban runoff (Balanced Environmental Services, 2010). Stormwater runoff can contain a variety of pollutants from urban and rural centers, including nutrients, hydrocarbons, metals, acute toxins from spills, POPs, and can alter turbidity and dissolved oxygen levels. Upland environmental planning is ongoing as municipalities in Metro Vancouver develop Integrated Stormwater Management Plans (ISMPs) to help control stormwater and its associated pollutants.

Contaminated Sites

Since the early 1900s, industrial activity has been ongoing around Burrard Inlet, including wood processing facilities, petroleum refineries, shipyards, a chlorine plant, seafood processing industries, fuel loading docks, and marinas (Levings *et al*., 2004). These have left a legacy of contamination at different sites in Burrard Inlet including wood waste, heavy metals, hydrocarbons, and other chemicals.

On-site Sewage Disposal

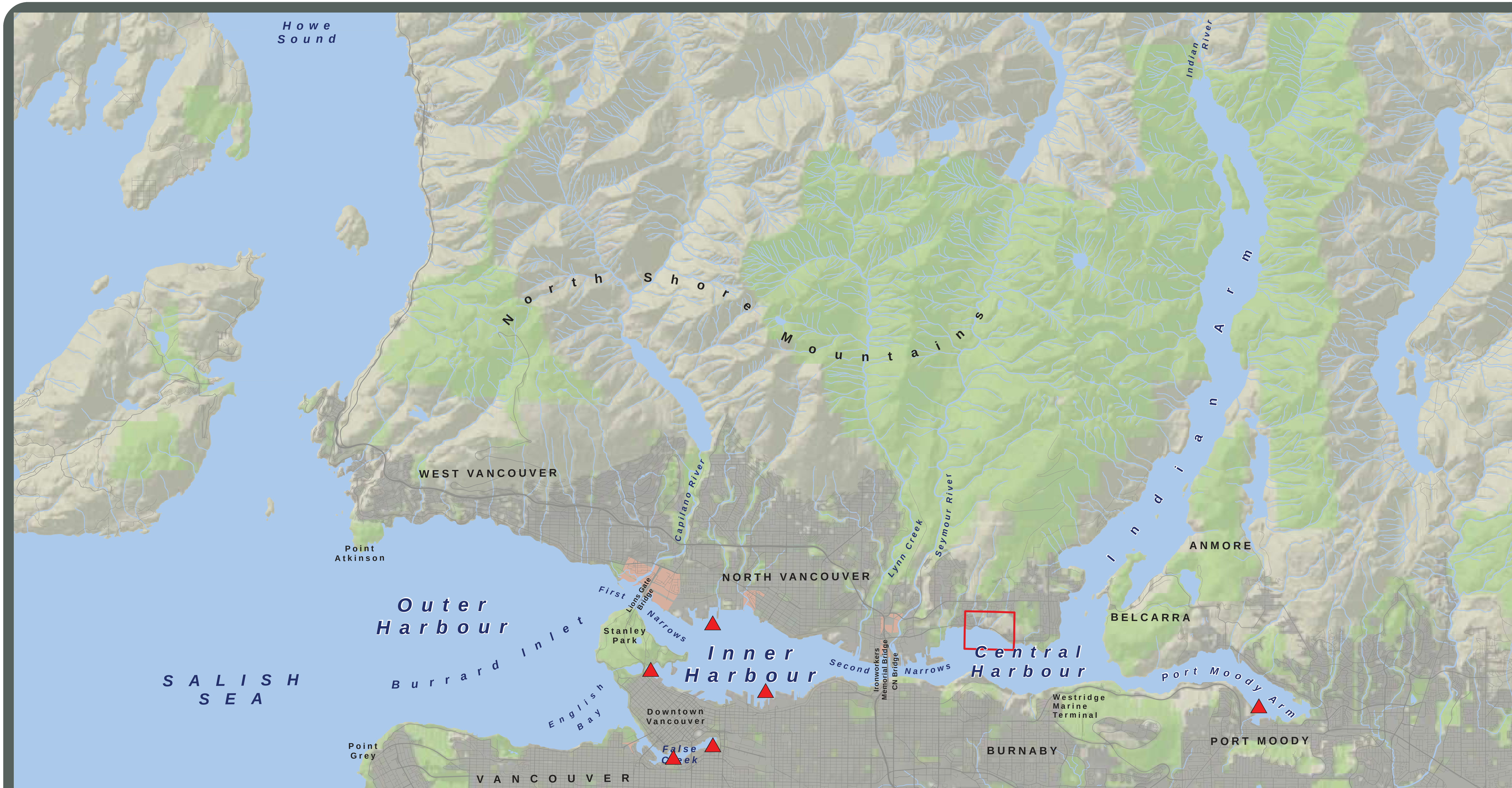
On-site sewage disposal may increasingly become a concern in Indian Arm. Currently there are 64 discharge outfalls from on-site sewage disposal systems in Indian Arm, but this is predicted to increase in the future (WorleyParsons Komex and Lorax Environmental, 2006) and could be a source of nutrients with the potential to contribute to eutrophication in Indian Arm.

Oil, Fuel and Other Spills

There have been a number of significant oil and fuel spills in Burrard Inlet. Most recently, in April 2015, approximately 2,700 L of bunker fuel from accidentally discharged into English Bay from an anchored bulk grain carrier, the M/V Marathassa. In November 2013, two tonnes of canola oil was spilled into Burrard Inlet from an onshore handling facility. In July 2007, an accidental rupture near the terminus of Kinder Morgan's Trans Mountain pipeline resulted in crude oil flowing into the Central Harbour near Barnet Highway. Concerns about contaminated sediments in the area from that spill are ongoing. In 1999, another significant amount of canola oil was spilled from a ship during loading (Jacques Whitford AXYS, 2008). In 1973, 189,000 litres of light bunker fuel were spilled at the mouth of Burrard Inlet as two ships collided (Kheraj, 2015). A smaller spill of bunker fuel occurred later that same year.

Other Non-point Sources

Sources of non-point source pollution can also include atmospheric fallout from air pollution, runoff from industrial sites, and groundwater seepage. Though difficult to track, non-point source pollution also comes from 29 marinas, 11 ship repair facilities, seven fueling operations, 29 ship loading facilities (sulfur, metal concentrates, coal, potash, phosphate rock, grain, forest products, chemicals, petroleum) and 38 anchorages (Levings *et al*., 2004).



Tsleil-Waututh Nation

Burrard Inlet Early Action Plan

Figure 2-1: 2002 Contamination Hot Spots in Burrard Inlet

Legend

- 2002 Contamination Hot Spot
- Developed Area
- Parks and Protected Areas
- Tsleil-Waututh Nation Reserve

Map Scale: 1:60,000

Projection: UTM, NAD 83, Zone 10

0 1.25 2.5 5 Kilometers

This map is a living document and is intended to be amended and refined over time. It is not an expression of the location of Tsleil-Waututh aboriginal title. The data used to produce this map originate from many sources and are presented without prejudice. This map is the property of the Tsleil-Waututh Nation and may not be reproduced without written permission.

Sources of spatial data for this map include Tsleil-Waututh Nation, BC Government, Government of Canada, Metro Vancouver.

Map produced December 2015 by the Tsleil-Waututh Nation.

2.2 Fish and Wildlife Habitat

2.2.1 Estuaries

Estuaries are highly productive ecosystems formed where rivers and streams enter the ocean, and freshwater and saltwater mix. They typically develop on shallow deltas of sediment (silt and sand) carried downstream and deposited as flows slow down and spread out over the gently sloping marine shoreline. Estuarine habitat in Burrard Inlet supports all seven (7) salmonid species, as well as a range of forage and flat fish, shorebird, and shellfish species. Approximately 112 streams flow directly into Burrard Inlet (Balanced Environmental Services, 2010); the three largest are the Seymour, Capilano and Indian Rivers. Smaller streams with estuaries of significance include Lynn Creek, Noons Creek, Mosquito Creek, and Mackay Creek. Many small streams do not have vegetated estuary habitat due to their size or locations of entry into the inlet, or because of human alterations. Yet, the freshwater entering the inlet from these small streams will still create localized estuarine conditions in the water column.

Status and Trends

Since 1930, 93% of the original extent of estuary habitat in Burrard Inlet has been lost to development, amounting to a loss of 130 ha (Levings and Thom, 1994). Estuaries in the Inner Harbour have seen the largest losses; only 1% remains of the Mackay Creek, Mosquito Creek, Lynn Creek and Seymour River estuaries (K. Ashley, pers. comm.). Estuary function has also been impacted by changes in circulation and flow patterns at some locations. For example, prior to 1927, the Capilano River had outlets to the east and west of First Narrows but flows were restricted to the west with the building of the Lions Gate Bridge (Stantec, 2009).

A total of 363 ha of Burrard Inlet has been filled over the last 100 years (Stantec, 2009), including significant estuary habitat. For example, only 5% (6.5 of 141 ha) of the original extent of Maplewood Flats remains (PSKF, 2015). Most of these losses occurred prior to the 1980s. Currently, 11% of the shoreline of Burrard Inlet is considered estuary or tidal flats, covering an area of 261 ha (Stantec, 2009). A significant portion of the remaining tidal flat areas are located on Maplewood Flats and in Port Moody Arm.

Threats

Though loss of estuaries has slowed down, remaining estuarine habitats in Burrard Inlet are still threatened by pollution, sea level rise, invasive species, and continued development:

- *Point and non-point source pollution*: Pollution can impact estuaries and associated fish and wildlife; contaminated sediments have been identified in multiple estuaries in Burrard Inlet.
- *Sea level rise*: Rising seas will cover shallow water habitats associated with estuaries. These ecosystems will be forced to migrate inland. This is not possible for most estuaries due to extensive lowland development and hardened shorelines.
- *Invasive non-native species*: Several non-native plant species can outcompete native salt marsh plants and change the hydrology of nearshore ecosystems. Although not found in Burrard Inlet yet, common cordgrass (*Spartina angelica*) has significantly altered some nearshore habitats in the Pacific Northwest with large ecological and economic consequences.

- *Urban development*: Extensive upland development throughout watersheds can impact estuaries through changes to water quality, stream flow, and sedimentation patterns, and more directly through stream channelization. Urban streams are highly managed to protect from floods including sediment removals, diking, and various forms of bank protection. Urbanization also reduces the quality of stormwater runoff.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Due to the importance of estuaries for fish and wildlife and their severely reduced extent in Burrard inlet, restoration of estuaries is a high priority. Restoration projects are currently underway through the Burrard Inlet Restoration Pilot Program and “Bringing it Back”, a Tsleil-Waututh initiative. The Burrard Inlet Restoration Pilot Program, which provided compensation funds from the 2007 oil spill to projects in Burrard Inlet, has funded projects at the Mackay Creek, Mosquito Creek, Lynn Creek, Seymour River, Beaver Creek, and Renfrew Creek estuaries. “Bringing it Back” is focussed on restoring Maplewood Flats and McCartney Creek.

2.2.2 Eelgrass Beds

Eelgrass (*Zostera marina*) beds typically grow in low to shallow intertidal areas on sandy or muddy substrates. They are often found near river deltas. Eelgrass beds play an important role in marine ecosystems, not only as significant primary producers, but also by acting as important nursery grounds for juvenile salmon, flatfish, crabs, and shellfish and spawning grounds for Pacific herring (Mumford, 2007). Though eelgrass was likely not a dominant habitat in Burrard Inlet historically due to the overall lack of shallow water, it was widely distributed throughout the inlet, from the Indian River estuary to West Vancouver (Foreshore Technologies, 1996). The rarity of eelgrass adds to its ecological importance in Burrard Inlet.

Status and Trends

Eelgrass is still present throughout Burrard Inlet from West Vancouver and Stanley Park to the Indian River Estuary (Foreshore Technologies, 1996; Levings and McDaniel, 1974; Mach, 2012; R. Butler, pers. comm.; Seacology, 2013; SeaChange, 2015; Village of Belcarra, 2007). The highest concentration of eelgrass bed locations are found in the Inner Harbour and the southern extent of the Indian Arm (SeaChange, 2015). Although eelgrass is widespread, the abundance of eelgrass in Burrard Inlet has likely declined since the early 1900s. The most suitable habitat for eelgrass is found in estuaries, lagoons, and bays, areas which have seen some of the largest losses due to development or other human impacts, such as pollution and boating. For example, Port Moody Arm and Bedwell Bay still contain eelgrass, but in much less abundance than was likely present historically (R. Butler, pers. comm.; Village of Belcarra, 2007). The Indian River estuary once contained “lush eelgrass fields” (Fedorenko and Shepherd, 1984), but recent surveys have found it to be absent, likely impacted by past forestry activities, logging road development, and linear energy infrastructure development (J. Konovsky, pers. comm.).

Though specific impacts of forestry activities on eelgrass in Burrard Inlet have not been studied or monitored, forestry activities are generally known to have detrimental and long-lasting impacts on eelgrass communities (Wright, 2015) particularly due to log-booming practices (bark chips smother eelgrass) and increased sedimentation from streams (reduces ability to photosynthesize). The watersheds of Burrard Inlet experienced extensive logging from the mid-1800s through to the early 1900s.

Threats

Eelgrass meadows remain under threat from a number of sources:

- *Sea level rise*: Rising water levels in Burrard Inlet will reduce the amount of shallow water habitat available in Burrard Inlet. Eelgrass is sensitive to the amount of light reaching the ocean floor and available for photosynthesis. As sea levels rise, eelgrass will be forced to migrate inland in order to obtain adequate light. This is not possible at most locations where eelgrass is found due to extensive shoreline hardening.
- *Non-point source pollution*: Pollution from non-point sources can increase nutrient levels, turbidity, and contaminant levels in eelgrass habitats. Increased nutrient input can cause algal blooms which smother eelgrass. Turbidity reduces light availability for eelgrass. Contaminants in sediments such as metals and persistent organic pollutants can impact the eelgrass fauna, including shellfish, fish species, and invertebrates, altering food web dynamics (Wright, 2015).
- *Recreational boating*: Recreational boating poses a continued threat to eelgrass as boat traffic increases water turbidity and reduces light levels. Boat propellers can physically disturb eelgrass beds, as can anchoring and mooring (Wright, 2015). Sites with eelgrass often also have large amounts of boat traffic (i.e., Port Moody Arm, Bedwell Bay, Deep Cove).
- *Shoreline development*: The development of shorelines physically destroys habitat, alters circulation patterns, and can shade eelgrass beds. Overwater structures, such as docks and wharves, cover almost 2 ha of nearshore habitat in Burrard Inlet (Stantec, 2009).
- *Invasive non-native species*: Non-native plants, such as non-native eelgrass (*Zostera japonica*) and common cordgrass (*Spartina angelica*), may have a significant impact on eelgrass communities. *Zostera japonica* may establish in some areas, however, it utilizes different habitat and are unlikely to compete with native eelgrass (*Z. marina*). *Spartina angelica*, if it established in Burrard Inlet, could have long-term potential impacts on eelgrass communities through changes in hydrology (N. Wright, pers. comm.).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Seachange Marine Conservation Society conducted detailed mapping of eelgrass communities in a portion of Burrard Inlet in spring 2015 (N. Wright, pers. comm.). The Pacific Wildlife Foundation has also undertaken some restoration of eelgrass beds in Port Moody Arm (Butler *et al*., 2011).

Due to the rarity and ecological significance of eelgrass beds, the conservation and restoration of eelgrass communities are a priority. Detailed mapping of eelgrass beds provides a baseline for conservation efforts, identifies key locations to protect, and helps identify sites on which to focus restoration efforts. Where eelgrass is present, efforts to understand limiting factors for recovery will be crucial.

2.2.3 Kelp Forests

Bull kelp (*Nereocystis luetkeana*) is a significant species of brown algae which forms kelp beds or "forests" in British Columbia's coastal waters. Kelp contributes significantly to the primary productivity of coastal ecosystems, and also provides structural complexity to shallow water habitats (Springer *et al*., 2007). Kelp forests are linked to commercially important fish including forage fish such as Pacific herring and Pacific sand lance, as well as salmon species at different life stages (Lamb *et al.,* 2011). In the early to mid-1990s, significant kelp forests still existed in Burrard Inlet at First Narrows around Stanley Park, throughout the Inner Harbour, and through Second Narrows (Foreshore Technologies, 1996).

Status and Trends

Bull kelp has not been monitored closely in Burrard Inlet, but declines in kelp beds in the middle latitudes of the Strait of Georgia have been observed over the past two decades (Lamb *et al*., 2011) and similar trends may exist in Burrard Inlet. A study conducted in 1916 showed one kelp bed in Burrard Inlet in Coal Harbour; this still exists and another has formed at Brockton Point (Levings and Thom, 1994). Alternatively, based on observations by Tsleil-Waututh community members, bull kelp was once abundant along the south shore of the Central Harbour but the size of patches in this area are much reduced. Log booms may have been responsible for reducing bull kelp at some sites. Bull kelp is sensitive to changes in light levels, nutrient availability, pH, salinity, and temperature (Lamb *et al.*, 2011) and physical changes to shorelines can also prevent the establishment of kelp on cobble substrates (R. de Graaf, pers. comm.).

Threats

Kelp forests in Burrard Inlet have the potential to be affected by a number of threats:

- *Overwater structures*: Docks, wharves, piers, and other overwater structures can reduce light levels and increase turbidity, sedimentation, and other forms of pollution.
- *Shoreline hardening*: The hardening of shorelines alters physical processes in nearshore habitats and can increase instability of cobble and boulder substrate. Bull kelp is an annual plant, and spores settle on stable sub-tidal cobble and boulders. Two-thirds of Burrard Inlet's shoreline has been hardened (Stantec, 2009).
- *Invasive non-native species*: Invasive non-native species can compete for habitat with native kelp species and are of potential concern. Japanese wireweed (*Sargassum muticum*), an invasive macroalga, can outcompete native bull kelp in some circumstances (Springer *et al*., 2007) and is known to exist in Burrard Inlet (Ankenman, 2013).
- *Changes in salinity*: Salinity levels in Burrard Inlet may be affected by climate change and could impact bull kelp as they are sensitive to decreases in salinity (Springer *et al*., 2007).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

The locations and extents of kelp forests in Burrard Inlet are not well known and should be mapped in more detail. Research to understand the limiting factors for kelp in Burrard Inlet would help to aid in the conservation and restoration of kelp beds.

Some small-scale kelp bed restoration has been attempted in conjunction with shoreline softening projects in West Vancouver. As beaches are re-established in front of seawalls, sediments stabilize sub-tidal cobble. Kelp spores have been introduced to some sites in the hope that kelp beds will regenerate (R. DeGraaf, pers. comm.).

2.2.4 Shorelines

Shoreline habitats include a variety of ecological community types that exist at the marine and terrestrial interface, including rocky intertidal areas, estuaries and tidal flats, rivers and streams, built structures like riprap and retaining walls, beaches, and vegetated riparian areas. Shoreline habitats are crucial habitats for juvenile salmon, flatfish, crabs, invertebrates, and birds. Beaches provide important spawning areas for forage fish, including sand lance and surf smelt. Vegetated shorelines provide food and cover for fish, stabilize shorelines and prevent erosion, filter pollution, and can moderate the intensity of changing environmental conditions.

