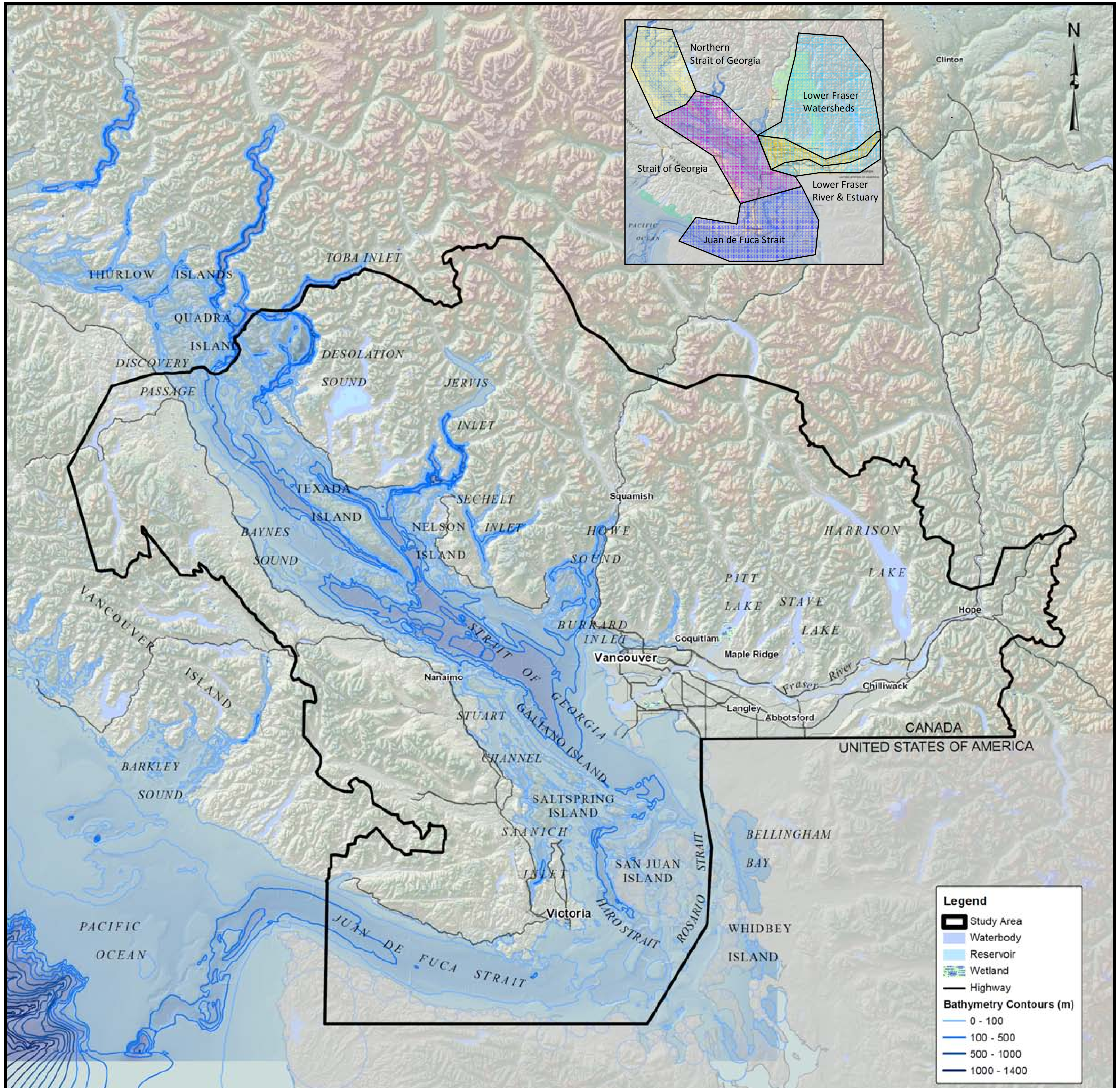


Map 1: Characteristics of the Lower Fraser River and Strait of Georgia Study Area

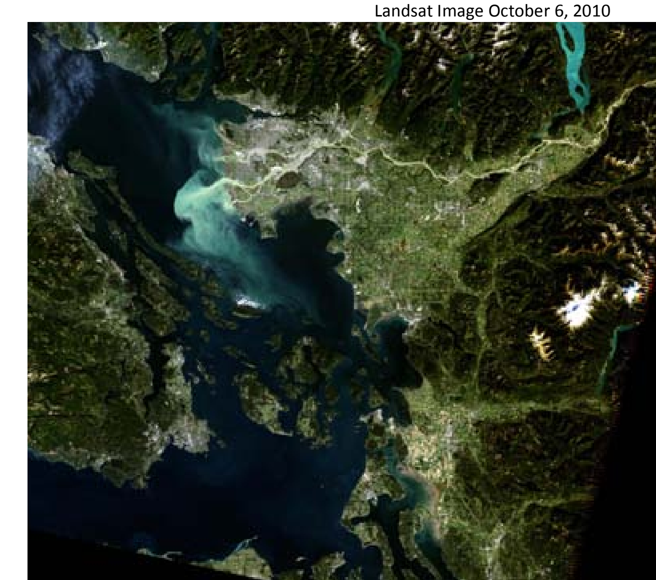
The Lower Fraser River, Fraser River estuary, Strait of Georgia and Juan de Fuca Strait are integral components of a large coastal estuarine ecosystem in south-western British Columbia. The area is used by all Fraser and coastal salmon species across all life history stages.

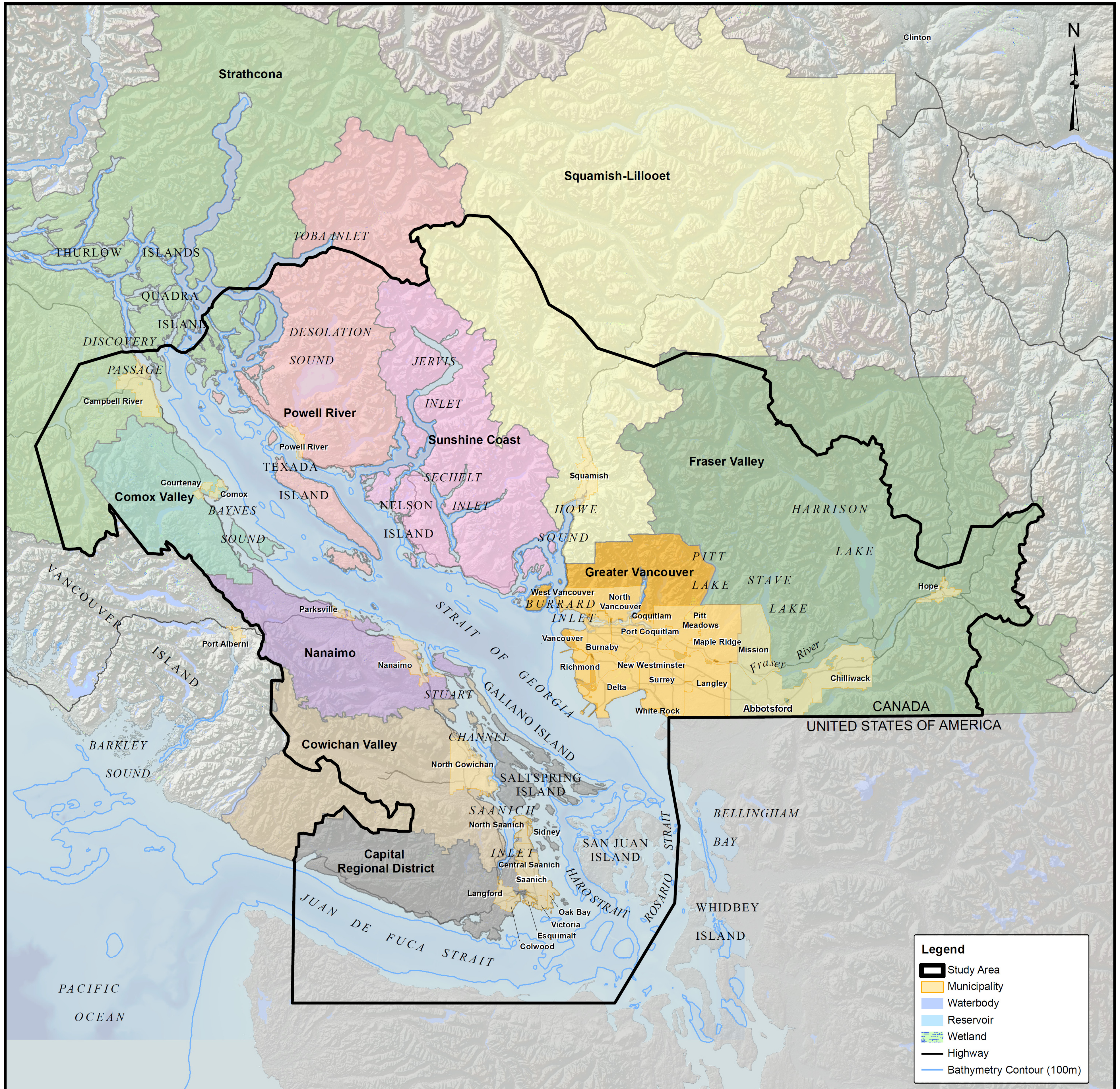
The Strait of Georgia is a semi-enclosed coastal sea over 200 km in length, with depths over 400m in central basin between Vancouver and Nanaimo. The Juan de Fuca Strait is the 100 km long basin and connects Puget Sound and the Strait of Georgia with the Pacific Ocean.

Downstream of Hope, the Fraser River enters the lower valley and a reach of relatively low gradient. The lower Fraser River and its estuary are turbid as a result of accumulation of suspended sediment supplied from a combination of glacial flour and insoluble silts and clays from bedrock and erosion of glacial deposits of fine sediment on river banks, particularly through the middle Fraser upstream of Hope.

The Georgia basin and Lower Fraser study area encompass an area of approximately 49,500 km^2. The lower Fraser River has a length of approximately 165 km from Hope to Sands Head at the outer extent of the Fraser delta (Ellis et al. 2004)

Landsat Image October 6, 2010





Map 2: Regional Districts in Lower Fraser River and Strait of Georgia Study Area

The study area, including the Strait of Georgia and lower Fraser River downstream of Hope, comprises 10 separate British Columbia Regional Districts and at least 30 moderate to large urban areas and cities.

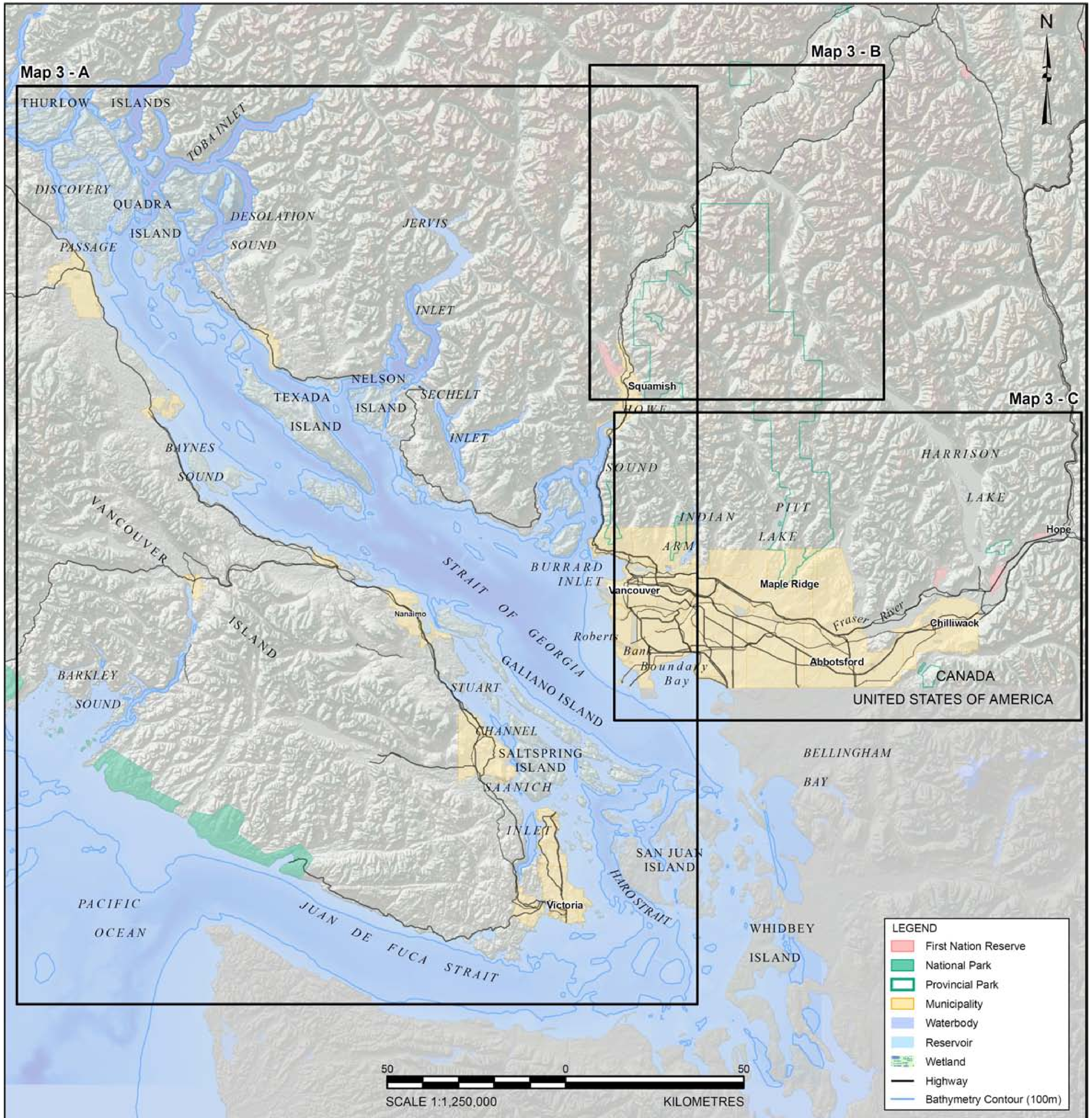
The Regional Districts include:

- Metro (Greater) Vancouver
- Fraser Valley
- Squamish-Lillooet
- Sunshine Coast
- Powell River
- Strathcona
- Comox Valley
- Nanaimo
- Cowichan Valley
- Capital

The larger cities and municipalities in the area include:

- Metro Vancouver (Vancouver, North and West Vancouver, Richmond, Surrey, Coquitlam, Port Coquitlam, Delta, White Rock, Port Moody, Pitt Meadows, Maple Ridge),
- Fraser Valley (Langley, Abbotsford, Chilliwack, Hope),
- Greater Victoria,
- Duncan,
- Nanaimo,
- Comox,
- Campbell River,
- Powell River and
- Sechelt.

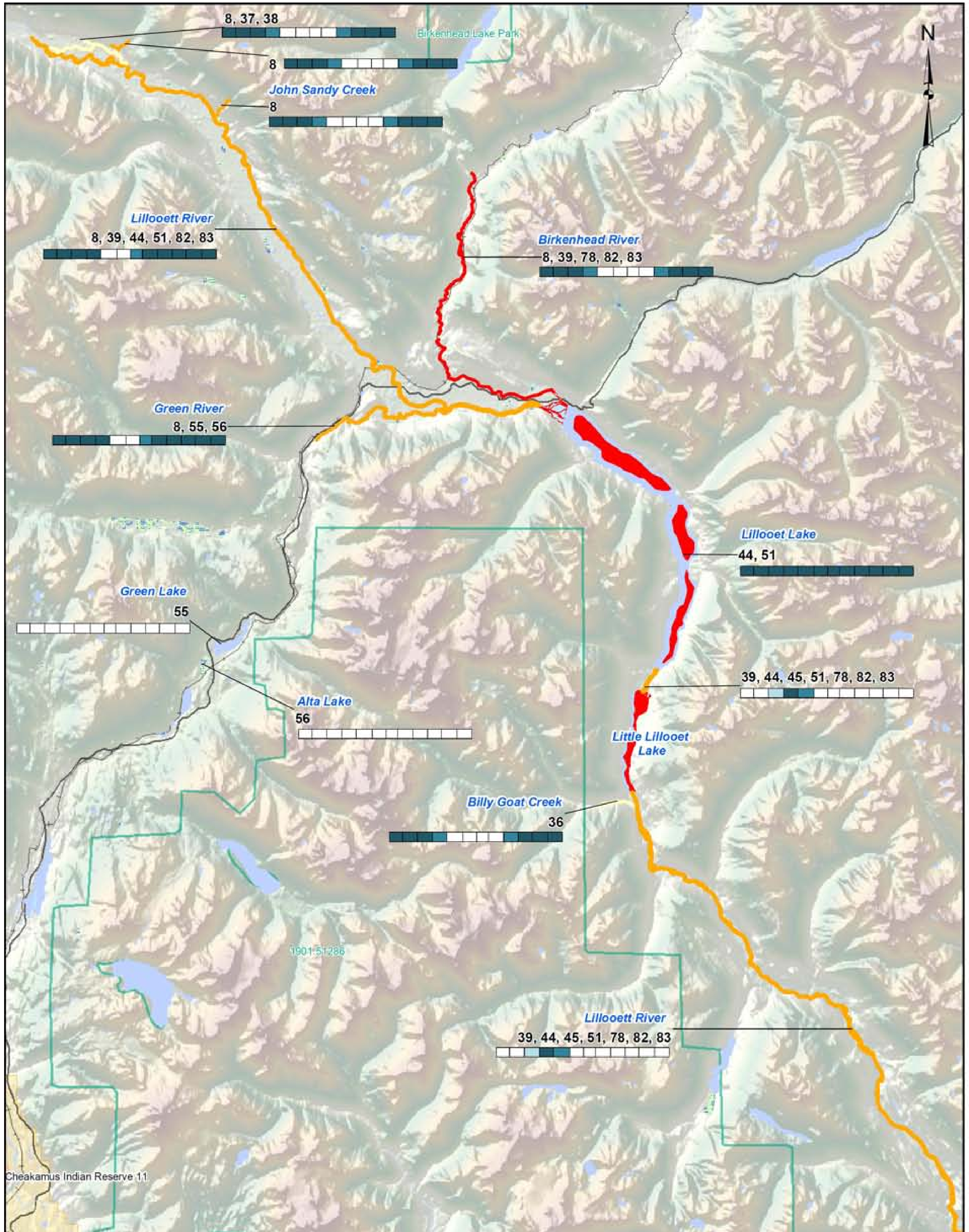
The Greater Vancouver and Fraser Valley areas are the largest urban areas in British Columbia and line the banks of the Lower Fraser River, estuary and Strait of Georgia.



Map 3: Key Map for Adult and Juvenile Fraser Sockeye Habitat Use in the Lower Fraser River and Strait of Georgia

Fraser sockeye salmon distribution and habitat use are presented in the following map series (Map 3-A to 3-D) across the study in Lower Fraser sockeye watersheds, the Lower Fraser River and estuary, and the Strait of Georgia and Juan de Fuca Strait.

The information presented in the maps is based on review of existing literature and data reports and compilation of summary results. The map presented here show Fraser sockeye salmon spawning, rearing and migration habitat use and residence period (timing) and key citations for these observations.



Number	Reference
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36	MELP 1995a
37	MELP 1995b
38	MELP 1996
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47	Richardson et.al. 2000
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75	McKinnell et.al. 1999
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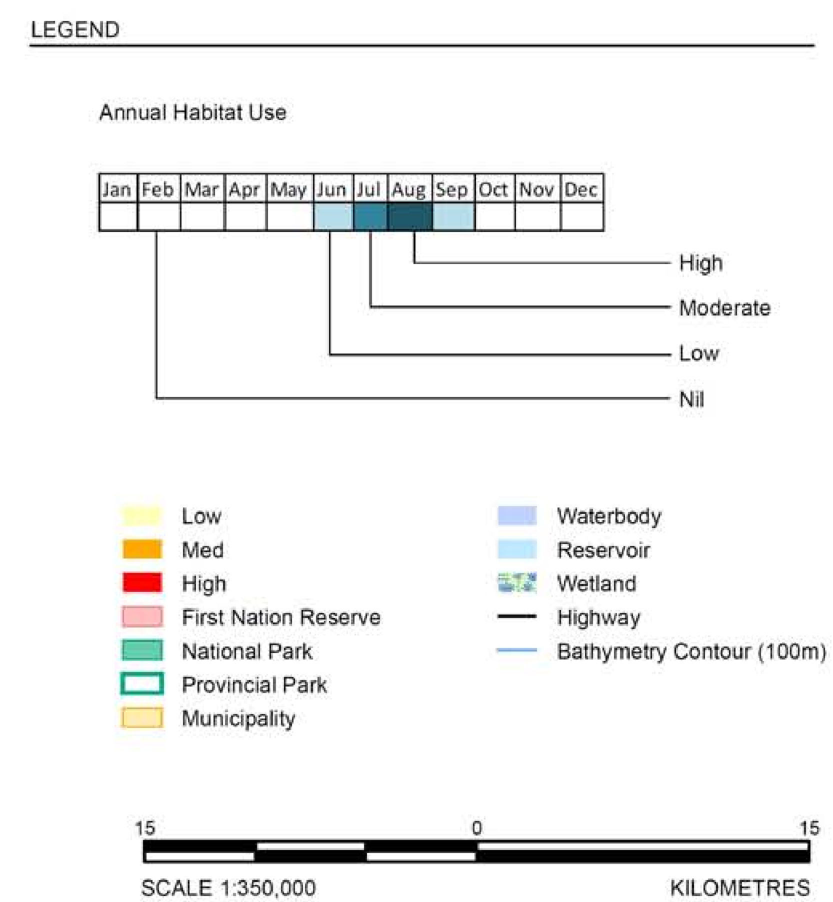
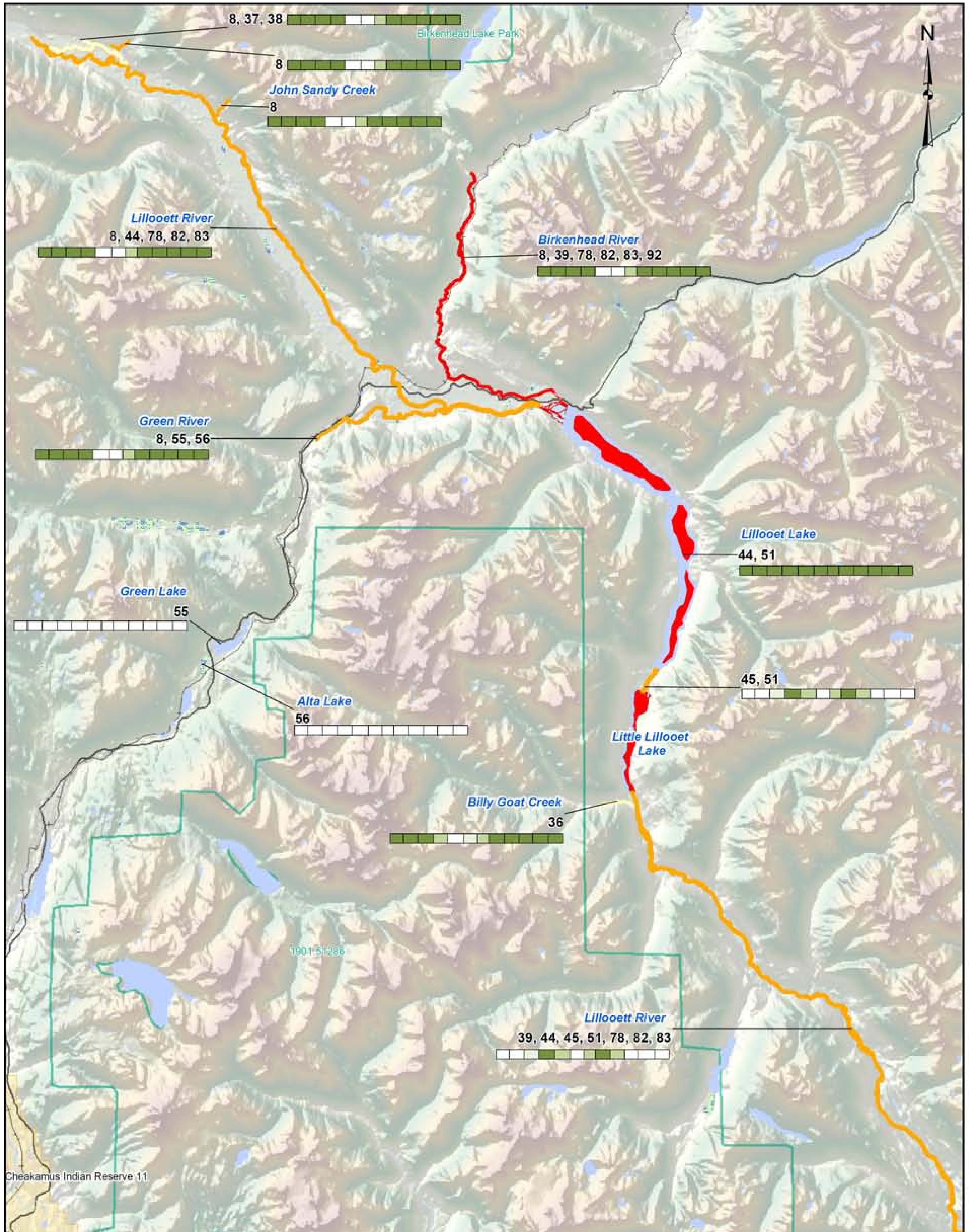
103	Levings 1985
104	Dunford 1975
105	Levings and Nishimura 1997
106	Levy and Northcote 1982
107	St. John et. et. 1992
108	Levings et.al. 2003
109	Brown et.al. 1989
110	Whitehouse and Levings 1989
111	Greer et. al. 1980
112	Levings and Kotyk 1983
113	Levings et.al. 1983

Map 3-A-i: Juvenile Fraser Sockeye Habitat Use in the Lillooet Sub Basin of the Lower Fraser River

A map Juvenile Fraser sockeye salmon habitat use in the Lillooet sub basin of the Harrison watershed was created based on known distribution and residence period in a habitat, derived from existing literature, data reports and available georeferenced spatial information. Citations are provided above each habitat timing (residence) bar graph. Habitats and habitat use were ranked as low, medium (med) or high based on the available literature for specific locations and the documented sensitivity or relative magnitude of habitat use (residence period, sensitivity of life history) by juvenile sockeye; for example a well documented juvenile habitat, known to provide a long term rearing (1 to 2 years) in Harrison Lake (water column greater than 10 m isobaths), was documented as high value habitat. The period of juvenile sockeye residence is provided for each the identified habitat based on use during a specific life history stage (i.e. incubation, fry emergence, rearing, smolt migration) in the Lillooet sub basin. Key habitats in the Lillooet area include juvenile rearing in Lillooet Lake.





