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Canadian Juvenile Salmon Surveys in 2012-2013

by

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1.0. INTRODUCTION

Pacific salmon have a complex life cycle that involves a freshwater phase for spawning and rearing, as well as an ocean phase where they spend the greater part of their lives and gain the bulk of their mass and energy necessary for successfully completing their spawning migration (Groot and Margolis 1991). Pacific salmon experience heavy and highly variable losses in the ocean, with natural mortality rates generally exceeding 90-95% during their marine life (Bradford 1995). Most of this mortality is thought to occur during two critical periods: an early predation-based mortality that occurs within the first few weeks to months following ocean entry and a starvation-based mortality that occurs following their first winter at sea (Beamish and Mankhen 2001). Hence, Canada currently maintains two research programs on the marine biology of Pacific salmon to understand the processes regulating Pacific salmon production in the marine environment, the interactions between wild and hatchery-reared salmon, the impacts of ocean conditions and climate change on marine ecosystems and salmon resources, and to provide a sound scientific basis for optimizing hatchery production. Thus, an offshore program conducts research off the west coast of British Columbia and Southeast Alaska, and an inshore program works in the Strait of Georgia and Puget Sound. In this document, we present the juvenile salmon research surveys that have been planned in Offshore and Inshore areas by Canada for 2012-2013.

2.0. JUVENILE SALMON RESEARCH SURVEYS

2.1. OFFSHORE AREAS

The Canadian Program on High Seas Salmon has been conducting integrated epipelagic ecosystem surveys from the west coast of British Columbia to Southeast Alaska since 1998 to assess the effects of ocean conditions and climate change on the distribution, migration, growth and survival of Pacific salmon, and to forecast salmon returns to British Columbia (Beamish et al. 2007; Appendix A). These midwater trawl surveys are usually conducted in late spring-early summer (June-July) and in the fall (October-November). In addition, these surveys have been conducted during winter (February-March) since 2001 to assess the effects of winter conditions on the ecology, bioenergetics, and survival of juvenile salmon (Trudel et al. 2007a).

The working hypothesis of this research is that fast growth enhances the marine survival of salmon, either because fast growing fish quickly reach a size that is sufficiently large to avoid predators (Holtby et al. 1988; Pearcy 1992), or because they accumulate enough energy reserves to better survive their first winter at sea, a period generally considered to be critical in the life cycle of salmon (Beamish and Mahnken 2001; Beamish et al. 2006). The comparative approach is used to relate changes in salmon growth and bioenergetics to ocean conditions in two contrasting ocean domains: the west coast of Vancouver Island is located at the north end of the California Current System and is affected by upwelling, whereas Southeast Alaska is located in the Alaska Coastal Current and is affected by downwelling (Ware and MacFarlane 1989). In general, sea surface temperature, phytoplankton and zooplankton biomass are higher off the west coast of Vancouver Island (Ware and Thomson 2005).

Three surveys have been planned by the Canadian Program on High Seas Salmon for 2012-2013: a summer survey on June 15 – July 3, 2012, a fall survey on October 1 – November 3, 2012, and a winter survey on February 28 – March 24, 2013. The primary objectives of these surveys will be to (1) collect biological information on Pacific salmon

(*Oncorhynchus* spp.) and associated epipelagic fish community, (2) describe the ambient oceanographic conditions, and (3) quantify the biomass of zooplankton and describe zooplankton species community composition in coastal waters of British Columbia and Southeast Alaska.

2.1.1. GENERAL SURVEY INFORMATION

The summer survey will conduct scientific operations primarily on the continental shelf off the west coast of Vancouver Island, in Queen Charlotte Sound, Hecate Strait, Dixon Entrance, Southeast Alaska, and off the west coast of the Queen Charlotte Islands (Table 1; Figure 1). The dates for this survey are currently tentative, as this survey will be conducted using a fishing vessel that will be chartered later this year. As a consequence, the number of berths available for this survey is currently unknown.

The fall and winter surveys will conduct scientific operations on the continental shelf off the west coast of Vancouver Island, in Queen Charlotte Sound, Hecate Strait, Dixon Entrance, Southeast Alaska, and off the west coast of the Queen Charlotte Islands, as well as the inlets of the west coast of Vancouver Island, central British Columbia, and straits of Southeast Alaska (Table 2-3; Figure 2). These surveys will be conducted using the *CCGS W.E. Ricker*. Additional scientists can be accommodated for these surveys, pending security clearance.

2.1.2. FISHING GEAR AND FISHING OPERATION

The research vessel will tow a mid-water trawl, originally manufactured by Cantrawl Nets Ltd., Richmond, BC, and later modified to a model 240 trawl by the fishing crew, for 30 minutes. The trawl has a heavy-duty front end of hexagonal web made from 3/8 in. (9.5 mm) and 5/16 in. (7.9 mm) Tenex rope, and a tapered body made-up of 64 in. (163 cm), 32 in. (81.3 cm), 16 in. (40.6 cm), 8 in. (20.3 cm) and 4 in. (10.2 cm) polypropylene sections, an intermediate section of 3 in. (7.6 cm) polypropylene, and a codend of 1.5 in. (3.8 cm) knotted nylon lined with 0.25 in. mesh (64 mm). The trawl has three 40 m bridles of 5/8 in. (1.6 cm) wire rope per side that are attached with a single hook-up to 5 m Jet doors. Typically, 100-150 m of 1.25 in. (3.2 cm) warp was paid out to tow the trawl at the surface. The trawl is towed at the surface at 5 knots (2.6 m s^{-1}) in good sea conditions, and this typically achieved a mouth opening that was approximately 28 m wide by 16 m deep as measured acoustically by a Scanmar trawl eye mounted on the headrope. In rough weather, the trawl is towed at headrope depths down to 15 m.