Status and Trends

Shorelines in Burrard Inlet have been heavily modified by industrial and urban development. Approximately 50% of Burrard Inlet's shorelines have been altered (e.g., docks, retaining walls, riprap). In total, 53 km of natural shoreline has been lost (Stantec, 2009). Shoreline alteration is highest in the Inner Harbour (90%) and lowest in Indian Arm (exact percentage not known). Indian Arm shorelines are dominated by steep-sided mountain walls with rocky intertidal habitat. Important beach habitat is located mostly in the Outer Harbour and, to a lesser extent, at Maplewood Flats, Port Moody, and the Indian River estuary. Intertidal habitat throughout the inlet is impacted by built overwater structures, including wharves and piers, which block sun and reduce the productivity of marine ecosystems. Overwater structures cover almost 20,000 m^2 in Burrard Inlet (Stantec, 2009).

Threats

Despite the considerable loss of shoreline habitat that has already taken place, continued threats remain:

- *Urban and industrial development*: Development along the shores of Burrard Inlet is less of a threat than it was historically, but proposals that further impact or modify natural and semi-natural shorelines must be reviewed carefully to prevent further incremental losses of shoreline habitat.
- *Climate change*: There are a number of ways climate change may impact shoreline structure and function. Sea level rise in the Outer Harbour may alter sediment transport patterns affecting beach development. Higher water levels and the potential for more intense storms will impact seawalls and other infrastructure. Sensitive shallow water habitats, including beaches, mudflats, and estuaries may not be able to migrate inland as sea levels rise because of existing hardened shorelines and development (Wright, 2015).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Shoreline softening is the use of techniques which reduce the impacts of shoreline hardening and return the shoreline to a more natural state. There is a need to identify other shoreline softening opportunities in Burrard Inlet and develop guidelines for softening techniques.

The District of West Vancouver is using shoreline softening techniques to protect some private residences and seawall infrastructure. Sand is being captured and beaches are being rebuilt in order to dissipate wave energy and create new habitat for spawning forage fish.

2.3 Key Species Populations and Food Webs

2.3.1 Salmon

Burrard Inlet is utilized for rearing and migration by seven species of Pacific salmon, including Chinook (*Oncorhynchus tshawytscha*), chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*), pink (*Oncorhynchus gorbuscha*), sockeye (*Oncorhynchus nerka*), steelhead (*Oncorhynchus mykiss*), and cutthroat trout (*Oncorhynchus clarki*) (Levings *et al*., 2004). Juvenile salmon use nearshore areas in Burrard Inlet during spring and summer months (Levy, 1996), and originate from 17 known spawning streams in the inlet, as well as from the Fraser River (Naito and Hwang, 2000). Total adult salmon returns from 1981–1985 to these streams averaged 1200 Chinook, 26,000 chum, 32,000 coho, 25,600 pink, 13 sockeye, and 840 steelhead (MacDonald and Chang, 1993). Chinook and coho were mostly hatchery fish from the Capilano and Seymour Rivers. Historically, wild Chinook were present in Lynn Creek, the Capilano River, and the Seymour River (TWN, 2005) but wild populations are unlikely to occur today. Pink and chum salmon are mostly wild fish from the Indian River system.

Juvenile pink, chum, and Chinook salmon are the most abundant salmonids in nearshore areas of Burrard Inlet, followed by coho (Haggerty, 2001). Hatchery programs exist on a number of streams in Burrard Inlet including the Capilano River, Seymour River, Mossom Creek, Noons Creek, and Lynn Creek (Morten Creek) and release large numbers of chum, Chinook, coho, and pink salmon into the inlet every year. In 1999, almost 2.5 million hatchery salmon were released in the Burrard Inlet catchment (Haggerty, 2001).

Recreational fisheries exist for Chinook salmon in the Outer Harbour and Indian Arm all-year round, and for hatchery coho in the fall in the Outer Harbour (Levings *et al*., 2004).

Status and Trends

Salmon populations have undergone significant reductions in Burrard Inlet since the early 1900s. Two of the three major salmon rivers, the Capilano and Seymour Rivers, were dammed, blocking access to spawning habitat and altering flow regimes. Coho returns to the Capilano River declined from 3500–7000 prior to the construction of Cleveland Dam in 1955 to about 2000 in the 1960s and early 1970s before hatchery production increased numbers again (Fedorenko and Perry, 1991). Indian River salmon numbers have recovered somewhat after declines in the mid-1900s. Salmon returns from 1934–1982 averaged 14,700 chum and 67,300 pink, respectively, increasing to 76,500 chum and 94,500 pink from 1982–2013. In contrast, coho returns declined from 1300 to 1050 on average between the two time periods. These numbers are estimated to be up to 10 times lower than historic returns (TWN, 2014; TWN, 2015).

Threats

Salmon in Burrard Inlet remain under considerable pressure due to a number of factors:

- *Loss of nearshore habitat*: In general, juvenile salmon restrict their movements to habitats between 0.1 m and 2.0 m depth until they reach a size that allows them to exploit deeper channel and open-water habitats and associated prey resources (Simensted *et al.*, 1982). They use shallower water both for feeding and to avoid predators that are too large to enter the shallower areas. When the salmon are large enough, they are then able to use the deeper habitats more extensively. The extent of estuaries, tidal flats, eelgrass beds, and other shallow water habitat in Burrard Inlet has been significantly reduced as a result of shoreline and overwater development (Stantec, 2009)

- *Barriers to fish migration and increased predation risk*: Juvenile salmon migrate along the shoreline as they leave Burrard Inlet and head out into the Strait of Georgia. Extensive shoreline development in the Inner Harbour may be creating physical and behavioural barriers as juvenile salmon migrate from Second to First Narrows. Overwater structures alter light patterns along shorelines and can cause disorientation, dispersal, break-up of schools and changes in migration routes to deeper water where predation risk is higher. Artificial light can also disrupt migration at night. An acoustic tracking study of hatchery release outmigrating steelhead smolts from the Seymour River suggested low early marine survival between Second and First Narrows (Balfry *et al*., 2011).
- *Lack of freshwater habitat*: Many of the streams flowing into Burrard Inlet are heavily urbanized. Urbanized streams often have low summer baseflows, increased peak flows during storms, may be channelized and physically altered, and have higher temperatures, among other changes. Much of the spawning habitat in streams around Burrard Inlet has also become inaccessible due to dams, culverts, and other obstructions.
- *Pollution and water quality*: Juvenile salmonids feed extensively on epibenthic invertebrates (Bravender *et al*., 1996). Sediment sampling in Burrard Inlet has indicated sites of contamination with heavy metals, PCBs, and other contaminants but little is known about the impact of contaminated sediments on epibenthic invertebrates. One study found the Inner Harbour and Port Moody Arm to be dominated by pollution tolerant benthic fauna (Je *et al*., 2004).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Due to the importance of salmonids in coastal BC, much research has been done on the biology of adult and juvenile salmon. However, key knowledge gaps for salmon populations in Burrard Inlet include:

- Impacts of overwater structures and shoreline development on juvenile salmon migration;
- Other factors affecting juvenile salmon mortality in marine waters;
- Extent that outmigrating Fraser River salmon use Burrard Inlet as rearing habitat; and
- Impact of contamination on juvenile salmon prey in nearshore environments.

Numerous projects have been conducted in Burrard Inlet to increase production of salmonids. Hatcheries were constructed on the Capilano and Seymour Rivers in 1971 and 1977, respectively, to mitigate the impacts of dams on coho and steelhead populations, as well as to introduce Chinook salmon (DFO, 2014). Metro Vancouver also captures and transports adult salmon above the Capilano and Seymour River dams and transports outmigrating juveniles below the dams (Walsh, 2014).

Chinook salmon fry were released in the Indian River in 1966 in an unsuccessful attempt to establish a run there. A pilot hatchery was also constructed and operated from 1979–1980 to raise Chinook (Fedorenko and Shepherd, 1984).

Freshwater habitat restoration projects have been conducted on streams throughout the Burrard Inlet catchment, including the Indian River, Capilano River, Seymour River, Mosquito Creek, Mackay Creek, Lynn Creek, and others. Current large-scale restoration projects on estuaries in North Vancouver and Vancouver are underway on the Seymour River, Lynn Creek, Mackay Creek, Mosquito Creek, Renfrew Creek, and McCartney Creek.

2.3.2 Forage Fish

Forage fish are small schooling fish such as Pacific herring (*Clupea pallasii*), capelin (*Mallotus villosus*), anchovy (*Engraulis mordax*), Pacific sand lance (*Ammodytes hexapterus*) and surf smelt (*Hypomesus pretiosus*) (de Graaf, 2014). Providing food for larger fish and other fish-eating marine species, they are a critical link in the marine food chain; hundreds of predators in the Strait of Georgia rely on them, including Chinook and coho salmon, and many birds, including the Marbled Murrelet (*Brachyramphus marmoratus*), Western Grebe, and Barrow's Goldeneye (de Graaf, 2014; Worcester, 2011). Sand lance and surf smelt are the two most common forage fish species in Burrard Inlet. Herring is also present.

Sand lance and surf smelt are beach spawners, while herring typically spawn on marine vegetation such as eelgrass and seaweeds (de Graaf, 2014). Sand lance and surf smelt need a mix of gravel and sand. Beaches with natural erosion processes and marine riparian vegetation provide optimal habitat. Important potential beach habitats for forage fish are located in the Outer Harbour (R. de Graaf, pers. comm.; Therriault and Hay, 2003), including Ambleside Beach and Wreck Beach. Forage fish are known to spawn at Cates Park as well (Stantec, 2009).

Status and Trends

Forage fish stocks in Burrard Inlet have declined since the late 1800s. A commercial fishery on surf smelt began in 1886, and catches began to decline after 1920, with particularly large declines in the 1950s (Therriault and Hay, 2005). Catches reached a peak of over 100 tonnes around 1910, but averaged less than two tonnes in the early 2000s, likely due to increased fishing pressure and human activity around the inlet (Therriault and Hay, 2005). Beaches in the Outer Harbour have been impacted by the deposition of dredged sand over the natural substrate, reducing the availability of spawning habitat (Levy, 1985). Recreational and commercial fisheries still operate on the beaches of the Outer Harbour, suggesting fish are still present, but numbers are not known (R. deGraaf, pers. comm.).

Burrard Inlet used to support large schools of Pacific herring (TWN, 2015), and herring were known to spawn at the mouth of the Capilano River and in Coal Harbour and West Bay (Kheraj, 2013; TWN, 2005). A fish rendering facility and cannery exploited the herring stocks between 1882 and 1885 using dynamite, and the fishery was destroyed by 1885. Afterward, there was significantly reduced herring present in Burrard Inlet. There are records of herring spawning in Port Moody Arm from the 1930s and in Indian Arm in the 1970s (D. Hay, pers. comm.). Between 1000 and 2000 tonnes of herring were estimated to be present in Burrard Inlet in 1973 (MacDonald and Chang, 1993). Recent records of herring spawning in False Creek, Port Moody Arm, and Indian Arm suggest some returns of spawning herring (S. Hollick-Kenyon, pers. comm.). Herring in Port Moody Arm spawn in June and could be related to the Cherry Point stock in Washington which also spawns later than other runs (Village of Belcarra, 2014). Herring were also seen spawning near the head of Indian Arm in June 2014, and near Best Point in Indian Arm in March 2015 (R. Butler, pers. comm.). In general, there is much uncertainty about herring stocks and spawning in Burrard Inlet (e.g., how often does spawning occur, are the stocks resident or migratory, etc.) and few quantitative records exist (D. Hay, pers. comm.).

Little is known about sand lance populations in Burrard Inlet, but there are reasons to suspect declines. They are an important food source for sea birds, and sea birds have been used as indicators of forage fish abundance in other areas. Forage fish dependent birds in Burrard Inlet have been on the decline (Butler *et al*., 2015; Worcester, 2011) indicating changes in forage fish abundance. Furthermore, important spawning habitat is threatened in Burrard Inlet, as beach habitat is quite limited and recreational use by humans is high.

High numbers of anchovies were observed throughout the Strait of Georgia and in Burrard Inlet in 2016, but the origin of the population is unclear. The anchovies observed in Burrard Inlet may be related to anchovy stocks in Puget Sound or from off-shore stocks (D. Hay, pers. comm.).

Threats

Forage fish populations in Burrard inlet continue to be limited by a number of factors:

- *Loss of spawning habitat*: All three major forage fish species known from Burrard Inlet have seen significant declines in the amount of available spawning habitat. Herring typically spawn on marine vegetation; eelgrass and kelp beds are fewer and smaller than the past (see Eelgrass Beds and Kelp Forests sections). Extensive modifications to shorelines have reduced the amount of beach habitat available for spawning sand lance and surf smelt (Stantec, 2009).
- *Overharvesting*: The most significant surf smelt fisheries in BC occur in the Burrard Inlet area. Recreational fisheries focus on spawning fish as they come to the beaches to spawn. The combined commercial and recreational fisheries in Burrard Inlet may be overharvesting surf smelt, and changes to management of the fishery are suggested (Therriault and Hay, 2003).
- *Increased predator numbers*: Harbour seals are major predators of forage fish in coastal BC. Numbers of harbour seals are at historic highs in the Salish Sea and may be at levels that could naturally depress forage fish stocks in Burrard Inlet (D. Hay, pers. comm.).
- *Pollution*: Herring are known to spawn on the pilings of wharves, piers, and other overwater structures. Creosote logs used for pilings kill herring eggs. Mass egg die-offs seen on the east coast of Vancouver Island are thought to be connected to pollution (D. Hay, pers. comm.).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Forage fish are an understudied aspect of Burrard Inlet's food web. Stock assessments are not conducted on any of the three major forage fish species making management of the fisheries difficult. Currently the fishery for surf smelt is an "unlimited entry, unlimited quota fishery where biological data are sparse or non-existent and formal assessments are not possible" (Therriault and Hay, 2003). Key knowledge gaps for forage fish populations in Burrard Inlet include:

- Population sizes and spawning biomass of different forage fish species;
- Potential spawning locations and their current utilization;
- Importance of particular spawning locations for different species;
- Potential impacts of sea level rise on forage fish habitat suitability;
- Priority sites for forage fish spawning habitat restoration;
- Effectiveness of shoreline softening in restoring forage fish habitat; and
- Whether Burrard Inlet herring populations are resident or migratory.

A few small-scale projects are currently underway in Burrard Inlet to research and restore forage fish populations. Efforts are being made in Deep Cove and False Creek to provide spawning substrate for herring free from chemical pollution. Beach spawning surveys in Port Moody Arm have been conducted with the BC Shore Spawners Alliance (R. de Graaf, pers. comm.). More intensive surveys were conducted in 2015 and 2016 in other areas of Burrard Inlet to identify potential beach spawning locations and create habitat suitability maps for sand lance and surf smelt. A report detailing the survey results is currently in preparation (R. de Graaf, pers. comm.).

2.3.3 Shellfish

Burrard Inlet contains a diverse community of shellfish including bivalve species like clams, mussels, and oysters. Shellfish play an important role in Burrard Inlet: they filter out and break down contaminants and are a reliable food source for seabirds, shorebirds, and other predators. In Burrard Inlet, shellfish can be found in rocky intertidal areas, tidal flats, and estuaries. As discussed in Section 1.2, shellfish were an important Tsleil-Waututh food source and harvest sites were distributed throughout the inlet. Harvested species include cockles, littleneck clams (*Protothaca staminea*), manila clams (*Venerupis philippinarum*), butter clams (*Saxidomus gigantean*), horse clams (*Tresus* spp.), and oysters. Important shellfish sites with abundant populations historically were between Maplewood Flats and Roche Point, at the mouth of the Capilano River, and in the Port Moody tidal flats. Shellfish were also harvested at Brockton Point, the Seymour River and Mosquito Creek estuaries, Indian River tidal flats, Jug Island, Barnet Marine Park, and Strathcona Bay (TWN, 2005). Shellfish are also important as a food source for wildlife. For example, beds of blue mussels (*Mytilus* spp.) are found off Stanley Park and are important feeding grounds for Surf Scoters (Worcester, 2011).

Status and Trends

Shellfish are present throughout the archaeological record in Burrard Inlet (TWN, 2015) and were a fundamental aspect of the Tsleil-Waututh's subsistence economy. Historical records of abundance are not readily available, but shellfish likely would have been abundant in shallow nearshore environments. Important nearshore habitats, including estuaries and tidal flats, have been severely impacted by development, decreasing available shellfish habitat. Estuaries are only 7% of their former size (Levings and Thom, 1994), and 363 ha of shallow water habitat has been lost in Burrard Inlet since the early 1900s (Stantec, 2009).

Community composition of shellfish communities has shifted as well. Native shellfish communities would have included littleneck clams, butter clams, and the Olympia oyster (*Ostrea conchaphila*). Over time, these species have been replaced by invasive non-native shellfish species, including the purple varnish clam (*Nuttallia obscurata*; also known as the dark mahogany clam) and the soft-shell clam (*Mya arenaria*). The Pacific oyster (*Crassostrea gigas*), introduced in the 1920s, replaced the Olympia oyster, but both have become rare (TWN, 2013; TWN, 2015). Recent stock assessments of shellfish found that soft-shell and purple varnish clams are abundant throughout Burrard Inlet, and are dominant in the Indian Arm estuary and Bishop North sites (TWN, 2013). At Maplewood Flats, butter and littleneck clams remain in equal abundance to soft-shell and purple varnish clams. Other species identified in the assessments include bent nose clams (*Macoma nasuta*), horse clams (*Tresus* spp.), and cockles (*Clinocardium* spp.) (TWN, 2013).

Threats

Threats to shellfish communities in Burrard Inlet include:

- *Acidification*: Shellfish that form calcium carbonate ($CaCO_3$) shells and skeletons are particularly susceptible to changes in pH. The seawater surrounding calcifying organisms needs to be saturated with carbonate ions to allow shells to form and to protect shells from dissolution (or breakdown into individual ions). Declines in pH will decrease the saturation state of $CaCO_3$. Shellfish larvae are particularly sensitive.
- *Sea level rise*: Estuaries, tidal flats, and other shallow water habitats are threatened by rising sea levels. The problem is exacerbated by shoreline developments that prevent the inland migration of these ecosystems.

- *Pollution*: Burrard Inlet was closed to shellfish harvesting in 1972 due to high levels of pathogens and other forms of contamination.
- *Invasive species*: The current dominance of shellfish communities by invasive species indicates purple varnish and soft-shell clams may be competitively excluding native species. Furthermore, varnish clams may alter ammonium cycling in marine sediments and could impact ecosystem functioning including primary productivity in intertidal areas (Chan, 2012).
- *Changing species interactions*: Changes in water salinity associated with climate change may impact important species interactions in Burrard Inlet. For example, when water is saltier, whelks and sea stars are favoured and they are able to exploit mussel beds more fully. In years where water is less saline, predators suffer and mussel beds recover (C. Harley, pers. comm.). This may have implications further up the food chain as well, as Surf Scoters, for example, rely heavily on blue mussel beds.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

There is little information available about the current or historic distribution of particular shellfish habitat types, such as clam beds, mussel beds, oyster reefs, or different shellfish species. Further work is also needed to understand how shellfish are likely to be impacted by acidification and which shallow nearshore locations are most at risk from sea level rise. Significant work is being done by Chris Harley from UBC on ocean acidification and species interactions in intertidal communities in the North Pacific that is relevant to Burrard Inlet (C. Harley, pers. comm.).

Leah Bendell from SFU and the Tsleil-Waututh Nation are using a site at Cates Park to research ways to mitigate the impacts of acidification on intertidal communities. Shell hash (mix of broken and small shells) is being dug into the sand, and pH is being measured to see if the shell hash can act as a buffer against changes in ocean pH in intertidal areas (L. Bendell, pers. comm.).