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33	Marshall and Hancock 1985
34	Marshall et.al. 1980
35	McMynn 1953
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38	MELP 1996
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46	Pottinger Gaherty 1996
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62	Tucker et.al. 2009
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108	Levings et.al. 2003
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112	Levings and Kotyk 1983
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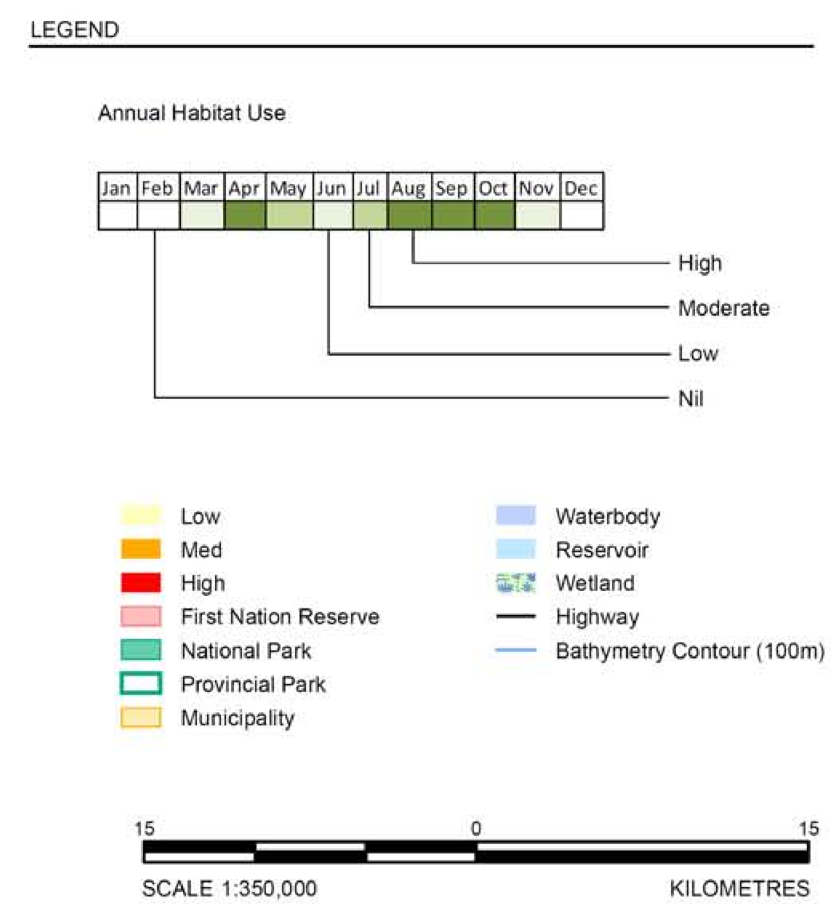
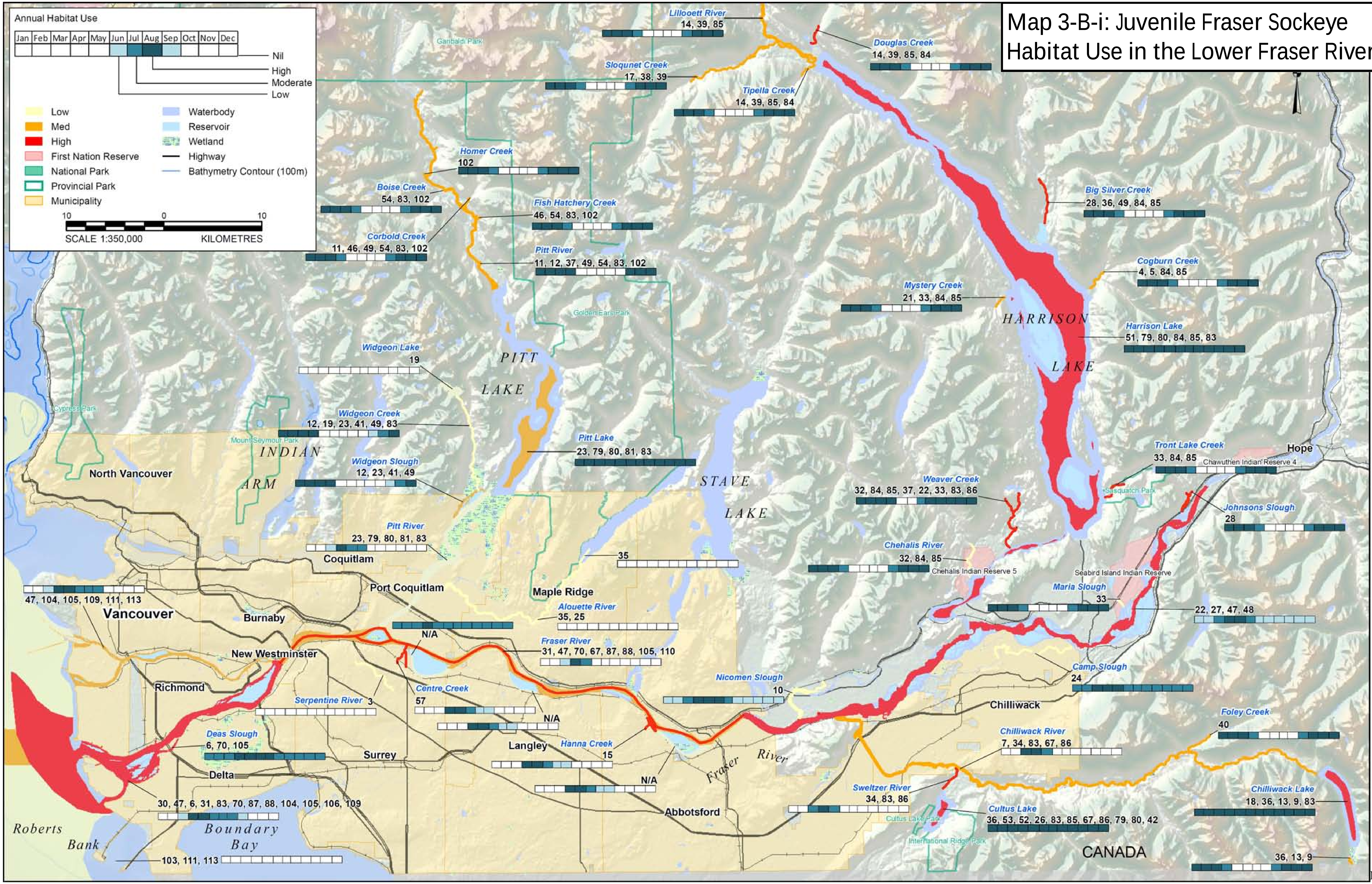
Map 3-A-ii: Juvenile and Adult Fraser Sockeye Habitat Use in the Lillooet Sub Basin of the Lower Fraser River

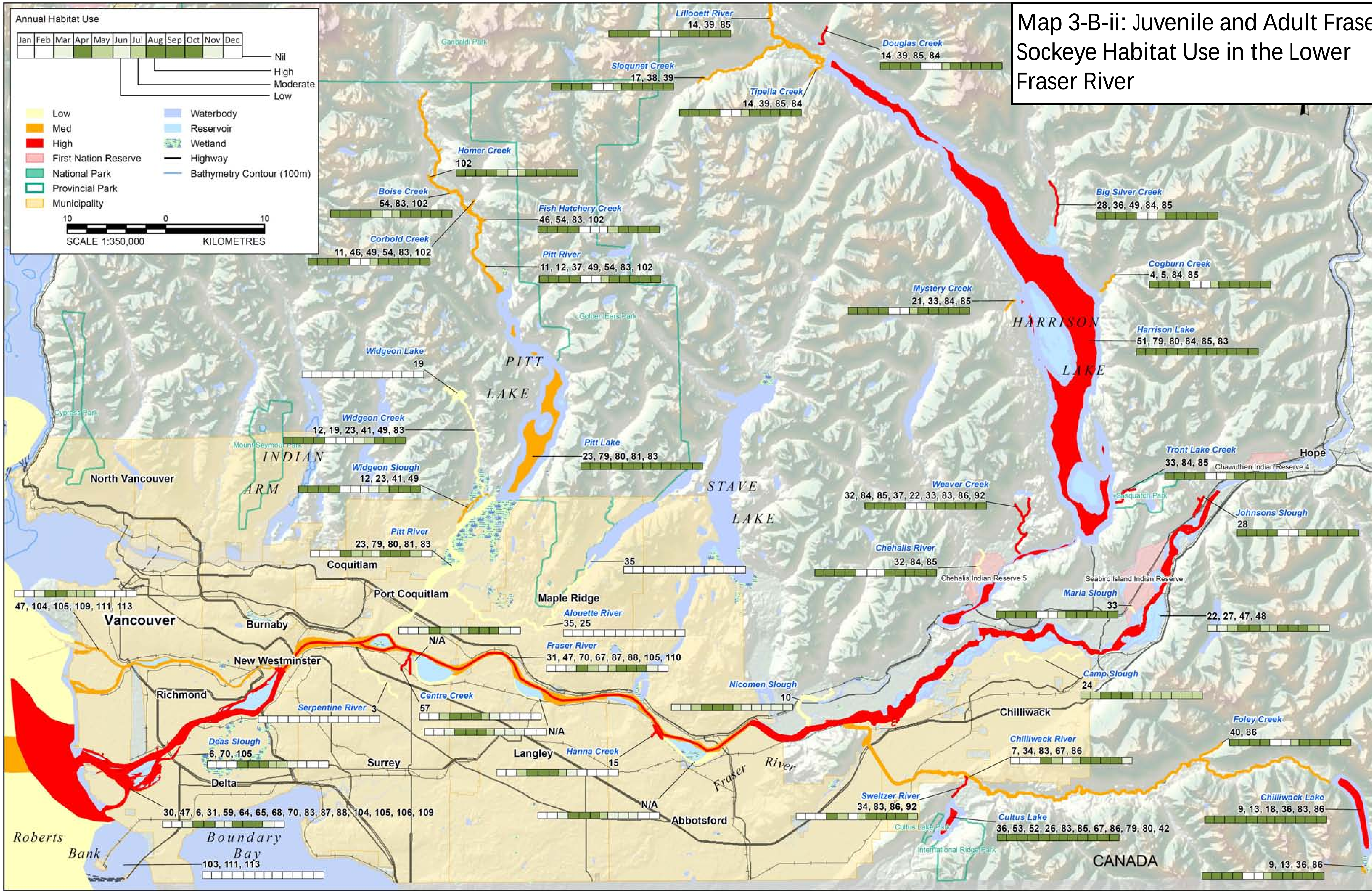
A combined map of adult and juvenile Fraser sockeye salmon habitat use in the Lillooet sub basin of the Harrison watershed was created based on known distribution and residence period derived from existing literature, data reports and available georeferenced spatial information. Citations are provided above each habitat timing (residence) bar graph. Habitats and habitat use were ranked as low, medium (med) or high based on the available literature for specific locations and the documented sensitivity or relative magnitude of habitat use (sensitivity of life history, residence period) by adult and juvenile sockeye; for example a well documented high use adult spawning and incubation habitat in Birkenhead River, Lillooet Lake, was documented as high value habitat. The period of sockeye residence is provided for each the identified habitat based on use during a specific life history stage (i.e. incubation, fry emergence, rearing, smolt migration, juvenile and adult migration in marine and freshwater) in the Lillooet sub basin.

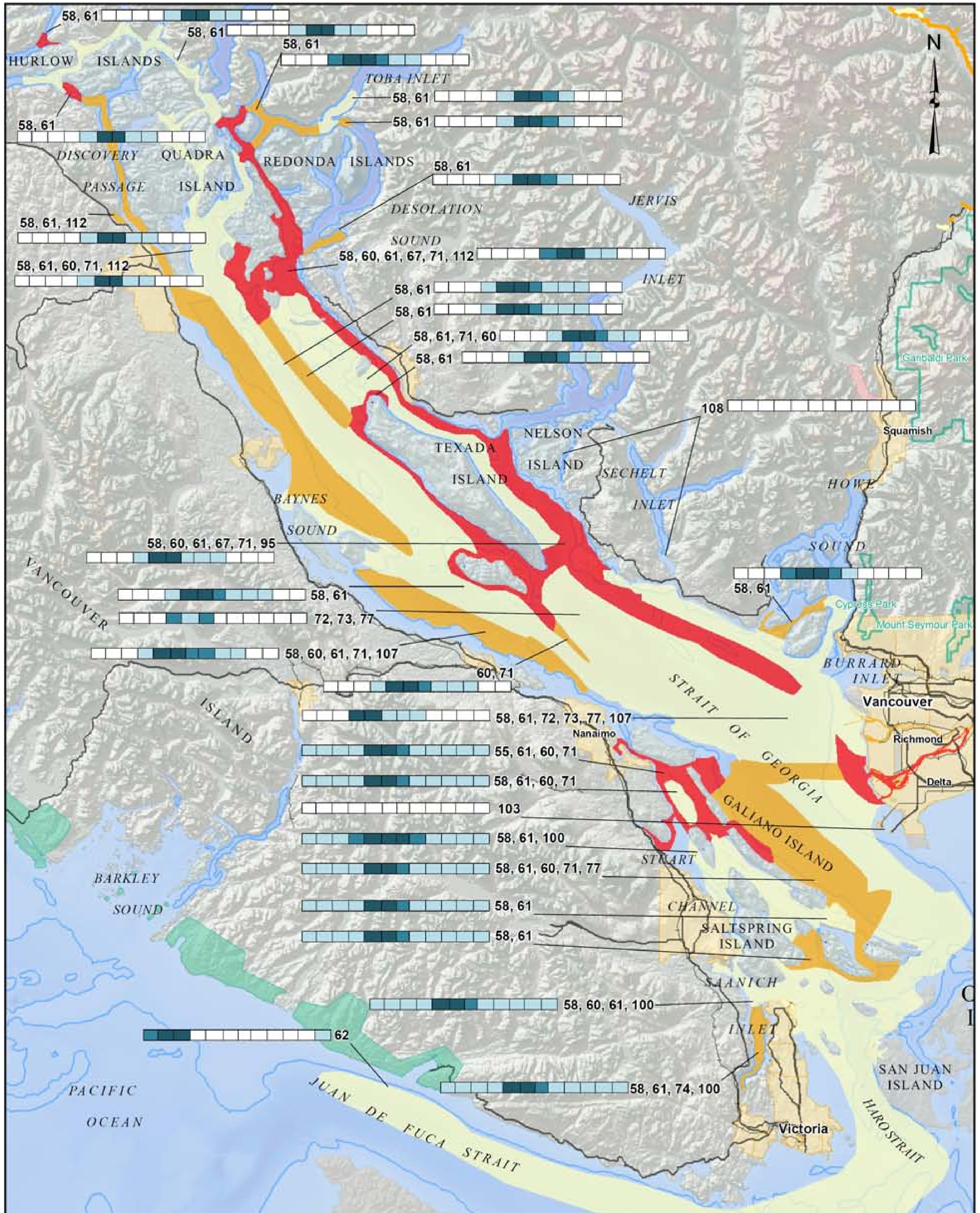


Map 3-B-i: Juvenile Fraser Sockeye Habitat Use in the Lower Fraser River



Map 3-B-ii: Juvenile and Adult Fraser Sockeye Habitat Use in the Lower Fraser River





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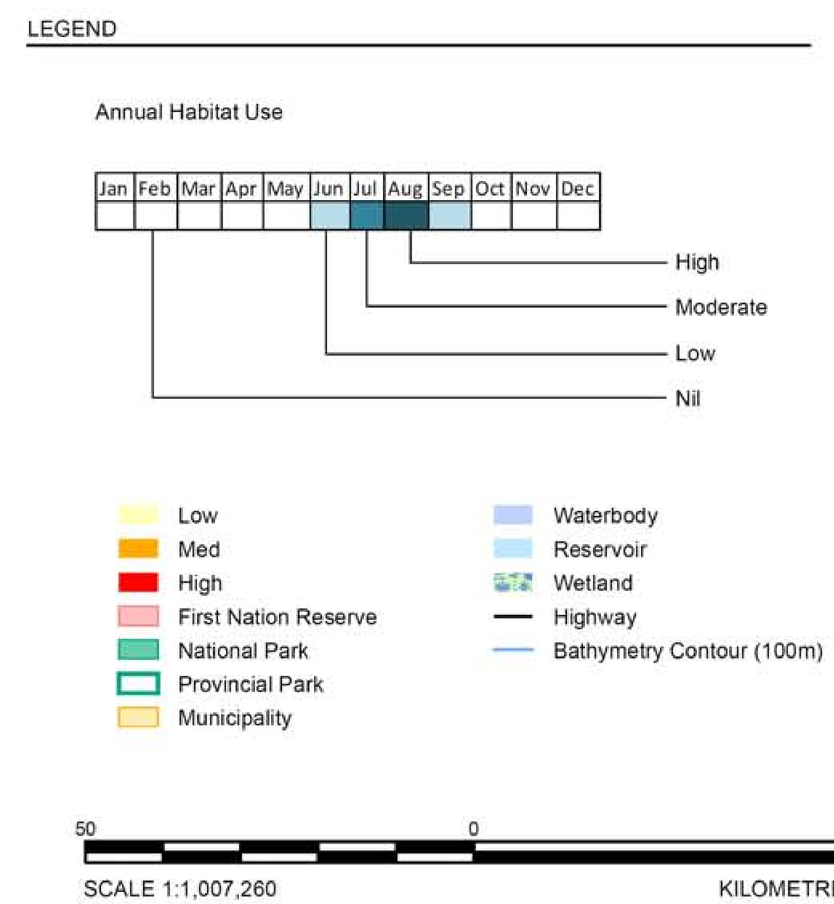
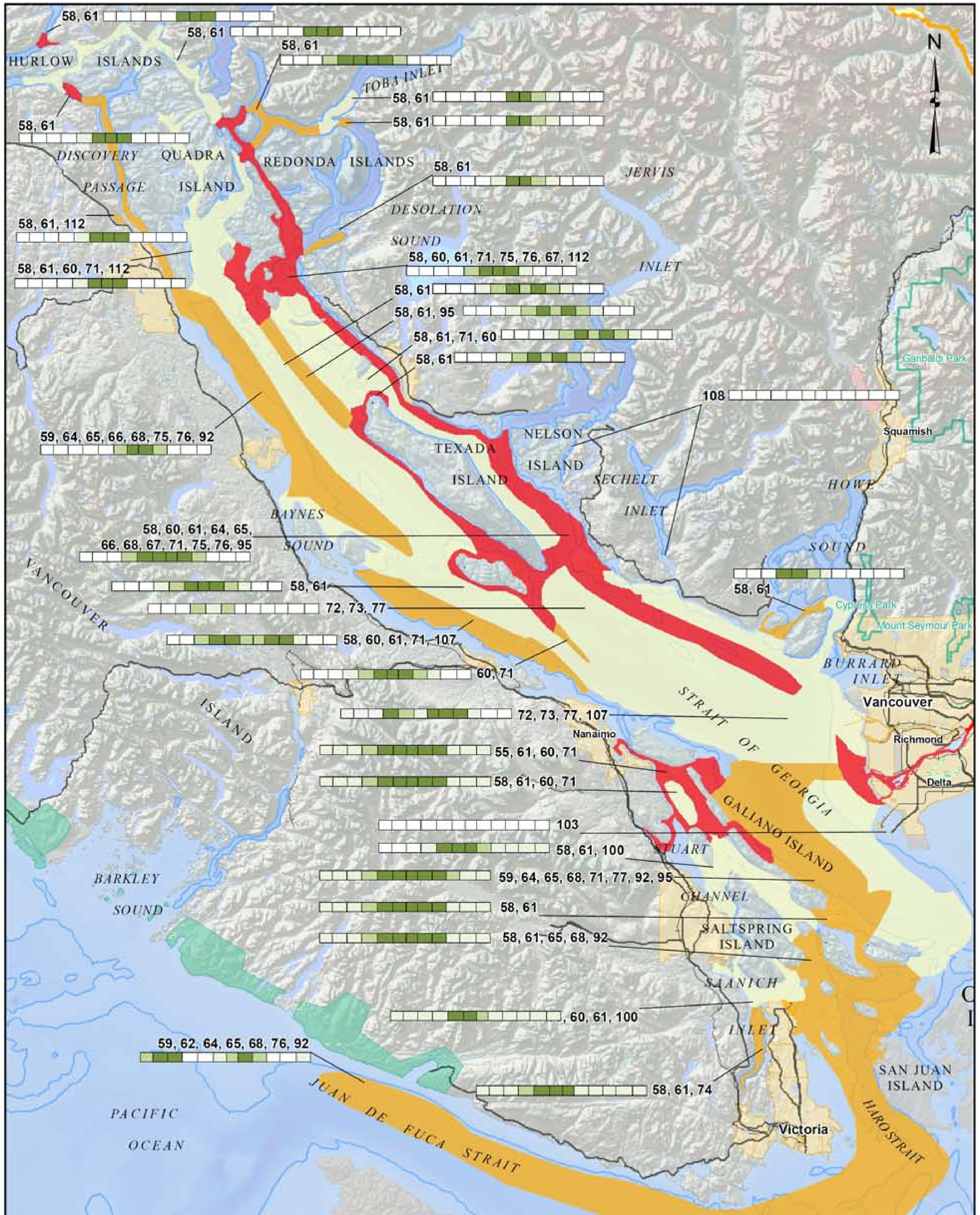
Map 3-C-i: Juvenile Fraser Sockeye Habitat Use in the Lower Fraser River and Strait of Georgia

A map of juvenile Fraser sockeye salmon habitat use in the Fraser River estuary, Strait of Georgia and Juan de Fuca was created based on known distribution and residence period in a habitat, derived from existing literature, site specific catch data reports and available georeferenced spatial information. Citations are provided above each habitat timing (residence) bar graph. Habitats and habitat use were ranked as low, medium (med) or high based on documented catch and relative abundance data in the literature for specific locations and the documented sensitivity or relative magnitude of habitat use (residence period, sensitivity of life history) by juvenile sockeye; for example a aged 1+ post smolt migration (Welch et al. 2009) in the Strait of Georgia using eastern and western migrations routes. The period of juvenile sockeye residence is provided for each identified habitat and migration route. Key habitats in the Strait of Georgia include juvenile migration route on the eastern side of Texada Island at depths 0– 15m, over the 100 m isobath.





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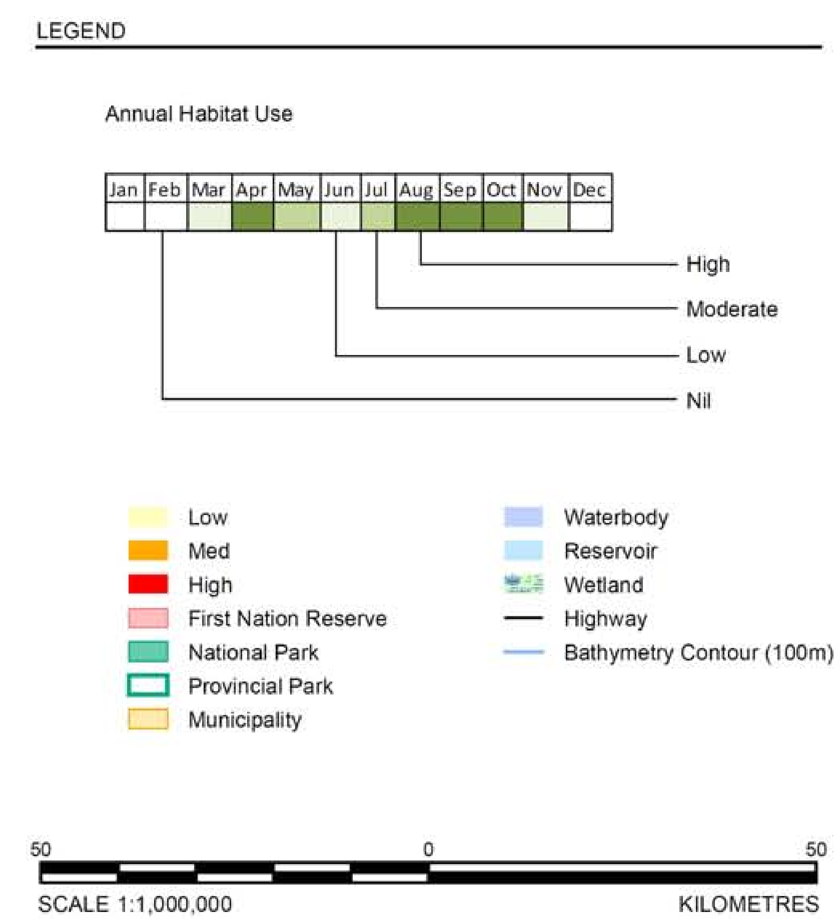
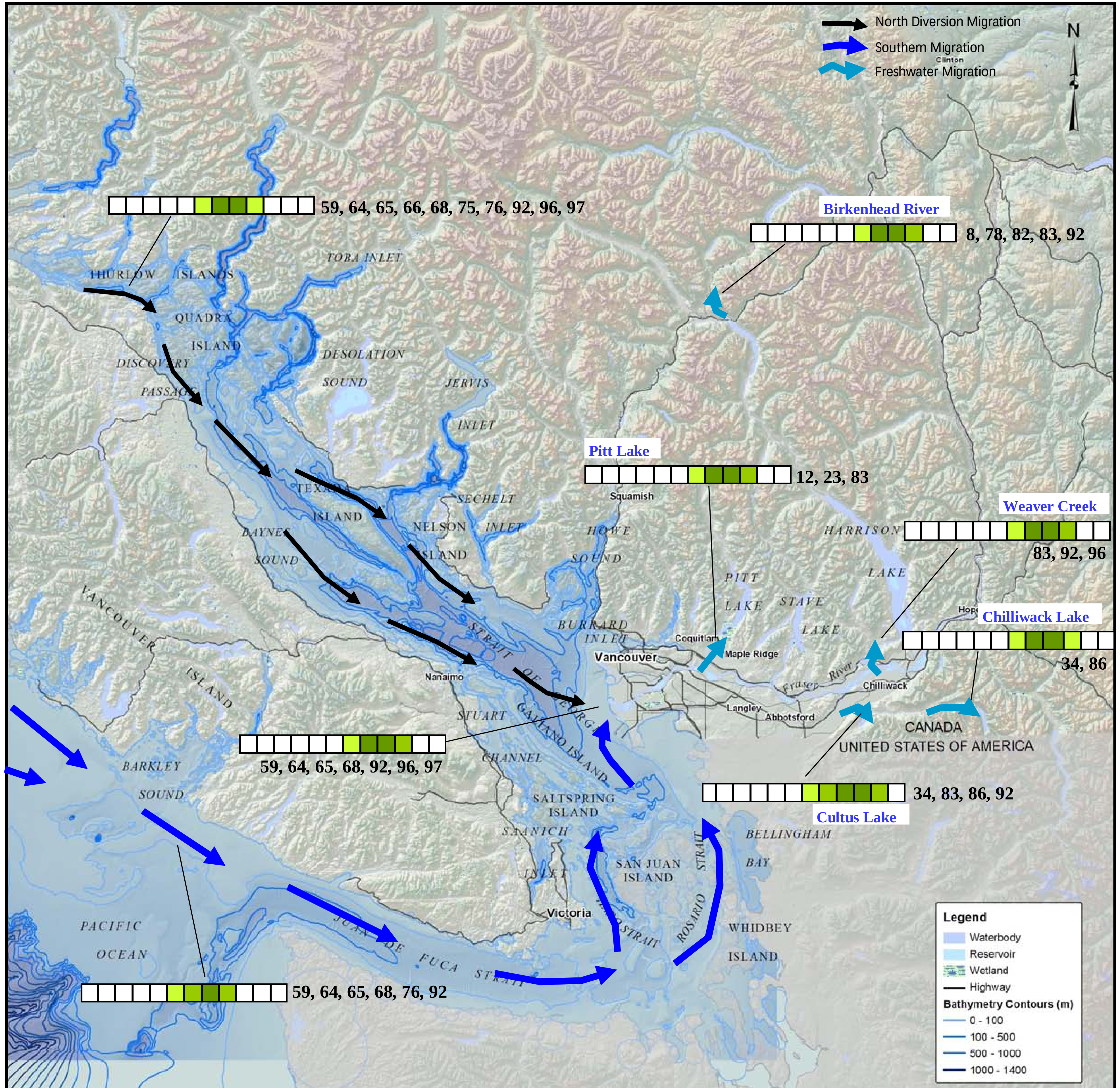
Map 3-C-ii: Juvenile and Adult Fraser Sockeye Habitat Use in the Lower Fraser River and Strait of Georgia

A combined map of adult and juvenile Fraser sockeye salmon habitat use in the Fraser River estuary, Strait of Georgia and Juan de Fuca was created based on known distribution and residence period in a habitat derived from existing literature, site specific catch or monitoring data reports and available georeferenced spatial information. Citations are provided above each habitat timing (residence) bar graph. Habitats and habitat use were ranked as low, medium (med) or high based on documented catch, indices and relative abundance data in the literature for specific locations and the documented sensitivity or relative magnitude of habitat use (residence period, sensitivity of life history) by adult and juvenile sockeye; for example the timing of adult migration (Cooke et al. 2008) in the Strait of Georgia / Lower Fraser using southern and northern diversion migrations routes. The period of adult and juvenile sockeye residence is provided for each identified habitat and migration route. Key habitats in the Strait of Georgia include key migration routes and adult holding areas in the strait and Fraser estuary.





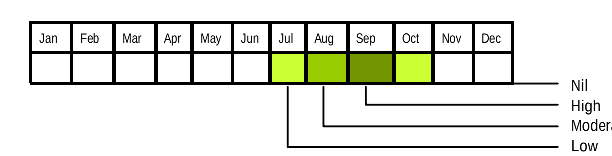
Map 3-D: Adult Migration Routes and Habitat Use in the Lower Fraser River and Strait of Georgia

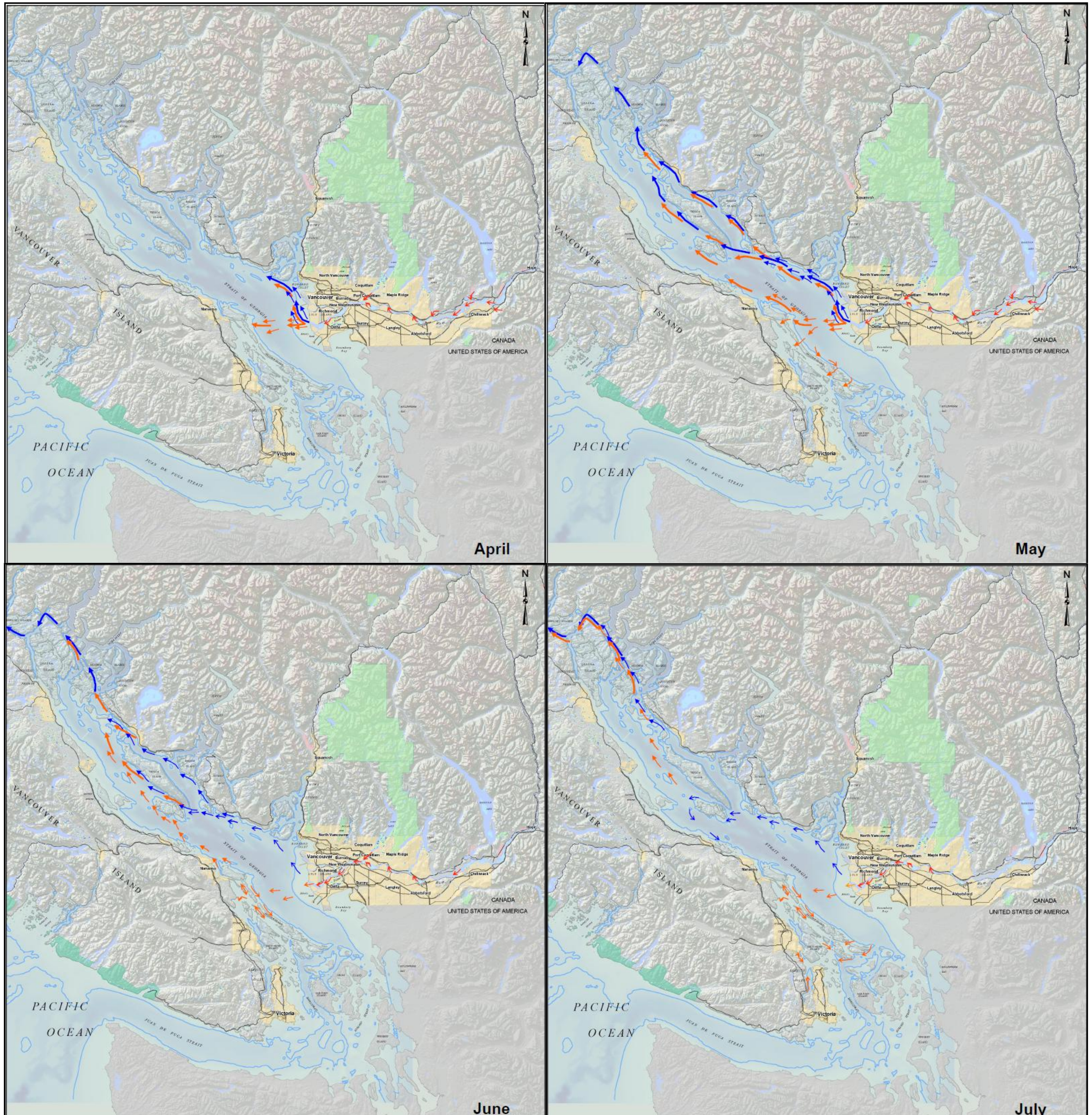
Adult sockeye salmon are distributed throughout the lower Fraser River and Strait of Georgia and use habitats for migration, holding and spawning. Migratory corridors and holding areas extend through the Strait of Georgia, Fraser estuary, Lower Fraser River, and lakes and rivers adjacent to spawning areas. The Strait of Georgia, Juan de Fuca and Lower Fraser River are used by all Fraser sockeye stocks migrating from rearing areas in the North Pacific Ocean to return to freshwater spawning areas. Two main migration routes have been observed through the Strait of Georgia including (a) southern higher use route, and (b) northern diversion route along the western edge of the Strait of Georgia.

Sockeye salmon spawning distribution in the Lower Fraser River, from Hope to Sands Head, extends into 4 watersheds including the Lillooet, Harrison, Chilliwack and Pitt. Key spawning habitats are found in the Lower Harrison at the Weaver Creek spawning channel, in portions of Harrison Lake and its tributaries, and in the upper Harrison watershed in the Lillooet sub basin in the Birkenhead River. Sockeye spawning habitats are also found in the Pitt watershed above Pitt Lake in the lower Pitt River and Widgeon Creek and slough, and in the Chilliwack watershed in tributaries and beaches in Cultus Lake and in the Chilliwack River upstream of Chilliwack Lake.

Adult sockeye salmon distribution and habitat use were derived based on review of existing literature and data reports. The map presented here shows the spatial distribution of adult sockeye habitat use, timing and key citations for these observations.

8	Brown et.al. 1979
23	Henderson et.al. 1991
34	Marshall et.al. 1980
59	Groot and Quinn 1987
64	Gable and Cox-Rogers 1993
65	Crossin et.al. 2007
66	Kolody and Healey 1998
68	Hamilton 1985
75	McKinnell et.al. 1999
76	Cave and Gazey 1994
78	Schubert and Tadey 1997
82	Houtman et.al. 2000
83	Schubert and Houtman 2007
86	Schubert et.al. 2002
92	Labelle 2009
96	Cooke et al. 2008a
97	Cooke et al. 2008b
98	Pascual and Quinn 1991





Map 4-A: Concept Model of Juvenile Sockeye Micro-Habitat Use and Migration in the Lower Fraser River and Strait of Georgia

April to July

Warm Low Productivity Year

Juvenile sockeye habitat use, residence period and migration routes were integrated into a concept model based on existing information and observations to derive a pattern of micro-habitat use and distribution. Key factors were identified which influence juvenile sockeye habitat use including:

- Lower Fraser River—timing and downstream aggregations (pulses) related to magnitude/timing of Fraser River discharge;
- Lower Fraser River—extent and timing of Fraser River freshet related to habitat use of sloughs, off channel areas by Harrison river-type 0+ sockeye;
- Strait of Georgia—eastern /western migration routes and residence period in the strait related to prevailing wind direction outside the Fraser estuary, surface currents related to marine water density (Fraser discharge, winds, tides), sockeye size, abundance and school size (swimming speed and density dependent feeding and predation);
- Strait of Georgia—residence period in northern migration related to warm years and increased spatial heterogeneity and lower abundance of available zooplankton prey and higher than optimal temperatures and altered surface currents;
- Strait of Georgia—residence period in western and southern migration related to size and swimming speed of Harrison river-type 0+ sockeye.

Sources: Barraclough and Phillips 1978, Healey 1978, Groot and Cooke 1987, Peterman et al. 1994, Crittenden 1994, Groot et al. 1989, Burgner 1991, Haegele 1997, DFO 2002, DFO 2003, Sweeting et al. 2008, Beamish et al. 2005, 2008, 2009, Welch et al. 2009, Preikshot et al. 2010)

Large sized 1+ aged smolts (fast swimming); NW wind direction

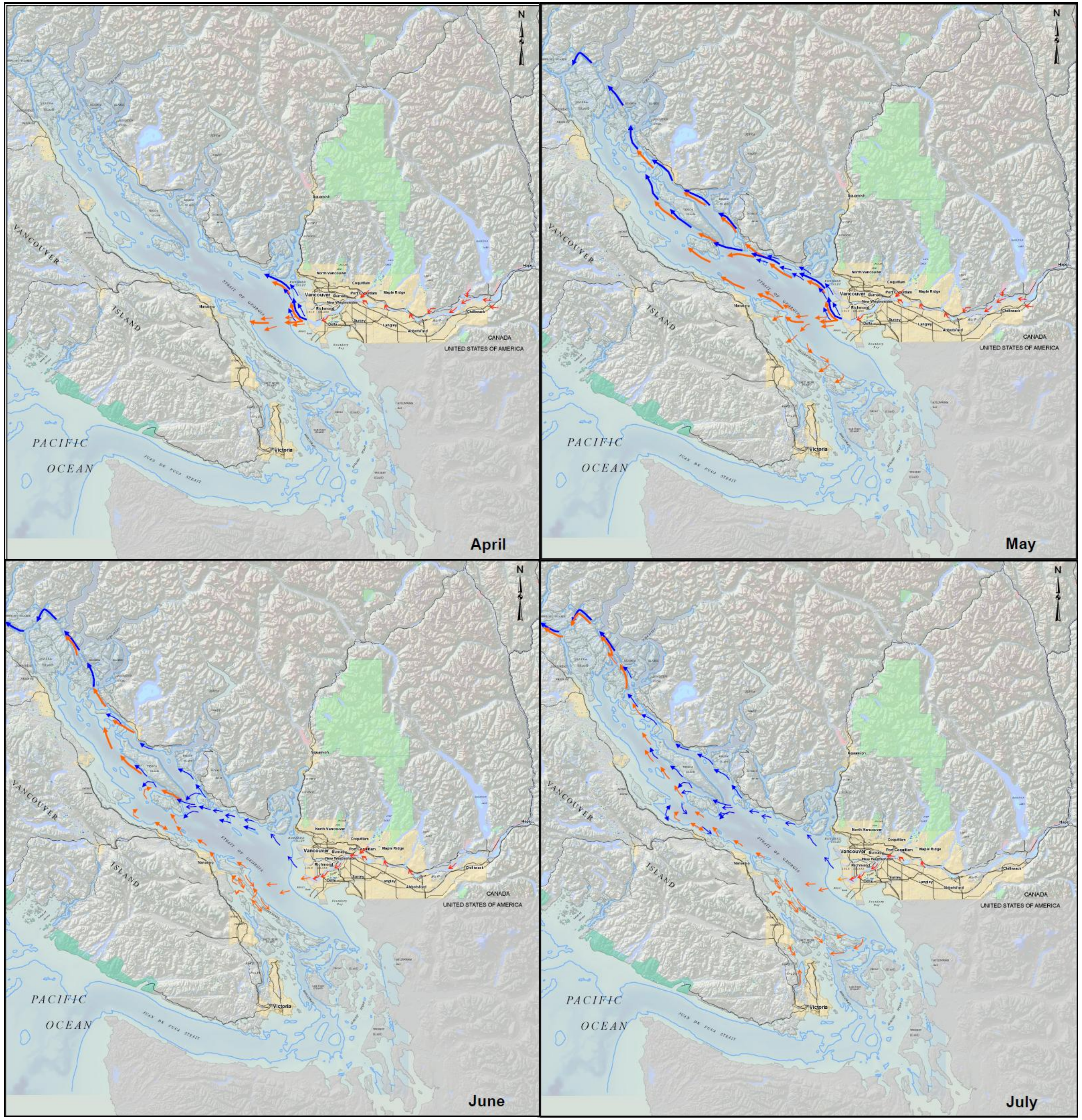
Small sized 1+ aged smolt (slow swimming); NW wind direction

0+ aged fry - Harrison, upper Fraser river-type sockeye (slow swimming); NW wind direction

Large sized 1+ aged smolts (fast swimming); SE wind direction

Small sized 1+ aged smolts (slow swimming); SE wind direction

0+ aged fry - Harrison, upper Fraser river-type sockeye (slow swimming); SE wind direction



Map 4-B: Concept Model of Juvenile Sockeye Micro-Habitat Use and Migration in the Lower Fraser River and Strait of Georgia

April to July

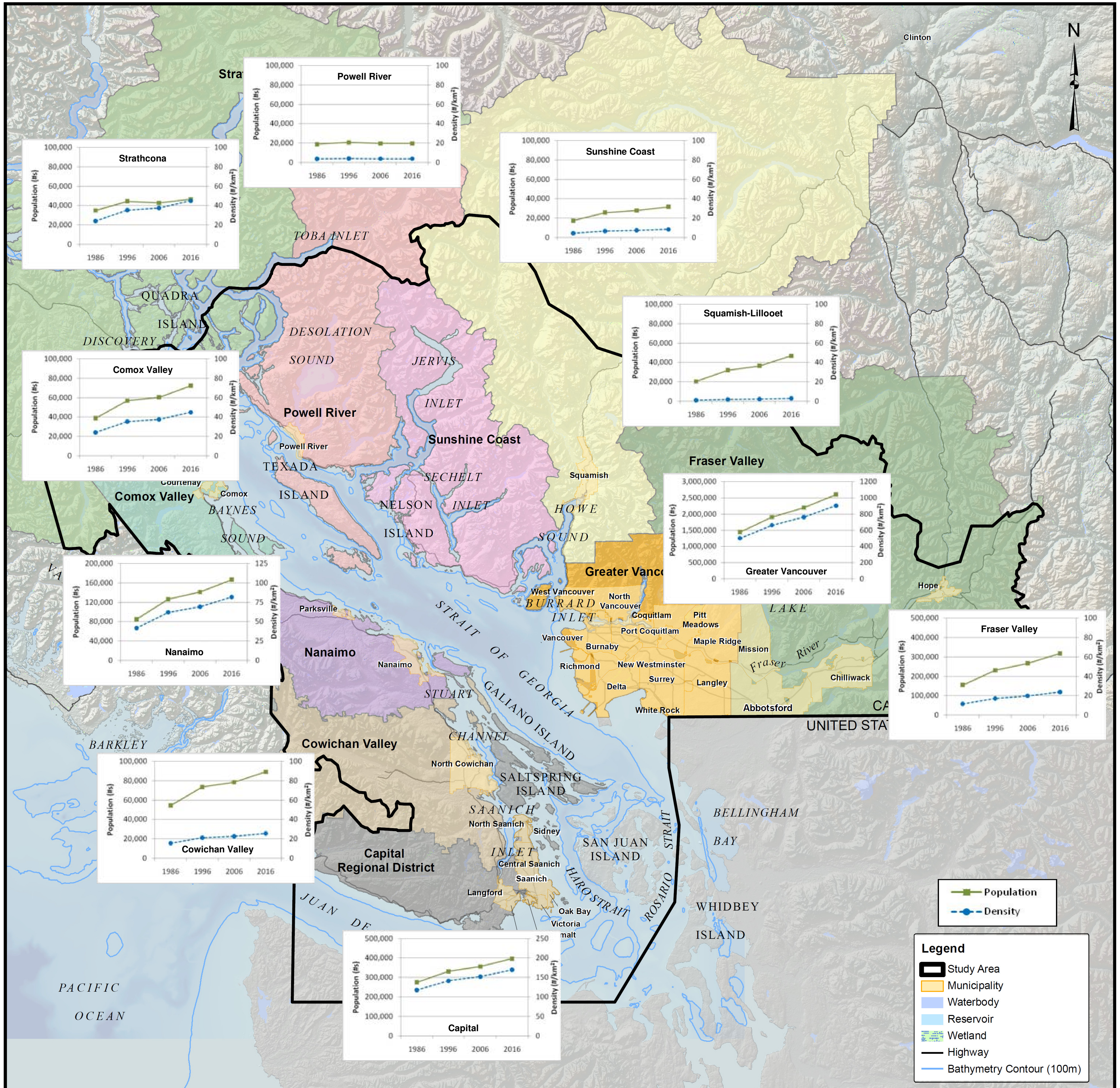
Cool High Productivity Year

Juvenile sockeye habitat use, residence period and migration routes were integrated into a concept model based on existing information and observations to derive a pattern of micro-habitat use and distribution. Key factors were identified which influence juvenile sockeye habitat use including:

- Lower Fraser River—timing and downstream aggregations (pulses) related to magnitude/timing of Fraser River discharge;
- Lower Fraser River—extent and timing of Fraser River freshet related to habitat use of sloughs, off channel areas by Harrison river-type 0+ sockeye;
- Strait of Georgia—eastern /western migration routes and residence period in the strait related to prevailing wind direction outside the Fraser estuary, surface currents related to marine water density (Fraser discharge, winds, tides), sockeye size, abundance and school size (swimming speed and density dependent feeding and predation);
- Strait of Georgia—residence period in northern migration related to cool years and reduced spatial heterogeneity and higher abundance of available zooplankton prey and optimal temperatures and surface currents;
- Strait of Georgia—residence period in western and southern migration related to size and swimming speed of Harrison river-type 0+ sockeye.

Sources: Barraclough and Phillips 1978, Healey 1978, Groot and Cooke 1987, Peterman et al. 1994, Crittenden 1994, Groot et al. 1989, Burgner 1991, Haegele 1997, DFO 2002, DFO 2003, Sweeting et al. 2008, Beamish et al. 2005, 2008, 2009, Welch et al. 2009, Preikshot et al. 2010)

- Large sized 1+ aged smolts (fast swimming); NW wind direction
- Small sized 1+ aged smolt (slow swimming); NW wind direction
- 0+ aged fry - Harrison, upper Fraser river-type sockeye (slow swimming); NW wind direction
- Large sized 1+ aged smolts (fast swimming); SE wind direction
- Small sized 1+ aged smolts (slow swimming); SE wind direction
- 0+ aged fry - Harrison, upper Fraser river-type sockeye (slow swimming); SE wind direction

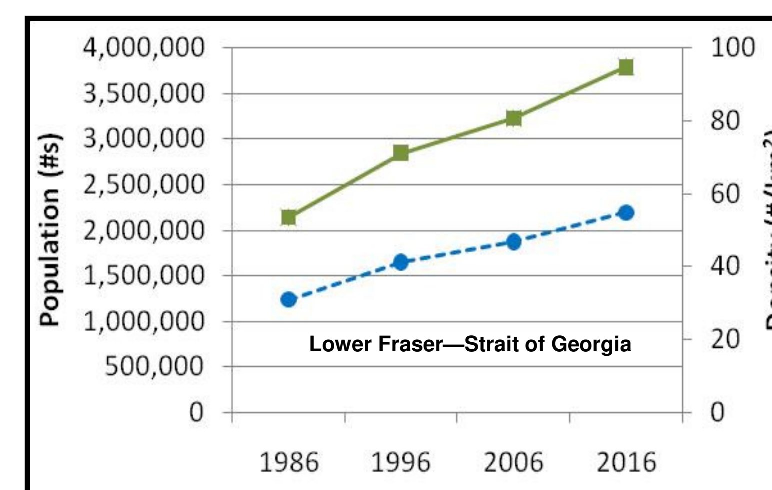


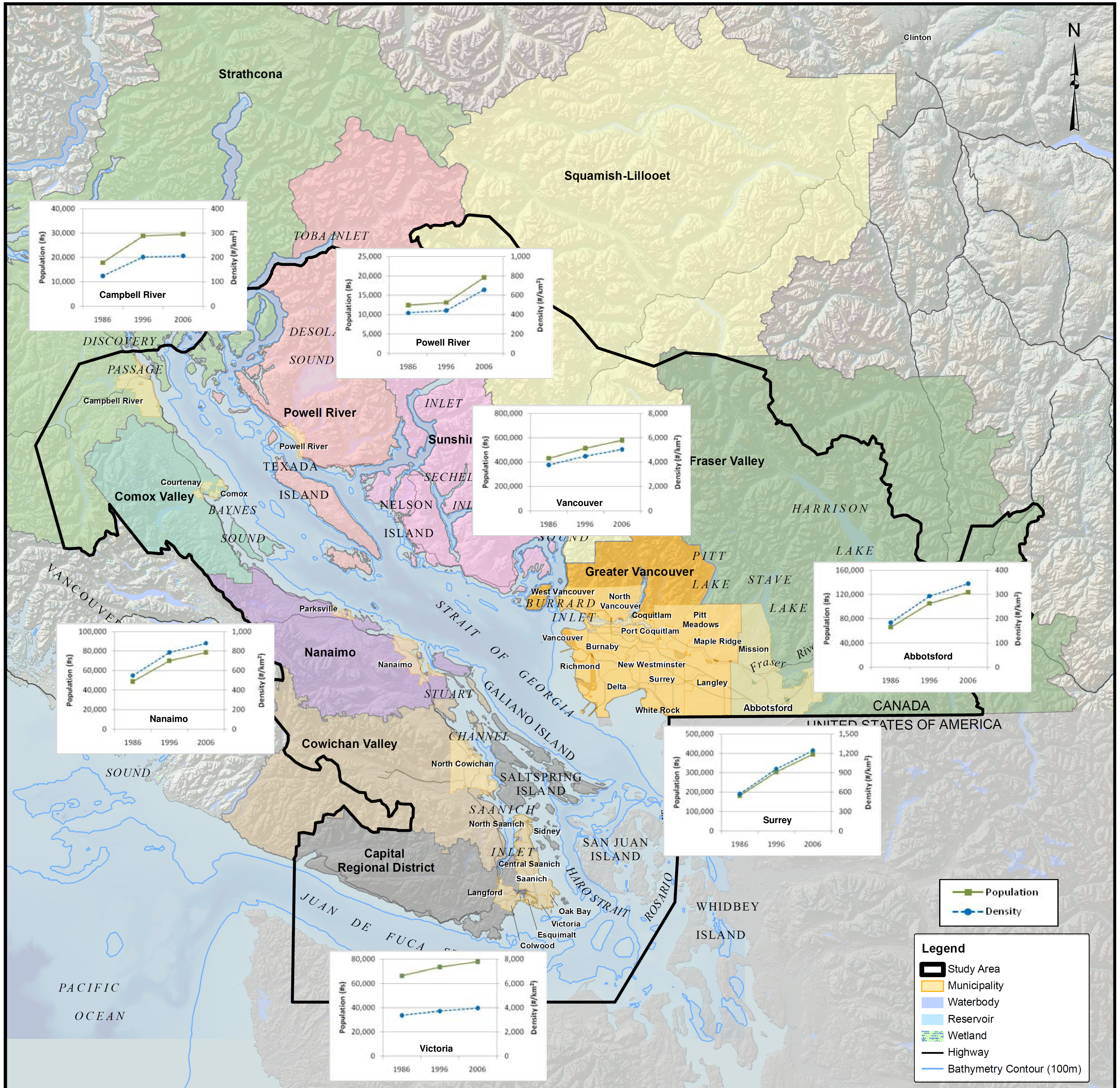
Map 5-A: Regional District Population Size and Density in the Lower Fraser River and Strait of Georgia

The distribution and population size and density are general indicators of human activities and development associated with potential effects on Fraser sockeye salmon habitats through direct loss or removal of habitats and degradation of habitats through contamination, nutrient and sediment discharge.

The Lower Fraser River and Strait of Georgia are home to more than 3.5 million residents in 10 regional districts and at least 30 large cities and urban centres. Projections from Stats Canada and BC Stats indicate a continued increase in population size and density across all Regional Districts. Population density is highest in the Greater Vancouver area (Metro Vancouver Regional District) with projections rising to approximately 1000 residents per square km by 2016.

Source: Population statistics for Regional Districts and municipalities were derived from national and provincial census data from 1986, 1991, 1996 and 2006, with projections of population size and density to 2010-2016 by BC Stats, BC Ministry of Citizens' Services.



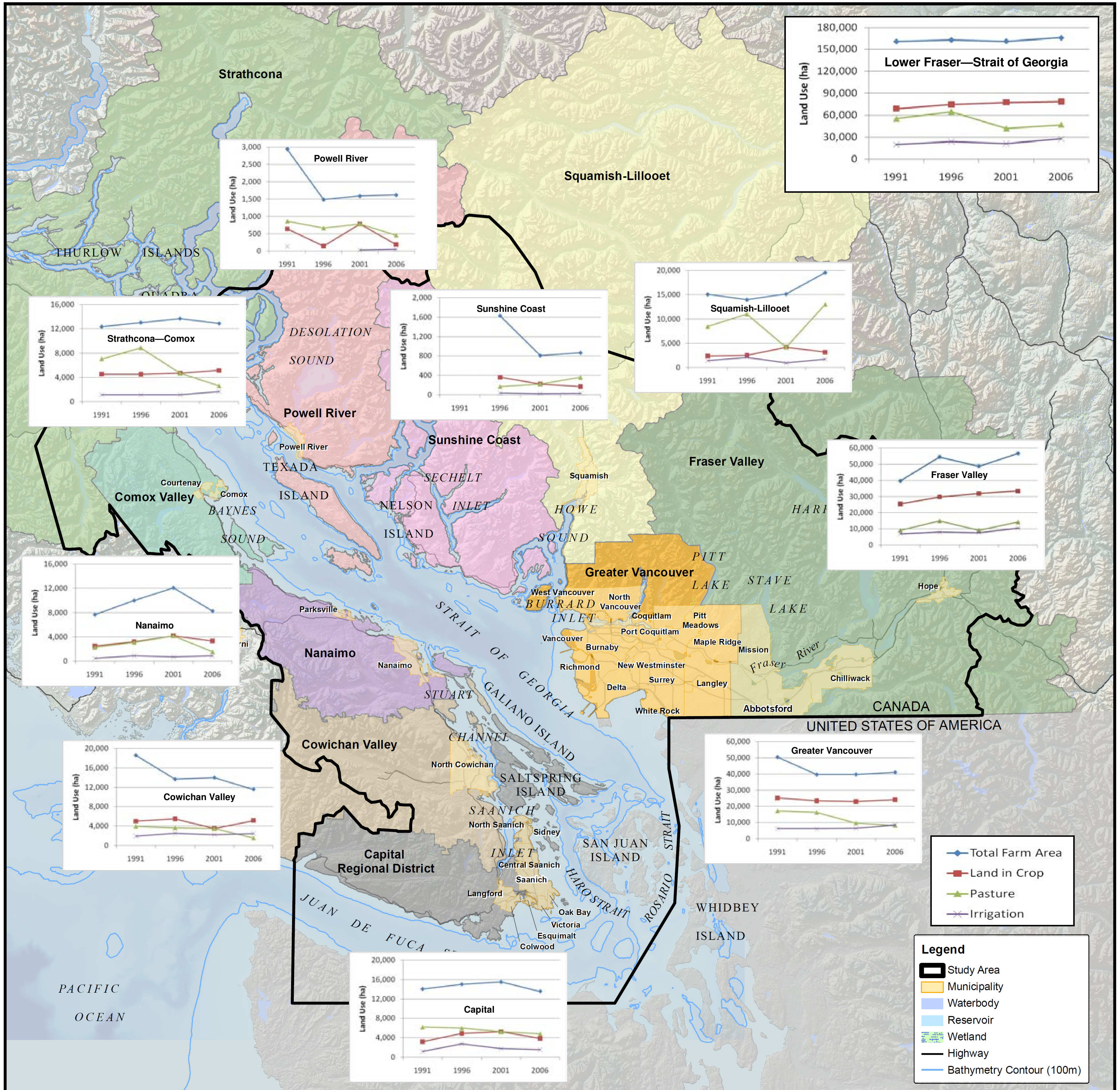


Map 5-B: Municipal Population Size and Density in the Lower Fraser River and Strait of Georgia

Population size and density have increased over the past 25 years more than two fold in many cities around the Strait of Georgia. Cities near to the lower Fraser River, like Surrey, Coquitlam, and Abbotsford, have shown large increases in population size and density over the past 25 years. The highest proportion of the population in the region and study area live around the lower Fraser River and estuary in the lower Mainland area comprising Greater Vancouver municipalities and to a smaller extent Fraser Valley cities. Many of the other smaller communities on the Georgia Basin including Sunshine Coast, Powell River, Strathcona and Vancouver Island communities, have also shown increased population size and density over the past 25 years.

Projections from Stats Canada and BC Stats indicate a continued increase in population size and density in all these communities across the study area. Population density is highest in the City of Vancouver with projections rising to greater than 5000 residents per square km by 2016.