2.3.4 Birds

Designated an Important Bird Area, Burrard Inlet is home to globally significant numbers of Western Grebe, Barrow's Goldeneye, and Surf Scoter, and nationally significant numbers of Great Blue Heron. At times, more than 7000 Surf Scoters have been observed in the inlet. Large cormorant colonies are found on the Second Narrows, Granville, and Burrard Street bridges, and Osprey and Bald Eagles can also be found nesting along the shores (Butler *et al.,* 2015; BSC, 2015). Fifty-three species of resident birds occupy the inlet, and make use of the tidal flats, estuaries, rocky intertidal habitat, and beaches (Stone *et al.,* 2013). Sixteen regularly occurring bird species in Burrard Inlet have been federally designated as endangered, threatened, or species of special concern, or have been red- or blue-listed by the B.C. Conservation Data Centre (Butler *et al.*, 2015).

Status and Trends

Overall, bird species in Burrard Inlet appear to be doing well, though most have likely declined from historic levels (Butler *et al.*, 2015). A number of species have declined more significantly in recent years, including the Horned Grebe (*Podiceps auritus*), Western Grebe, Marbled Murrelet, and Barrow's Goldeneye (Butler *et al*., 2015). Western Grebe numbers reached 15,000 in 1970, and Barrow's Goldeneye reached 7126 in 1990; since 2000, numbers of Western Grebe and Barrow's Goldeneye have only reached 1029 and 1901, respectively (Worcester, 2011). Marbled Murrelets were plentiful in the 1970s (Butler *et al.*, 2015). These declines may be linked to decreases in forage fish populations (Butler *et al.*, 2015). Other fish-feeding birds that have declined include loons, other grebes, and mergansers (SPES, 2010). Declines in forage fish abundance can have devastating impacts on bird populations (R. de Graaf, pers. comm.). Shorebirds and Glaucous-winged Gulls (*Larus glaucescens*) have also declined in abundance though the reasons are less clear (Jacques Whitford AXYS, 2008; Worcester, 2011).

Some species are stable or increasing in number, including four resident species, Black Oystercatchers, Double-crested Cormorants (*Phalacrocorax auritus*), Pelagic Cormorants (*Phalacrocorax pelagicus*) and Great Blue Herons (Jacques Whitford AXYS, 2008; Worcester, 2011). Surf Scoters and Canada Geese (*Branta canadensis*) are also increasing (Worcester, 2011).

Threats

Birds in Burrard Inlet continue to be threatened by a number of factors:

- *Declines in forage fish abundance*: Many of the bird species in decline share forage fish as a primary food source. In a study, further north on the coast, when forage fish stocks collapsed, 85% of Rhinocerous Auklet (*Cerorhinca monocerata*) chicks died (R. de Graaf, pers. comm.). Declines in alcids and grebes have also been noted in the Salish Sea as a whole (R. de Graaf, pers. comm.).
- *Oil spills or other acute pollution*: Because some species form large congregations within the inlet, a large oil spill could significantly impact a population of a species (R. Butler, pers. comm.).
- *Boat and tanker traffic*: Traffic from boats and tankers can disturb feeding and resting birds on the water, reducing the time spent doing these activities.
- *Disturbance from recreational activity*: Birds resting and feeding close to shore can be disturbed by dogs on beaches, kayakers, boaters, and other recreational activities along beaches and shorelines.

- *Loss of habitat due to sea level rise*: Bird species that utilize nearshore habitats, particularly estuaries, tidal flats, and salt marshes, will likely lose habitat as sea levels rise.
- *Acidification*: Shellfish and other invertebrates are significant prey sources for bird species in Burrard Inlet. Mussels, clams, and other calcifying organisms are vulnerable to increasing acidity in the inlet.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Monitoring of birds in Burrard Inlet has been ongoing for many years. Bird Studies Canada supports volunteer efforts including the Coastal Waterbird Survey and Christmas Bird Counts. The Stanley Park Ecology Society and British Columbia Institute of Technology (BCIT) also work together on conducting yearly bird surveys, focussed on Barrow's Goldeneye near Stanley Park.

Bird Studies Canada and the Pacific Wildlife Foundation recently reported on monthly surveys of birds by boat from the Outer Harbour to Indian Arm from 2011–2013 (Butler *et al.*, 2015). There is also research currently being conducted by Sean Boyd on the movements and habitat usage of Barrow's Goldeneye using satellite tracking technology (R. Butler, pers. comm.).

Despite the significant amount of research and monitoring that has been done, key questions still remain about bird populations in Burrard Inlet. These include:

- Are declines in Western Grebe and Barrow's Goldeneye linked to changes in forage fish abundance?
- Are populations really in decline, or have they simply moved to other locations? Migratory birds are extremely difficult to study as they travel great distances across many jurisdictions.

2.3.5 Marine Mammals

A variety of marine mammals make use of Burrard Inlet, though most are occasional visitors. Harbour seals (*Phoca vitulina richardsii*) are the most common marine mammal in the inlet with populations estimated at 300 in 2005 (TWN, 2005). Other sightings of marine mammals include false killer whales *(Pseudorca crassidens),* orcas (*Orcinus orca*), grey whales (*Eschrichtius robustus*), humpback whales (*Megaptera novaeangliae),* harbour porpoise *(Phocoena phocoena)*, Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), Stellar's sea lions (*Eumetopias jubatus)*, and California sea lions (*Zalophus californianus*) (BCCSN, 2015). Historically, Dall's porpoise (*Phocoenoides dalli*) and northern elephant seals (*Mirounga angustirostris*) would also have been present but rare (Page, 2012).

Status and Trends

Approximately 300 harbour seals live in Burrard Inlet (TWN, 2005). Harbour seals throughout the Strait of Georgia have increased in abundance in recent years, and are thought to represent a recovery of the population from overharvesting (D. Hay, pers. comm.). Other marine mammals, including sea lions and whales are rare and likely have never been abundant (TWN, 2005). Not enough information exists to assess trends, but there are indications that whales may be returning more frequently. Since 2013, both humpback whales and orcas have been sighted in the inlet (BCCSN, 2015). Humpback whales had been extirpated from the Strait of Georgia since 1908 (Page, 2012). Pacific white-sided dolphins are also being sighted more regularly after being extirpated historically (BCCSN, 2015; Page, 2012).

Threats

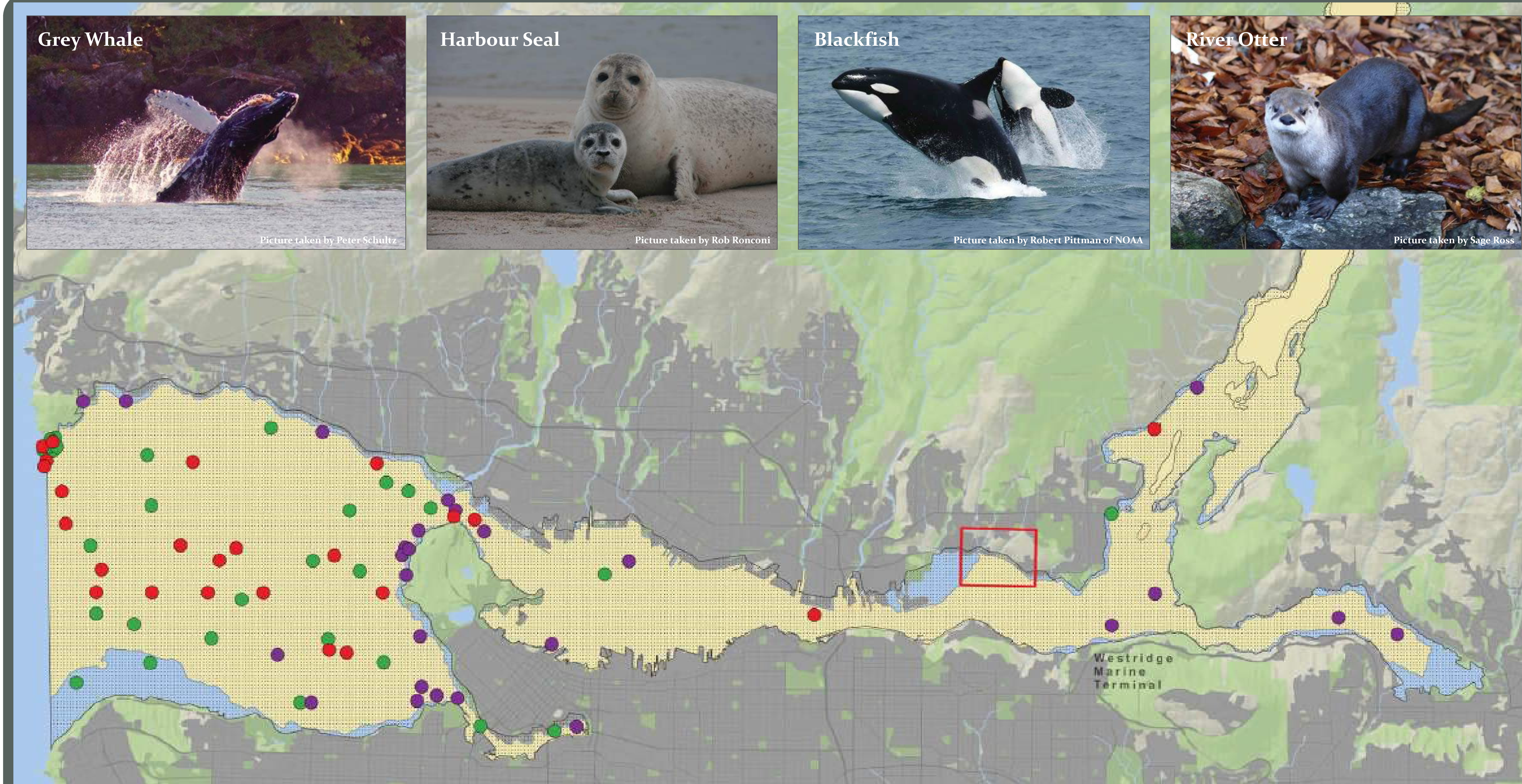
- *Boat and tanker traffic*: Metro Vancouver hosts one of the busiest ports in North America. The high number of boats and tankers utilizing Burrard Inlet may disrupt the movements of marine mammals and interfere with hunting and communication. Direct boat-mammal collisions can cause injury or death.
- *Noise pollution*: Noise from boat and tanker traffic and nearshore industry can alter behaviour patterns, disturb mating and reproduction, and deter use of certain areas.
- *Pollutants*: Orcas of the North Pacific are some of the most contaminated animals on the planet due to the ingestion of contaminated prey (Ross *et al*., 2000). Harbour seals have also been shown to have high levels of contamination (Vancouver Aquarium, 2015). Accumulations of toxins in other marine mammals have been less well studied.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Studies of marine mammals do not generally focus on Burrard Inlet. Key questions remain about the utilization of different habitat in Burrard Inlet by marine mammals including:

- How are contaminants accumulating in marine mammals in Burrard Inlet, namely in harbour seals, and what is the impact?
- What is the impact of a relatively abundant population of harbour seals on salmonid and forage fish populations in Burrard Inlet?

Sightings of cetaceans are monitored by the B.C. Cetacean Sightings Network, a conservation and research program of the Coastal Ocean Research Institute at the Vancouver Aquarium. Impacts of pollution on marine mammals are also studied through the Aquarium's Ocean Pollution Research Program.



Tsleil-Waututh Nation

Burrard Inlet Action Plan

Figure 2-2: Marine Mammal Sightings 1990 to 2014 in Burrard Inlet

Legend

Sightings[1,2]

- Blackfish Sighting
- Gray Whale Sighting
- Harbour Porpoise Sighting
- Harbour Seal and River Otter[2]
- Blackfish and Dall's Porpoise[2]
- Developed Area
- Parks and Protected Areas
- Tsleil-Waututh Nation Reserve

Map Scale: 1:40,000

Projection: UTM, NAD 83, Zone 10

0 1.25 2.5 5 Kilometers

This map is a living document and is intended to be amended and refined over time. It is not an expression of the location of Tsleil-Waututh aboriginal title, rights, or interests. The data used to produce this map originate from many sources and are presented without prejudice. This map is the property of the Tsleil-Waututh Nation and may not be reproduced without written permission. Sources of spatial data for this map include Tsleil-Waututh Nation, BC Government, Government of Canada, Integrated Cadastral Information Society, Vancouver Aquarium, Metro Vancouver.

Map produced December 2015 by the Tsleil-Waututh Nation.

[1]Sightings data from the B.C. Cetacean Sightings Network. 2013. Vancouver Aquarium Marine Science Centre and Fisheries and Oceans Canada. Data not corrected for effort. Used with permission.

[2]Data outside of Burrard Inlet is not depicted on the map.

2.4 Biophysical Processes/Ecological Integrity

2.4.1 Circulation Patterns/Sediment Transport

Circulation and sediment transport patterns are important processes in the maintenance of key nearshore habitats, including salt marshes, mud and sand flats, estuaries, and beaches. Circulation and patterns of sediment transport in Burrard Inlet are controlled predominantly by the tides, inputs of freshwater from the Fraser River, and major streams flowing directly into the inlet, as well as sills between basins and constrictions in flow through narrower parts of the inlet (e.g., First Narrows, Second Narrows). Each basin has unique flows and patterns. In general, sediment transport occurs on the southern side on flood tides, while the ebb tide dominates sediment transport on central and northern halves of the inlet (Levings *et al*., 2004).

The Outer Harbour is strongly influenced by the Fraser River, especially during spring freshet (Thompson, 1981). As water flows towards First Narrows, two eddies are formed. A large counter-clockwise eddy forms to the south in English Bay, and a smaller counter-clockwise eddy forms to the north along West Vancouver. As the tide ebbs, a complicated counter-clockwise gyre forms in English Bay, but is disrupted by ebbing flows from False Creek and continued inputs from the Fraser River off of Point Grey. There is some net erosion on the northern shore just to the west of First Narrows (McLaren, 1994). Beach sediments are transported from the bluffs at Point Grey eastward along the southern shore of the Outer Harbour (J. Clague, pers. comm.).

After currents speed up through First Narrows on flood tides, the water slows down in the Inner Harbour and forms a clockwise eddy to the south, and a counter-clockwise eddy to the north. The eddies reverse on the ebb tide (Haggerty, 2001). Sediment transport pathways are complicated, but sediments accrete through much of the central and southern half of the Inner Harbour. The most significant deposition occurs just to the east of Brockton Point (McLaren, 1994). Dredging is required periodically in First Narrows indicating sediment deposition (Levings *et al*., 2004). Some erosion occurs along the northern shore. Patterns of sediment transport in the Inner Harbour reflect tidal currents quite well (McLaren, 1994).

Water again speeds up and passes through Second Narrows, then enters the Central Harbour and slows down again. Two clockwise eddies form to the south and a counterclockwise eddy forms to the north. These reverse during the ebb tide (Haggerty, 2001). The western half of the Central Harbour, to the west of Roche Point, is a sediment accretion zone (McLaren, 1994), though there is some erosion along the southern side. East of Roche Point, sediments generally neither accumulate nor erode, and could be directed back towards Second Narrows, or to Port Moody Arm and Indian Arm (McLaren, 1994).

Port Moody Arm has slow circulation in a counterclockwise direction (McLaren, 1994). Sediments are deposited here at approximately 0.3–1 cm per year (Levings *et al.,* 2004; McLaren, 1994). Dredging also occurs here in order to maintain deep-sea berths (Levings *et al*., 2004).

A sill at the mouth of Indian Arm restricts water transport between Indian Arm and the Central Harbour. There is a slow flow of brackish water from the head of the arm at Indian River to the mouth of the inlet. More saline water is replaced underneath from the well-mixed waters of the Central Harbour; full deep water renewal can take 7–10 years (BIEAP, 2002a). Indian Arm receives small amounts of sediment from both its north and south ends. A small amount of sediment is carried northward by bottom currents from the Central Harbour and deposits north of the sill. Some sediment is also transported in the outflow from the Indian River, though the quantities are not considered significant (McLaren, 1994).

Status and Trends

Though many of the large-scale circulation and sediment transport pathways are likely largely intact in Burrard Inlet, urban development and industrialization of the shorelines have altered some circulation patterns. For example, during the construction of the Lions Gate Bridge, the Capilano River outflow was moved to the west side of First Narrows, where historically it flowed on either side of the Narrows. Furthermore, after the river was dammed in 1955, less sediment was released into the inlet as it was captured by the dam. Most major streams flowing into Burrard Inlet have been significantly altered, and sediment is dredged from the streams to prevent flooding instead of allowing natural river processes to bring it to the inlet.

Shoreline hardening and the building of overwater structures alter how energy is dissipated and how sediment is transported through the harbour areas. There is concern from TWN community members that shoreline hardening has altered sediment transport in the Central Harbour, increasing sediment deposition in Maplewood Flats and increasing erosion towards Roche Point. Dredging to maintain port activity also likely changes long-term processes of sediment deposition.

Threats

Current threats to water circulation and sediment transport include:

- *Climate change*: Sea level rise and in the intensity and frequency of storm events will likely have impacts on sediment transport along the beaches of the Outer Harbour, especially increasing erosion along the Point Grey bluffs. Little is known about this potential impact (J. Clague, pers. comm.). Climate change is also predicted to change yearly flow patterns in the Fraser River, with potentially significant impacts on circulation patterns in Burrard Inlet.
- *Shoreline development*: Although significant new shoreline development is not expected in the near future, current hardened shorelines can transfer energy to new locations, potentially changing erosion and deposition patterns in the inlet. Furthermore, overwater structures, such as finger docks, can accrete sediment and disrupt sediment transport patterns (McLaren, 1994).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

There are a number of knowledge gaps concerning circulation patterns and sediment transport in Burrard Inlet including:

- How will climate change impact erosion and sediment transport patterns in the Outer Harbour as sea levels rise and storms intensify?
- How will projected changes in flow patterns in the Fraser River impact Burrard Inlet?
- Has shoreline hardening and development contributed to altered erosion and sediment deposition patterns between Maplewood Flats and Roche Point?
- How has urban development impacted the role of streams in circulation patterns in Burrard Inlet? For example, how has restricting the Capilano River outflow to the west side of First Narrows impacted the Inner and Outer Harbours?

There do not appear to be any current projects addressing circulation and sediment transport in Burrard Inlet. On a small scale, West Vancouver is entraining beach sediments in order to build up soft shorelines in front of seawalls in order to protect property and increase the ecological health of the nearshore habitats (R. de Graaf, pers. comm.).

2.4.2 Primary Productivity

Primary production in aquatic systems refers to the conversion of sunlight to energy and biomass by phytoplankton and algae. Plankton is the basis of the food chain in ocean environments, and therefore is critical to overall ecosystem health. Burrard Inlet is a moderately productive system, with mean annual estimates of primary production of 350 g C/m^2/yr, a contrast to most urban embayments and estuaries and lower than measurements from Puget Sound (Stocker and Cliff, 1979). Primary productivity ranges from a high of 532 g C/m^2/yr in Port Moody Arm and decreases towards the Outer Harbour, with the lowest values in the Inner Harbour (254 g C /m^2/yr). The combination of tidal mixing and increased turbidity from the Fraser River decreases productivity in the Inner and Outer Harbours (Haggerty, 2001).

Port Moody Arm has the best conditions for plankton growth, with high nutrient levels, a stable surface layer, and low rates of flushing. It is the most susceptible area to eutrophication, and daily production is among the highest recorded for coastal marine Pacific waters (Stockner and Cliff, 1979).

Indian Arm has also has low rates of productivity at 260 g C/m^2/yr (Stockner and Cliff 1979). Other studies have found the productivity in Indian Arm to be higher (455 g C/m^2/yr), an atypical feature of coastal fjords (Gilmartin, 1964). Productivity levels in the latter study were more similar to zones with coastal upwelling.