Source: Population statistics for municipalities were derived from national and provincial census data from 1986, 1991, 1996 and 2006, with projections of population size and density to 2010-2016 by BC Stats, BC Ministry of Citizens' Services. Municipal population data for the study area was collected from the 1986-2006 Census Profiles from Statistics Canada, but prepared by BC Stats. In some cases, data was aggregated to reflect changes in municipal delineations or changes in how data was presented from census to census.



Map 6-A: Regional District Agricultural Land Use and Area in the Lower Fraser River and Strait of Georgia

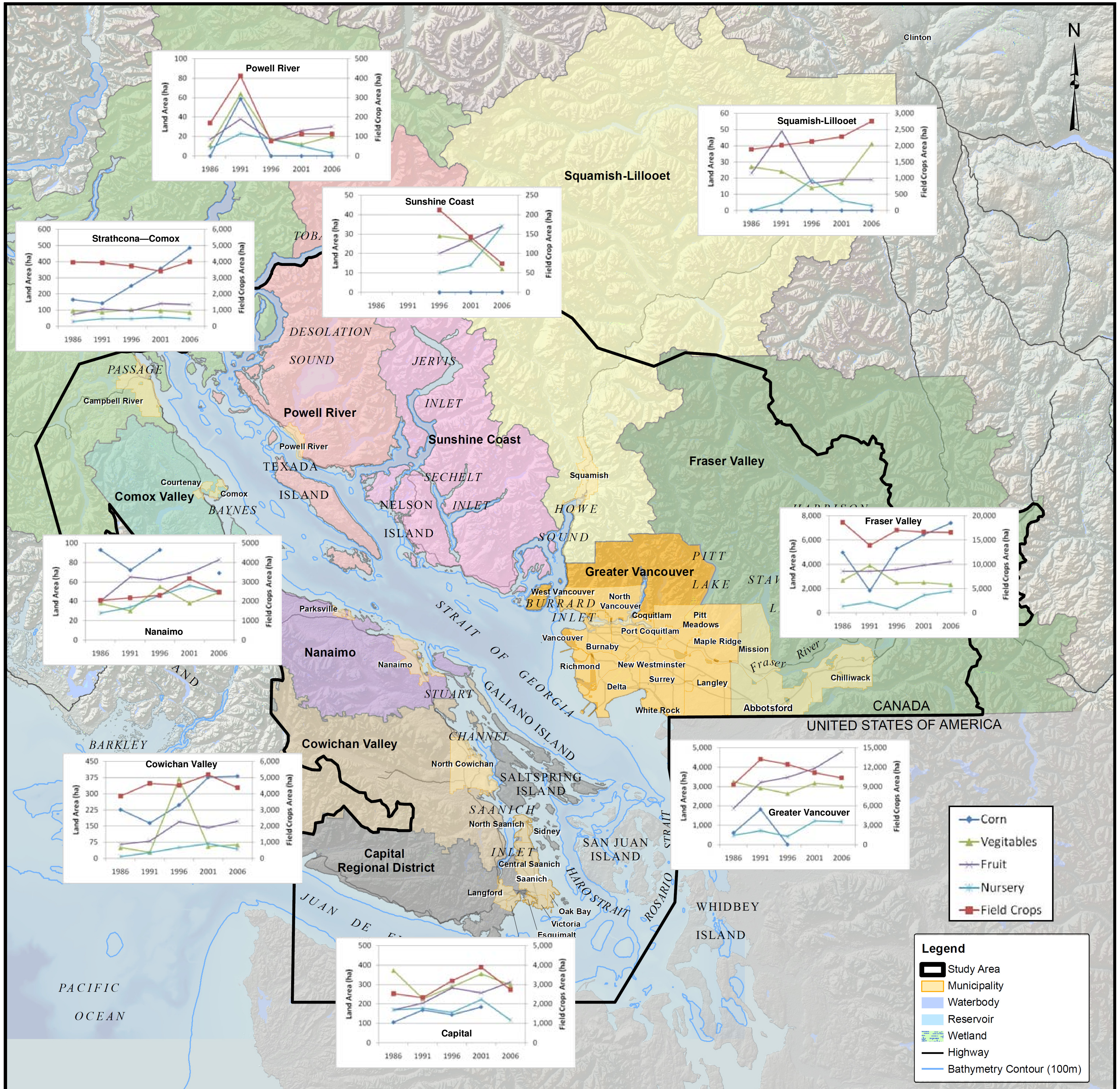
The characteristics of resource and land use provide an indication of potential effects of human activities and development and on Fraser sockeye salmon habitats in the lower Fraser River and Strait of Georgia. Impacts to sockeye salmon from agricultural land use arise from loss or degradation of freshwater habitats used by sockeye salmon for spawning, incubating and rearing; for example enhanced or reduced erosion and sediment transport in key sockeye incubation habitats. Changes in agricultural land use and practices can often have a more direct link than population size and density, to potential changes in the quality and quantity of habitats available for sockeye salmon use.

The lower Fraser River, Fraser Valley and Georgia Basin have a mix of land uses, ranging from the urban and industrial centres of Greater Vancouver and the Fraser Valley through recreation and urban and rural forest lands and farm lands.

Much of the agricultural land around the Georgia Basin and Vancouver and Fraser Valley areas is protected from residential and industrial development by the Agricultural Land Reserve. Agricultural land is often intensively farmed through a combination of crops, pasture, animal production. The Vancouver area and Fraser Valley support greater than half of British Columbia's annual agricultural revenue, but comprise a small proportion of BC's total farm land area.

Total agricultural land area, and the portion of land comprising crops, pastures and irrigated lands has not shown large change over the past 20 years. Areas of the Fraser Valley, and Squamish-Lillooet Regional District have shown a 20 percent increase in agricultural land use.

Source: Agricultural data for the study area was collected from the 1986 to 2006 Agricultural Census data tables. In some cases, data was aggregated to reflect changes in Regional District delineations or changes in how data was presented from census to census.



Map 6-B: Regional District Agricultural Crop Area and Livestock Production in the Lower Fraser River and Strait of Georgia

Total agricultural land area, and the portion of land comprising specific intensively farmed crops and farmed animals (livestock) has shown a 10 percent increase in land use and production over the past 20 years in the Lower Fraser River and Strait of Georgia basin. The Fraser, Cowichan and Comox Valleys have shown an increase in corn producing farm area, while nursery and fruit tree farm area have increased in Vancouver and Victoria. Total farm animal production has increased in the Fraser Valley. Farm animal production and management practices have changed over the past half century and have greatly improved control to limit potential nutrient runoff associated with farm animal waste. Nursery and fruit tree farms often have a lower general impact on aquatic habitats than active and intensive farm practices which require higher levels of tilling and fertilizer use associated with corn, vegetables and field crops.

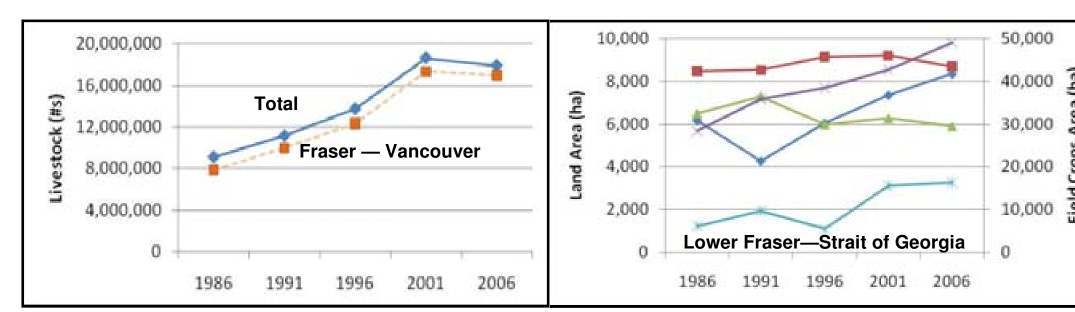
Source: Statistics Canada— Census of Agriculture.

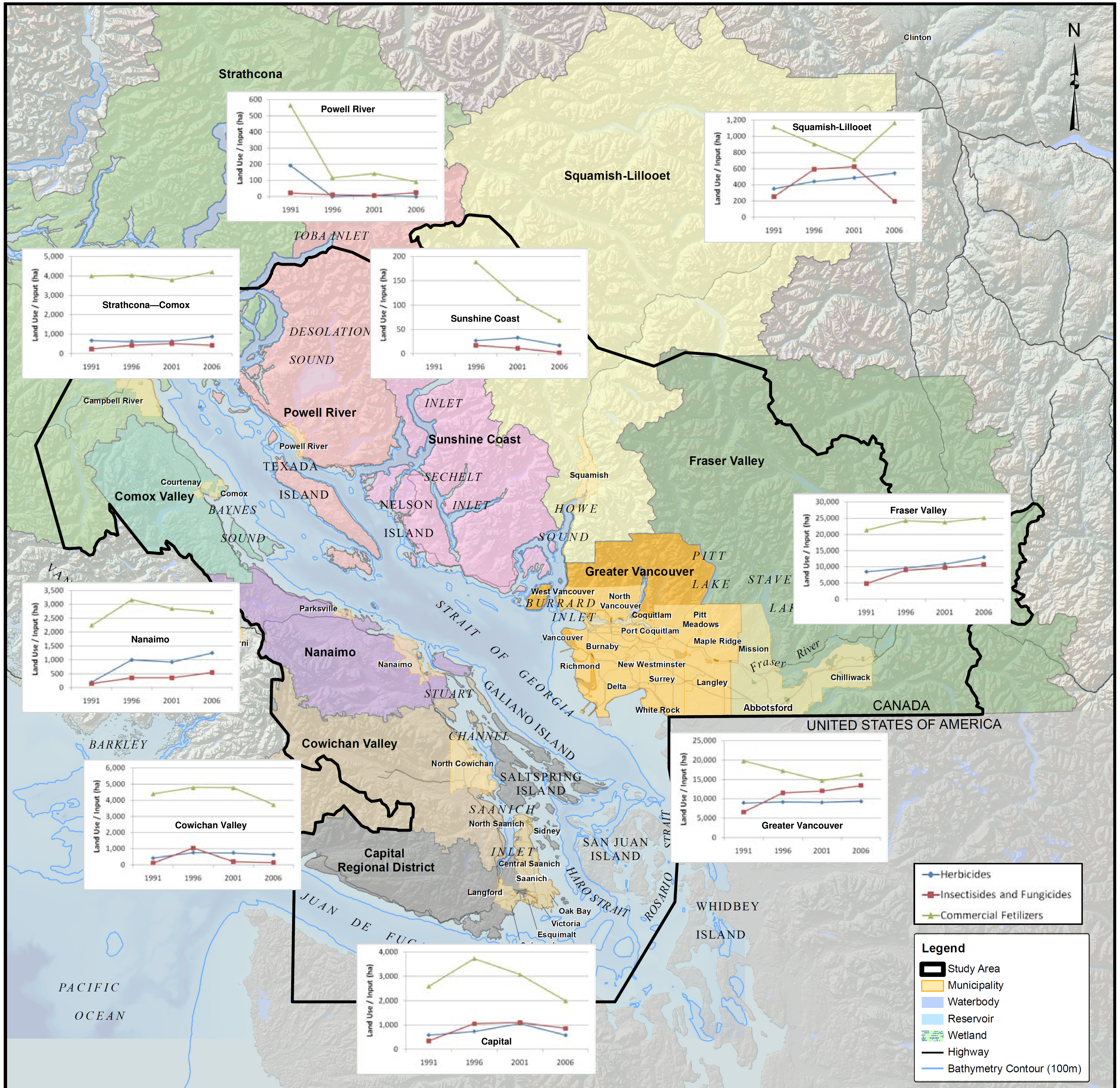
1986 Canadian Census of Agriculture: British Columbia. Ottawa: Ministry of Supply and Service Canada, 1987. Catalogue number 96-112

1991 Agricultural Profile of British Columbia, Part One. Ottawa: Ministry of Industry, Science, and Technology, 1992. Catalogue number 95-393

1996 Agricultural Profile of British Columbia. Ottawa: Ministry of Industry, 1997. Catalogue number 95-181-XPB

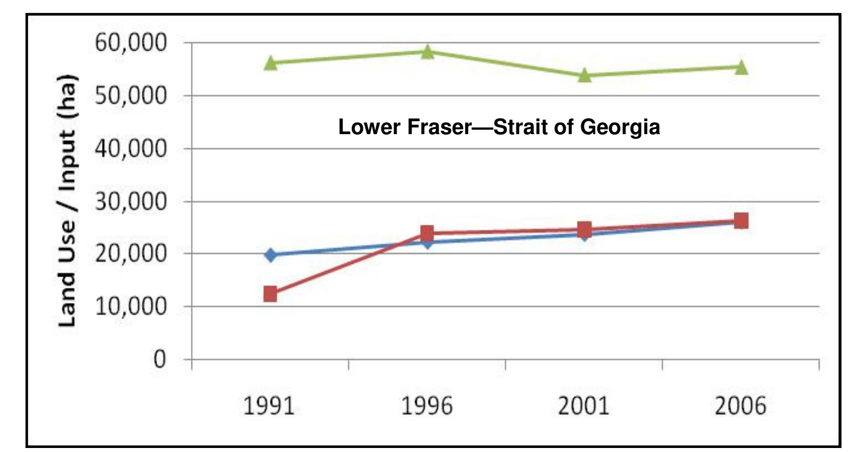
2006 Census of Agriculture, Farm Data and Farm Operator Data, for British Columbia Census Subdivisions, 2006 and 2001 Agricultural Census Data (table). Catalogue no. 95-629-XWE. Ottawa. May 16

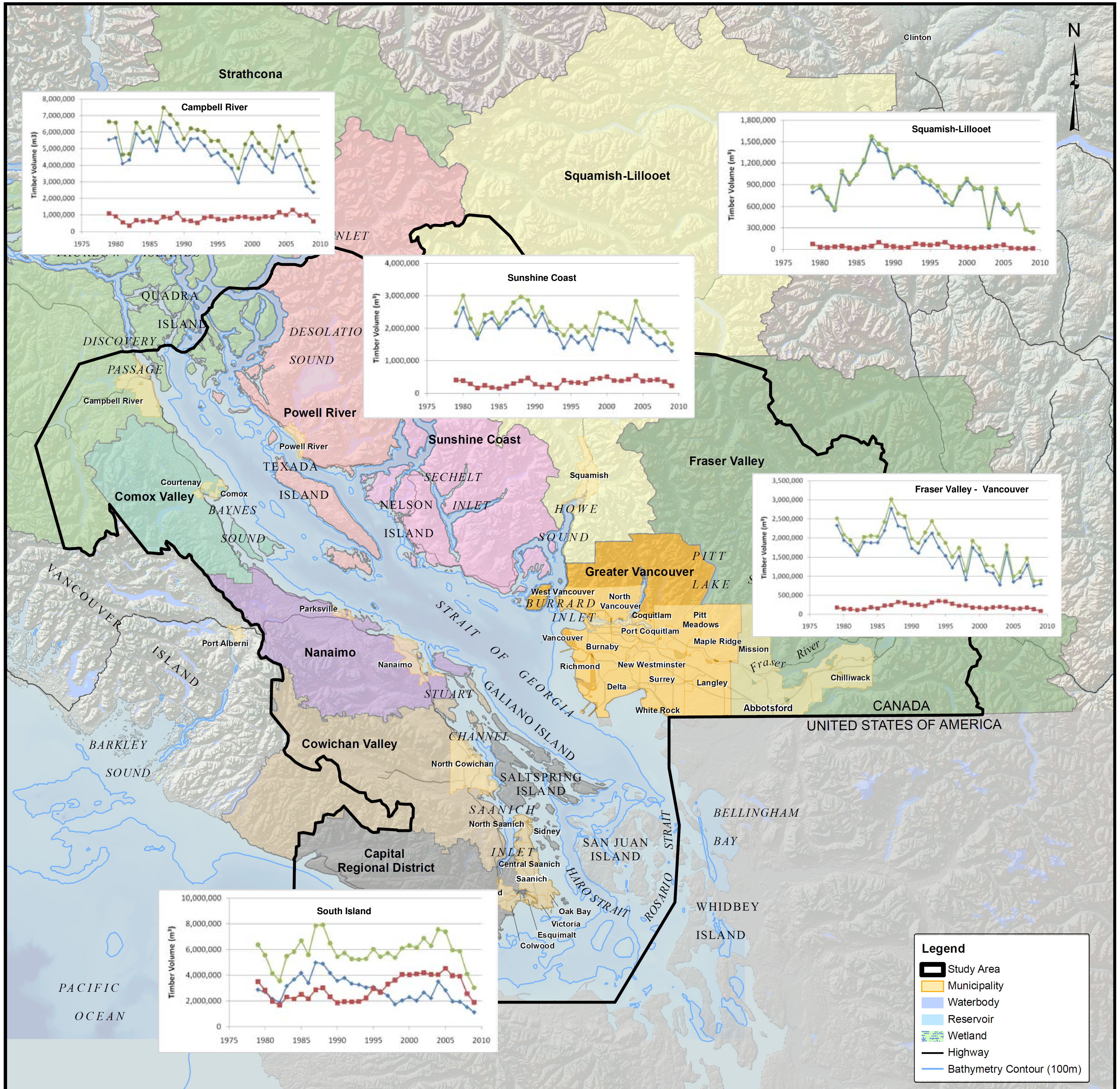




Map 6-C: Regional District Agricultural Land Use Practices and Applications in the Lower Fraser River and Strait of Georgia

Agricultural practices and application of herbicides, pesticides (both insecticides and fungicides) and fertilizers to farm lands and crops has remained consistent or shown a slight decline in use and land area application during the past 2 decades. Herbicide, pesticide and fertilizer use for crops and the associated land and surface runoff, local discharge and transport have been identified in as contaminants in aquatic habitats and a variety of freshwater and marine species in the Lower Fraser River and Strait of Georgia (i.e., Johannessen et al. 2008). Due to regulation and best practices, herbicides, pesticides and fertilizers concentrations in aquatic ecosystems have demonstrated a trend over time associated with early use in the 1950's, concentration increase and subsequent decrease in use to present (see Map 14).



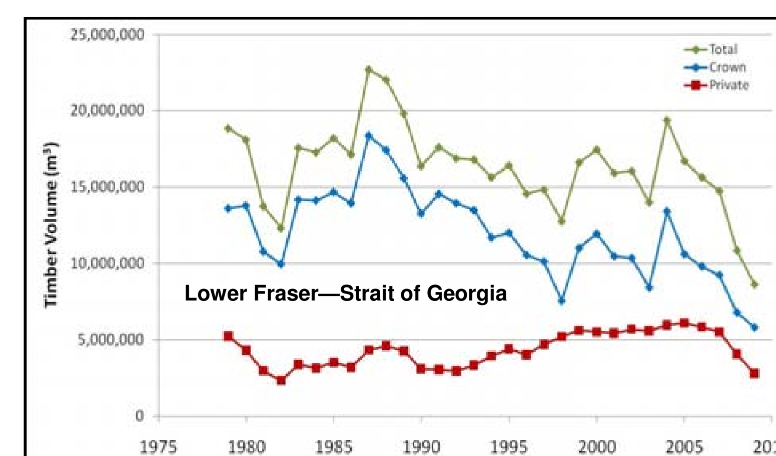


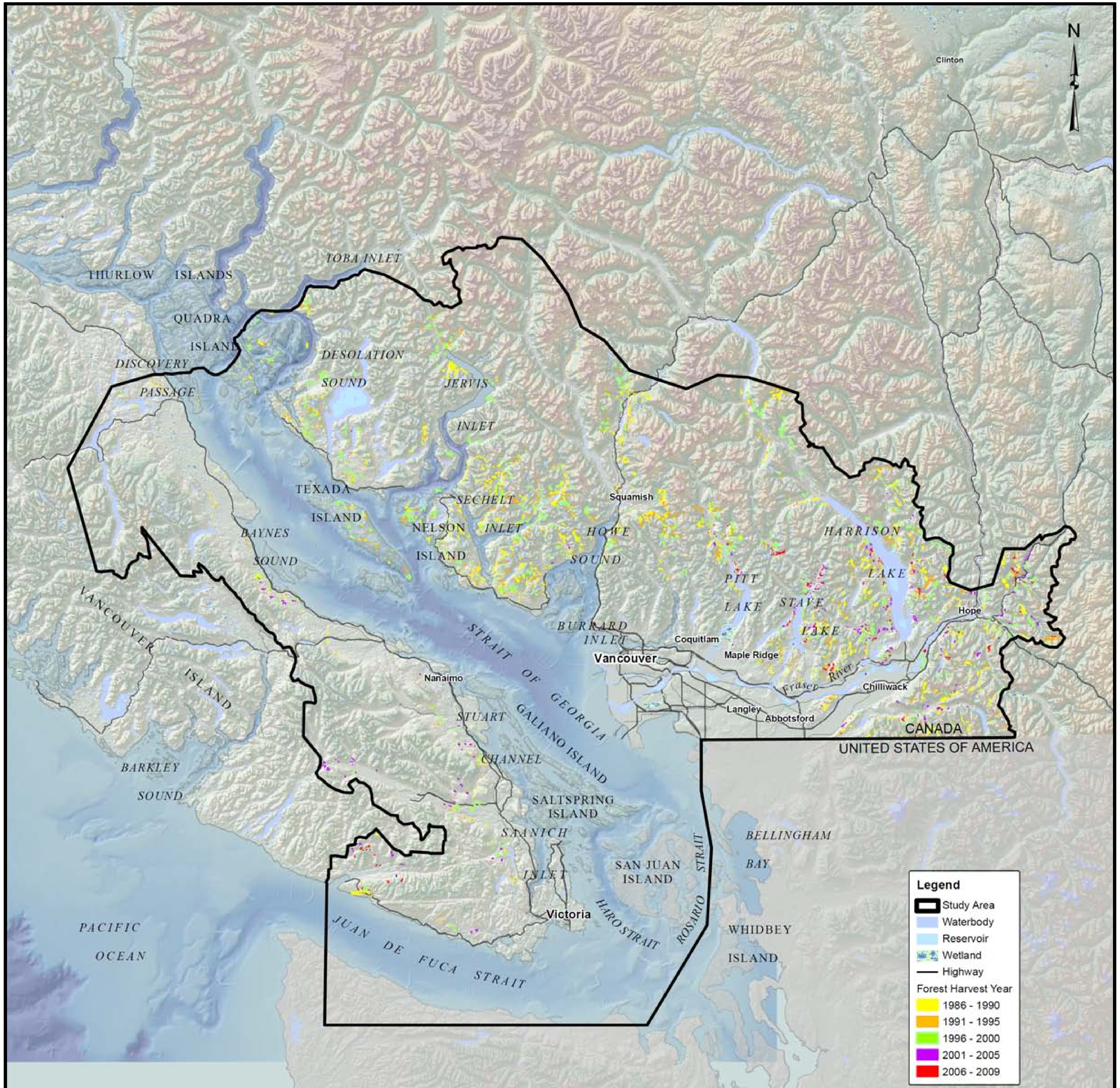
Map 7-A: Forest Timber Volume in the Lower Fraser River and Strait of Georgia

Forest harvesting activities are used as an indicator of human development and land and resource use and inferred potential impacts on Fraser sockeye salmon habitats in the Lower Fraser River and Strait of Georgia. Forest harvesting activities are known to have a negative effect on water quality and quantity and adverse impacts to freshwater and estuarine salmon habitats, and potentially salmon production at various freshwater life history stages (i.e., coho—Holtby and Scrivener 1989; sockeye— MacIsaac 2003).

Forest harvesting is often the major land use activity in coastal British Columbia. Forest harvesting in the Georgia Basin began in the 1800's and had increased until the 1950's. Forest harvesting has shown considerable variation in the amount of harvested timber volume over the past 3 decades across all regions of the Georgia Basin; presumably associated with market driven demand for timber and wood fibre (i.e., recent economic down-term. Over the past 2 decades, forest harvesting across all regions in Lower Fraser and Strait of Georgia area has declined 50% in the amount of harvested timber volume.

Source: Ministry of Forests and Range, Timber Supply Area timber volume statistics 1975 to 2009.





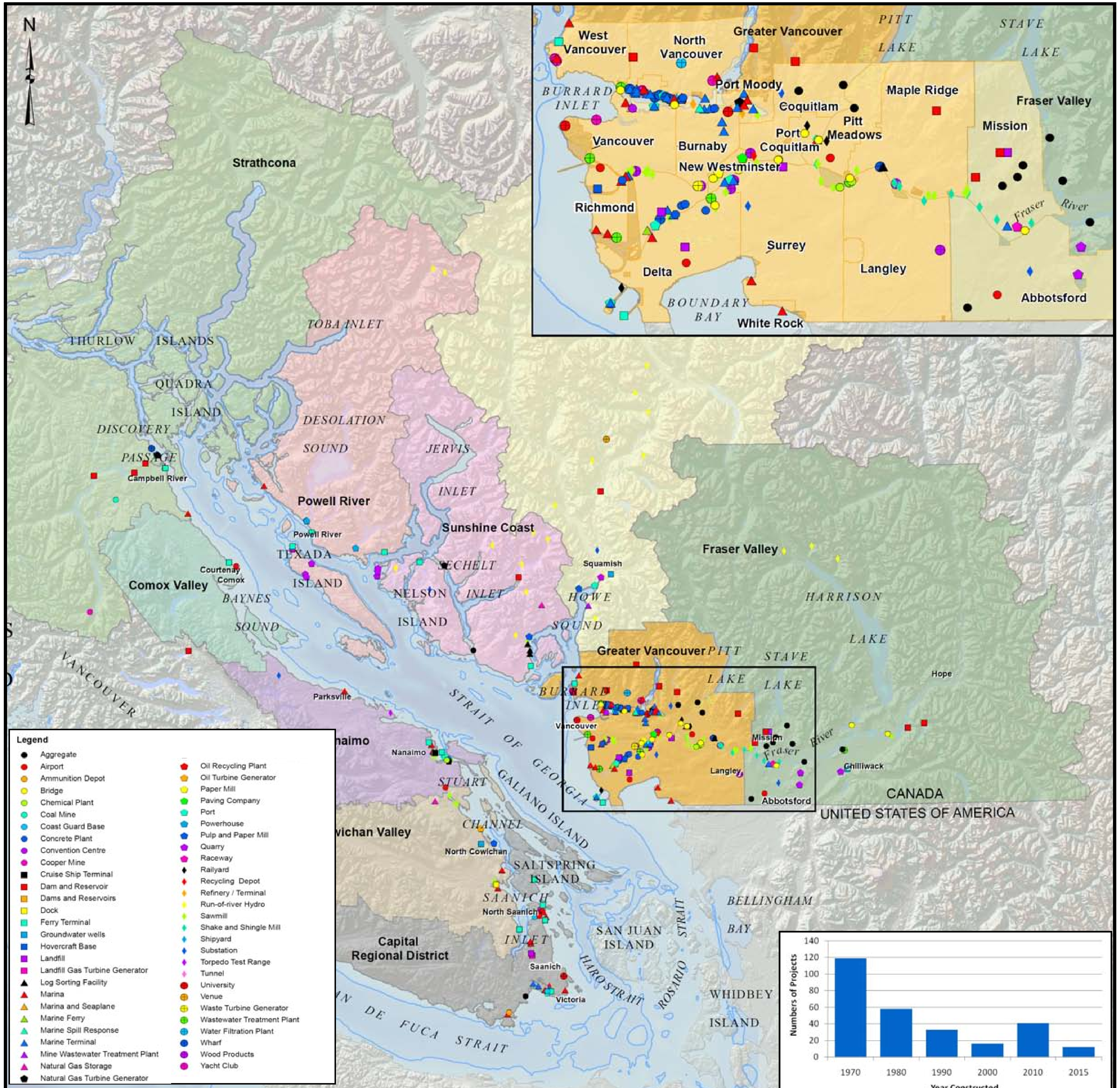
Map 7-B: Distribution of Forest Harvesting in the Lower Fraser River and Strait of Georgia

Forest harvesting was active in the 1980's and early 1990's in sub basins supporting key sockeye spawning habitats in the Harrison (Birkenhead), Pitt (upper Pitt River), and Chilliwack watersheds. The decline in areas harvested in the past two decades is consistent with patterns of declining harvested timber volumes in Map 10 and reflects regulations mandated under the Forest Practices Code to support improved forest harvesting practices on crown and forest lands.