Data from the late 1970s identified over 85 taxa of phytoplankton in Burrard Inlet from six major groups, with diatoms and dinoflagellates being most dominant (Stockner and Cliff, 1979). Phytoplankton blooms begin in spring between mid-March and early April with peak rates of growth in mid-May to early June. Zooplankton production typically lags behind phytoplankton by a couple of weeks.

Status and Trends

Not enough data exists to assess trends in the primary productivity of Burrard Inlet. Historically, there was little evidence of eutrophication in Port Moody Arm or anywhere else (Stockner and Cliff, 1979). By the mid-1970s, much of the sewage effluent entering Burrard Inlet had been redirected to sewage treatment facilities along the Fraser River, reducing nutrient loading in the inlet and reducing the threat of a major algal bloom. Generally, Indian Arm contains no areas of excessive algal growth (WorleyParsons Komex and Lorax Environmental, 2006), though a significant algal bloom occurred in July 2014 throughout Burrard Inlet, including Indian Arm (Huffington Post Canada, 2014).

Threats

Threats to primary productivity include:

- *Acidification*: Acidification has the potential to impact primary production by kelp and phytoplankton, and could produce harmful algal blooms (C. Harley, pers. comm.). Acidification will likely have negative impacts on herbivores of seaweeds and algal species as well with uncertain consequences (Harley *et al*., 2012).
- *Climate change*: The rate of nutrient cycling, in particular ammonium cycling, is likely to increase with warmer ocean temperatures. As ammonium becomes more available, it is likely to stimulate algal growth (L. Bendell, pers. comm.). Changes in water temperature and salinity will likely alter interactions between predators, herbivores, and seaweeds/algal species (Harley *et al*., 2012).
- *Pollution*: Increased nutrients and turbidity (affecting light levels) has the potential to significantly affect primary production in the inlet. Nutrient addition can increase primary productivity and promote algal growth, while increased turbidity can decrease light availability and reduce primary production.

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Significant knowledge gaps exist in the understanding of primary productivity in Burrard Inlet. The majority of studies were conducted in the 1960s and 1970s and have not been updated. It is unknown how acidification and warming ocean temperatures associated with climate change will impact seaweeds and algal species. Direct impacts of climate change reducing or increasing algal growth are possible, and changing species interactions between herbivores and their prey may increase or decrease primary productivity as well.

No known projects are currently ongoing or imminent.

2.4.3 Invasive Non-native Species

Invasive non-native species (INS) are one of the biggest threats to biodiversity globally (Millennium Ecosystem Assessment, 2005). Once established, INS can cause changes to habitat, and alter competitive and predatory interactions. Much work has been conducted in Metro Vancouver on terrestrial INS but much less is known about their marine counterparts (Ankenman, 2013). Burrard Inlet is particularly susceptible to INS due to the high volume of marine traffic, both recreational and commercial, and the large human population that surrounds the inlet. This increases the number of introductions and the likelihood of establishment of aquatic INS.

Status and Trends

A total of 37 INS have been identified in Burrard Inlet and its marine riparian area (Ankenman, 2013). An additional 53 non-indigenous and 98 cryptogenic species (unknown origin) were identified. Of these, 158 were marine, 27 were terrestrial, and three species were in both terrestrial and intertidal areas (Ankenman, 2013). Little is known about many of the marine species and their potential impacts; 68% of the identified marine species are cryptogenic (Ankenman, 2013). A total of 89 INS have been identified in the Strait of Georgia more broadly (Levings *et al.,* 2002).

A number of species of concern have been identified, or are of potential future threat, in Burrard Inlet:

- Japanese wireweed (*Sargassum muticum*): Japanese wireweed is a large brown seaweed that forms dense single-species stands. It was brought to British Columbia prior to 1940 along with oyster spat (Scagel *et al.,* 1993). *Sargassum* is known to compete with bull kelp in shallow areas and can also overgrow eelgrass (N. Wright, pers. comm.; Springer *et al*., 2007). It has been identified in West Vancouver and on floats off North Vancouver and is likely widespread (Richoux *et al*., 2006). Increased salinity and higher water temperatures associated with climate change may facilitate its invasion (C. Harley, pers. comm.).
- Saltmeadow cordgrass (*Spartina patens*): *Spartina patens* is an invasive cordgrass that grows in intertidal areas and is known to outcompete native species in salt marshes (CMN, 2015a). *Spartina* species are ecosystem engineers; they help collect sediment and raise salt marshes, changing the ecosystem hydrology (Keskinen, 2014). *S. patens* has been identified in Burrard Inlet at Maplewood Flats and in Port Moody Arm (CMN, 2015b).
- Purple varnish clam (*Nuttalia obscurata*): Currently, purple varnish clams do not appear to be having negative impacts on ecosystems or other native shellfish species, as they tend to bury deeper. It is possible, however, that as numbers increase they may have impacts on benthic communities, nutrient cycling, and chemistry in sediments (Chan, 2012; Dudas, 2005). Recent shellfish surveys have shown high numbers of purple varnish clams in Burrard Inlet (TWN, 2013).

- Common periwinkle (*Littorina littorea*): The common periwinkle was identified in Burrard Inlet in surveys from 2010–2012, but it is unclear whether this species has become established (C. Harley, pers. comm.). They can outcompete native species, change species diversity, and have been shown to be capable of altering salt marsh into cobble shores (Harley *et al*., 2013).
- Common cordgrass (*Spartina angelica*): Another invasive cordgrass in salt marshes, *Spartina angelica* has become a significant problem down the coast of Washington, out-competing native species and changing the hydrology of salt marshes. Though not a direct threat to eelgrass, its impact on shallow water hydrology could have long-term negative impacts (N. Wright, pers. comm.).
- European green crab (*Carcinus maenas*): The European green crab is a competitor with native crabs and preys on clams, mussels, and juvenile fishes. It is native to the Western Atlantic (Gillespie *et al*., 2006). Though not currently found in Burrard Inlet, it has been identified on Vancouver Island (Gillespie *et al*., 2006).
- Golden star tunicate (*Botryllus schlosseri*) and violet tunicate (*Botrylloides violaceus*): These colonial tunicates have been identified in Burrard Inlet (T. Therriault, pers. comm.). They can outgrow and smother other native invertebrate species that grow on wharves, docks, and natural substrates, and they may be able to outcompete native filter feeders for food (Carver *et al.,* 2006). Potential saltier water and higher water temperatures associated with climate change may facilitate their invasion (C. Harley, pers. comm.).

Threats

There are numerous pathways for INS to enter Burrard Inlet. Current threats include:

- *Live markets*: Food markets for live shellfish and fish are common in urban areas, and thereby create risks that species, such as the common periwinkle, may be become established in Burrard Inlet.
- *Marinas*: As ships and boats move around the ocean, and they collect fouling organisms on their hulls and anchors. Little is being done to monitor or regulate organisms that boats may be bringing into marinas in Burrard Inlet.
- *Climate change*: Climate change and ocean acidification, and the associated changes in salinity and water temperature, will likely allow certain invasive species to move northward and invade new areas like Burrard Inlet.
- *Ballast water*: Ballast water, even in small quantities, can be a significant source of INS (DiBacco *et al.* 2012; Levings, 1999). Large quantities of ballast water are regularly discharged into Burrard Inlet harbours from ships coming from across the world. Between September 2006 and September 2007, a total of 887 vessels reported discharging ballast water into Vancouver Harbour, releasing approximately 6,721,336 m^3 of ballast water (Humphrey, 2008). Policies are in place to make sure trans-oceanic vessels have done a mid-ocean exchange of their ballast water to prevent INS introductions. If this has not occurred, ships can be sent to a location in the Juan de Fuca Strait to exchange ballast water. Vessels travelling up and down the coast may or may not need to do mid-ocean exchange, depending on their point of origin (Humphrey, 2008). Ships with less than 1000 tonnes of ballast water are exempt (Levings, 1999). Although this is a progressive policy, it may not be enough to prevent INS from entering Burrard Inlet (Humphrey, 2008; Levings, 1999).

Knowledge Gaps, Research Needs, and Current Recovery Efforts

Understanding of marine invasive species is low in Burrard Inlet, and currently there is no coordinated program to identify and control marine INS in Burrard Inlet. A lack of knowledge for most marine INS exists, including basic understanding of invasion pathways, potential impacts on ecosystems, and methods of control once species are present. Other knowledge gaps include:

- How will climate change facilitate new INS to become established?
- Which species are of most concern?

A number of projects focussing on INS are underway in and around Burrard Inlet:

- Attempts to control *Spartina patens* are underway in Burrard Inlet by the BC Spartina Working Group. This includes mapping and conducting baseline monitoring for *Spartina patens;* pilot projects are on-going to determine the best methods of control (CMN, 2015a).
- The Invasive Species Council of Metro Vancouver (ISCMV) has been mapping or conducting control work on some of the terrestrial invasive species found in marine riparian areas, including Japanese knotweed (*Fallopia japonica*), giant hogweed (*Heracleum mantegazzianum*), *Spartina* spp., and purple loosestrife (*Lythrum salicaria*) (A. Hendel, pers. comm.).
- Fisheries and Oceans Canada has a project in its beginning stages to look at INS in the Strait of Georgia. Two of the monitoring stations for the project are in Burrard Inlet. A project looking at plankton communities in port areas from Delta to Burrard Inlet is also on-going but in early stages, and is attempting to use genetically based rapid assay techniques to identify INS (T. Therriault, pers. comm.).

2.5 Emerging Issues

Emerging issues are issues that have only appeared in recent years and whose impacts are not yet fully known or understood. Because emerging issues are new, there is usually insufficient data to assess their status and trends. Three emerging issues for Burrard Inlet are discussed briefly below: contaminants of emerging concern, marine debris and microplastics, and underwater noise pollution. While other emerging issues for Burrard Inlet may exist, they are not addressed in this report.

2.5.1 Contaminants of Emerging Concern

Contaminants of emerging concern (CECs), such as newer persistent organic pollutants, pharmaceuticals and personal care products, and endocrine-disrupting chemicals, are pollutants that are increasingly being detected in surface waters at low levels and which may have an impact on aquatic life. They typically have no regulatory guideline for safe levels because their toxicity and impacts have not been fully studied. In general, they tend to be found in higher concentrations near urban areas.

Emerging Persistent Organic Pollutants

Examples of emerging persistent organic pollutants (POPs) include perfluorinated compounds (PFCs), such as perfluorooctane sulfonic acid (PFOS) and its salts, as well as perfluorooctane sulfonyl fluoride (PFOS-F). Perfluorinated compounds (PFCs) represent a significant threat to wildlife as they are ubiquitous, can bioaccumulate, and are transported easily in natural environments (Vancouver Aquarium, 2015). They are used to prevent stains, grease, and water from sticking to everyday products, including cookware, clothes, and furniture. They are also found in paper and packaging, cleaning products, and pesticides (US EPA, 2014).

To date, there has been no sampling of these emerging POPs in Burrard Inlet.

Pharmaceuticals and Personal Care Products

Pharmaceuticals and personal care products (PPCPs) have the potential to have adverse effects on fish, wildlife and human health in Burrard Inlet. PPCPs of potential concern include pain-killers, anti-inflammatories, natural and synthetic hormones, hair products, sunscreens, and fragrances. They can enter marine environments through wastewater, landfill leachate, and stormwater runoff and are typically not removed in wastewater treatment facilities. They can accumulate in the water column, sediments, and marine biota. Pharmaceuticals can impact feeding rates, reproduction, and immune health in marine animals (Gaw *et al*., 2014).

Proper disposal of pharmaceuticals is important to prevent them from entering marine ecosystems. In BC, there is a medications returns program that will ensure proper disposal.

2.5.2 Microplastics

Microplastic pollution in oceans has the potential to negatively impact marine organisms, and potentially alter nutrient cycling in sediments (L. Bendell, pers. comm.). Microplastics refer to small plastic particles (up to 5 mm in diameter) that are either intentionally manufactured (e.g., microbeads in facial cleansers and toothpastes) or are broken down from bigger plastic chunks (e.g., plastic bags). Microplastics enter oceans from household and industrial waste, wastewater, as well as fishing, aquaculture and shipping (Ross, 2015). Microplastics have been found in zooplankton in Strait of Georgia and there are concerns of their impact up the food chain (Ross, 2015). In sediments, anti-bacterial properties of microplastics may kill bacteria important in the cycling of nitrogen and its ammonification (L. Bendell, pers. comm.).

Microplastics have not been studied in Burrard Inlet but are likely ubiquitous due to the inlet's high level of urban and industrial development. Recent studies conducted in the Strait of Georgia showed 3000–4000 particles of plastic/m^3. Zooplankton studies in Strait of Georgia showed plastic in one in every 38 organisms in one species, and one in 17 of another species, which are concerning numbers when trillions of organisms are present (Ross, 2015).

Key questions about the origin, circulation patterns, and locations of build-up need to be studied. While there may be similarities to sediment transport in the inlet, microplastics may behave differently due to differences in density, reactivity, and size. Current studies are underway to compare concentrations of microplastics in Burrard Inlet at Horseshoe Bay, Cates Park, and potentially Mosquito Creek, and to investigate the impacts of microplastics on nutrient cycling in sediments (L. Bendell, pers. comm.).

2.5.3 Underwater Noise Pollution

Underwater noise pollution is increasingly seen as a threat to marine animals. Marine animals and fish are very sensitive to sound and there are concerns that elevated noise due to shipping and other human activity may interfere with many important aspects of life, including reproduction, feeding, navigation, and predator avoidance (Weilgart, 2008). Sound travels great distances underwater and hearing is often the primary sense used by animals. In British Columbia, shipping and small vessels are the predominant cause of ocean noise (Erbe *et al*., 2012). Although studies specific to Burrard Inlet have not been conducted, noise levels of concern are almost certainly present due to large numbers of industrial, commercial, and recreational activities that take place in the inlet (Erbe *et al*., 2012).

More research needs to be done to understand the impacts of ocean noise on different wildlife species in Burrard Inlet and to determine solutions to the issue. Currently, the Vancouver Fraser Port Authority has an acoustic monitoring program to look at the impact of terminal construction and shipping activity on at-risk marine mammals called the Enhancing Cetacean Habitat and Observation (ECHO) Program, but monitoring efforts appear to be focussed in Delta at present (Port Metro Vancouver, 2015b).

2.6 Summary of Key Findings

The following points summarize the key findings of the review of scientific information and traditional knowledge available on the status and trends in the Burrard Inlet ecosystem:

- Long-term changes in physical water quality parameters, such as water temperature, salinity, dissolved oxygen, and pH are of concern. The extent to which changes observed to date are natural or human-caused is largely unknown. Climate change is expected to further impact physical water quality, with a wide variety of potential ecological impacts.
- Polluted water and contaminated sediments are broadly impacting environmental quality, affecting key species and food webs, and limiting human uses of Burrard Inlet. Primary contaminants of concern include pathogens, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and legacy persistent organic pollutants such as polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs). Levels of many contaminants still regularly exceed water quality objectives.
- Potential sources of contamination are diverse and not well characterized for most pollutants. Major sources of pollution include authorized industrial discharges, the Lions Gate Wastewater Treatment Plant, occasional combined sewer overflows and sanitary sewer overflows, urban and industrial stormwater runoff, contaminated sites, on-site sewage disposal, and spills of oil, fuel, and other hazardous substances. In Puget Sound, Washington State Department of Ecology studies have identified that the largest source of contaminants is not from regulated point source discharges (e.g., industrial discharges) but polluted stormwater runoff (non-point sources). Polluted stormwater runoff is also likely the leading pollution threat to Burrard Inlet.
- Over 93% of the historic extent of estuaries in Burrard Inlet has been lost due to development. Localized losses of other nearshore habitats such as eelgrass beds, kelp forests, and productive beaches have also been observed, although these declines and their causes are not well-documented.
- Approximately half of Burrard Inlet’s shorelines have been altered and 53 km of natural shoreline has been lost. Shoreline alteration is highest in the Inner Harbour (90%) and lowest in Indian Arm (exact percentage not known). Shoreline alteration and hardening has had negative impacts on nearshore habitats and key species, and impacted circulation and sediment transport.
- Salmon, forage fish, shellfish, birds, and marine mammal populations have all declined from historic levels. While recovery in some salmon and bird species has been observed, other species are still declining. Commonly identified threats include loss of habitat and prey species, human disturbance, pollution, and climate change.
- Shoreline hardening, construction of overwater structures, and dredging appears to have changed circulation and sediment transport patterns and rates of deposition and erosion in some parts of Burrard Inlet (e.g., Central Harbour). Climate change is predicted to change yearly flow patterns in the Fraser River, with potentially significant impacts on circulation patterns and sediment transport into Burrard Inlet.
- Thirty-seven invasive non-native species have been identified in Burrard Inlet and its marine riparian area. Little is known about many of the marine species and their potential impacts.

- Climate change is predicted to raise sea level and change annual river discharge patterns, particularly for the Fraser River. Both could have significant detrimental impacts on Burrard Inlet.
- Emerging issues of concern in Burrard Inlet include newer contaminants (such as emerging persistent organic pollutants, pharmaceuticals and personal care products, and endocrine-disrupting chemicals), microplastics, and underwater noise pollution.

Another important finding of the status and trends assessment was that, in general, there is insufficient, up-to-date data to inform strategic environmental stewardship planning. Furthermore, existing research and monitoring efforts are not coordinated and information is not widely shared. Priority knowledge gaps and research needs that were identified include:

- Collecting up-to-date, high resolution data on physical water quality parameters;
- Identifying the locations of contamination hotspots;
- Improving mapping of important nearshore habitat types;
- Improving knowledge about forage fish populations and juvenile salmon migration routes and survival;
- Understanding the locations, sources, and potential effects of emerging pollutants; and
- Potential impacts of climate change on key species and habitats and large-scale physical processes.

3. What Does a Healthy Burrard Inlet Look Like?

This section of the plan describes a Tsleil-Waututh vision and near-term priorities for a healthy Burrard Inlet, describes a series of broad recovery goals reflecting these priorities, guiding principles for Burrard Inlet recovery, and linkages to plans and initiatives being spearheaded by other potential partners.

3.1 A Tsleil-Waututh Vision for a Healthy Burrard Inlet

Members of Tsleil-Waututh have long been concerned about declining environmental quality within the marine waters of their territory. The observations most often heard are that community members can no longer eat the wild marine foods and can no longer swim or enjoy the waterways because of pollution, and that marine species and habitat are disappearing at an alarming rate.

The Tsleil-Waututh Nation, working with its partners, desires to raise awareness regarding the health of the marine ecosystems within its territory and to devise and manage a long-term plan for recovery of Burrard Inlet (TWN, 2005). To this end, TWN are taking a leadership role in this process.

Reflecting a desire for abundant natural resources and cultural practices which have been sustained by the marine waters in their territory, TWN envisions a productive, resilient, and diverse Burrard Inlet ecosystem where:

- Healthy, wild foods can be harvested safely and sustainably;
- Water and sediment is safe and clean for cultural, spiritual, ceremonial, and recreational activities;
- Important habitats are plentiful, productive, and connected; and
- High levels of biodiversity and healthy populations of key species are viable and will continue to persist in the long term.

Though today Burrard Inlet is a working harbour and will never be returned to the condition that Tsleil-Waututh experienced prior to European contact, TWN believes it is still possible to improve the health of the inlet such that the above outcomes can be achieved.

In addition to the above outcomes, a healthy Burrard Inlet ecosystem in its current context should also have the following attributes:

- *Resiliency*: The ecosystem should be able to withstand a certain amount of disturbance caused by humans or natural events should these events unexpectedly occur. Resilient ecosystems are at lower risk for major changes or collapse.
- *Redundancy*: Species and habitats are not found at a single location but are found at multiple locations and in high enough numbers to be viable in the long term.
- *Representativeness*: The species and habitat present should represent the range of species and habitats once more broadly present.

Seeking to build these ecosystem attributes as part of the recovery process will ensure that a healthy Burrard Inlet, once achieved, will continue to persist for the benefit of future generations.

3.2 Near-term Priorities

Three near-term priorities have been identified as being particularly important to Tsleil-Waututh to fulfill their desire to re-establish aspects of their subsistence use of Burrard Inlet in the near-term:

1. **TWN would like to see Indian Arm re-opened to traditional shellfish harvesting.**

   Based on existing information regarding contamination levels in shellfish within the inlet, the most likely location is midway up Indian Arm where bacteriological and other contamination levels are lower because of the limited surrounding development, dilution effects, and lack of significant tidal exchange between Indian Arm and the rest of Burrard Inlet. On October 26, 2015, the Canadian Shellfish Sanitation Program opened a small beach in Indian Arm for ceremonial harvest of bivalves. However, further efforts are needed to ensure progress is sustained and openings can be expanded.

2. **TWN would like to ensure safe, clean water for cultural and spiritual practices in Burrard Inlet, particularly in the Central Harbour near their reserve.**

   TWN members would like to be able to engage in cultural and spiritual practices in areas where it has been traditionally practiced. Lowering pathogen levels is particularly important to achieving this goal.

3. **TWN would like to see estuaries in Burrard Inlet enhanced and restored.**

   Many of Tsleil-Waututh's traditional harvesting practices were centred around estuaries. Recognizing the importance of these habitats for finfish, shellfish, and wildlife and their current levels of degradation, TWN would like to see remaining estuaries enhanced and restored.

3.3 Recovery Goals

Based on the findings of the status and trends assessment and TWN's vision of a healthy Burrard Inlet, the following five broad goals have been identified as critical to recovering the Burrard Inlet ecosystem:

Goal 1: Improve water quality and reduce contamination

One of the largest threats to Burrard Inlet is pollution which contaminates water, sediment, and biota. Pollution is directly degrading habitat, affecting the health of aquatic life, and limiting traditional First Nation and other uses of the ecosystem. Addressing pollution will involve both reducing the amount of pollution entering Burrard Inlet and dealing with legacies of past pollution. Pollution sources and issues are diverse and dispersed throughout the inlet.

Goal 2: Protect and enhance fish and wildlife habitat

Fish and wildlife habitat, particularly nearshore habitats, have been severely reduced by built structures and shoreline modification, particularly in the Inner Harbour and False Creek. Development has also impacted the biophysical processes which sustain key habitat areas. Action is needed to protect remaining habitats and to restore sites that have been degraded. The already high level of permanent habitat loss means that further habitat losses must be minimized and that recovery is unlikely without significant habitat restoration efforts.

Goal 3: Protect and recover key species populations and food webs

Populations of key species have and continue to be affected by a range of threats which have depressed their numbers and altered food web structure and function. Although addressing Goals 1 and 2 will address some of the threats faced by key species, other targeted actions may be needed to recover particular species. Attention should be given to the specific resource and habitat needs of key species as part of recovery planning.

Goal 4: Protect and restore supporting biophysical processes/ecological integrity

It is important to recognize that elements of the Burrard Inlet ecosystem do not exist in isolation but function together as an interconnected system. In order to recover key habitats and species, it is necessary to recognize the biophysical processes underlying key aspects of their ecology, and to limit threats to the integrity of these processes, such as invasive non-native species.

Goal 5: Identify and track emerging issues

Actions should be taken to proactively address emerging threats to the ecosystem and take measures to prevent damage before it occurs or becomes a larger problem.

3.4 Guiding Principles for Recovery

Building on the above vision and recovery goals, several guiding principles for recovery were used to develop the particular strategies and actions outlined in subsequent sections of the plan:

- **Use the best available science.** Science should be used to understand the extent, causes, and relative importance of issues and threats, and to prioritize which actions are most likely to achieve results. Science should also be used to develop a monitoring and adaptive management framework that allows for evaluation and appropriate adjustments in actions over time.
- **Incorporate traditional ecological knowledge.** Tsleil-Waututh believes that traditional ecological knowledge is a vital and important part of understanding the Burrard Inlet ecosystem and can complement scientific knowledge, particularly with respect to how the ecosystem functioned historically and for defining what constitutes sustainable use. Another important use of traditional ecological knowledge is to define historical baselines for recovery.
- **Use the precautionary principle.** A lack of scientific information or certainty about a problem or threat should not be used as an excuse for inaction. Actions should be undertaken when there is a reasonable level of certainty that they will result in improvements or yield the desired results, or when uncertain, to protect against significant potential risks.
- **Focus on restoration, not just protection.** Because of the level of degradation that has already occurred, restoration of populations, habitat, and the ecosystem processes and functions that sustain them will be necessary to improve the health of the inlet. Although protecting remaining species and habitats is important, protection will not be sufficient to achieve the recovery goals.
- **Aim for cost-effective, efficient solutions to problems.** Because funding and resources are not unlimited, actions selected should be those that are expected to achieve the desired results as quickly and efficiently as possible. Actions which address multiple threats or that work together with other actions are preferred over actions taken in isolation.

- **Address the root causes of degradation.** Actions to recover Burrard Inlet should address the threats and pressures rather than only dealing with the consequences of those pressures, whenever possible. Similarly, it is better to anticipate and prevent degradation rather than dealing with it after the damage has been done.
- **Think long-term.** Improving some aspects of Burrard Inlet ecosystem will require multiple approaches and a long-term focus. Tsleil-Waututh is committed to the recovery of the Burrard Inlet ecosystem over the long-term and for the future.
- **Collaborate with others able to effect change.** Collaboration can multiply recovery actions and increase what can be done versus acting alone. Coordinated, collaborative actions are generally more likely to be successful as they can drastically increase the sphere of influence.
- **Embrace human presence and use as part of the Burrard Inlet ecosystem.** Human communities should be recognized as embedded in the Burrard Inlet ecosystem and part of a broader social-ecological system.

3.5 Linkages to Other Plans and Initiatives

Plans and initiatives developed by other partners and stakeholders in environmental management in Burrard Inlet provide important context for developing a new plan to improve the health of Burrard Inlet. For example, proposed actions may also meet the goals and objectives of other plans, adding to the justification and support for implementing specific actions. These overlaps present important opportunities for potential partnerships in implementing the plan.

The following plans and initiatives have the potential to link directly to the *Burrard Inlet Action Plan*:

- The **Burrard Inlet Consolidated Environmental Management Plan** (CEMP), developed by BIEAP in 2002 and updated in 2011, is also aimed at improving the health of Burrard Inlet. The 2011 CEMP provides an environmental policy framework to achieve several environmental goals in Burrard Inlet including improved water quality, improved sediment quality, protection and enhancement of fish and wildlife habitat, awareness and environmental stewardship. The Action Plan includes several similar goals. The closure of BIEAP has left uncertainty with respect to if and how the CEMP will be implemented, but the two plans are complementary in their approach.
- Metro Vancouver's **Integrated Liquid Waste and Resource Management Plan**, adopted in 2011, identifies what the region and its member municipalities intend to do to use liquid waste as a resource, minimize treatment costs, and better protect the environment and public health. A specific goal of the ILWRMP is to protect public health and the environment. The ILWRMP also includes specific monitoring requirements for liquid waste discharges, which could be met in a more coordinated monitoring program.
- Metro Vancouver's new **Regional Growth Strategy–Metro 2040**, includes a goal to protect the environment and respond to climate change impacts, as well as a specific strategy to protect enhance natural features and their connectivity.

- **Official community plans** in many municipalities include environmental goals such as water quality protection, shoreline protection, and habitat restoration, all of which is encompassed in the goals of the Action Plan.
- Some municipalities also have **specific green plans and initiatives** with specific environmental goals. For example, the City of Vancouver's Greenest City 2020 Action Plan, includes goals that encompass clean air and clean water. The City of Vancouver recently developed a Bird Strategy and a Biodiversity Strategy. The City of Burnaby also recently approved an Environmental Sustainability Strategy.
- The Vancouver Aquarium has developed ***PollutionTracker***, a new monitoring initiative to evaluate the status and trends of pollutants in coastal British Columbia. The project is coordinated by the Aquarium's Ocean Pollution Research Program, but composed of a network of local partners who have helped to initiate and fund monitoring at specific sites.
- Environment Canada's First Nations **Cumulative Effects Monitoring Initiative**, an effort to develop a monitoring plan to characterize baseline environmental conditions. The data can be used to evaluate the effects of the current level of urban, commercial, and industrial development on First Nations, and to predict how future projects might contribute to cumulative effects.
- The Georgia Strait Alliance has initiated the **Waterfront Initiative**, a collaborative project working with stakeholders in the City of Vancouver's shoreline to define a common agenda with measurable objectives and actionable steps towards a healthy and prosperous Vancouver waterfront.

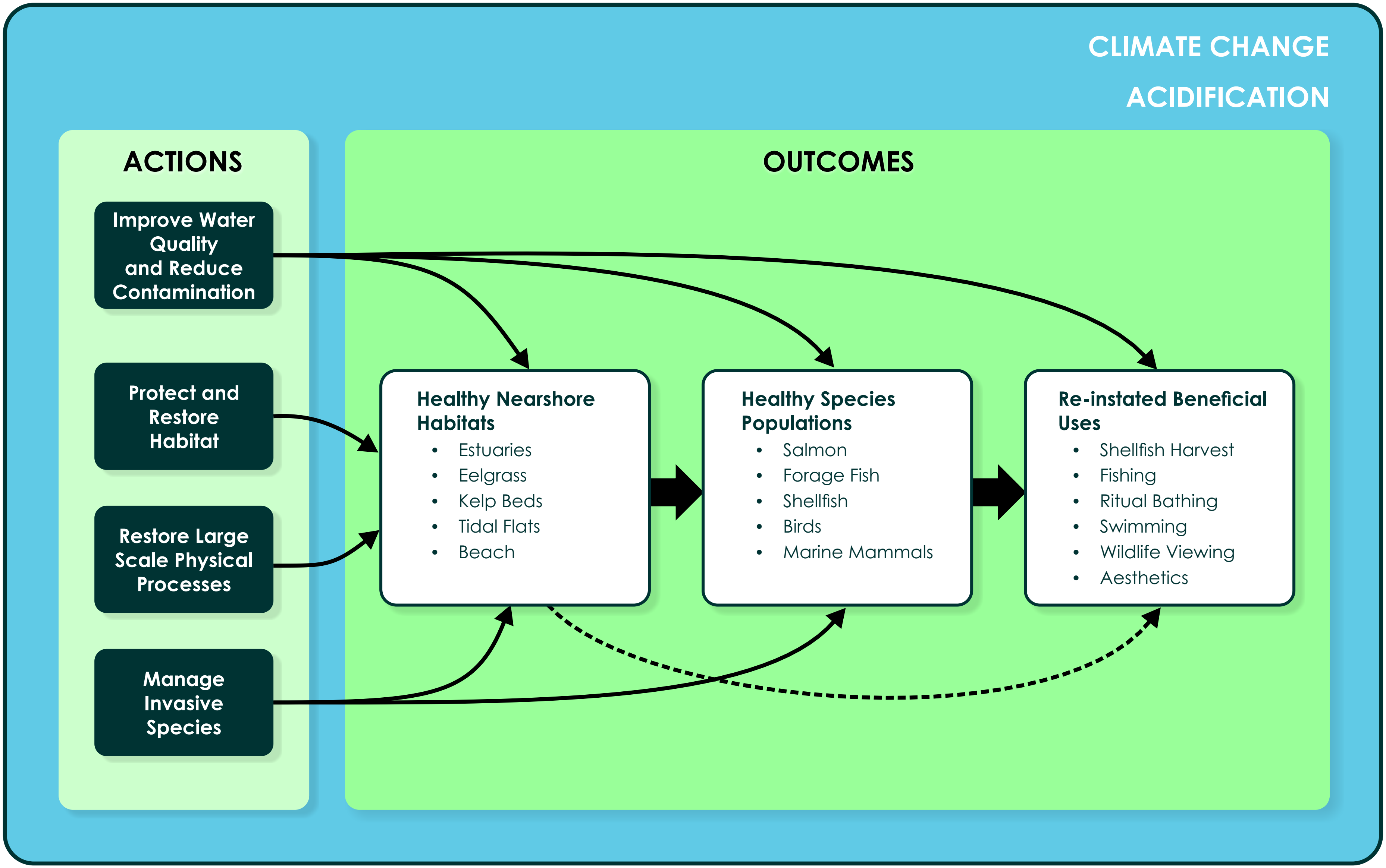
4. Goals, Strategies, and Actions

The Burrard Inlet ecosystem has been dramatically altered over the last 150 years. Flows of liquid wastes that impact water quality and introduce contaminants continue to enter Burrard Inlet from a variety of sources. Important habitats have been lost due to pollution, overwater structures, shoreline hardening and filling, and changes in the physical processes that create and maintain habitat. Populations of key species, from the bottom to the top of the food web, have declined due to habitat loss, pollution, overexploitation, and changes in species interactions. Changes to circulation and sediment transport and the introduction of invasive species are undermining the physical processes and ecological integrity that sustain the ecosystem. Climate change and ocean acidification will continue to put pressure on the ecosystem, both due to direct impacts and indirect impacts from climate change adaptation.

Figure 4-1 provides a diagram showing the pathway to recovery for Burrard Inlet and shows how actions related to the Plan's five goals can over time restore habitat, recover key species populations, and re-instate many of the beneficial uses that have been lost. Collective and tangible action in many different areas is needed to reach these desired outcomes.

Based on the findings of the status and trends assessment, this section describes 16 strategies and 66 actions which will contribute most significantly to ecosystem recovery in Burrard Inlet by 2025. As a result, the focus of the strategies and actions is near-term—actions that can be implemented and should lead to measurable change with 5 to 10 years. The actions are organized under the Plan's five goals. The year 2025 has been chosen as the timeline for the plan because Tsleil-Waututh wants to see significant progress towards recovery in a short timeframe and believes this is achievable. The Plan includes a mix of actions related to science, policy, on-the-ground initiatives, capacity-building, and education and outreach.

Most of the actions described below are focussed at the scale of the whole inlet, however, some actions are focussed on specific sites. Local-scale actions are aimed at addressing localized issues or tied to the unique conditions of smaller parts of the inlet.



Pathway of Ecosystem Recovery in Burrard Inlet

4.1 Goal A: Improve Water Quality and Reduce Contamination

Strategy A-1: Review and update water quality objectives for Burrard Inlet

A-1.1. Initiate a Burrard Inlet Water Quality Monitoring Working Group

Given the number of monitoring initiatives past and present, a working group is needed to better harmonize methodologies, reduce duplication, ensure data sharing, and improve overall monitoring approaches. The working group should include representation from government, municipalities, First Nations, industry, and the scientific community as well as all groups conducting monitoring. Although the group could develop a broad focus over time, an initial purpose for formation would be to review and update existing water quality objectives for Burrard Inlet.

A-1.2. Collate and share existing water and sediment quality and contamination information for Burrard Inlet

Although a large amount of sampling has been undertaken to characterize and assess water and sediment quality in Burrard Inlet, much of the data and reports are not freely available or easily accessible. Developing a centralized, shared metadatabase of monitoring results would increase the availability of data for use as indicators and for long-term assessment of trends. The database could also be used to identify sampling gaps that need to be addressed in order to update the water quality objectives.

A-1.3. Review and update the 1990 provisional Water Quality Objectives for Burrard Inlet.

The water quality objectives set by BC Ministry of Environment in 1990 were provisional and are now over 25 years old. The objectives should be reviewed and updated to better reflect new monitoring data, current science on biological thresholds of effects, and Tsleil-Waututh's priorities to re-instate certain beneficial uses in particular areas of Burrard Inlet. This will lay the groundwork for further efforts and coordination to reduce or abate the sources of pollution.

Strategy A-2: Harmonize and improve water quality and pollution monitoring and reporting

A-2.1. Develop standardized water and sediment quality sampling and laboratory methods to ensure consistency in future data collected among the various monitoring programs

Existing monitoring programs should develop standardized methods for field sampling, laboratory, and data QA/QC methods appropriate for water, sediment, and biota sampling in Burrard Inlet. One potential mechanism for standardization is through participation in the Salish Sea Ambient Monitoring Exchange (SSAMEX), an initiative supported by the Vancouver Aquarium to harmonize ambient water and sediment quality monitoring methods across the Salish Sea.

A-2.2. Advocate for increased and standardized compliance monitoring for authorized industrial discharges

BC Ministry of Environment does not currently require standardized monitoring for authorized waste discharges. As a result, monitoring results are not consistent and difficult to compare from permit to permit. In some cases, it is also difficult to assess compliance with allowable discharge amounts due to a lack of adequate sampling. Developing and implementing a standardized monitoring protocol across all waste discharge authorization permit holders would allow for better assessments of compliance, improved comparability across permits, and better understanding of the relative contributions of industrial discharges to water pollution issues in Burrard Inlet.

A-2.3. Support development and implementation of a new environmental quality monitoring program focussed on nearshore habitats to complement existing monitoring programs

An identified gap in existing monitoring programs in Burrard Inlet is the status of contamination in shallow nearshore habitats. A program is needed to assess and monitor these habitats. As well, the suite of contaminants being monitored should be expanded to include contaminants of emerging concern. The Vancouver Aquarium's *PollutionTracker* could potentially be adopted for this purpose and its standardized protocols would allow for comparison with other sites in coastal BC.

A-2.4. Expand water quality and flow monitoring for rivers, creeks, and stormwater outfalls entering Burrard Inlet

Being able to characterize and understand trends in pollutant loadings from specific sources depends on regularly monitoring both flows and water quality. While CSOs and wastewater effluent outflows are monitored regularly, many rivers, creeks, and stormwater outfalls are sampled infrequently or have never been sampled. Work should be coordinated with the implementation of the *Monitoring and Adaptive Management Framework for Stormwater* (Metro Vancouver, 2014) by municipalities, which has been developed to monitor the implementation of Integrated Stormwater Management Plans (ISMPs) in urban watersheds, and monitoring activities of Streamkeeper and other stewardship groups.

A-2.5. Install a network of scientific instruments to continuously monitor physical water quality in Burrard Inlet in conjunction with Oceans Networks Canada

There is a lack of high-resolution physical water quality data for Burrard Inlet. Recent developments in technologies and implementation of ocean monitoring networks elsewhere have reduced the costs of such monitoring. Such data will become increasingly important to track and understand impacts from pollution sources, climate change, and ocean acidification. Ocean Networks Canada operates ocean observatories that collect data on physical, chemical, and biological conditions in the North Pacific Ocean, including a network of instruments to collect data on oceanographic conditions in the Strait of Georgia. A partnership with Ocean Networks Canada can advance this objective.

A-2.6. Coordinate monitoring with new efforts like the Vancouver Aquarium's *PollutionTracker* and Environment Canada's Cumulative Effects Monitoring Initiative

Several new monitoring initiatives have been or are in the process of being initiated in Burrard Inlet with the potential to provide important data to inform strategic environmental stewardship planning. These include the Vancouver Aquarium's *PollutionTracker* and Environment Canada's Cumulative Effects Monitoring Initiative. Where possible, efforts should be coordinated to harmonize methodologies, reduce duplication, and maximize the overall efficiency of monitoring activities in Burrard Inlet.