The distribution of pulp and paper mills across the Strait of Georgia and associated water quality issues are presented in Maps 8 and 14-A respectively.

Areas of forest harvest disturbance were mapped based on BC Ministry of Forest and Range Vegetation Resource Inventory data for Crown lands separated into the following time periods: 1986-1990, 1991-1995, 1996-2000, 2000-2005, and after 2005. No information was readily available for private lands on Vancouver Island north of Victoria.

Year	Harvested Crown Land Area (ha)
1986-1990	28011
1991-1995	14649
1996-2000	10946
2001-2005	4151
2006-2009	1964
Total	**59722**



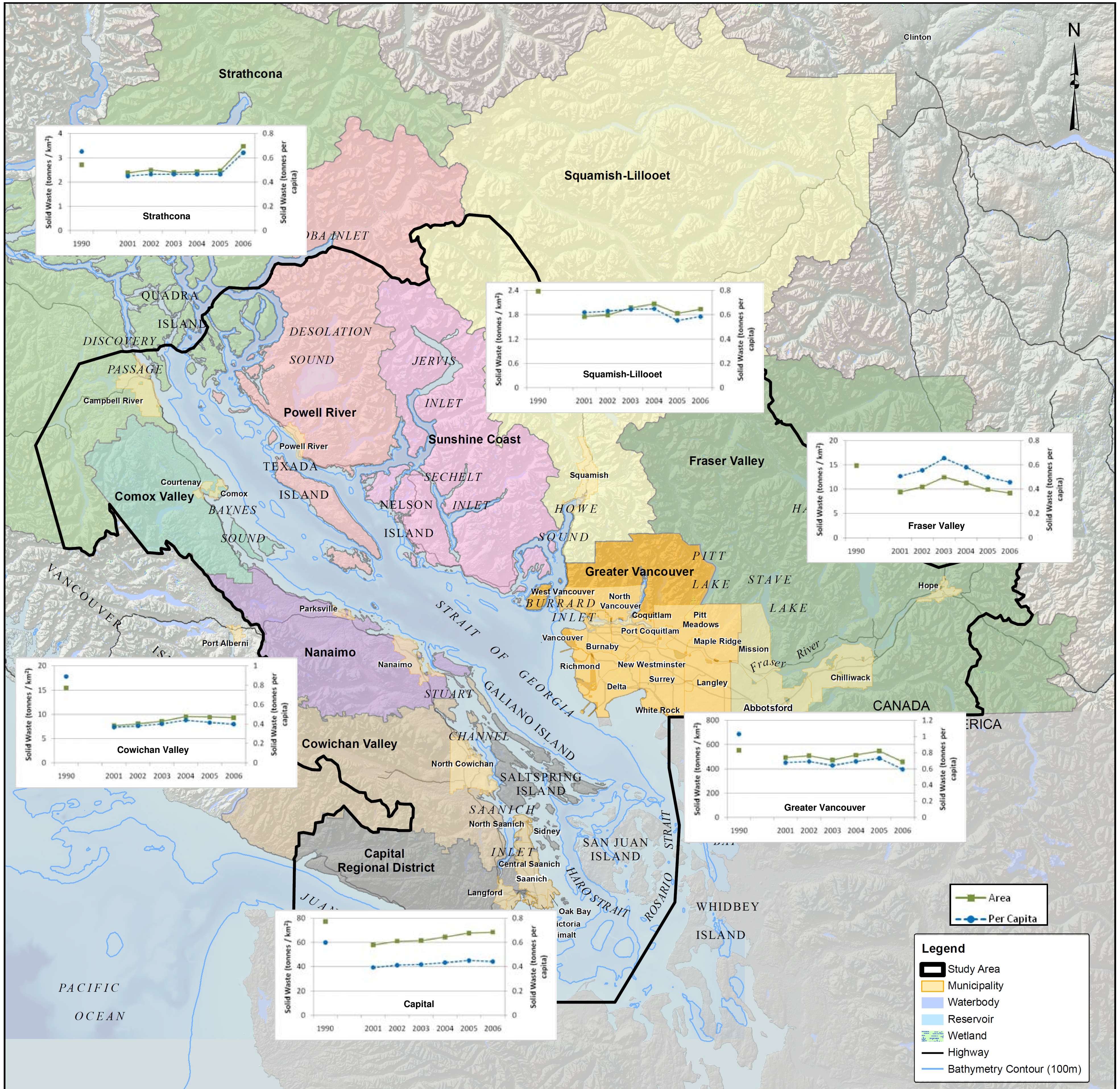
Map 8: Industrial and Public Projects, Sites and Infrastructure in the Lower Fraser River and Strait of Georgia

The distribution, type and extent of large industrial projects, sites and infrastructure can potentially affect Fraser sockeye salmon through direct loss or removal of habitats and indirect effects through increased erosion, sediment, nutrients and contaminant discharge and changes in water quality.

More than 300 large industrial sites and infrastructure projects were constructed and operated in the lower Fraser River and Strait of Georgia during the past century. Approximately 70 projects were constructed and began operations from 1990 to 2010. Twelve major projects are currently proposed, including Terminal 2, Delta Port in Richmond.

The number and distribution of large infrastructure and industrial projects constructed and operated prior to 1980 are included in this report. Large projects were identified as those industrial or public infrastructure / project / development sites which were considered to have potential interaction through geographic overlap, magnitude and duration of effects with sockeye aquatic habitats (this report see Table 1 and Section 3). The potential interactions of large projects on loss or degradation of sockeye salmon habitats was qualified over the study period from 1990 to 2010, but included industrial and infrastructure sites in operation. For example, these include pulp and papers mills constructed and operated from the early 1900's to present (Squamish, Port Mellon, Elk Falls, Powell River, Nanaimo and Crofton) and regional district wastewater treatment plants and operated since the 1960's (Iona, Lulu, Annacis Islands, Lions Gate and NW Langley).

Source: BC Stats Major Projects Inventory 2004-2010.
BC Environmental Assessment Office Project Information Centre 1995-2010.
Canadian Environmental Assessment Agency CEAA Registry 2000-2010.
Online and Wikimapia map based searches for large industrial projects.



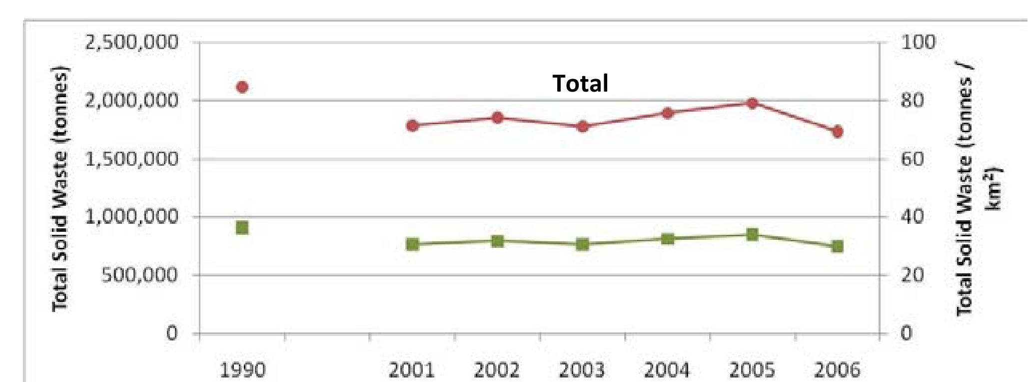
Map 9-A: Solid Waste in the Lower Fraser River and Strait of Georgia

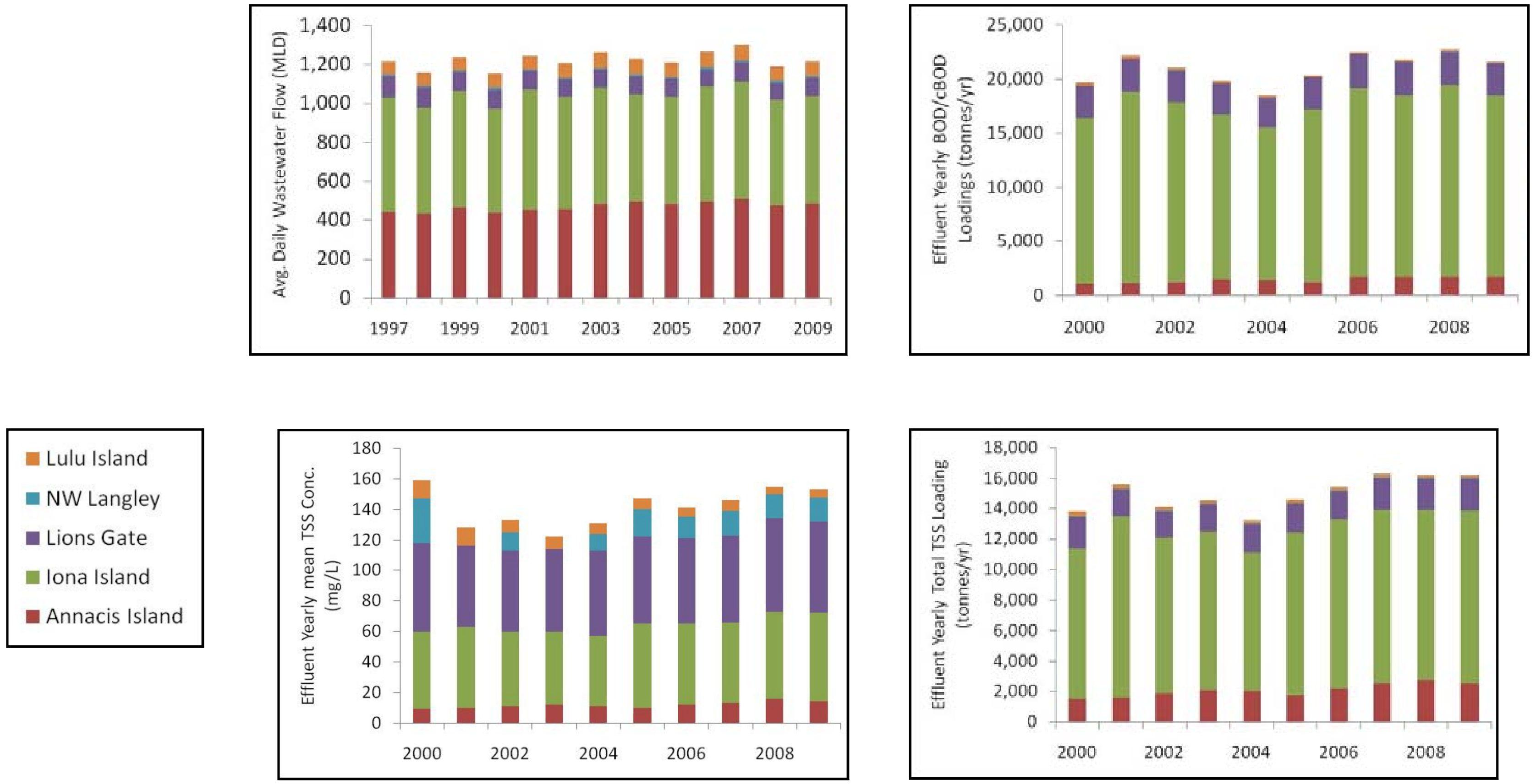
The local and regional volume of residential and industrial solid waste disposed at landfills is associated with local household and industrial resource use and potential interactions with sockeye habitats through reduced water quality due to discharge of contaminants and nutrients.

The lower Fraser River and Strait of Georgia are home to greater than 3.5 million residents and over 300 large industrial and infrastructure sites. Across the study area and in all regions, solid waste per capita and per area (km^2) has shown a slight decrease between 1990 and 2001-2006. Over the past 2 decades, household, industry and municipalities have developed and refined waste management, disposal and recycling programs. In all regions reporting across the Lower Fraser and Strait of Georgia, total tonnage of solid waste disposed of at landfills has declined over from 1990 to 2000, and remained stable over the past decade. Although these have been several landfills closed in within the lower mainland in the past 20 years, a large proportion of Metro Vancouver municipal and industrial solid waste is hauled outside the region to Cache Creek. Another large proportion continues to be transported to the Vancouver landfill in Delta.

Source: B.C. Municipal Solid Waste Tracking Report (2006), MOE, Victoria; MOE (2006b).

Six regional districts out of 10 within our study area had available solid waste data which were included in these results. Less populated regional districts do not routinely monitor or have available data time series for solid waste disposal including: Nanaimo, Comox Valley, Powell River, and Sunshine Coast. Data from these regional districts were not included in the results presented.



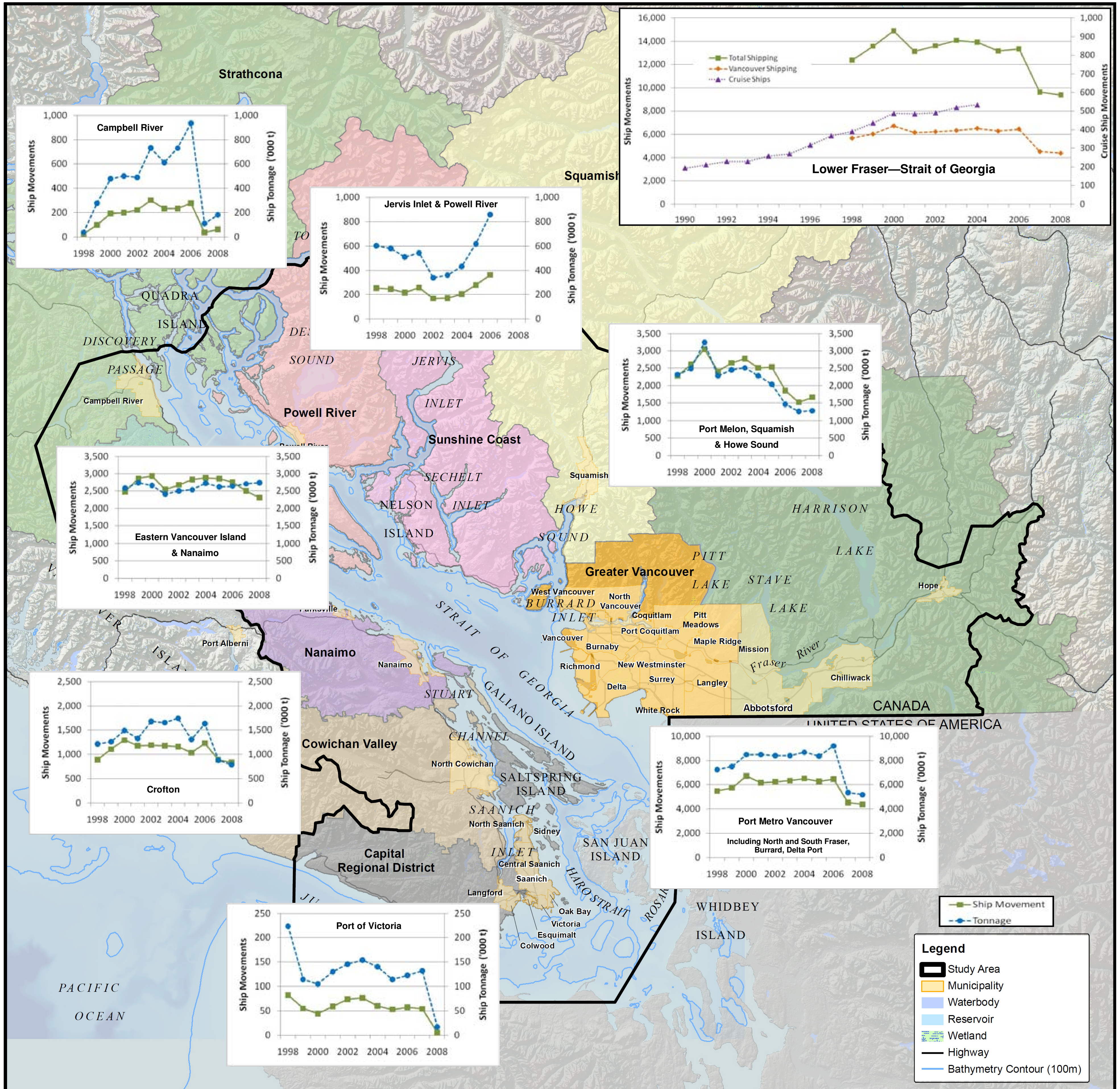


Map 9-B: Liquid Waste from Wastewater Treatment Plants in the Lower Fraser River

Liquid wastewater discharge and effluent water quality is measured in the lower Fraser River and estuary by Metro Vancouver Regional District as part their ongoing management and monitoring of Greater Vancouver wastewater treatment plants (WWTP). Metro Vancouver WWTP effluent volumes, biological oxygen demand (BOD) and total suspended solids (TSS) are associated with potential interactions on water quality and potential risk of degradation to sockeye habitats in the Lower Fraser River and estuary. Given the capacity for treatment of wastewater and population size serviced by the five WWTPs, these plants are considered potential factors indicating general trends in wastewater discharge across the study area. The five plants also represent treat wastewater discharge from areas with the greatest density and population size for urban centres across the Strait of Georgia. These urban centres are adjacent to many key sockeye habitats in the Lower Fraser relative to other regional districts and municipalities in the study area. Information on wastewater discharge from the other 9 regional districts not available in time for this study. However, treatment of wastewater across the Georgia Basin population showed an increase of 40% in secondary from primary treatment during the 1989 to 1999 time period (MOE 2006a).

Total wastewater daily flow shows a consistent average flow across all years of record. The highest effluent daily volume, BOD and TSS discharged was observed at Iona Island on the north arm of the Fraser River, followed by Annacis Island on the main channel of the Fraser River and Lions Gate in Burrard Inlet. Annacis Island and Iona Island have the greatest capacity for treatment of wastewater servicing a population of over 1.5 million Vancouver residents. Iona Islandand Lions Gate have been upgraded numerous times, but were originally constructed in the early 1960's. The other 3 large WWTP in the Lower Fraser River were constructed in mid and late 1970's and Annacis Island was upgraded in the mid 1990's.

Source: Metro Vancouver Wastewater Treatment, http://www.metrovancouver.org/services/wastewater/treatment/Pages/treatmentplants.aspx



Map 10: Marine Vessel Traffic and Cargo Tonnage in the Lower Fraser River and Strait of Georgia

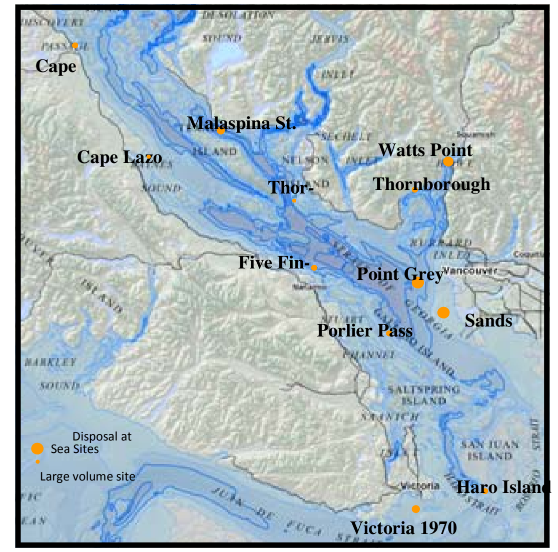
Marine vessel traffic is associated with potential effects such as noise and ballast water and hull fouling for introduction of non indigenous species, and contaminants from spills or vessel discharge. Port vessel movements (into and out-of port) and traffic cargo tonnage across the lower Fraser River, and Strait of Georgia can be used as an indicator of potential effect or change on Fraser sockeye salmon habitats.

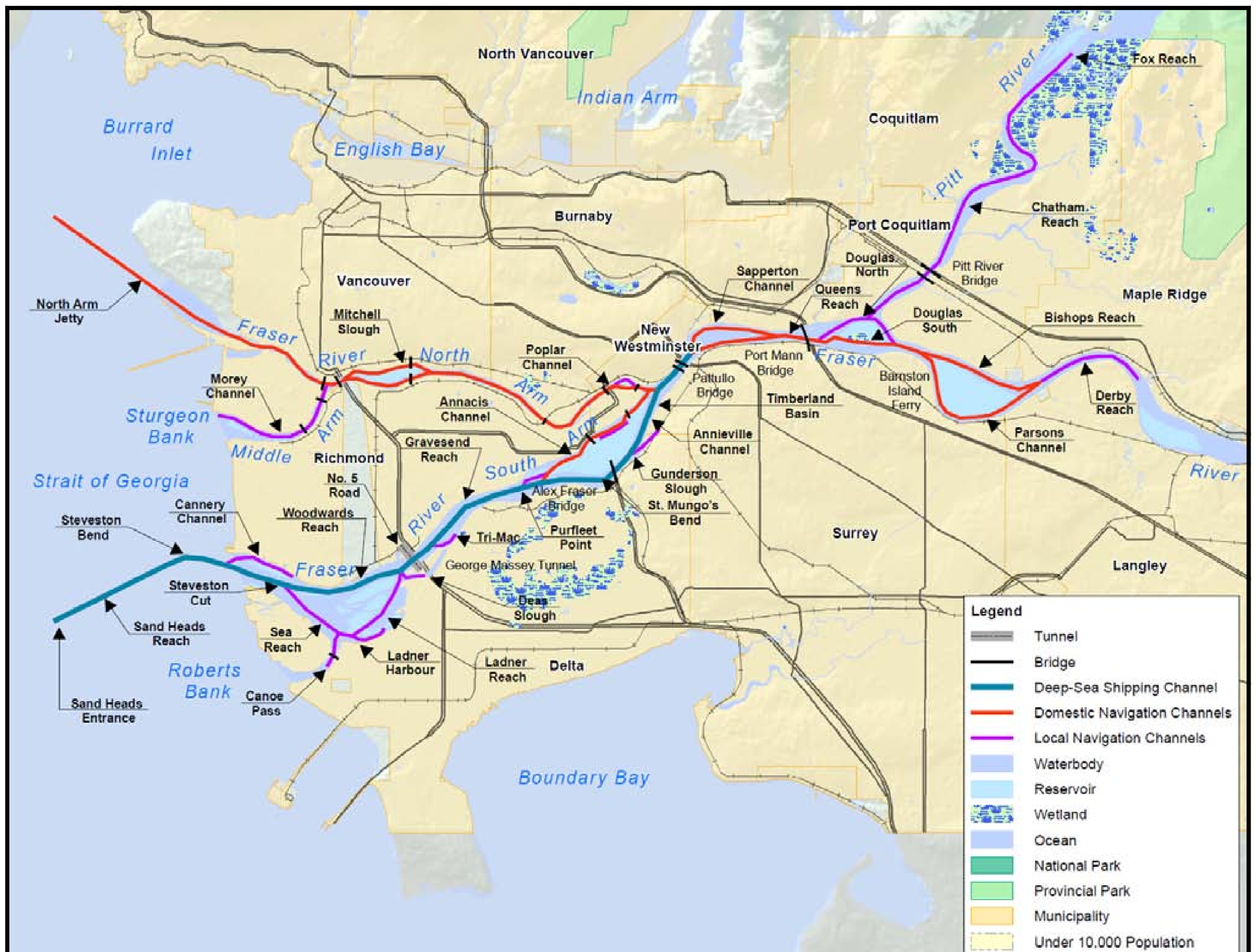
The potential impact of marine traffic on sockeye habitats depends in part on the vessel type, destination port and time of year. The highest proportion of vessel movements originated from passenger ferries, followed by tug and barge traffic and cruise ships (Vancouver) (MOE 2006a). Cruise ships travel predominately during the summer season. Dry and bulk tankers and cargo (containers) vessels had the highest proportion of tonnage with consistent vessel traffic across all seasons.

Port vessel traffic across the Strait of Georgia remained generally stable during the past decade with some decline in ship movement and tonnage in recent years associated with slower economic conditions. Vessel traffic showed an increase in Jervis Inlet and Powell River, but represented a small proportion of total vessel movement and tonnage in the area. Cruise ship traffic has been projected to continue to rise over the next decade. Ferry traffic has remained stable throughout the past two decades. Pollution incident reports for marine vessels on the west coast has remained stable between 1999 and 2004, but are considered to under represent the frequency of small spills (MOE 2006a).

Sources: Statistics Canada (2008): Shipping in Canada (1998-2008), published from 2000-2010, Statistics Canada, Ottawa. Website: http://www.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=54-205-X&chropg=1&lang=eng Data is derived from a series of publications (1998-2008) which present an overview of domestic and international shipping activities at Canadian ports. Data was collected for ports within our study area from table labeled "Domestic shipping – Number of movements, vessel capacity and tonnage transported by province or territory and port – BC".

Lower Fraser River Dredge Location	Year									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
North Arm Tidal (North Arm Jetty, Morey Channel)	-	-	-	-	-	-	-	-	-	-
North Arm Meso-tidal (Mitchell Slough, Poplar Channel)	-	-	-	-	-	-	-	-	-	-
Sand Heads Reach	√	√	√	√	√	√	√	√	√	√
South Arm Tidal (Steveston Bend, Steveston Cut, Sea Reach, Woodwards Reach, Ladner Reach)	-	-	√	√	√	√	√	√	√	√
South Arm Meso-tidal (Gravesand Reach, Purfleet Point Reach, St. Mungo's Bend, Annieville Channel,	√	√	√	√	√	√	√	√	√	√
Annacis Channel	-	-	-	-	-	-	-	-	-	-
Sapperton Channel	-	-	-	-	-	-	-	-	√	-
Lower Pitt River (Douglas North, Chatham Reach, Fox Reach)	-	-	-	-	-	-	-	-	-	-
Barnston (Douglas North, Douglas South, Bishops Reach, Parsons Channel, Derby Reach)	-	-	√	-	-	-	-	-	√	√





Map 11-A: Navigation Channels, Channel Characteristics, Dredging and Disposal at Sea in the Lower Fraser River and Strait of Georgia

The extent of dredging in the lower Fraser River and disposal at sea of dredged materials is associated with potential interactions on Fraser sockeye salmon including direct loss or removal of habitats and indirect degradation of habitats through increased erosion, sediment, nutrients and introduction of contaminants accumulated in sediments.

Annual dredging is undertaken in 9 reaches in lower the Fraser River below Mission, to maintain navigation channels in the Fraser River South Arm to provide access for container and cargo vessel traffic and to accommodate upstream access for some of these larger vessels (FREMP 2006). Sands Head, South Arm tidal, and South Arm meso-tidal channels have been routinely dredged over at least the past three decades. Two-thirds of the dredge sand (1-2 x 10^6 m^3 / year) is sold annually and the remaining one-third is disposed at Sands Head or Point Grey disposal at sea sites. Since 1998, dredging has been managed by Port Metro Vancouver rather than the Canadian federal government. Dredging activities are currently restricted by Fisheries and Oceans Canada to periods between January 1st to March 1st, and depending on the timing of the Fraser River freshet, from June 15th to December 31st.

Dredging in the lower Fraser River below Mission, has removed more material than has inflowed into the lower reaches over the past 3 decades (1:1 ratio of dredged to material inflow) (see Figure 2). Dredging has resulted in the navigation channel bed level being reduced by 3 m over a 30 year dredging period. The volume of dredged material removed from the river has declined annually since the early 1990's, ranging in volume from 2 to 3 million cubic metres. Dredging is also conducted annually in gravel reaches of the Fraser River between Hope and Mission to maintain flood protection and reduce freshet water levels in the Fraser Valley (NHC 2009, Church 2010).

Source: Data derived from results published by Fraser River Estuary Management Program. http://www.pep.bc.ca/floods/fraser_sediment_prog.html. Data also derived from results published in NHC 2006, 2008, 2009, Church 2010. Mapping derived from Port Metro Vancouver navigational channel maps and Environment Canada Fact Sheet—Disposal at Sea in British Columbia.