A-2.7. Establish reporting format and report on the consolidated results of water quality and contamination monitoring

All monitoring data should be freely available and fully reported on in a timely fashion. Developing a shared report format, such as a report card or online water quality monitoring dashboard or atlas would help make status and trends information more available and accessible to the public and decision-makers.

Strategy A-3: Review, characterize, and prioritize sources of pollution

A-3.1. Update the existing point source discharge inventory for Burrard Inlet to include new outfalls and point sources of pollution every five years

The last discharge inventory was created by BIEAP in 2010. Having an updated inventory is a first step in further work to understand the relative contributions of different discharges to pollution issues in Burrard Inlet. The inventory should include a series of maps or an online atlas.

A-3.2. Review monitoring, reporting, and oversight of authorized industrial discharges

Based on existing information on authorized industrial discharges in Burrard Inlet, it appears that current discharge permits have not been recently reviewed and, in some cases, their current status is unknown. Existing discharge permits and discharge reporting should be reviewed to assess whether existing monitoring is adequate, whether permit holders are complying with discharge limits, and whether appropriate compliance actions are being taken.

A-3.3. Characterize pollutant loadings from stormwater and other non-point sources of pollution to Burrard Inlet

Although significant work has been done to characterize pollutant loadings from stormwater entering Puget Sound in Washington State, similar studies for the Metro Vancouver region are limited and most of the data comes from catchments that discharge into the Fraser River (e.g., Swain, 1983). There is a need to quantify contributions of priority contaminants (e.g., pathogens, metals, POPs) to Burrard Inlet from stormwater. Improved data collection (Action A-2.4) would be required.

A-3.4. Conduct a review of information in the provincial Contaminated Sites Registry and federal Contaminated Sites Inventory on contaminated sites in close proximity to Burrard Inlet

It would be useful to gather and collate information in the provincial and federal contaminated sites registries for all sites within close proximity to Burrard Inlet to understand the extent of and risks for migration of contaminants into Burrard Inlet from contaminated sites and progress in remediation to date.

A-3.5. Update inventory and review status of on-site sewage disposal systems in Indian Arm in coordination with Vancouver Coastal Health

There is limited information on the status of existing on-site sewage disposal systems in Indian Arm, the position and depth of outfalls, and whether any of them are failing. The existing inventory developed in 2006 (WorleyParsons Komex and Lorax Environmental, 2006) should be updated and additional information collected (type, outfall location, condition) to better understand their potential to be potential sources of pathogen contamination to Indian Arm. Vancouver Coastal Health is responsible for regulating on-site sewage disposal systems in Indian Arm under the provincial Sewerage System Regulation.

A-3.6. Develop a water quality model and decision-support tool for Burrard Inlet for one or more pollutants of concern based on limiting pollutant loads to levels that allow achievement of water quality objectives

GIS-integrated modelling of pollutant mass balance(s) would provide a decision support tool and could also be used for scenarios and forecasting of impacts, and understanding how water quality objectives could potentially be achieved through water quality management. The GIS-integrated Structural BMP Prioritization and Assessment Tool (SBPAT) is an example of this type of model/tool that has been developed and used for similar projects in Washington, Oregon, and California.

Strategy A-4: Reduce levels of pollution from existing sources

A-4.1. Actively participate in Metro Vancouver's liquid waste and air quality management planning initiatives for Burrard Inlet

Under its Integrated Liquid Waste and Resource Management and Integrated Air Quality and Greenhouse Gas Management Plans with the Province, Metro Vancouver has responsibilities to monitor and progressively reduce water and air pollution in the region. Through participation in various planning initiatives, Tsleil-Waututh should encourage Metro Vancouver to continue to collect and utilize the best available science, to incorporate knowledge and protection of downstream beneficial uses in prioritizing actions, and to use all of the tools at its disposal to reduce pollution to Burrard Inlet through the sources of pollution it manages or regulates.

A-4.2. Develop an industry-specific eco-certification program to encourage adoption of best management practices for reducing non-point source pollution

Voluntary stewardship approaches to pollution prevention can help to supplement regulatory approaches and increase compliance. An eco-certification program, targeted at specific industries, would provide an incentive for adoption of best management practices. The program could be targeted at specific industries that have pollutant loadings such as boat repair facilities, automobile repair facilities, marinas, and dry cleaning facilities. Salmon Safe (http://salmonsafe.org/) is an example of a program that could be adapted to have this focus. BIEAP and several municipalities worked on a similar initiative in recent years but it was never completed and implemented.

A-4.3. Develop a targeted, region-wide social marketing campaign focused on pollution prevention from specific industries and households

Changes in attitude toward pollution are needed to reduce non-point source of pollution from specific industries and from households. A creative social marketing campaign could be used to raise awareness of the issue, and educate businesses and the public, and provide specific information about measures and practices that can prevent pollution discharges that can harm Burrard Inlet.

A-4.4. Work with local governments to designate and keep Burrard Inlet as a no-discharge zone for boats

Transport Canada is considering changes that would allow boats to dump sewage within one nautical mile of shore. Some areas of Burrard Inlet are further than one nautical mile from shore. The Vancouver Park Board has advocated for designating Burrard Inlet as a no-discharge zone for boats, and the Village of Belcarra is currently pursuing the designation for Bedwell Bay with Transport Canada.

A-4.5. Conduct an assessment of pump-out facilities and other discharge alternatives for recreational vessels in Burrard Inlet

Providing adequate pump-out facilities for recreational vessels will help prevent illicit discharges in Burrard Inlet. Pump-out facilities must be easily accessible for recreational vessels to encourage use. An assessment of currently available pump-out facilities would help identify locations where facilities are limited and help prioritize development of new facilities where appropriate.

A-4.6. Advocate for phasing out the use of copper in automotive brake pads and shoes to reduce contamination in stormwater runoff from roads

Automobile brake pads are the largest source of copper in urban watersheds accounting for approximately 30–65% of the copper contamination in some California streams and up to 80% of the copper in South San Francisco Bay (Brake Pad Partnership, 2015). Even low concentrations of copper have been found to have acute and chronic impacts on juvenile salmonids (Hecht *et al.*, 2007). In 2010, Washington State adopted a Better Brakes Law to reduce the use of toxic material in automotive brake pads and shoes and phase out the use of copper. California has a similar law.

A-4.7. Advocate for adoption of provincial or federal laws and approaches to identify, reduce use of, or phase out and properly dispose of toxic materials, particularly those that persist or bioaccumulate in the marine environment

Although some chemicals, such as PCBs and PBDEs, have been banned from further manufacture or use, many other chemicals have not yet been properly assessed for their safety. Proper disposal requirements are still a regulatory gap for some banned chemicals (P. Ross, pers. comm.).

Strategy A-5: Limit impacts from future discharges, new development, and spills

A-5.1. Advocate for a regional requirement that new authorized industrial discharges consider projects in the context of cumulative effects to Burrard Inlet from all forms of development

Evaluations of applications for new industrial discharges should consider cumulative effects to Burrard Inlet from all existing and future pollution sources.

A-5.2. Advocate for municipal, regional, or provincial development standards that protect watershed health and the health of receiving environments such as Burrard Inlet

Integrated stormwater management plans (ISMPs) have been promoted as a means of mitigating the impacts of future development on watershed health. However, there is currently no mechanism to ensure implementation within the land use planning process or effectiveness monitoring to ensure results are being achieved. Watershed health objectives should be more strongly linked to development planning through the development and adoption of specific standards for implementation and monitoring.

A-5.3. Continue to improve spill prevention and response planning and execution for oil, fuel, and other types of spills in Burrard Inlet

Spills represent a small but important potential source of contamination and acute exposure to hydrocarbons and other contaminants. Recent spills in 2007 and 2015 have highlighted that current spill plans are inadequate to address emerging needs and that improved training and practice is required so that plans can be exercised in a timely and efficient manner during actual events.

4.2 Goal B: Protect and Enhance Fish and Wildlife Habitat

Strategy B-1: Map and monitor priority habitat types

B-1.1. Update existing shoreline habitat inventories and classifications every five years to look at the amount habitat lost/gained over time

The most recent shoreline inventory was completed in 2009. Having an updated inventory is a first step in further work to understand trends in shoreline development, to ensure no net loss of natural shoreline, and to identify opportunities for shoreline softening. The inventory should include a series of maps or an online atlas.

B-1.2. Conduct more detailed mapping and assessment of trends in the extent and condition of important nearshore habitats, such as estuaries, salt marshes, tidal mudflats, eelgrass meadows, kelp beds, and productive beaches

In general, important nearshore habitats in Burrard Inlet are not well mapped. Mapping should be undertaken using a mix of historical mapping, airphoto interpretation, field verification, habitat modelling, and traditional ecological knowledge.

B-1.3. Map potential forage fish spawning habitat and develop a habitat suitability model for different species

As mentioned earlier, forage fish are an understudied aspect of Burrard Inlet's food web and have severely declined from historic levels. Basic information is needed as a basis for stock rebuilding and habitat restoration.

B-1.4. Conduct an analysis of the state of habitat compensation sites to assess function and quantify amount of productive habitat gained/lost over time

Although habitat is frequently created to compensate for unavoidable impacts of development on natural habitats, there is often very little follow-up to understand whether compensation habitat is functioning and productive. Past projects should be assessed to help understand what has worked and what hasn't to inform future projects in Burrard Inlet.

Strategy B-2: Identify, prioritize, and protect high priority habitats

B-2.1. Develop and regularly update a "top ten list" of the highest priority sites for protection

High priority sites should be identified and brought to the attention of federal, provincial, and municipal decision-makers so they can be protected from development and other threats. Sites should be evaluated based on their habitat type, representativeness, sensitivity, long-term viability, and beneficial uses of habitats present.

B-2.2. Advocate for protection of identified high priority sites through acquisition, designation, or changes in management

Land use decision-makers, other stakeholders, and the public should be educated about potential mechanisms for protecting sensitive habitat areas.

Strategy B-3: Identify and prioritize high priority sites for habitat restoration

B-3.1. Develop a "top ten list" of the highest priority sites for habitat restoration and enhancement

Habitat restoration should be prioritized where it is likely to have the largest maximum sustained benefit for key species and ecosystems. Potential restoration sites in Burrard Inlet should be evaluated to understand their current condition and level of functioning and to prioritize sites for restoration based on type, representativeness, significance, long-term viability, and beneficial uses of habitats present.

B-3.2. Continue to support the Burrard Inlet Estuary Restoration Pilot Program

The pilot program has initiated restoration of several estuaries through a collaborative approach involving municipalities, First Nations, local stewardship organizations, consultants, and BCIT. Estuaries are an important and severely limited habitat type in Burrard Inlet. Although the existing funding that was available from HCTF has been fully utilized, projects should continue to be developed and supported. Stable long-term funding sources should be secured for this program.

B-3.3. Conduct a pilot project to develop a comprehensive conservation strategy for one of the large high priority nearshore habitat complexes in Burrard Inlet

Several of the larger marine habitat areas in Burrard Inlet are part of larger habitat complexes that include multiple important upland and nearshore habitat types, such as Spanish Banks, Maplewood Flats, and Port Moody Arm. Site-specific conservation strategies for these high priority areas that address specific management issues and threats should be developed. Maplewood Flats and the McCartney Creek estuary currently is the site of a pilot project called "Bringing it Back". It is one of the most ecologically important remaining large habitat complexes in Burrard Inlet and a priority site for Tsleil-Waututh.

B-3.4. Support the development of guidance in best management practices for restoration techniques likely to be used in Burrard Inlet.

Development of a guidance document would help to ensure best available science and practices are being used to increase the likelihood of success in restoration projects. Examples of habitat restoration techniques that could be covered include beach nourishment, eelgrass planting, and kelp re-establishment.

Strategy B-4: Reduce or manage threats to habitat

B-4.1. Develop pilot projects, case studies, and best management practices for shoreline softening to encourage their wider use within Burrard Inlet

Shoreline softening techniques have not been widely adopted in Burrard Inlet to date. Pilot projects could be developed and undertaken, or successful projects from other jurisdictions reviewed and documented to show potential techniques and best practices.

B-4.2. Advocate for phasing out the use of new treated-wood pilings and other treated structures in freshwater and marine waters within the Burrard Inlet catchment

Treated-wood pilings are known to kill herring eggs. Steel and concrete pilings should be utilized rather than treated wood as part of maintenance and end-of-life replacement for wharves and other in-water structures.

B-4.3. Cover treated-wood pilings in areas of high density and where leaching may occur into vulnerable habitats

As an interim approach, covering treated-wood pilings has been shown to reduce herring egg kills and increase available spawning habitat. However, this technique is a temporary measure and should not be used as a long-term strategy for forage fish habitat creation.

B-4.4. Direct new shoreline development and outfalls away from vulnerable habitats

Planning policies for municipalities should be updated to include consideration of rare, vulnerable, and sensitive habitats near proposed developments. An important part of this approach requires having comprehensive, up-to-date information on the status of shorelines and nearshore habitats (Action B-1.1).

B-4.5. Advocate for a policy of no net increase in shoreline hardening associated with shoreline development

Shoreline hardening has incrementally reduced the amount of natural shorelines remaining in Burrard Inlet. If new shoreline hardening is required, it should be accompanied by compensatory efforts to reduce shoreline hardening and naturalize shorelines elsewhere.

4.3 Goal C: Protect and Recover Key Species Populations and Food Webs

Strategy C-1: Assess and monitor priority species populations

C-1.1. Collate and develop a common database for salmon escapement data for Burrard Inlet rivers and creeks

Although this data was collated and reported on up until the 1980s, there is no formal data collation and reporting process for salmon escapement from Burrard Inlet rivers and creeks. Data on adult salmon returns from DFO, Tsleil-Waututh, hatchery programs, and community stewardship groups should be collected annually and recorded in a database to better track and understand overall status and trends across Burrard Inlet as a whole and trends for individual streams.

C-1.2. Further study the migration routes and survival of juvenile salmon in Burrard Inlet as they leave local rivers and creeks

Preliminary data has suggested low early marine survival of out-migrating steelhead smolts before they reach the Outer Harbour. Ongoing work is needed to understand whether survival rates are similar for other species, the potential reasons for this mortality, and the role of built structures (e.g., docks, walls, piers) in impacting movement of out-migrating juvenile salmonids through the Inner Harbour.

C-1.3. Conduct a study to assess use of Burrard Inlet by out-migrating juvenile salmon from the Fraser River

Little is known about how Burrard Inlet is used by out-migrating juvenile salmon from the Fraser River. Acoustic tracking methods being used to study outmigration could also be used to study immigration and use of Burrard Inlet by salmon from the Fraser River.

C-1.4. Conduct a baseline study of forage fish use and develop a long-term forage fish stock assessment and monitoring program

Information is needed on the size of populations, locations of spawning for different species, the extent of impacts from shoreline development, and potential habitat restoration opportunities that may exist.

C-1.5. Expand regular bivalve surveys to other priority sites within Burrard Inlet and investigate the nature and extent of transition from native to invasive non-native species

There is a need to better understand both historic and current distribution of particular bivalve species relative to habitat conditions and human impacts, as well as the nature and extent of transition from native shellfish species like butter and littleneck clams to invasive non-native shellfish species like soft-shell and purple varnish clams, and how these species may be interacting.

C-1.6. Continue to study how finfish and shellfish will be influenced by continued acidification of marine waters and potential ways to mitigate those impacts

Acidification has the potential to significantly impact bivalve populations on the BC coast, with implications for First Nations traditional use. Work already being conducted at Cates Park by Leah Bendell (SFU) and Tsleil-Waututh should be continued and built upon.

C-1.7. Participate in ongoing monthly bird surveys by Bird Studies Canada and Pacific Wildlife Foundation

The existing survey program has been structured to provide comprehensive coverage of the inlet and provide important ongoing data of the status and trends of particular bird species in Burrard Inlet over time.

C-1.8. Collaborate with marine mammal monitoring through the B.C. Cetacean Sightings Network and other databases

Sightings of cetaceans in Burrard Inlet, although infrequent, are one indicator of the health of the food web in Burrard Inlet, and of broad interest to the public.

C-1.9. Develop and maintain a spatial database of occurrences for all priority species found in Burrard Inlet, including fish, birds, marine mammals, and marine invertebrates

A comprehensive species database will help to provide a baseline of what species are present now and highlight the importance of Burrard Inlet for biodiversity broadly.

Strategy C-2: Manage unique threats to key species not covered by broader ecosystem-based approaches

C-2.1. Identify and manage the sources of contamination to priority shellfish beds, and the possible role climate change may play in the frequency of harmful algal blooms

Because of the significance of shellfish in Tsleil-Waututh diet and culture, identifying the sources of contamination to specific priority shellfish beds and developing prioritized plans to reduce their sources will provide the best means to meeting the near-term priority of re-opening Burrard Inlet to shellfish harvesting. The role of climate in increasing the frequency of harmful algal blooms in the inlet and how that might influence shellfish harvesting opportunities should also be further understood.

C-2.2. Collect or collate information on harvest levels for commercially or recreationally harvested species and evaluate to assess whether levels are sustainable

Although overharvesting is not thought to be an issue for most species in Burrard Inlet, there is limited information on harvest rates for some species, for example, crabs and surf smelt. Where possible, harvest data should be collected, collated, and reviewed to identify if any potential for overharvesting exists for key species.

C-2.3. Work with the Vancouver Fraser Port Authority to mitigate the impacts of overwater structures and artificial lighting at night on fish species

Studies in Puget Sound have implicated overwater structures and shore lighting as potential factors increasing predation rates on fish species migrating past port facilities similar to those found in Burrard Inlet. Work in Puget Sound has also looked at some possible mitigation measures including softening the shadow lines of overwater structures, creating artificial complexity such as reefs, reducing lighting, changing the type of lighting, or using more directed lighting in shoreline areas.

4.4 Goal D: Protect and Restore Supporting Biophysical Processes/ Ecological Integrity

Strategy D-1: Build our understanding of how Burrard Inlet functions as an interconnected system

D-1.1. Improve knowledge of circulation patterns, sediment transport, and climate change related impacts to circulation in Burrard Inlet

Circulation in Burrard Inlet is influenced by several natural factors (tides, currents, freshwater inputs) which vary widely at different times of year and will change in response to climate change. Further understanding circulation patterns is a key part of understanding physical water quality, the distribution of contaminants, and better preparing for potential spills. Detailed modelling and monitoring stations at key locations are both possible means of further understanding circulation patterns.

D-1.2. Study impacts of shoreline hardening on erosion, deposition, and drift cell function

There is evidence to suggest that shoreline hardening and development has contributed to altered erosion and sediment deposition patterns in specific parts of the inlet (e.g., Roche Point to Maplewood Flats) but further work, such as a historical air photo analysis or modelling, could be used to identify potential causes of changes and assess trends.

Strategy D-2: Address threats to ecological integrity

D-2.1. Support the BC Spartina Working Group's existing *Spartina* surveillance and control measures in Central Harbour and Port Moody Arm

Spartina is the highest priority invasive non-native species of concern in Burrard Inlet and should continue to be managed to reduce the number of sites occupied and the size of populations at those sites. Ongoing surveillance is also needed to detect new populations early in their invasion so they can be eradicated before they become larger populations that are more difficult to manage and eradicate.

D-2.2. Develop an early detection rapid response program for high priority future invasive non-native species within Burrard Inlet

An early detection rapid response program would include tools to identify high priority invaders, widespread surveillance likely shared among groups, and the ability to mobilize quickly to eradicate newly established populations in the event of the arrival of a new species of concern.

D-2.3. Review existing ballast water management procedures to understand the potential risks of species introductions into Burrard Inlet

While there are regulations in place, managed by Transport Canada, which mandate mid-ocean exchange for transoceanic vessels and vessels coming from far enough away on the coast, it is unclear whether this is sufficient to protect Burrard Inlet from potential invasions by non-native species. Mid-ocean water also may have many species which can do well in coastal waters. Existing ballast water management procedures should be reviewed to understand the potential risk of species introductions.

Strategy D-3: Restore ecological integrity over time

D-3.1. Seek to reduce or modify the influence of shoreline or overwater structures which have altered sediment transport and circulation patterns

End-of-life replacement and maintenance of docks, wharves, breakwaters, bridges, bridge piers, and other structures represent rare opportunities to recover more natural sediment transport and circulation patterns and should be maximized by incorporating these goals in strategies of cooperating municipalities so that development reviews consider marine impacts and benefits.

4.5 Goal E: Identify and Track Emerging Issues

Strategy E-1: Identify, characterize, and track emerging issues

E-1.1. Conduct a review of emerging pollutants based on land use and industry types present in Burrard Inlet

As discussed earlier in the plan, emerging pollutants represent a potential threat to species and habitats although there is little known about them. Reviewing studies and research from other similar marine ecosystems with similar surrounding land uses would help to identify which emerging pollutants are of most concern and the potential risks to Burrard Inlet.

E-1.2. Advocate for continued study and information sharing on contaminants of emerging concern and microplastics in sewage treatment effluent and at sewer outfalls, and advocate for adoption of treatment technologies that remove contaminants of emerging concern

Although Metro Vancouver is studying these contaminants in wastewater entering Burrard Inlet, results have not been made available. More information is required about the concentrations and effects of certain emerging chemicals to better understand the associated risks to aquatic life and human health.

E-1.3. Conduct a baseline study of marine debris and microplastics in Burrard Inlet to characterize extent of problem, specific sources, and effects on fish, wildlife, and the marine environment

Work has been initiated to understand the extent and distribution of microplastics in Burrard Inlet. Data on marine debris is also collected as part of shoreline cleanup. Where possible, the amount and sources of marine debris should be characterized to help target prevention measures.

E-1.4. Support research on the effects of underwater noise on marine mammals in Burrard Inlet

Based on the amount of development present in Burrard Inlet, it is likely to be a concern. Specific studies could look at impacts as well as investigating options for reducing underwater noise in Burrard Inlet.

Strategy E-2: Take a proactive approach to managing emerging issues

E-2.1. Promote proper disposal of pharmaceuticals and other contaminants of emerging concern

Such an effort could be combined with a broader social marketing effort aimed at reducing pollution from households (Action A-4.3) and could be coordinated with existing Metro Vancouver initiatives to encourage proper handling and disposal.

E-2.2. Work with the Vancouver Fraser Port Authority, local municipalities, boating groups, and other stakeholder groups to reduce the amount of marine debris in Burrard Inlet

This action should include both shoreline cleanups to reduce marine debris already on beaches and in the water as well as prevention measures to reduce the amount marine debris entering Burrard Inlet from all sources. Gathering data on marine debris has already been initiated as part of the Great Canadian Shoreline Cleanups which occur annually in Burrard Inlet, coordinated by the Vancouver Aquarium.

E-2.3. Advocate for controls on the manufacture and sale of products containing microplastics as part of broader national and international efforts

Microplastics are a broad issue facing oceans globally although they have the potential for localized impacts that require support for larger issues to curb their use.

5. Monitoring and Adaptive Management

Monitoring the implementation of the actions that make up the Action Plan is an important part of ensuring its success. Monitoring is a form of performance management, allowing progress towards the plan's goals to be assessed and reported on to decision-makers, stakeholders, and the public. It is also a means of obtaining regular feedback on the effectiveness of actions such that informed decisions can be made about future actions based on whether existing actions are achieving the desired results. In cases where actions are not achieving results, actions can be changed or modified to improve their effectiveness. Known as adaptive management, this feedback mechanism is critical to efficient and effective environmental management.

5.1 Existing Monitoring Programs

One of the challenges of developing a monitoring framework for the Action Plan is the number of existing monitoring programs that either have occurred or are occurring in Burrard Inlet. For example, past and current water quality monitoring programs include authorized discharge monitoring by industrial permit holders, water quality objective attainment monitoring by BC Ministry of Environment, outfall, ambient, and recreational beach monitoring by Metro Vancouver, and stormwater monitoring by municipalities. Some species and habitats are also being monitored. Adult salmon returns have been monitored in the past by DFO, bird surveys are conducted regularly by Bird Studies Canada and Pacific Wildlife Foundation, and some monitoring of specific habitat types such as eelgrass and forage fish beaches is being contemplated. While some monitoring is a regulatory requirement, other monitoring is conducted voluntarily by groups within an interest in conserving and restoring Burrard Inlet.

Developing a broader monitoring plan for Burrard Inlet should not seek to replace existing monitoring efforts but to better integrate and coordinate these efforts, streamline approaches, fill information gaps, and improve the availability of monitoring results and their use in the performance monitoring and adaptive management processes. Ideally, ongoing monitoring will build on past datasets, rather than collect entirely new data, to allow for the assessment of trends from past to present day.

Because monitoring efforts have not been coordinated to date for the most part, it may take some effort to encourage and develop a more shared, collaborative approach. Forming a monitoring working group would help to develop shared approaches and common objectives. Working with regulatory agencies may also be necessary to convince them to change their regulatory requirements for monitoring. Developing a shared approach to monitoring among stakeholders has the potential to avoid overlapping costs and efforts, and reduce potential duplication.

Inventories of monitoring programs and environmental benchmarks for Burrard Inlet have been conducted in the past (2WE, 1999; Entech, 2002; Lee and Rudd, 2003; MacDonald *et al*., 1999; Yarnell, 2004). Initially, it would be helpful to collate these previous inventories and update them to include more recent studies and monitoring work. Information should be collected on the objectives of the program, type of data collected, its availability, sites sampled, protocols followed, and reporting methods, and whether this monitoring will be sustained into the future and at what frequency. Existing programs could then be evaluated as to whether they can provide past, current, or ongoing data relevant to the Action Plan's goals and could be used in performance monitoring, and what gaps may exist that would require new types of data to be collected.

5.2 Performance Indicators and Targets

An important part of developing an effective monitoring framework is the development of a clear set of measurable indicators and benchmarks from which progress can be measured and reported on. To develop an overall monitoring framework for Burrard Inlet, a set of performance indicators and targets which tie directly to the goals of the plan need to be determined. Preferably, indicators should be able to be easily assessed using existing data or easily collectable data. They should also be able to be reported on in a timely fashion.

Developing an appropriate set of indicators and targets involves the following process:

1. Identifying existing or future datasets that may provide a basis for indicator development;
2. Identifying a list of potential indicators based on the datasets available;
3. Selecting an appropriate set of indicators that cover all of the goals of the Action Plan;
4. Establishing proposed 2025 performance targets for the indicators and potential interim targets (if applicable);
5. Collecting data for each indicator on a regular basis using consistent methods;
6. Developing a reporting approach for regularly reporting on progress over time; and
7. Ensuring ongoing data collection, indicator assessment, and reporting through adequate planning and funding.

Potential environmental indicators for Burrard Inlet have been reviewed, recommended, and initially reported on in the past. Yarnell (2004) recommended 12 potential indicators for State of the Environment reporting in Burrard Inlet covering seven focal areas: water quality, sediment quality, air quality, fish and wildlife populations, fish and wildlife health, habitat gains and losses, and protected areas. A public consultation document on environmental indicators was also produced for BIEAP in 2008 that initially reviewed the status and trends for seven proposed indicators: tree canopy cover, parks and protected areas, waterbird abundance, air quality, greenhouse gas emissions, water and sediment quality, and recreational water quality/fecal coliforms (Jacques Whitford AXYS, 2008).

Although these initial efforts to develop indicators illustrated some important trends and progress, they do not appear to have been adopted for ongoing performance monitoring or adaptive management. One reason is that indicators appear to have been selected more on the availability of data rather than on specific management goals or objectives. Thus, many areas of action were not covered. Furthermore, previously used indicators have lacked associated measurable targets or benchmarks against which progress can be assessed. Developing both indicators and targets is critical to establishing a clear relationship between actions and goals, and ensuring that the results influence future actions.

Table 5-1 provides a potential set of performance indicators and targets for Burrard Inlet that correspond directly with the Action Plan's goals. While many of the previously recommended or used indicators are included, several new indicators have been added. As much as possible, proposed targets that relate directly to the Tsleil-Waututh Nation's vision of a healthy Burrard Inlet and to their near-term priorities for improving the health of the inlet have also been included. Indicators (and associated targets) include both *output indicators*, which assess progress of implementation (e.g., number of square meters of habitat restored) as well as *outcome indicators* which assess progress in improving ecological health (e.g., reduced contamination, size of key species populations). Numerical targets are largely tentative and will need further refinement based on more detailed analysis.

While some of the indicators rely on data collected regularly through existing monitoring programs, the adoption of some indicators and appropriate related targets is dependent on carrying out new baseline inventories and developing new monitoring initiatives to provide quality ongoing data. For example, mapping and monitoring eelgrass beds and developing forage fish monitoring and stock assessment protocols would be new types of monitoring not currently conducted. Thus, while placeholders are included to show the importance of developing indicators and targets in these areas, specific targets are not proposed at this time.

Although most of the targets are stated as targets to be achieved by 2025, for some indicators, it may also be appropriate to set interim targets, however, there was not information to set these targets at this time.

Table 5-1: Potential Performance Indicators and Targets

Indicator	Related Performance Targets – By 2025
Marine Water Quality	• All BC Ministry of Environment water quality monitoring sites attain provincial water quality guidelines.
Recreational Water Quality	• All monitored beaches meet the BC Ministry of Environment water quality guidelines for recreational water quality.
Marine Sediment Quality	• All sediment quality monitoring sites achieve Canadian Council of Ministers of the Environment (CCME) sediment quality guidelines for metals, PCBs, and PAHs.
Contaminants in Fish and Mammals	• Bioaccumulative contaminants (PCBs, PDBEs) measured in English sole are below threshold levels. • In response to PAHs and endocrine-disrupting contaminants, English sole in Burrard Inlet exhibit no PAH-related liver disease or toxics-related reproductive impairment. • Contaminant concentrations (metals, PAHs) measured in mussels are trending downward. • Bioaccumulative contaminants (PCBs, PBDEs) measured in harbour seals are trending downward.
Shellfish Beds	• At least 10 hectares of shellfish beds are open to limited harvesting at least 80% of the year. (Shellfish harvesting has been closed in Burrard Inlet since 1972.)
Estuaries	• An increase of 50 hectares in estuarine habitat basin-wide and an increase in at least 25% habitat area in each of five different estuaries.
Eelgrass	• *No target set at this time – baseline needed.*
Shoreline	• Total amount of shoreline hardening removed is greater than the total amount of new shoreline hardening (total metres removed > total metres added).
Salmon	• Stable or increasing trends in salmon returns to Capilano, Seymour, and Indian rivers relative to baseline period.
Herring/Surf Smelt	• *No target set at this time – baseline needed.*
Birds	• Stable or increasing trend in four key species relative to baseline period – Western Grebe, Barrow's Goldeneye, Surf Scoter, and Great Blue Heron.
Marine Mammals	• Increased number of key species of marine mammal sightings relative to baseline period.
Invasive Non-native Species	• Number of occurrences of *Spartina patens* in Burrard Inlet salt marshes has been reduced by 50% and the total coverage has been reduced by 75%. • By 2025, no new aquatic invasive non-native species have established.

Generally, the indicators proposed at this time are specific to the health of the marine environment. Additional indicators could be added which focus on other important areas of environmental management not covered in this version of the Action Plan, such as upland land cover and land use, and air quality.

5.3 Toward a Coordinated Monitoring Program for Burrard Inlet

Many of the actions described in the Goals, Strategies, and Actions section are aimed at bringing improved coordination to monitoring in Burrard Inlet as well as filling information gaps such that data is more applicable to performance monitoring and that a more complete picture of progress toward the plan's five goals can be achieved.

For example, one of the purposes of the formation of a Water Quality Working Group (Action A-1.1) would be to discuss improvements to existing water quality monitoring. Other specific actions are aimed at improving the availability and quality of data for performance monitoring purposes:

- Better collation and sharing of existing water and sediment quality data (Action A-1.2);
- Standardization of water and sediment quality sampling methods (Action A-2.1); and
- Standardization of compliance monitoring for authorized industrial discharges (Action A-2.2).

Several of the plan's actions are to collect new data for issues where there is currently insufficient data such that it could be used for performance monitoring:

- Development of a new environmental quality monitoring program focussed on nearshore habitats (Action A-2.3);
- Mapping and monitoring of important nearshore habitat types, such as eelgrass beds, kelp forests, mudflats, and beaches (Action B-1.2);
- Data collation and ongoing collection of historic and future data on adult salmon returns in major Burrard Inlet rivers (Action C-1.1);
- Monitoring and stock assessment of forage fish populations (Action C-1.4); and
- Expansion of regular bivalve surveys (Action C-1.5).

It is expected that progress on improving monitoring and being able to fully report on all of the potential indicators and targets will be incremental. While data is available to report on some indicators right away, others will require some lead time to develop the appropriate data collection methods and collect the necessary data.

Ideally, a formal monitoring plan will be developed to support the Action Plan that:

- Reviews and evaluates a wide range of potential performance indicators and targets in light of the plan's goals;
- Confirms selected performance indicators and targets;
- Details the data sources to be used or the new data collected and from what sites to support regular use of the indicators evaluation of performance with the indicators;
- Assigns specific roles and responsibilities to Plan partners with respect to monitoring;
- Outlines reporting tools to be used to report out on monitoring results and progress towards the performance targets; and
- Establishes expected reporting timelines and frequencies.

5.4 Reporting Tools

Previous reporting on indicators has focussed on technical reports and documents. Based on review of the reporting done in other jurisdictions, we recommend three potential tools for reporting on progress in implementing the *Burrard Inlet Action Plan*, with suggested frequencies for each type of reporting:

- **Implementation Progress Reports (every two years):** The progress reports would focus more on implementation progress and outline what actions have been taken under the identified goals and strategies, who has responsibility for implementing those actions, how performance is being measured, and over what time frame implementation is occurring.
- **Ecological Health Report Card (every two years):** The report card would report on the status and trends in key environmental indicators related to performance targets defined in the Action Plan under each goal. The report card would be short, have an infographic style, and be aimed at decision-makers and the public. A related dashboard of indicators with more detailed technical information to support each indicator could also be made available online.
- **Online Project Atlas (ongoing):** The online project atlas would document the status and locations of important initiatives and projects to improve the health of Burrard Inlet as they are implemented, provide the measurable outputs achieved (e.g., area of habitat restored), as well as provide links to any resulting data, reports, and measurable outcomes.

If desired, a more comprehensive approach to performance management is encompassed by the *Open Standards for the Practice of Conservation* (http://cmp-openstandards.org). The Open Standards are a science-based performance management tool that can be used to develop adaptive management frameworks, planning tools, and actions for conservation projects. The Open Standards could be used to develop a more formal adaptive management framework. The Open Standards have been used successfully to develop and track the implementation of action plans in Puget Sound and, more locally, in the Coquitlam River watershed.

6. Implementation

If recovery of the Burrard Inlet ecosystem is to be achieved by 2025, implementation of the Action Plan will take strategic prioritization of efforts, thoughtful leadership, more collaboration among interested parties, and adequate funding. Although a full implementation strategy was beyond the scope of the plan at this time, recommendations for several important next steps are provided below.

6.1 Strategic Priorities for Near-term Action

Part of developing the Action Plan was to prioritize which actions are most important to making progress in environmental management in Burrard Inlet in the next 5–10 years.

Although all actions that have been identified as important to recovery in Burrard Inlet, six strategic priorities have been identified as being the highest priorities for near-term action, because they begin to address some of the most pressing problems, combine several previously identified individual actions, and have the potential to catalyze collaboration, partnerships, and political and public will to support wider recovery initiatives. The following six strategic priorities are recommended as an initial focus of efforts:

Priority 1: Update Water Quality Objectives for Burrard Inlet

The current water quality objectives for Burrard Inlet were created in 1990 by BC Ministry of Environment as provisional objectives. They were developed to protect aquatic life, wildlife, and human recreation from pollution in the inlet. Water quality objectives define what can be considered clean, safe, or within the range of natural conditions. They represent important thresholds which can be used as triggers for remedial action and against which progress in environmental management can be assessed.

Updating the water quality objectives for Burrard Inlet would provide an initial focus for which to share and combine existing data, and begin to prioritize issues and solutions. Undertaking this task will require formation of a working group representing diverse interests. It is hoped that this initiative would lay the groundwork for further efforts and coordination to reduce or abate the sources of pollution.

Updating the water quality objectives for Burrard Inlet has been identified as a priority by BC Ministry of Environment staff and has been recognized as a key need by Metro Vancouver in the 2013 Liquid Waste and Integrated Resource Management Plan. Although MOE is not in a position to lead the review and update process, they have participated in other collaborative reviews of water quality objectives in other locations around BC and are interested to do the same for Burrard Inlet. A similar approach was recently undertaken for updating water quality objectives for Cowichan River and Cowichan Bay on Vancouver Island.

The water quality objectives review and update process would encompass several actions identified as near-term priorities:

- Collation of existing environmental quality reports and data;
- Review and assessment of data for trends and information gaps;
- Development of new sampling or monitoring programs to fill those gaps;
- Development of new objectives; and
- Review by MOE science staff in Victoria and formal adoption by the Province.

It is recommended that the working group formed to conduct this process include representation from government, municipalities, First Nations, industry, and the scientific community.

Priority 2: Install Scientific Instruments to Monitor Water Quality in Burrard Inlet

High-resolution water quality data is essential for strategic environmental stewardship planning for the inlet. Lack of up-to-date data, particularly with respect to physical water quality, was identified as an important knowledge gap. At this time, scientific instruments that continuously monitor water quality are deployed in the Strait of Georgia and elsewhere in the Salish Sea, but not in Burrard Inlet. A priority should be placed on installing permanent instrument arrays at one or more key locations in the inlet to provide important water quality data.

As mentioned above, Ocean Networks Canada already operates similar instruments on the BC coast and would be an ideal partner for this action.

Priority 3: Characterize and Reduce Pollution from Stormwater Runoff – Pilot Project on TWN Reserve

Stormwater runoff is likely the largest source of pollution to Burrard Inlet, but is one of the most challenging to manage. It is best addressed on a catchment-by-catchment basis consistent with the region's Integrated Stormwater Management Planning initiatives. Major pollutants of concern in urban stormwater typically include pathogens, metals, and PAHs.

Since the TWN Reserve in North Vancouver (Burrard I.R. #3) is one important location for cultural, spiritual, and ceremonial activities, characterizing and reducing pollutants in stormwater in streams originating upland, running through the reserve, and flowing into Burrard Inlet is recommended as a potential initial pilot project. This would involve bringing cutting-edge strategies, practices, and technologies to measure and improve stormwater quality, within the context of also addressing quantity-related impacts of stormwater to creeks and streams. The lessons learned through this pilot project can be applied in other catchments around the inlet.

Examples of measures that could be taken to improve the quality of stormwater runoff entering Burrard Inlet near the TWN Reserve include:

- Wider adoption of municipal Best Management Practices, such as regular street sweeping and cleaning of sediments from municipal stormwater pipes, sumps, and catch basins;
- Establishment of industry-specific Best Management Practices or codes of practice that prevent pollution from entering the stormwater system;
- Retrofitting of existing streets and neighbourhoods with landscape features that capture and infiltrate or treat runoff rather than piping it directly to creeks and streams;
- Increased use of low impact development (LID) measures and water quality performance criteria in urban development and re-development; and
- Development of an eco-certification program and other incentives to encourage adoption of BMPs.