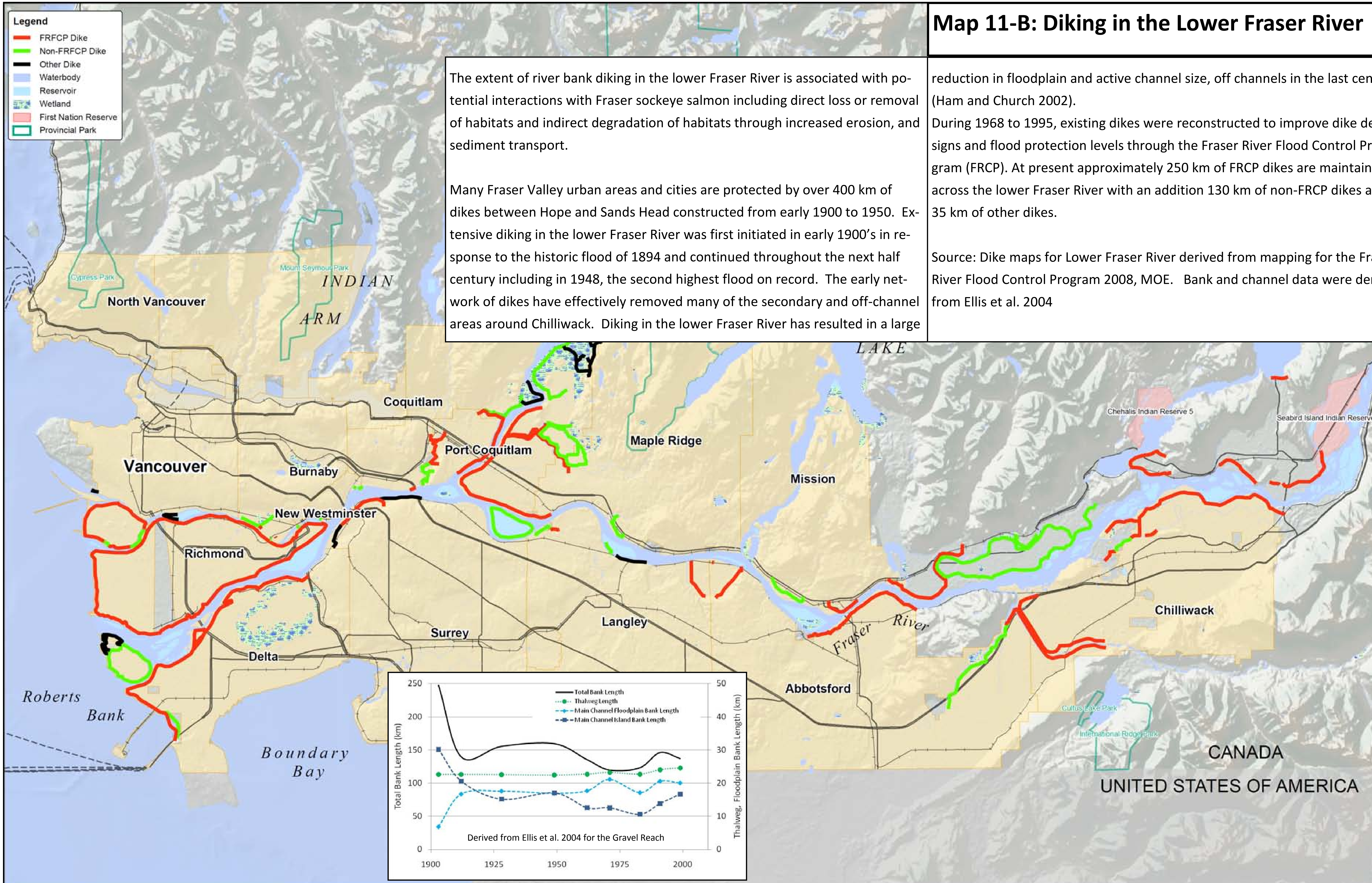
Map 11-B: Diking in the Lower Fraser River

The extent of river bank diking in the lower Fraser River is associated with potential interactions with Fraser sockeye salmon including direct loss or removal of habitats and indirect degradation of habitats through increased erosion, and sediment transport.

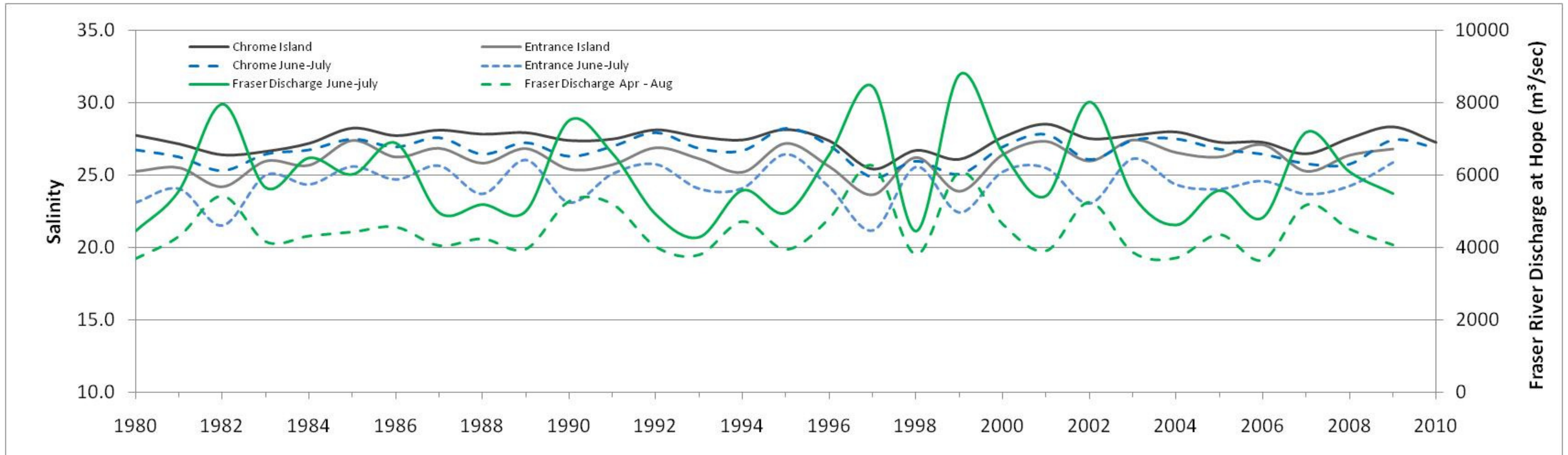
Many Fraser Valley urban areas and cities are protected by over 400 km of dikes between Hope and Sands Head constructed from early 1900 to 1950. Extensive diking in the lower Fraser River was first initiated in early 1900's in response to the historic flood of 1894 and continued throughout the next half century including in 1948, the second highest flood on record. The early network of dikes have effectively removed many of the secondary and off-channel areas around Chilliwack. Diking in the lower Fraser River has resulted in a large reduction in floodplain and active channel size, off channels in the last century (Ham and Church 2002).

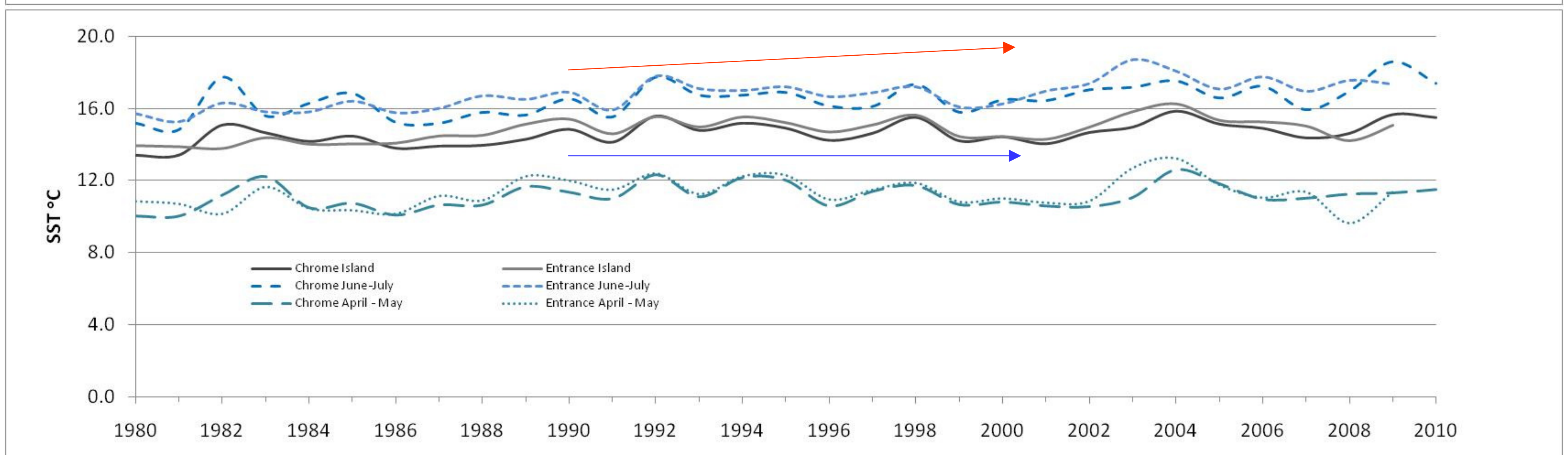
During 1968 to 1995, existing dikes were reconstructed to improve dike designs and flood protection levels through the Fraser River Flood Control Program (FRCP). At present approximately 250 km of FRCP dikes are maintained across the lower Fraser River with an addition 130 km of non-FRCP dikes and 35 km of other dikes.

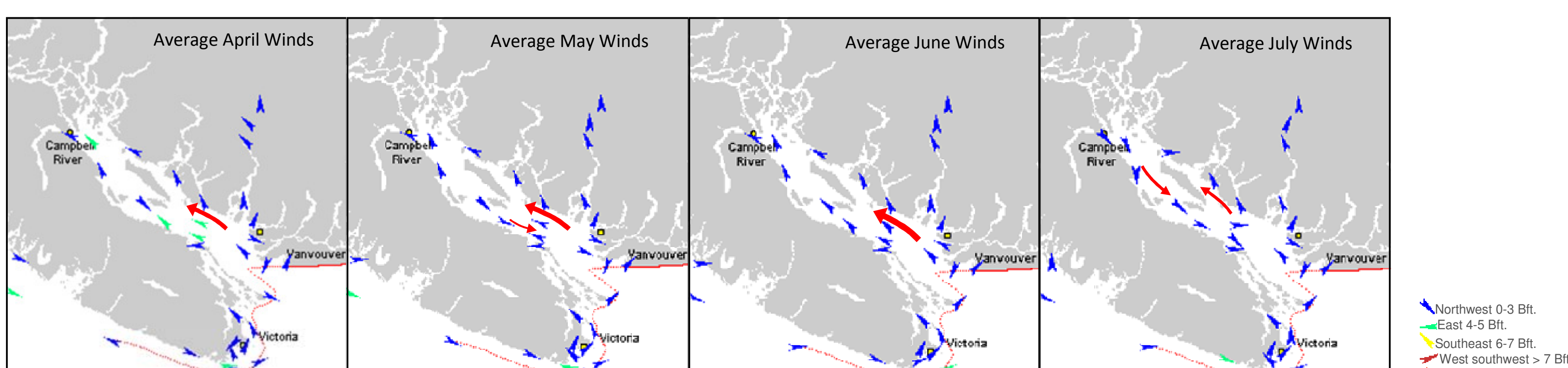
Source: Dike maps for Lower Fraser River derived from mapping for the Fraser River Flood Control Program 2008, MOE. Bank and channel data were derived from Ellis et al. 2004



Derived from Ellis et al. 2004 for the Gravel Reach





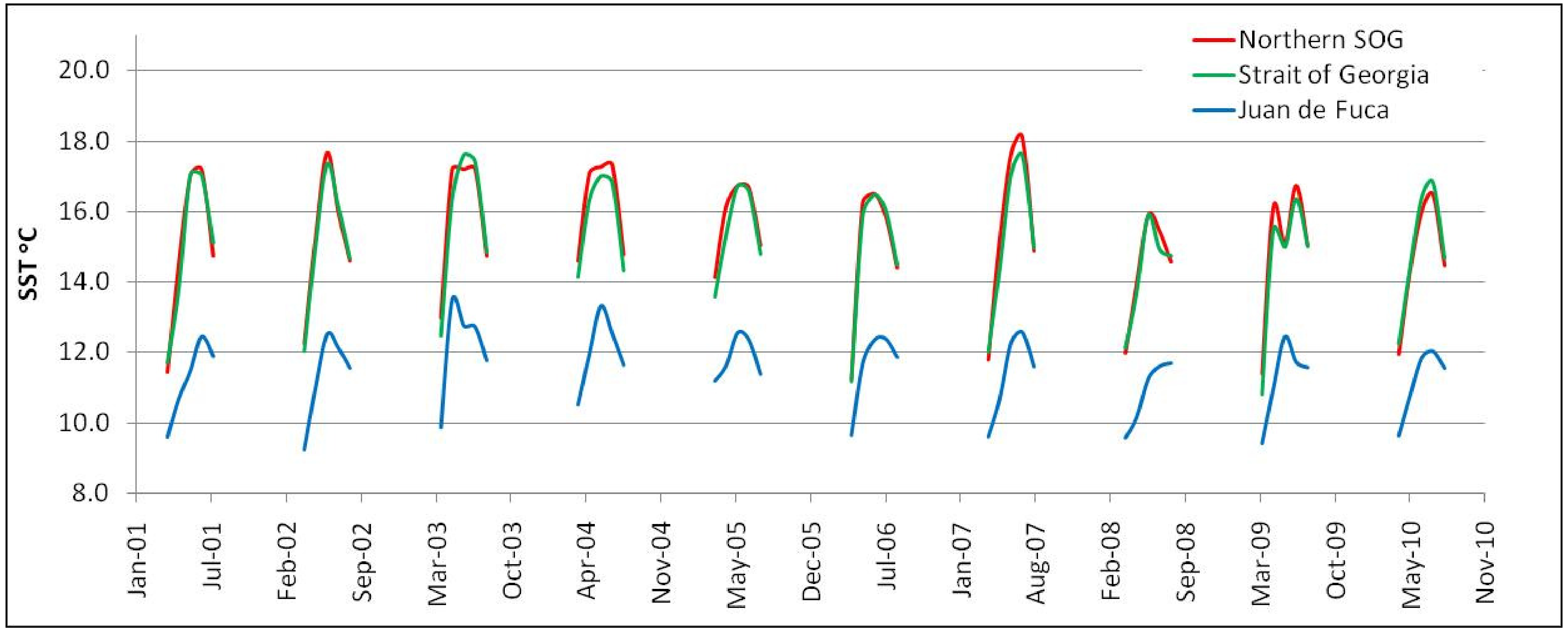


Map 12-A: Water Properties in the Strait of Georgia

The physical changes observed represent a large spatial scale that overlaps extensively with Fraser sockeye habitat use. Changes in the physical water properties in the strait are linked to biological production which have combined implications on the distribution, growth and survival of sockeye.

Based on these integration of these water properties, including seasonal patterns of temperature, mixing and currents driven in part by freshwater discharge and winds, determines the spatial distribution and physical habitat use of juvenile sockeye from June through August and adult sockeye from May to June.

The physical properties of marine water in the Strait of Georgia, including sea surface temperature (SST), sea surface salinity salinity (SSS) and nutrient properties and distribution, are determined through a combination of the Strait's physical bathymetry and dimensions (semi-enclosed sea), and energy from tidal mixing, currents, prevailing winds and freshwater input from the Fraser River. The strait is comprised of two shallow sills at the south (Victoria Sill, Boundary Pass) and north (Discovery Passage) ends (Map 1) which restrict water exchange and ocean upwelling from the Pacific Ocean through both the Juan de Fuca Strait and Johnston Strait (Waldichuk 1957, Davenne and Masson 2001). Water properties and circulation in the Strait of Georgia are primarily determined by the seasonality of freshwater discharge from the Fraser River, variation and strength of prevailing winds and strong tidal mixing and currents influence by climate and Pacific ocean conditions (Davenne and Masson 2001, Masson 2002). The variation in SSS associated with inverse association with Fraser discharge. This relationship dampens as freshwater input from the Fraser is diluted in northern portions of the Strait of Georgia. SST generally shows an independent pattern to Fraser River discharge and is controlled in part by climate patterns and regimes, level and intensity of stratification in the Strait, ocean upwelling, and prevailing winds.



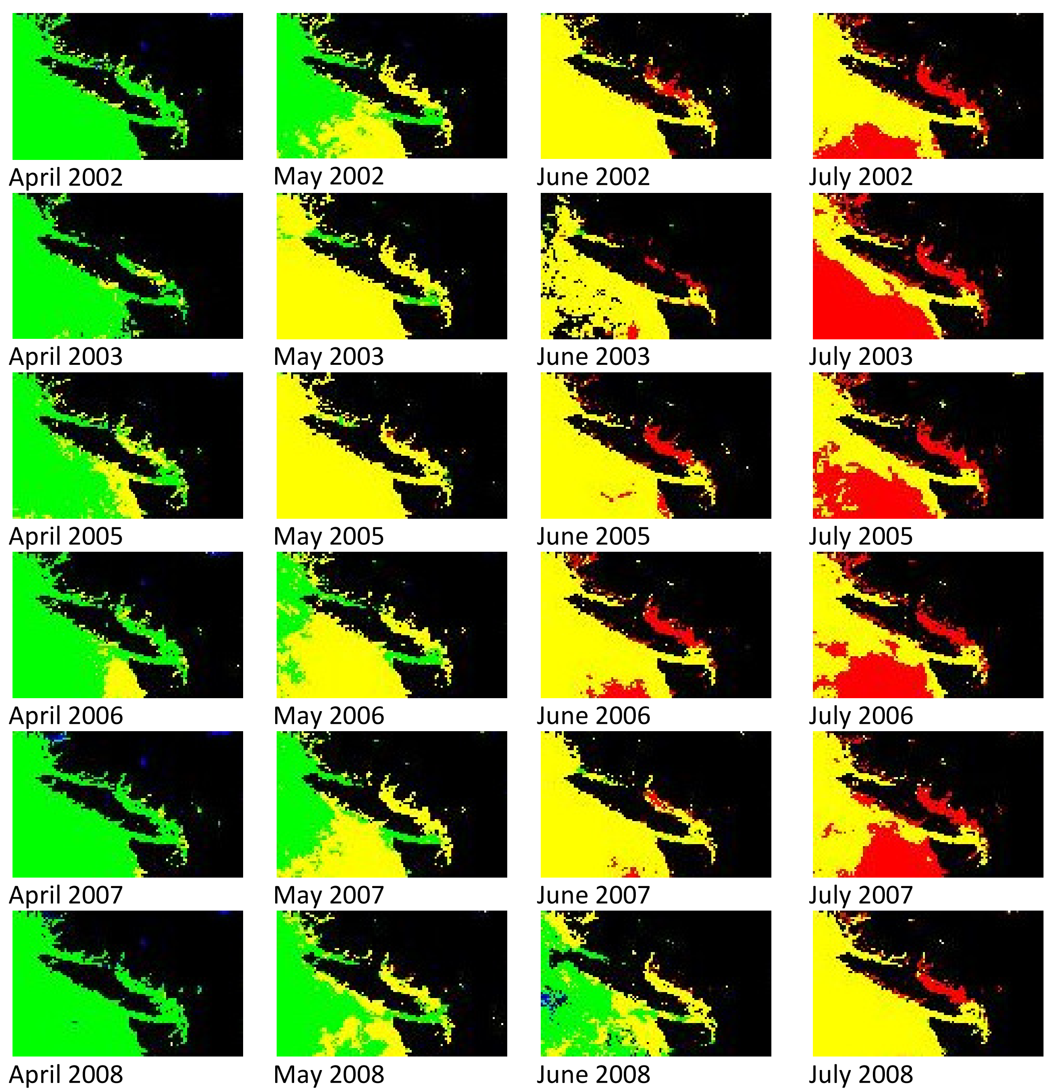
Map 12-B: Water Properties in the Strait of Georgia

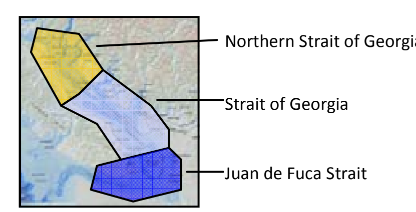
Long-term time series of monthly temperature anomalies from Entrance Island lighthouse (Figure 3) relative to the long term average, suggest that the period from the late 1980's to present experienced warmer conditions than those during the antecedent period from 1940. Similarly patterns of daily temperature from Chrome (northern strait) and Entrance Island lighthouses show a general trend in increased SST from 1980 to present (Map 12-A).

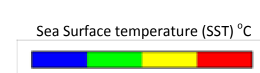
A time series of sea surface temperature (SST) and chlorophyll *a* (Map 12-C) was obtained and analyzed from the Ocean Web site (http://oceancolor.gsfc.nasa.gov/) using MODIS satellite imagery. Each satellite image and file was integrated in a georeferenced layer stack the facilitate the statistic extraction over the time series for each month (April to Aug) 2001-2010 for three areas of interest including Southern Strait of Georgia, Northern Strait of Georgia and Juan de Fuca Strait.

The seasonal warming and cooling pattern was observed in the central and northern Strait of Georgia and Juan de Fuca Strait areas. SST in Juan de Fuca Strait was cooler at all time periods than the SST observed in the Strait of Georgia. The warmest seasonal temperatures were observed in August of each year with the warmest growing season during the 2001 to 2010 period occurring in 2007, and the coolest period occurring in 2008.

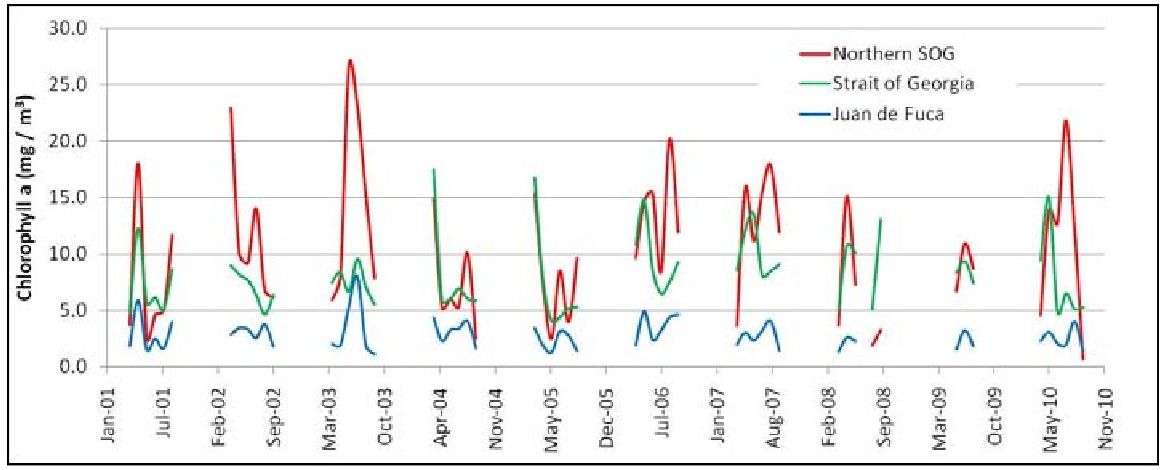
Juvenile sockeye take advantage of the seasonality of surface currents for a northward migration through the strait, and the onset of seasonal increased spring planktonic prey abundance (Mackas et al. 2007, Haro-Garay and Soberanis 2008, Trudel et al. 2008, 2010, El-Sabaawi et al. 2010). Adult sockeye use two alternative migration routes through the Strait of Georgia including a southern route through Juan De Fuca Strait with holding areas above the southern Gulf Islands and Fraser plume and estuary, and a second northern diversion route through Johnstone Strait and Discovery Passage along an western route in the Strait of Georgia to holding areas in the Fraser plume and estuary. Migration routes and timing for adult sockeye are determined in part by outflow water properties (SST, SSS) and conditions from the Strait through Queen Charlotte Sound and Juan de Fuca Strait.

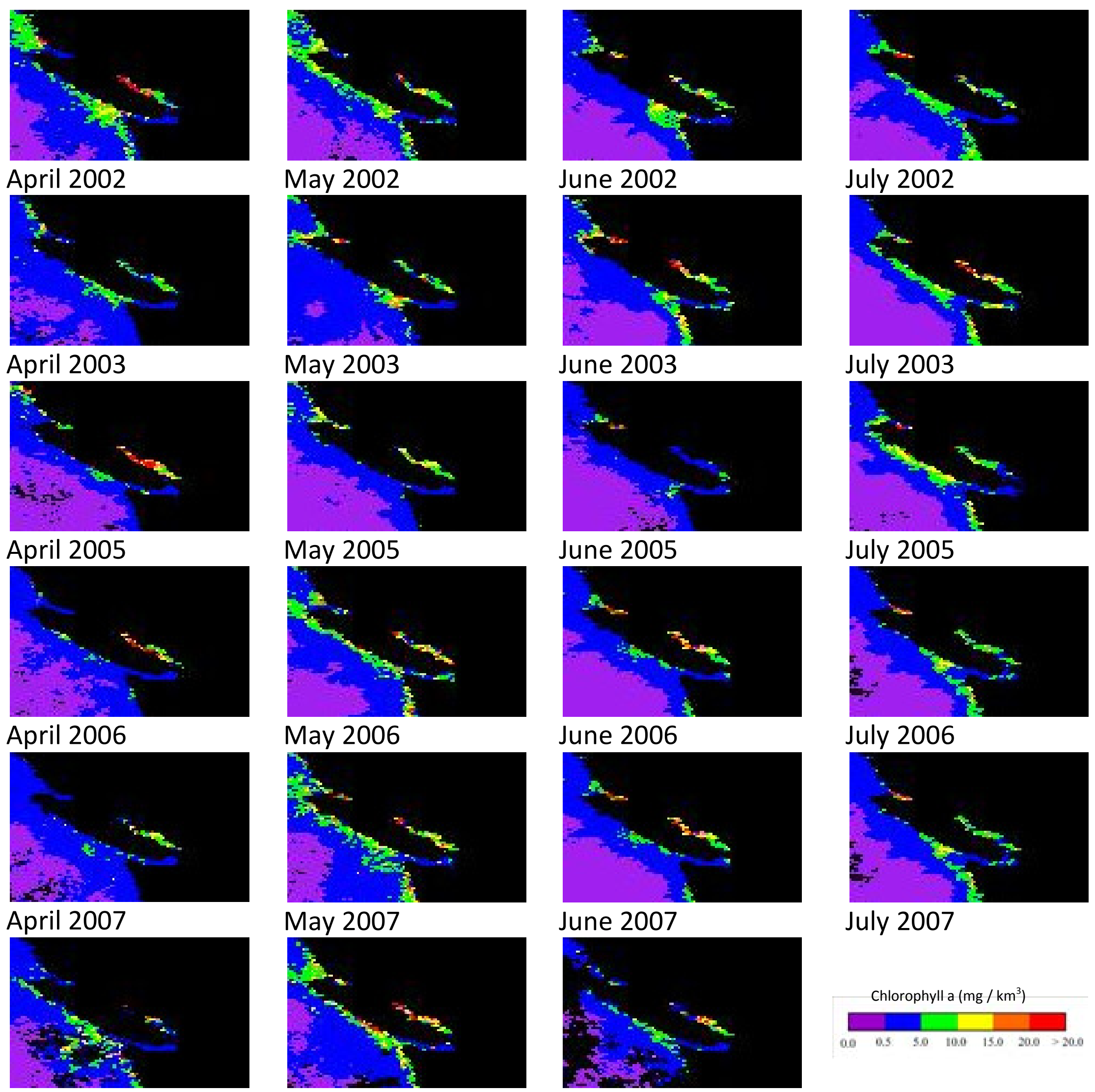


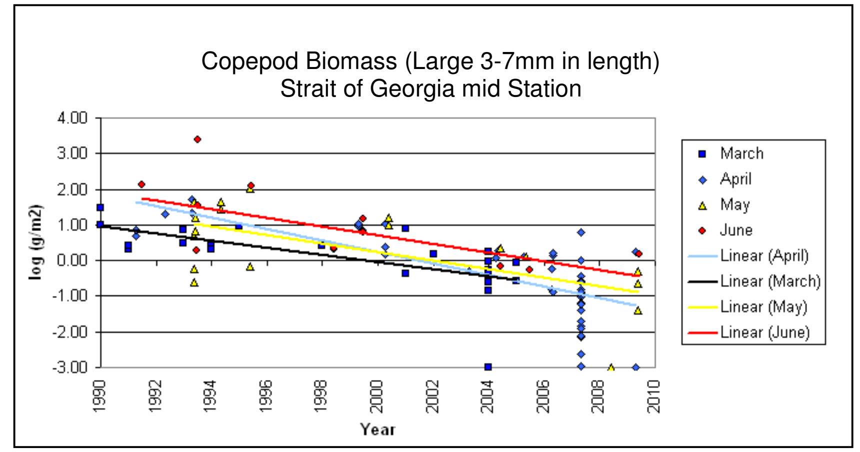


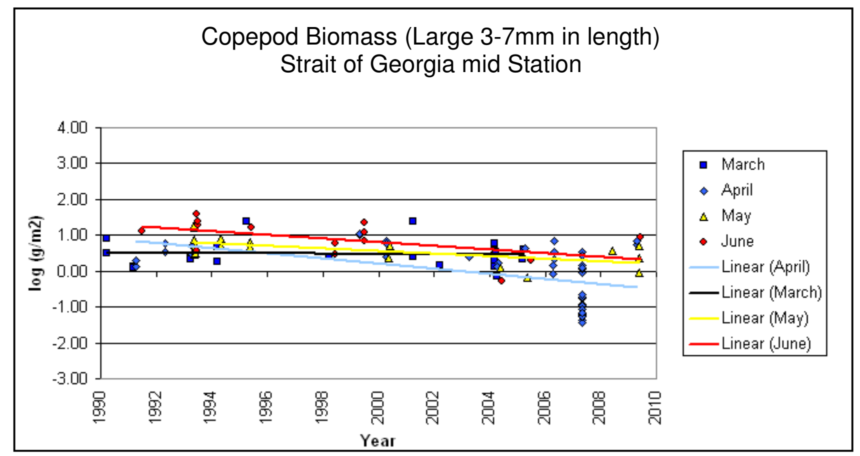


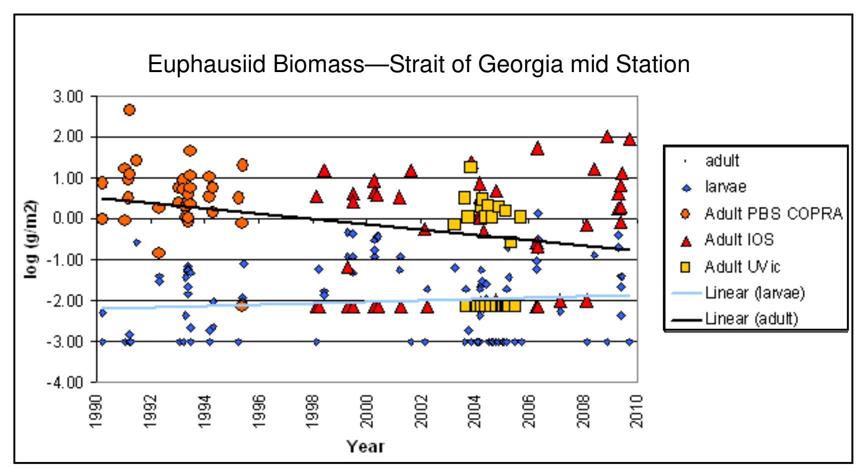
Map 12-C: Biological Properties in the Strait of Georgia