Although Metro Vancouver has been working in this area, acceleration of approaches to address water quality is needed. First Nations, working with municipalities, could potentially play a lead role in piloting some of these initiatives.

Priority 4: Map Nearshore Habitats and Forage Fish Spawning Beaches

The loss of habitat in Burrard Inlet has been identified as a primary driver of declines in key species of finfish, shellfish, birds, marine mammals, and many other species. Nearshore habitats, in particular small estuaries, eelgrass meadows, kelp beds, and productive beaches, have been extensively lost to urban, industrial, and port development. In addition, forage fish are an extremely important component of the food web in Burrard Inlet. They are the essential link between plankton and larger predators including fish, birds, and mammals. However, there is limited information on the locations of these habitat types within Burrard Inlet.

Efforts should be undertaken to map the locations of important nearshore habitats and forage fish spawning beaches and fill these two very important knowledge gaps for strategic environmental stewardship planning.

Priority 5: Conserve Critical Nearshore Habitat Complexes – Pilot Project at Maplewood Flats

As identified in Priority 4, the loss of nearshore habitat is a primary driver of environmental degradation and species declines. Development of a pilot project focused on reducing threats and improving environmental conditions at one of the larger, centrally-located nearshore habitat complexes should be a priority action.

Maplewood Flats is one of the largest intertidal habitat complexes as yet unaddressed in Burrard Inlet. The area has cultural, spiritual, and ceremonial significance for TWN members. It is home to Wild Bird Trust of British Columbia, a non-governmental organization. A pilot project there can improve conditions by addressing numerous environmental issues including creosote piles, sediment contamination, substrate embeddedness, wood waste, depleted bivalve populations, and invasive species. It can also include restoration of another small estuary at the mouth of McCartney Creek.

Priority 6: Recover Shellfish Beds – Pilot Project in Indian Arm

Being able to once again safely harvest traditional wild foods, particularly bivalves, in Burrard Inlet is deeply important to the TWN. Its achievement will represent an important milestone in the environmental recovery of Burrard Inlet.

Shellfish health begins upland with controlling the sources of pollution, particularly pathogens. Significant progress on this issue has been achieved in Indian Arm. On October 26, 2015, the Canadian Shellfish Sanitation Program opened a small beach in Indian Arm for ceremonial harvest of bivalves. Additional investigation and correction of any sources of pollution in Indian Arm will ensure that progress to date is sustained and expanded. The lessons learned through this pilot project can be applied at other locations around the inlet.

Although microbiological contamination is widespread in Burrard Inlet, it is thought that specific sources of pathogens are directly impacting specific sites. Identifying and addressing the sources of pathogens would include investigating potential origins and sources of contamination (humans, pets, wildlife, creeks, stormwater outfalls, discharges from boats, combined sewer outflows, potential sanitary-storm sewer cross-connections, and failing septic systems), characterizing their relative importance, and taking remedial actions to incrementally reduce these sources.

Other Implementation Priorities

Other implementation priorities include continual improvement in spill prevention and response and phasing out the use of treated-wood pilings and other treated structures. Priority research questions include the effects and mitigation of acidification in marine waters, the sources and effects of marine debris and microplastics, underwater noise effects on marine mammals, and identifying the preferred migration routes for juvenile salmon through Burrard Inlet.

6.2 Toward Renewed Collaboration on Burrard Inlet Stewardship

The Musqueam, Squamish, and Tsleil-Waututh people have always assumed the role of caretakers of their territories and have a deep understanding of what the health of the environment means to the lives of their community members. The principles that guide their approach to stewardship are built from teachings passed on from Elders and a strong relationship to the land.

As stated previously, TWN is prepared to take a leadership role in recovering the Burrard Inlet ecosystem. However, they also desire to work broadly with other groups concerned about health of Burrard Inlet, including other First Nations, government, industry, stewardship groups, and the public. Because each group has different roles and responsibilities for environmental management in Burrard Inlet, each of these groups can influence change in different ways. As for all of its relationships with other groups and levels of government, TWN seeks to build strong working relationships based on trust and mutual respect.

With respect to building capacity and renewing collaborative action on a shared strategic stewardship agenda for Burrard Inlet, the following measures are recommended:

1. Develop Action-Based Partnerships

The emphasis of the Action Plan is on taking action to achieve desired outcomes. Undoubtedly, partnerships will be a more effective and efficient way to implement some actions. Working jointly on specific actions can bring increased capacity, provide more effective approaches that reduce duplication of efforts, and can sometimes reduce costs. Potential examples of specific actions where collaboration could be beneficial include:

- Undertaking habitat inventories or mapping;
- Implementing monitoring programs;
- Developing municipal bylaws or land development guidelines such as pollution prevention best management practices or source control guidelines for specific industries;
- Developing incentive programs;
- Developing technical decision support tools and technologies; and
- Developing education and outreach approaches and materials.

While developing a more formal partnership to guide Burrard Inlet stewardship may ultimately be desired, the absence of such a partnership or group should not preclude beginning to work together around specific priority actions.

2. Form a Scientific Advisory Panel

Efforts to recover Burrard Inlet should utilize the best available science to inform recovery efforts. Formation a scientific advisory panel would help to achieve this goal. The purpose of the scientific advisory panel would be to provide independent scientific advice to Burrard Inlet recovery efforts, to ensure the best available scientific information is used in the recovery planning process, and to facilitate collaboration of scientists and other science-interested individuals to support an improvement over time in the quality of scientific information available to support Burrard Inlet ecosystem recovery efforts. The panel would include local academic scientists, government scientists, and consultants with expertise in the issues important to Burrard Inlet recovery. A science panel has helped to oversee recovery efforts for Puget Sound in Washington State since early 2008.

3. Develop a Formal Partnership Model for Burrard Inlet Stewardship

With the closure of BIEAP in 2013, there is no longer a formal partnership or group aimed at recovering the Burrard Inlet from a whole ecosystem perspective. While the closure of BIEAP has a created a gap in management, it has also created an opportunity to re-evaluate what type of collaborative model would be most productive moving forward. Although senior levels of governments have important regulatory abilities, they also have less capacity than they once did and an increasingly limited focus on their role as environmental regulators. As a collaboration of federal, provincial, and regional governments, as well as the Vancouver Fraser Port Authority, BIEAP was not structured to embrace the increasing roles of municipalities, First Nations, and non-government organizations in advancing environmental protection and management.

Based on the current gap in coordinating capacity for environmental management in Burrard Inlet, Musqueam, Squamish, and Tsleil-Waututh have been exploring the potential of a formal partnership organization or umbrella group to coordinate ecosystem recovery planning and actions in Burrard Inlet. The purpose of the partnership would be to implement actions that are shared in nature, continue to revise and update the Action Plan, report on progress, and to provide overall coordination to implementation. There is also the potential for a broader partnership that could include First Nations, non-government organizations (e.g., Vancouver Aquarium, Georgia Strait Alliance), as well as interested levels of governments.

At this time, no formal partnership is in place but discussions should continue to determine if and how such as partnership should be structured.

6.3 Funding Strategy

Implementing the actions outlined in this plan will require significant financial resources. There is a need to increase the financial capacity of all groups currently involved in working to recover the Burrard Inlet ecosystem. Without a significant increase in financial resources, it is unlikely that the above goals can be achieved by 2025.

A comprehensive funding strategy that identifies potential sources of funding and funding mechanisms would help to identify the potential sources of federal, provincial, regional, municipal, and private funds available.

Some potential sources of initial project funding that have been identified include:

- EcoAction Community Funding Program (Environment Canada) – funds projects which encourage Canadians to take action to address clean air, clean water, climate changes, and nature issues, and to build the capacity of communities to sustain these activities into the future.
- Habitat Stewardship Program for Species at Risk (Environment Canada, Fisheries and Oceans Canada) – provides funding to stewards for implementing activities that protect or conserve habitats for species at risk and for priority species that are not at risk to prevent them from becoming a conservation concern.
- Aboriginal Funds for Species at Risk (Environment Canada, Fisheries and Oceans Canada) – supports Aboriginal organizations and communities across Canada in building their ability to participate in the protection and recovery of species at risk, preventing species from becoming a conservation concern, and recovering and protecting important habitat on Aboriginal lands.

- National Wetland Conservation Fund (Environment Canada) – supports projects that restore degraded or lost wetlands, enhance degraded wetlands, scientifically assess and monitor the health and functionality of wetlands and the species that use them, and encourage stewardship and wetland appreciation by a wide variety of partners to build support for future wetland conservation and restoration activities.
- Environmental Damages Fund (Environment Canada) – supports the restoration of natural resources and environment, and wildlife conservation projects in the same geographic area where environmental damage has occurred and funds were received as compensation for that damage.
- Aboriginal Affairs and Northern Development Canada, Climate Change Adaptation Projects – projects in Aboriginal and northern communities to help communities adapt to the impacts of climate change.
- Habitat Conservation Trust Foundation – fund projects that focus on freshwater wild fish, native wildlife species and their habitats, have the potential to achieve a significant conservation outcome, while maintaining or enhance opportunities for fishing, hunting, trapping, wildlife viewing and associated outdoor recreational activities.
- Pacific Salmon Foundation – makes grants to organizations that undertake Pacific salmon conservation and restoration or science and research.
- Natural Resources Canada Strategic Partnership Initiative – funding program designed to increase Aboriginal participation in emerging economic development opportunities across the country, particularly in the natural resource sectors.

Although it may be possible to pursue funding to implement individual actions on a case-by-case basis, ideally, stable long-term funding would be available to support the coordination of a potential partnership. Funding for coordination would likely need to be shared and come from one or a number of levels of government with a regulatory responsibility for environmental management in Burrard Inlet.

For comparison purposes, in the years prior to its closure in 2013, the BIEAP-FREMP secretariat had three staff and a core annual operating budget of approximately $400,000, funded equally by the six partner government agencies in the program (Environment Canada, Fisheries and Oceans Canada, Transport Canada, BC Ministry of Environment, Metro Vancouver, and the Vancouver Fraser Port Authority).

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Revision History

Revision #	Date	Status	Revision	Author
4	October 19, 2017	2017 Version	Updated version for public distribution	PL/PDK
3	January 12, 2016	Public Review Draft	Final draft report for public review	PL/PDK
2	June 30, 2015	Final Draft	Final draft report for submission	PL/PDK
1	June 16, 2015	Draft	Draft for review by client	PL/PDK

Appendix A

Summary of Ambient Water Quality Objectives for Burrard Inlet

Appendix A – Summary of Ambient Water Quality Objectives for Burrard Inlet

Provisional ambient water quality objectives were set in 1990 for Burrard Inlet. The provisional objectives for water (Table A-1), sediment (Table A-2), and contaminants in fish (Table A-3) by subbasin are summarized below. Depending on the designated water uses in the subbasin, objectives have been set to protect aquatic life, wildlife and primary-contact recreation. Objectives were also set for three tributaries of Burrard Inlet, Lynn Creek in North Vancouver, Schoolhouse Brook in Port Moody, and the Capilano River between North and West Vancouver, but are not summarized here. See Nijman (1990) for further details.

Table A-1: Provisional Water Quality Objectives for Burrard Inlet (Nijman, 1990)

<table>
<tr><th>Water Body</th><th>False Creek</th><th>Outer Harbour</th><th>Inner Harbour</th><th>Central Harbour</th><th>Port Moody Arm</th><th>Indian Arm</th></tr>
<tr><td>Designated Water Use</td><td>aquatic life, wildlife</td><td colspan="5">primary contact recreation, aquatic life, wildlife</td></tr>
<tr><td>Fecal coliforms</td><td colspan="6">less than or equal to 200/100 mL geometric mean</td></tr>
<tr><td>Enterococci</td><td colspan="6">less than or equal to 20/100 mL geometric mean</td></tr>
<tr><td>Total suspended solids</td><td colspan="5">10 mg/L maximum increase</td><td>not applicable</td></tr>
<tr><td>Turbidity</td><td colspan="5">5 NTU maximum increase</td><td>not applicable</td></tr>
<tr><td>Total ammonia-N</td><td>less than or equal to 1 mg/L average; 2.5 mg/L maximum</td><td>not applicable</td><td colspan="3">less than or equal to 1 mg/L average; 2.5 mg/L maximum</td><td>not applicable</td></tr>
<tr><td>Dissolved oxygen</td><td colspan="6">6.5 mg/L minimum</td></tr>
<tr><td>pH</td><td colspan="3">not applicable</td><td>6.5 to 8.5</td><td colspan="2">not applicable</td></tr>
<tr><td>Total arsenic</td><td colspan="2">not applicable</td><td colspan="2">10 micrograms/L maximum</td><td colspan="2">not applicable</td></tr>
<tr><td>Total barium</td><td colspan="3">not applicable</td><td>0.5 mg/L</td><td colspan="2">not applicable</td></tr>
<tr><td>Total cadmium</td><td colspan="2">not applicable</td><td colspan="4">less than or equal to 9 micrograms/L mean and 43 micrograms/L maximum</td></tr>
<tr><td>Total copper</td><td colspan="6">less than or equal to 2 micrograms/L mean and 3 micrograms/L maximum</td></tr>
<tr><td>Total chromium</td><td>50 micrograms/L maximum</td><td colspan="2">not applicable</td><td colspan="2">50 micrograms/L maximum</td><td>not applicable</td></tr>
<tr><td>Total lead</td><td colspan="6">less than or equal to 2 micrograms/g dry weight mean and 140 micrograms/L maximum</td></tr>
<tr><td>Total mercury</td><td colspan="4">0.02 micrograms/L mean and 2 micrograms/L maximum</td><td colspan="2">not applicable</td></tr>
</table>

<table>
<tr><th>Water Body</th><th>False Creek</th><th>Outer Harbour</th><th>Inner Harbour</th><th>Central Harbour</th><th>Port Moody Arm</th><th>Indian Arm</th></tr>
<tr><td>Total nickel</td><td>less than or equal to 8 micrograms/g dry weight mean and 75 micrograms/L maximum</td><td>not applicable</td><td colspan="2">less than or equal to 8 micrograms/g dry weight mean and 75 micrograms/L maximum</td><td colspan="2">not applicable</td></tr>
<tr><td>Total zinc</td><td colspan="6">less than or equal to 0.086 mg/L mean and 0.095 mg/L maximum</td></tr>
<tr><td>Chlorophenols</td><td colspan="2">not applicable</td><td>0.2 micrograms/L maximum</td><td colspan="3">not applicable</td></tr>
<tr><td>Tributyl tin (TBT)</td><td colspan="3">10 ng/L maximum</td><td>not applicable</td><td colspan="2">10 ng/L maximum</td></tr>
<tr><td>Phenols</td><td colspan="3">not applicable</td><td colspan="2">1 microgram/L maximum</td><td>not applicable</td></tr>
<tr><td>Styrene</td><td colspan="4">not applicable</td><td>0.05 mg/L maximum</td><td>not applicable</td></tr>
<tr><td>1,2-dichloroethane or ethylene dichloride</td><td colspan="2">not applicable</td><td>less than or equal to 0.2 mg/L mean and 2 mg/L maximum</td><td colspan="3">not applicable</td></tr>
<tr><td>Chlorine-produced oxidants</td><td colspan="3">not applicable</td><td colspan="2">less than or equal to 3 micrograms/L average</td><td>not applicable</td></tr>
<tr><td>Cyanide, weak acid dissociable</td><td colspan="4">not applicable</td><td>1 microgram/L maximum</td><td>not applicable</td></tr>
<tr><td>Sulphide, undissociated H2S</td><td colspan="2">not applicable</td><td>2 microgram/L maximum</td><td>not applicable</td><td>2 microgram/L maximum</td><td>not applicable</td></tr>
</table>

Table A-2: Sediment Quality Objectives for Burrard Inlet (Nijman, 1990)

Water Body	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Designated Water Use	*aquatic life, wildlife*	*primary contact recreation, aquatic life, wildlife*				
Total arsenic (in sediments)	20 micrograms/g dry weight maximum					not applicable
Total cadmium (in sediments)	1 micrograms/g dry weight maximum (interim value:less than 9 micrograms/L mean and 43 micrograsms.L maximum)	1 micrograms/g dry weight maximum				less than 9 micrograms/L mean and 43 micrograms/L maximum
Total chromium (in sediments)	60 micrograms/g dry weight maximum					not applicable
Total copper (in sediments)	100 micrograms/g dry weight maximum					not applicable
Total lead (in sediments)	30 micrograms/g dry weight maximum					not applicable
Total nickel (in sediments)	45 micrograms/g dry weight maximum					not applicable
Total mercury (in sediments)	0.15 micrograms/g dry weight maximum					not applicable
Total zinc (in sediment)	150 micrograms/g dry weight maximum					not applicable
PCBs (in sediment)	0.03 micrograms/g dry weight maximum					not applicable
Chlorophenols (in sediment)	not applicable		0.01 micrograms/g dry weight maximum	not applicable		
Total LPAHs (in sediment)	0.5 micrograms/g dry weight maximum in sediment, long-term					not applicable
Naphthalene (in sediment)	0.2 micrograms/g dry weight maximum in sediment, long-term					not applicable
Acenaphthylene (in sediment)	0.06 micrograms/g dry weight maximum in sediment, long-term					not applicable
Acenaphthene (in sediment)	0.05 micrograms/g dry weight maximum in sediment, long-term					not applicable
Fluorene (in sediment)	0.05 micrograms/g dry weight maximum in sediment, long-term					not applicable
Phenanthrene (in sediment)	0.15 micrograms/g dry weight maximum in sediment, long-term					not applicable

Water Body	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Anthracene (in sediment)	0.1 micrograms/g dry weight maximum in sediment, long-term					not applicable
Total LHAHs (in sediment)	1.2 micrograms/g dry weight maximum in sediment, long-term					not applicable
Fluoranthene (in sediment)	0.17 micrograms/g dry weight maximum in sediment, long-term					not applicable
Pyrene (in sediment)	0.26 micrograms/g dry weight maximum in sediment, long-term					not applicable
Benzo(a)anthracene (in sediment)	0.13 micrograms/g dry weight maximum in sediment, long-term					not applicable
Chrysene (in sediment)	0.14 micrograms/g dry weight maximum in sediment, long-term					not applicable
Benzo-fluoranthene (in sediment)	0.32 micrograms/g dry weight maximum in sediment, long-term					not applicable
Benzo(a)pyrene (in sediment)	0.16 micrograms/g dry weight maximum in sediment, long-term					not applicable
Indeno (1,2,3-c,d) pyrene (in sediment)	0.06 micrograms/g dry weight maximum in sediment, long-term					not applicable
Dibenzo (a,h) anthacene (in sediment)	0.06 micrograms/g dry weight maximum in sediment, long-term					not applicable
Benzo (g,h,i) perylene (in sediment)	0.07 micrograms/g dry weight maximum in sediment, long-term					not applicable

Table A-3: Contaminant Level Objectives for Fish in Burrard Inlet (Nijman, 1990)

Water Body	False Creek	Outer Harbour	Inner Harbour	Central Harbour	Port Moody Arm	Indian Arm
Designated Water Use	*aquatic life, wildlife*	*primary contact recreation, aquatic life, wildlife*				
Total lead (in fish muscle)	0.8 micrograms/g wet weight maximum					
Total mercury (in fish tissue)	0.5 micrograms/g weight wet maximum				not applicable	
PCBs (in fish tissue)	0.5 micrograms/g wet weight maximum					not applicable
Chlorophenols (in fish flesh)	not applicable		0.1 micrograms/g wet weight maximum	not applicable		

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