PBS — Pacific Biological Station (DFO)
IOS—Institute of Ocean Sciences (DFO)
COPRA—Cooperative Plankton Research Monitoring Program
UVIC—University of Victoria

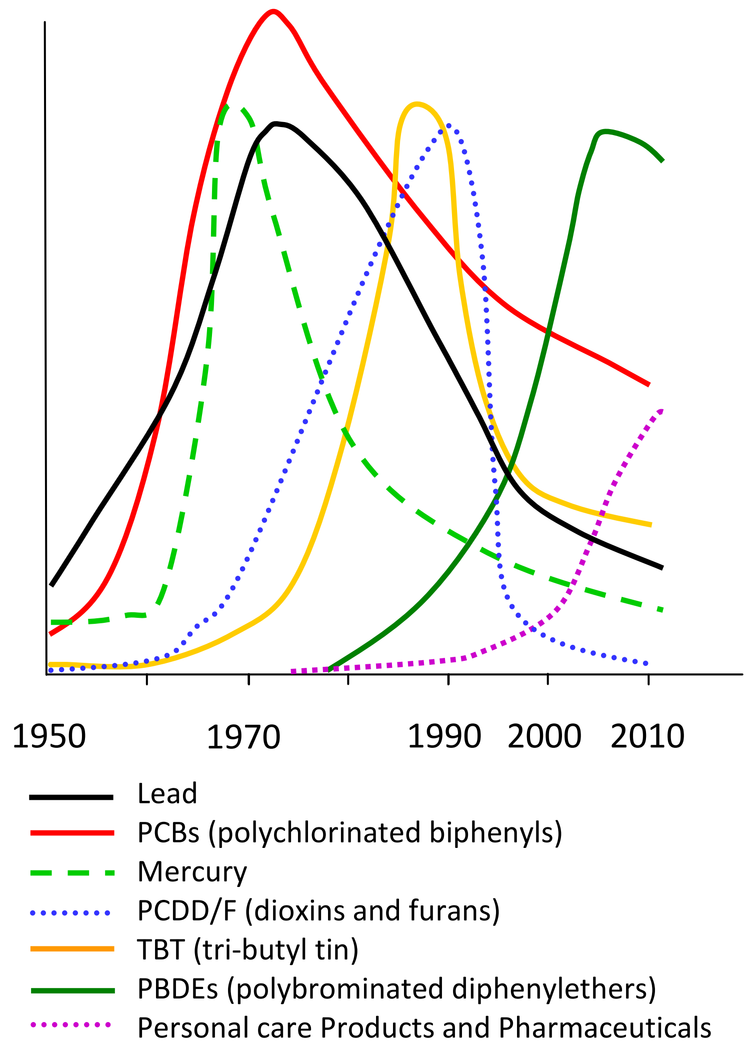
Source: Data obtained from D. Mackas and M. Galbraith, IOS, DFO, Sydney, BC (Mackas and Galbraith pers. comm. 2010)

Relative of other factors examined in our review, changes and variation in the biophysical conditions associated with cool or warm years (Map 4, 12-A, B, Figure 3) can be widespread and extend over large areas of sockeye habitats and periods of habitat use for both juvenile and adult life histories. In some seasons or years, changes in biophysical conditions and resulting sockeye preferred food availability, as demonstrated by patterns of abundance in copepods and euphausiids, can be expected to have profound positive or negative effects on sockeye growth and production. The physical water properties in the Strait will have direct influence and impact on changes and variation to higher trophic levels including phyto and zooplankton, larval invertebrates and fish as food for sockeye, other plankton feeding competitors and piscivorous predators.

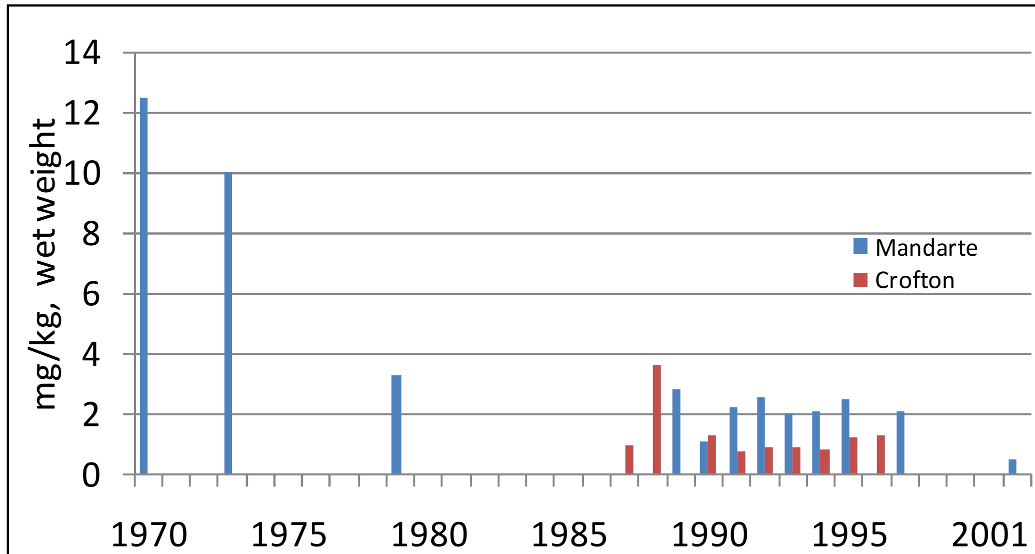
Data from Mackas and Galbraith (pers. comm. 2010) showed downward trends from 1990 to the present for spring season (log) biomass of large copepods (3-7 mm length), medium copepods (1-3 mm), and adult euphausiids in the Strait. Although 2007 data were obtained with different sampling methods, they suggest that 2007 zooplankton abundance represented near low levels across already lower abundance during the past decade.

Sub optimal sockeye habitat conditions in warmer years can lead to slower growth through changes in the availability of, or reduced preferred sockeye food abundance (Mackas et al. 2007), altered migration routes (Blackbourn 1987, Peterman et al. 1994), higher levels of predation (Beamish and Neville 2001) and pathogen and parasite exposure and directly impact sockeye survival. Cooler years in the Strait of Georgia are expected to comprise habitats with higher abundance and availability of preferred (larger sized, higher energy content) sockeye prey and lower levels of competitors and predators. Juvenile sockeye will experience greater sensitivity to changes in the biophysical habitats characteristics relative to adult sockeye, due to higher proportionate use of northern strait habitats and migration routes (Groot and Cooke 1987), small size (i.e. Beamish and Mahnken 2001) and altered swimming speeds (both juvenile — Peterman et al. 1994, and adults — i.e., Thomson et al. 1992) which can limit foraging opportunities (Beacham 1986, Preikshot et al. 2010) and enhance vulnerability to predators (i.e., Gregory and Levings 1998, Beamish and Neville 2001, Beamish and Mahnken 2001, Beamish et al. 2010, Irvine et al. 2010, Trudel et al. 2010).

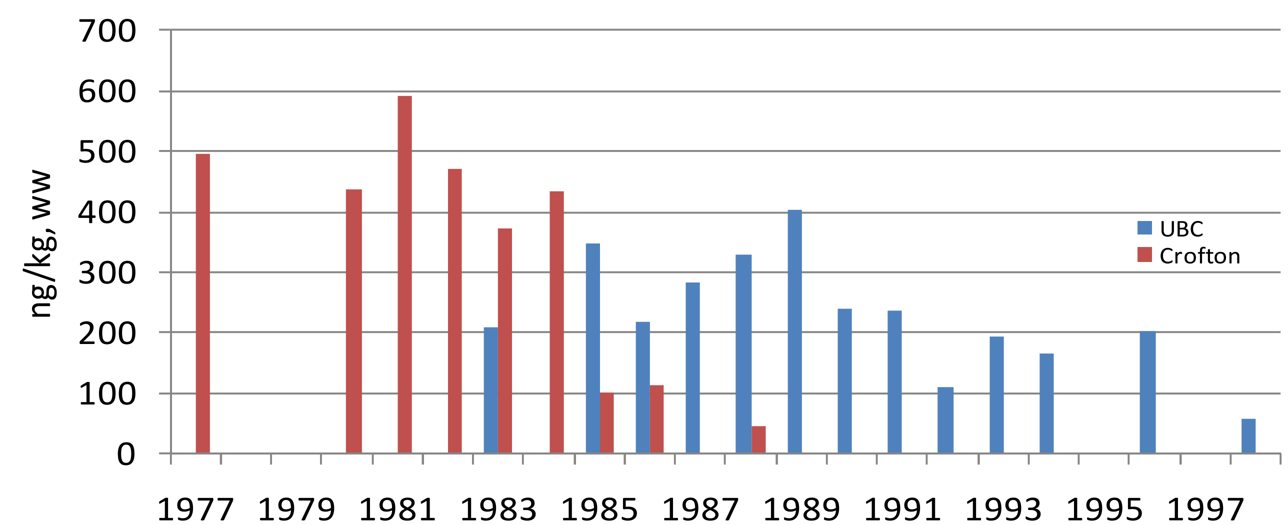
Map 13-A: Contaminants in the Strait of Georgia



Redrawn from Johannessen et al. 2008, and Johannessen and Macdonald 2009



Concentration of total-PCBs in double-crested cormorant eggs collected from the two long-term monitoring colonies located in the Strait of Georgia (Source: Harris et al. 2005).

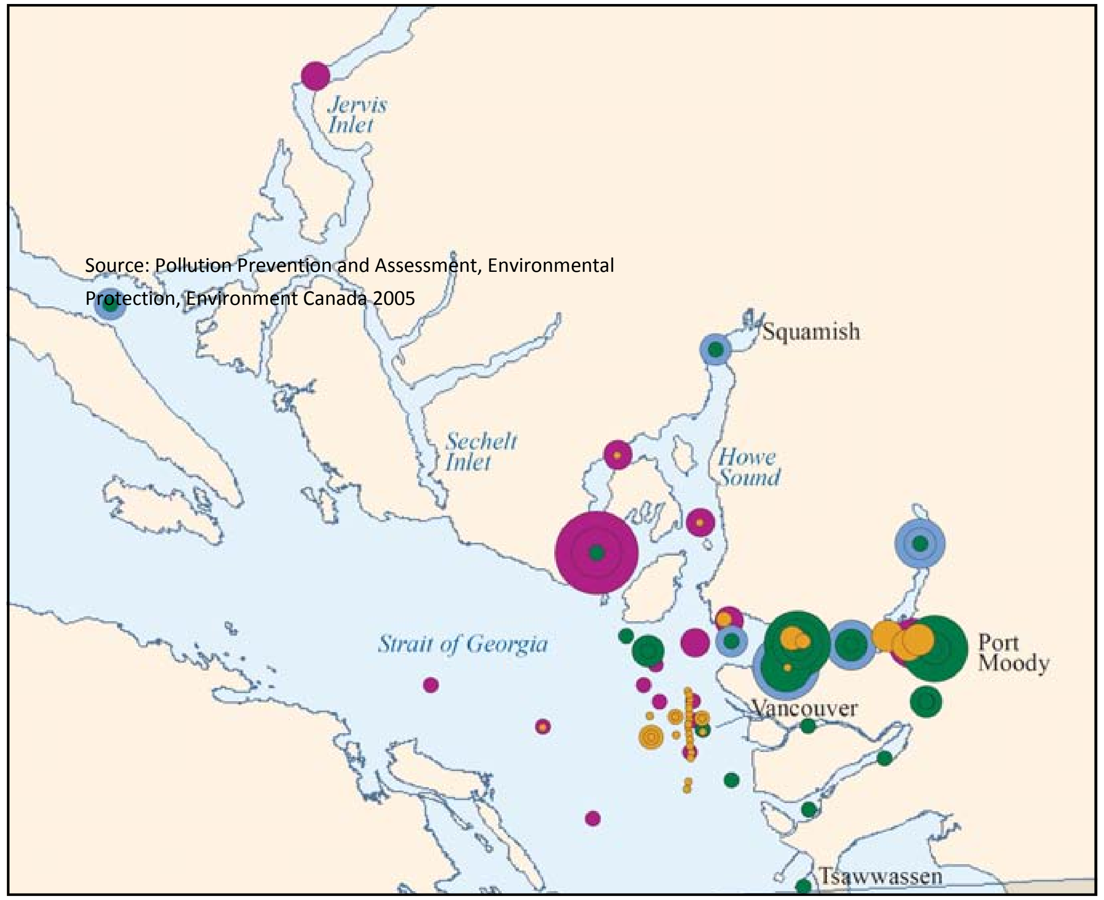


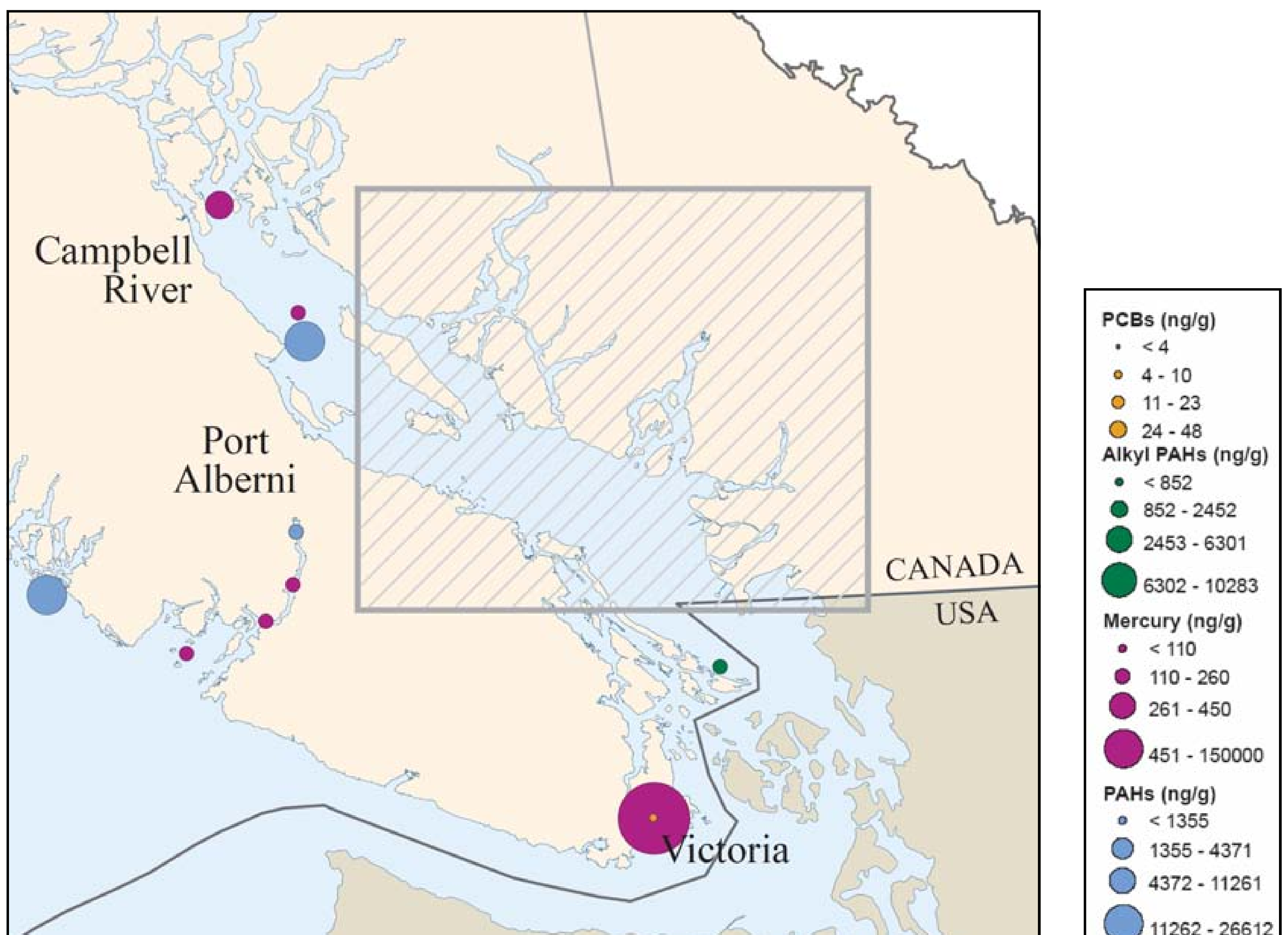
Concentrations of PCBs, PCDDs, and PCDFs in heron eggs are displayed as toxic equivalent concentrations (TEQs) collected from the two long-term monitoring colonies in the Strait of Georgia (Source: Elliott et al. 2001)

Contaminants enter and are distributed in the Strait of Georgia through local industry and municipal discharges and long range transport from the Fraser River and ocean mixing. Urban and industrial activities in the Strait have resulted in a history of contaminants (metals, organic pollutants and other chemicals) observed in the marine sediment core records. These contaminants show a general decreasing trend over time in many organisms including marine birds, presumably as a result of decreases associated with discharge effluent regulation, improved treatment, remediation of contaminated sites, and other initiatives. In contrast, there appears to be an increase in polybrominated diphenylethers (PBDEs) associated with increased use over the past decade or two and an apparent increase in contaminants associated with personal care and pharmaceutical products. The production and use of PBDEs has been banned in Canada and several other countries, but they are still present in fabrics (curtains, furniture, carpeting) and electronics.

Great blue herons (*Ardea herodias*), double-crested cormorants (*Phalacrocorax auritus albociliatus*), and pelagic cormorants (*P. pelagicus resplendens*) can be used as indicators of the health of the Strait of Georgia marine environment because they primarily feed on small forage fish whose contaminant levels can reflect local conditions. In addition, populations of herons and cormorants along the coast of BC are resident year-round and do not migrate outside the region and can provide an indication of the level of contaminant exposure to local sources of contaminants. Temporal patterns in environmental contamination can be evaluated by measuring contaminant concentrations in heron and cormorant eggs. Since great blue herons and cormorants predominantly feed on small fish, changes in the amount of contaminants entering the marine food chain are rapidly reflected in contaminant levels in their prey, and subsequently in their eggs. Observation from long term records maintained by Environment Canada indicate:

- Concentrations of PCBs and DDE (and other dominant OCPs) in great blue heron and double-crested cormorant eggs collected from the Strait have declined and stabilized since the late 1970s(Harris et el. 2003, 2005, Elliot et al. 2005);
- Concentrations of TEQs (from PCDDs and PCDFs in particular) in great blue heron eggs collected from the Strait of Georgia have declined since the 1990s.



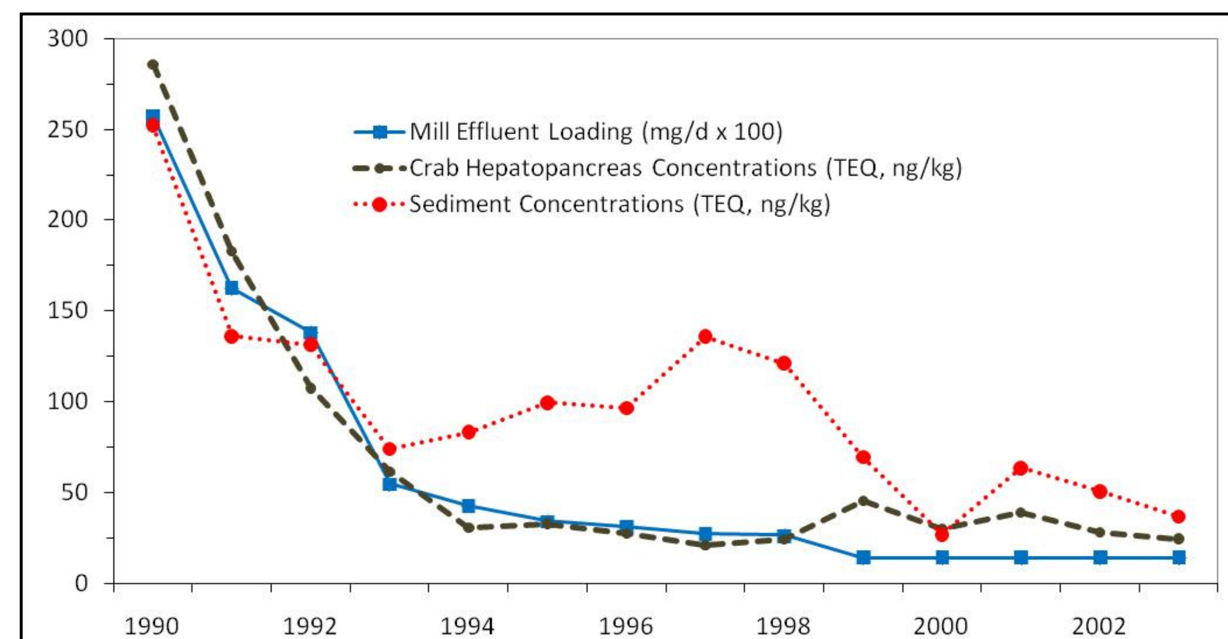


Map 13-B: Water Quality in the Lower Fraser River and Strait of Georgia

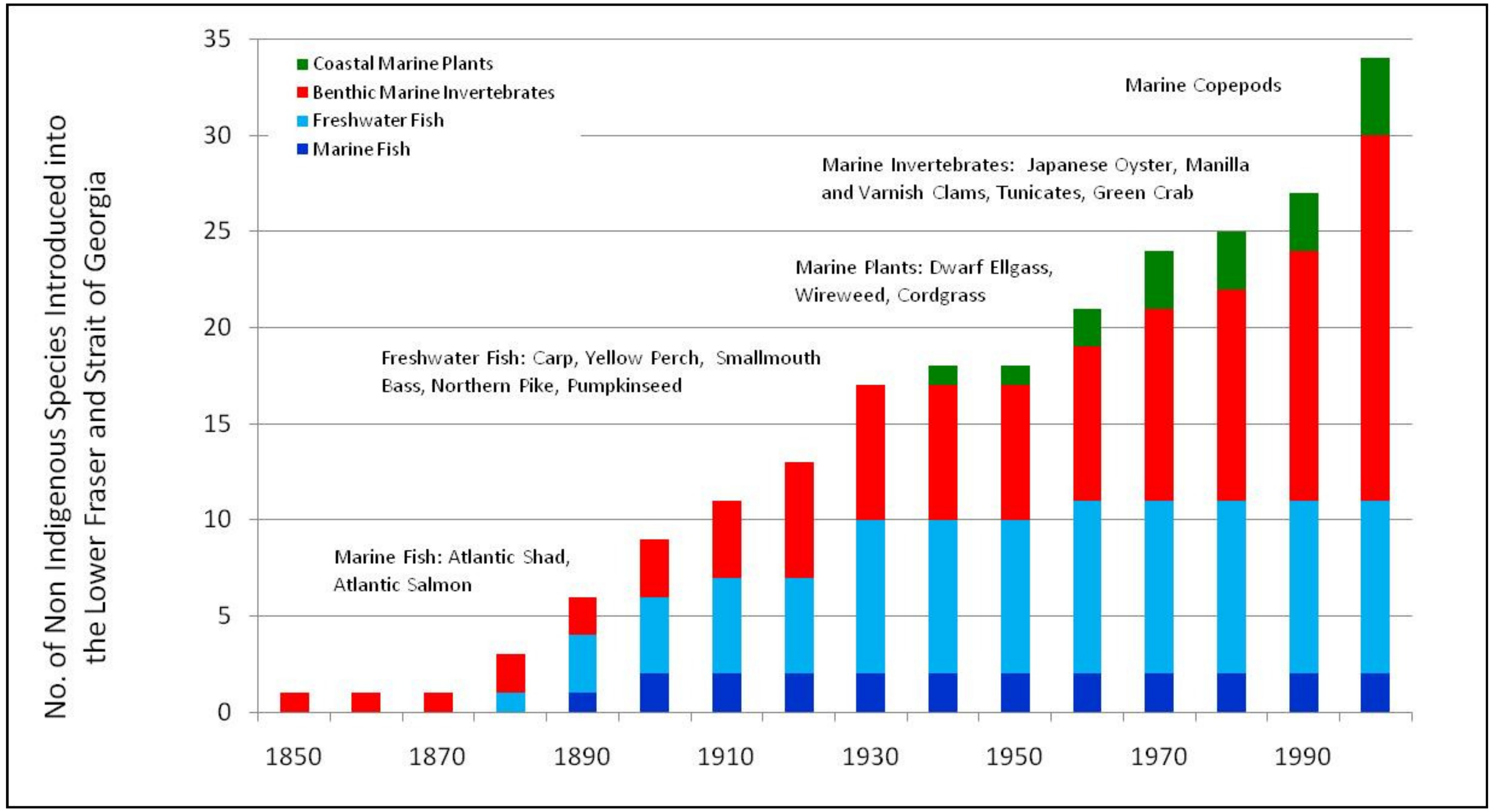
Six pulp and paper mills have operated on the shores of the Strait of Georgia during the period from 1990 to 2010; Squamish (Woodfibre) and Elk Falls closed in 2006 and 2010 respectively.

During the 1970s and 80s, these six mills were major sources of nutrients and contamination of the Strait's coastal marine environment because they discharged large volumes of process effluents that contained pulp and bleaching chemicals including dioxins and furans (MOE 2006c). Stronger regulation and process improvement were implemented in the 1980's and have resulted in more than 100-fold reductions in loads of dioxins and furans in mill effluent. These reductions resulted in almost simultaneous reductions in levels of these compounds in crabs. Contaminant concentrations have shown a decline in sediments and accumulation in marine species monitored including crabs and birds (herons and cormorants—Map 13-A).

Source: MOE 2006c: British Columbia Coast and Marine Environment Project 2006: Industrial Contaminants. Ministry of the Environment, Vancouver.



Map 14: Non Indigenous Species in the Lower Fraser River and Strait of Georgia



Non Indigenous Species Introduction Pathways	
Aquaculture (Accidental)	13
Aquaculture (Introduced)	5
Natural Dispersal	5
Hull Fouling	4
Ballast Water Exchange	2
Recreational (Introduced)	4

Data sources: Gillespie et al. 2006. Sanderson et al. 2009, Tovey et al. 2008, Bradford et al. 2008a,b.

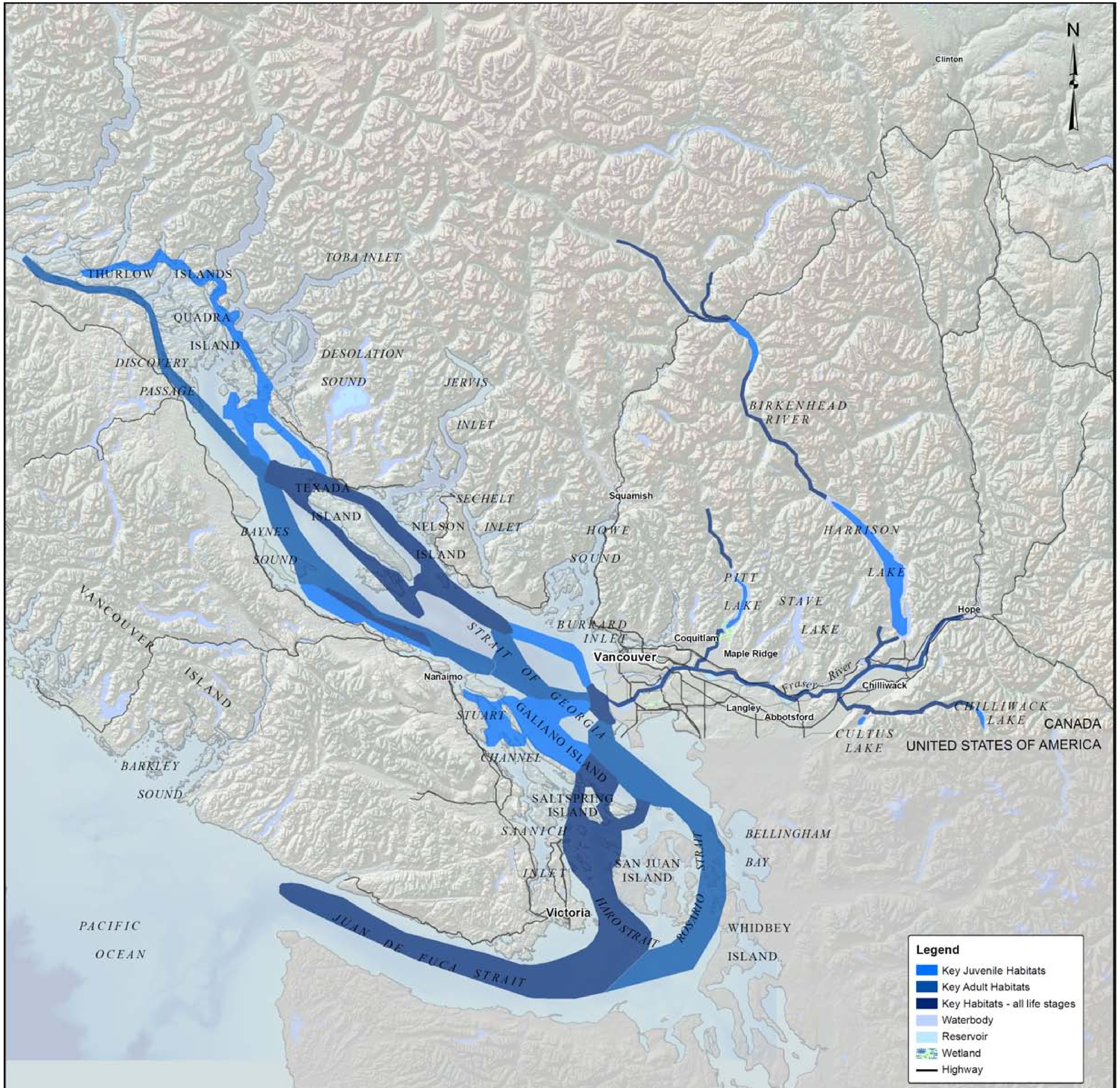
The largest proportion of known introductions of NIS species in the Strait of Georgia and lower Fraser River has occurred in the marine inter and subtidal benthos during the past two decades. With the exception of intertidal benthos, the number of NIS species in freshwater and marine environments have remained stable from 1990 to 2010.

Source: Data derived from published results including—Sanderson et al. 2009, Gillespie 2007, Gillespie et al. 2006, MOE 2006d, Richoux et al. 2006, Levings et al. 2002, Macdonald et al. 2000, Waldichuk et al. 1994.

The introduction, distribution, growth and survival of non indigenous species (NIS) in the Strait of Georgia and lower Fraser River is associated with potential effects on Fraser sockeye salmon including loss and degradation of habitats, increased competition and predation. Non indigenous species are considered one of the major environmental threats to many listed species at risk and natural ecosystem structure and function.

The Strait of Georgia and the lower Fraser River, support a large number of non indigenous species (NIS), greater than twice the number found elsewhere on the Canada's West Coast (Gillespie 2007). The Strait of Georgia's relatively large number of NIS is a function of the combined effects of its long history of human habitation, concentrated aquaculture (e.g., shellfish and finfish), international shipping (associated with transport through hull fouling and ballast water), local estuarine circulation patterns and seasonal refuge habitats, diversity of colonizable habitats, and proximity to populations of NIS in more southern waters like Puget Sound. The number of invasive species in the strait have increased 40-fold since the 1880s (Gillespie 2007, Levings et al. 2002, Macdonald et al. 2000, Richoux et al. 2006, and Waldichuk et al. 1994). Gillespie (2007) estimates that as of 2007, six plant species and 29 invertebrate species had become established in intertidal habitats in the strait . In addition, another 9 fish species have been introduced into freshwater in the Lower Fraser River and an additional 2 species into the Strait of Georgia. Non indigenous smallmouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*) are active freshwater predators and have the potential to directly effect sockeye salmon survival during early life history growth in nursery habitats in Pitt, Harrison and Cultus Lakes (c.f. Ricker 1933, Bradford et al. 2008a, b, Tovey et al. 2008).

It has been estimated that over 117 non indigenous species (terrestrial and aquatic) have established populations in the Strait of Georgia and lower Fraser or along its shoreline and banks. There is uncertainty about when most of these species arrived or their modes of introduction, however it is suspected that many arrived accidentally or were introduced through aquaculture and smaller numbers through hull fouling and ballast water. For example. some species of the dinoflagellates may have been introduced from vessel ballast water and influence secondary plankton production and sockeye food supply.



Map 15: Key Sockeye Habitats in the Lower Fraser River and Strait of Georgia

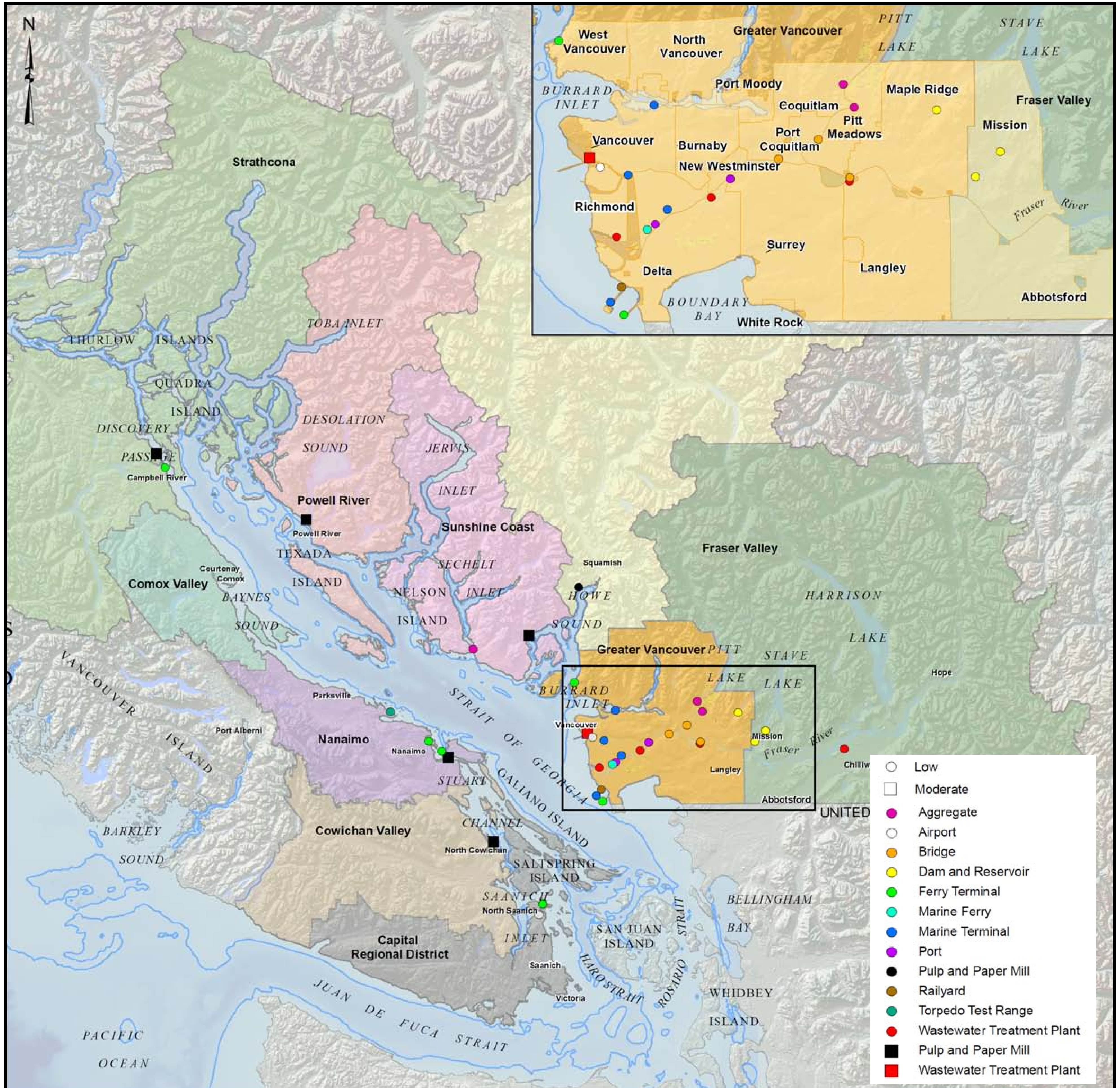
Illustration of key sockeye habitats was based on known distribution and residence period in a general habitat derived from existing literature, site specific catch or monitoring data reports and available georeferenced spatial information. Key habitats and habitat use were mapped as those having medium and high habitat use based on results for juvenile (Map 3-A-i; B-i; C-i) and adult (Map 3-A-ii; B-ii; C-ii; 3-D) sockeye.

Sockeye salmon freshwater distribution in the Lower Fraser River, from Hope to the Fraser River estuary, extends to 4 major watersheds including Harrison and Lillooet, Chilliwack, and Pitt Rivers, and so some limited extent the Coquitlam. Sockeye habitats in the Harrison, Chilliwack and Pitt watersheds are used for a residence period of 4 to 6 months by 0+ aged river-type sockeye (Harrison), and 1 or 2 years by lake-type sockeye for spawning, incubation and juvenile nursery rearing in Lillooet, Harrison, Chilliwack Cultus and Pitt lake areas . The 160 km portion of the lower Fraser River and estuary is used as a migratory pathway for smolts and adults with a residence period of often less than one week.

River-type sockeye aged 0+ originating from Harrison Lake (Harrison rapids) use various sloughs and off channel areas in the lower Fraser River above the tidal area, for rearing for a period of 2 to 6 months (Appendix 3). The Harrison river-type sockeye fry are small sized and rear / migrate slowly out of the Fraser River and estuary across the Strait of Georgia to use rearing habitats around the southern Gulf Islands for a residence period of 4 to 6 months. Harrison river-type sockeye juveniles were observed in the Juan De Fuca Strait and west coast Vancouver Island in February through June , one year after emergence.

Larger sized sockeye post smolts (juveniles) from the upstream mixed Fraser sockeye stock (Chilko, Stuart, Adams etc) have a short residence period (< 2 days) throughout the Fraser estuary and use a northern migration route through the Strait of Georgia to Queen Charlotte Sound ranging from 20 to 30 km / day in travel speeds. Specific eastern (preferred) and western migration routes and residence periods in specific habitats varies based on swimming speed, sockeye size, prevailing winds, surface currents, heterogeneity of plankton prey and general cool / warm biophysical characteristics of the Strait of Georgia. The residence period across the Strait of Georgia ranges from April to August with limited use in September and highest use in May and early June.

Adult sockeye use two alternative migration routes through the Strait of Georgia including a southern route through Juan De Fuca Strait, with holding areas above the southern Gulf Islands and Fraser plume and estuary, and a second northern diversion route through Johnstone Strait and Discovery Passage along an western route in the Strait of Georgia to holding areas in the Fraser plume and estuary. Migration residence periods for an individual migrating adult are often less than 1 month in the Strait of Georgia and lower Fraser River.

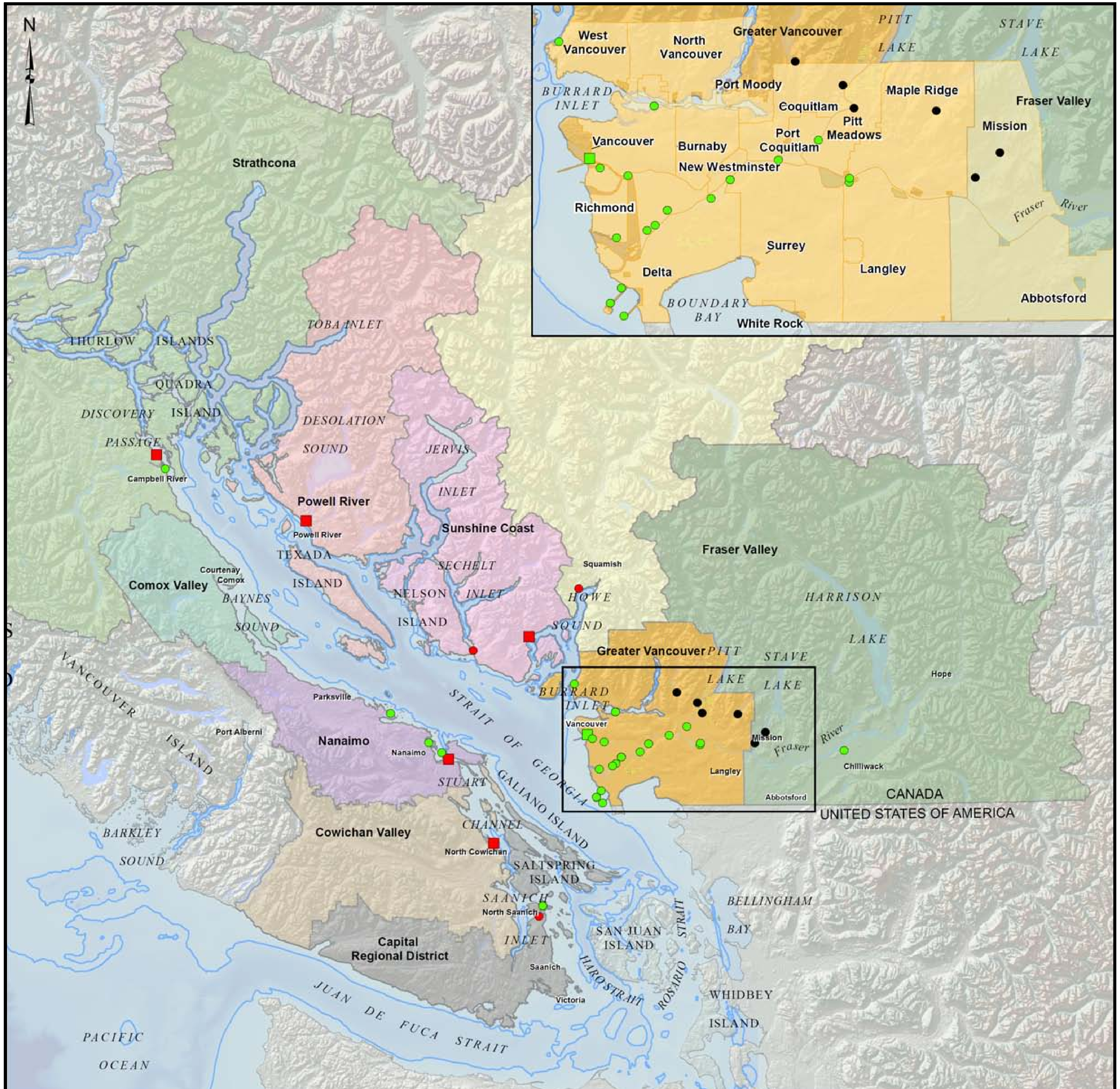


Map 16-A: Potential Interaction between Large Industrial and Public Projects, Sites and Infrastructure in the Lower Fraser River and Strait of Georgia with Key Fraser Sockeye Salmon Habitats

Human development across the Georgia basin has seen large changes in population size and density in urban centres. Most of the population and project development is centred in the lower mainland and south-eastern Vancouver Island. Changes in population reflects increasing pressures on the environment because of the potential for higher levels of residential and industrial water use and pollution, nutrients and contaminants from wastewater and runoff, conversion of vegetated lands (natural, forests, agricultural) to urban and industrial areas.

During that same time, environmental management programs have been in place to curb and manage runoff and human related discharges. Contaminants in the Strait of Georgia show a general improvement over time, with decreases associated with effluent regulation and improved treatment in recent years.

The physical construction of development projects adjacent to sockeye habitats has also been regulated over the period of study and there is evidence that habitat conservation efforts, through regulatory review and through restoration of previously impacted habitats, have resulted in habitat gains in the Fraser River estuary over the period of study for this report (1990 – 2010). However, some of the earlier habitat projects, carried out prior to the present period of study, were not successful at achieving "no net loss" of fish habitat. There is evidence that information learned from those projects has been incorporated into successful compensatory designs on contemporary projects in the Fraser estuary, underlining the importance of continued scientific learning regarding habitat ecology.



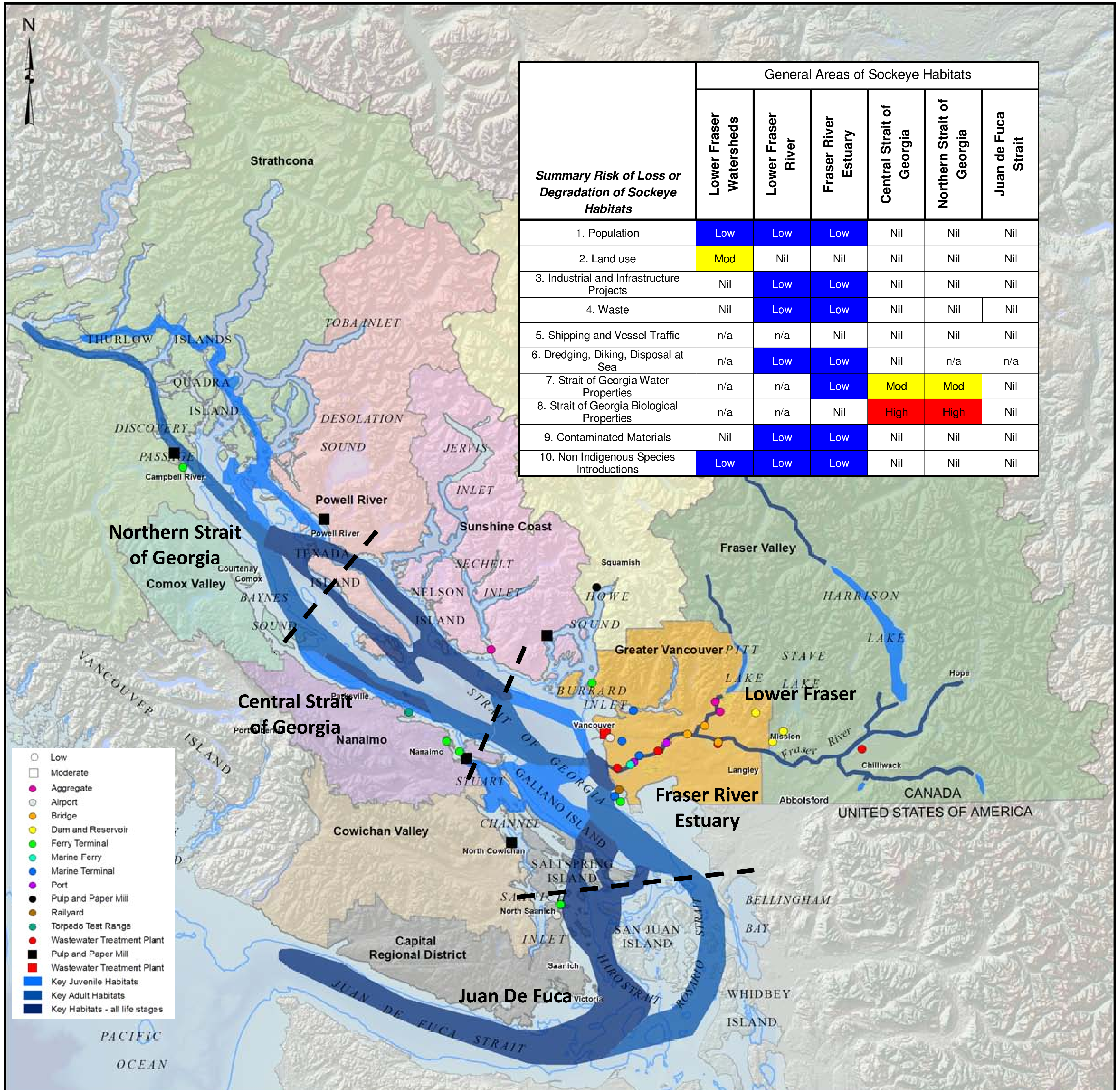
Map 16-B: Potential Interaction between Large Industrial and Public Projects, Sites and Infrastructure in the Lower Fraser River and Strait of Georgia with Key Life History Based Fraser Sockeye Salmon Habitats

Changes in the level of human activity in the lower Fraser River and Strait of Georgia were compared against spatial and temporal habitat use by Fraser River sockeye salmon to evaluate the potential past, current and future risk of loss or degradation to juvenile and adult Fraser sockeye salmon habitats as a result of these activities. The risk of loss or degradation of sockeye habitats is used here as a qualitative (ordinal) metric and provides one approach to classify the current and / or future change or impacts to sockeye habitats based on interaction or overlay with factors used to express changes in human activities in the lower Fraser River and Strait of Georgia. Potential interactions were reviewed over the 1990 to 2010 period across six general habitat areas.

A classification was first applied to potential interactions between human activities, identified as “factors”, and sockeye habitats generalized to six areas. A classification of “likely”, “limited” or “nil” was assigned to define the interaction. Where interactions were identified either as being “likely” or “limited”, they were further ranked to assign a level of interaction between that human activity and sockeye habitats. This ranking was based on the extent of geographic overlap, magnitude of the interaction and duration of effects used as interaction criteria between human activity and overlap with sockeye habitats (Table 1). The level of interaction between human activities and habitat areas were evaluated across an ordinal scale from nil, low, moderate or high level of interaction. A summary ranking combined predicted geographic, magnitude and duration effects to an overall level of past, current and potentially future risk of loss or degradation (interaction and overlap) of juvenile and adult (Table 2) sockeye habitats associated with human development and activities. Rankings for each of the six general habitat areas were assigned through a combination of expert opinion, the results for the factor being evaluated and an overall ranking based on the interaction criteria (Table 1). Ranks assigned to the potential for loss/degradation of sockeye habitat from human activities over the 1990 to 2010 period are detailed in Table 2 and 4, and summarized in Map 17.

- ● Low - freshwater juvenile and adult sockeye habitats
- ● Low - marine juvenile sockeye habitats
- ● Low - marine juvenile and adult sockeye habitats
- ■ Moderate - marine juvenile sockeye habitats
- ■ Moderate - marine juvenile and adult sockeye habitats

Map 17: Potential Risk of Loss or Degradation of Sockeye Habitats in the Lower Fraser River and Strait of Georgia



Summary Risk of Loss or Degradation of Sockeye Habitats	General Areas of Sockeye Habitats					
	Lower Fraser Watersheds	Lower Fraser River	Fraser River Estuary	Central Strait of Georgia	Northern Strait of Georgia	Juan de Fuca Strait
1. Population	Low	Low	Low	Nil	Nil	Nil
2. Land use	Mod	Nil	Nil	Nil	Nil	Nil
3. Industrial and Infrastructure Projects	Nil	Low	Low	Nil	Nil	Nil
4. Waste	Nil	Low	Low	Nil	Nil	Nil
5. Shipping and Vessel Traffic	n/a	n/a	Nil	Nil	Nil	Nil
6. Dredging, Diking, Disposal at Sea	n/a	Low	Low	Nil	n/a	n/a
7. Strait of Georgia Water Properties	n/a	n/a	Low	Mod	Mod	Nil
8. Strait of Georgia Biological Properties	n/a	n/a	Nil	High	High	Nil
9. Contaminated Materials	Nil	Low	Low	Nil	Nil	Nil
10. Non Indigenous Species Introductions	Low	Low	Low	Nil	Nil	Nil

Summary ranks were derived through consideration of the level of significance expressed across interaction criteria (Table 1) for each human activity factor (Table 2, 4) assigned to the potential for loss/degradation of sockeye habitat from human activities over the 1990 to 2010 period. Professional judgement was used to review final summary ranks to the extent of the space and time interaction and overlap for each human activity factor relative of the area and timing of sockeye habitat use. Factors used to express changes in human activities werepresented in Maps 5 to 14 and used to evaluate the extent of spatial or temporal overlap (Maps 16-A, 16-B) with key sockeye habitats (Maps 3, 4 and 15).

Increasing population size, urban density, industrial and infrastructure development and associated land use and waste as factors in the decline of Fraser sockeye were ranked as having low to moderate potential for impacts on juvenile and adult sockeye habitats in the lower Fraser River and adult sockeye habitats in the Fraser estuary. As a result of regulatory pressures and technological changes and despite population growth, solid waste, wastewater, contaminants and non indigenous species introductions appear to have remained mostly stable over the time covered by this review, in contrast to Fraser sockeye production which has declined. Changes in urban and rural land use have implications on increased sediment and erosion, nutrient, contaminant and stormwater runoff which could affect sockeye habitat use in the lower Fraser River, particularly in habitats used in locations off of the main channel.

In many areas where human activities and development are concentrated, sockeye often have limited residence periods in adjacent habitats. Historically (i.e., over the past century), many human activities may have had moderate to severe effects on sockeye habitats, but these impacts have not been generally observed during the last 2 decades and importantly, these impacts have not been observed to coincide with the decline of the Fraser River sockeye. The human activities often exhibited limited spatial and temporal (duration, timing) overlap with spatial and temporal sockeye habitat use. In a number of instances, additional regulatory controls (agricultural and forestry practices, shipping, ballast discharge, regulatory review of project development, non indigenous species introductions), improvements to industrial and municipal practices (solid and liquid waste management), and management regimes and protocols (urban development, agricultural and forestry practices, project development, dredging, dikes) have resulted in reduced or declining potential effects and reduced interactions and risk of loss or degradation of existing sockeye habitats relative to periods prior to the last two decades.