The fish samples are sorted by species, enumerated, and measured onboard the ship to characterize the nekton community in epipelagic waters of British Columbia and Southeast Alaska (Brodeur et al. 2006; Orsi et al. 2007). All the juvenile coho and Chinook salmon are systematically scanned for coded-wire tags, irrespective if their adipose fin has been clipped or not, as not all the tagged fish are clipped (Morris et al. 2005). For juvenile salmon, we will also take a skin sample from the operculum using a hole-punch and preserved in 95% ethanol to determine their stock of origin using microsatellite DNA (Beacham et al. 2001, 2005, 2006) and remove calcified-structures (i.e. scales and otoliths) for age determination. Stomach contents of juvenile salmon will also be removed, weighted individually, and pooled by species and tow for dietary analyses (Brodeur et al. 2007). A subsample of the catch is preserved frozen individually at –20ºC for various chemical and calorimetric analyses such as stable isotopes, and to examine their stomach contents.

Biological data collected for each salmon will include species common name, fork length, total length, and observed fin clip. It will also include, when available, whole body weight (g wet), sex, stomach content weight (g wet), % water that is based on the ratio of dry to wet whole body weight, coded wire tag number, and pit tag number. Age separation is generally determined based on examination of fork length distributions, that showed non-overlapping size modes for chum, coho, pink, and sockeye salmon (Trudel et al. 2007b). For Chinook salmon, we used a combination of coded-wire tag recoveries of known-age fish and DNA analyses to establish size-classes to separate juveniles from adults, and life history types (Fisher et al. 2007; Trudel et al. 2007c), as there is considerable overlap among size modes that represent the multiple age groups.

2.1.3. OCEANOGRAPHIC SAMPLING

At oceanographic stations, the scientific crew will (1) conduct CTD (conductivity-temperature-depth) casts, (2) collect seawater samples at 10 m from the surface with a Niskin bottle for nitrate, phosphate, silicate, and salinity, and (3) filter surface seawater on GF/F glass fibre filter disks for chlorophyll a. Nitrate, phosphate, and silicate samples will be collected in acid-washed glass test tubes, whereas the glass fiber disks will be folded and placed in polypropylene scintillation vials. All these samples will be stored frozen. CTD casts will be conducted to 250 m or within 5 m of the bottom with a Seabird SBE 911+ probe. Several calibration samples from selected CTD casts will be collected over the course of the survey with Niskin bottles at depths where the salinities are stable. The oceanographic data collected in these surveys will be stored on a database maintained at the Institute of Ocean Sciences (Sidney, British Columbia).

2.1.4. ZOOPLANKTON SAMPLING

Vertical bongo tows to approximately 150 m or within 10 m of the bottom will be conducted with two 57 cm diameter, 253 μm Nitex nets. One of the nets is equipped with a flowmeter. Zooplankton collected from the flowmeter side will be preserved in 10% formalin and sent to the zooplankton laboratory at the Institute of Ocean Sciences, Fisheries and Oceans Canada (Sidney, BC) for species classification and enumeration. Zooplankton taken from the net without flowmeter will be sorted into four size fractions by successively sieving through 8.0, 1.7, 1.0, and 0.25 mm screens. Each size fraction will then be weighed wet, dried at 60ºC for 48 hours, re-weighed, and stored in plastic bags for future stable isotope, bomb calorimetry, and proximate analyses. The zooplankton data collected in these surveys will be stored on a database maintained at the Institute of Ocean Sciences (Sidney, British Columbia).

2.2. INSHORE AREAS

The Canadian Program on Neashore or Coastal Salmon Investigations has been conducting intensive ecosystem surveys in the Strait of Georgia and surrounding inlets, since the early 1990s. The purpose of these surveys has been to determine the size, distribution, diets, mortality and migration of juvenile salmonids in this unique rearing area and the impact of climate change on these variables. These epipelagic ecosystem surveys were initially conducted with beam trawls, but in 1998 the program switched to midwater trawls, as it was determined we could achieve higher towing speeds, conduct research in more inclement weather conditions, and tow at sub-surface depths (Beamish et al. 2000). Since 1998, the surveys in the Strait of Georgia have been conducted in early summer (June-July) and in the early fall (September-October), following an established track line (Figure 3). We also began to conduct research in Queen Charlotte Strait, Puget Sound, Juan de Fuca Strait and the west coast of British Columbia. Work in Puget Sound is in cooperation with the Washington Department of Fish and Wildlife and involves several of their personnel joining us (eg., J. Anderson, G. Bargmann) as well as colleagues from the University of Washington (D. Beauchamp, L. Duffy).

The working hypotheses of our research in the Strait of Georgia are, as noted earlier, twofold. First, the primary goal of juvenile Pacific salmon entering the ocean is to grow as quickly as possible, thus enhancing their marine survival (Holtby et al. 1988; Pearcy 1992). This enhanced survival may be achieved either by larger fish avoiding predation via enhanced swimming speeds and/or by discouraging predation by merely being larger than predators can easily manage. Shifts in size may also result in shifts in diet and/or diet availability (eg., piscivory in juvenile Chinook). Secondly, salmon surviving the initial 2-4 months in the marine environment shift from a primarily growth status (in the late summer) to one of energy accumulation, to better survive their first winter at sea (Beamish and Mahnken 2001). The current trend in the literature continues to support both of these hypotheses, which are not exclusive with each other. The timing of our seasonal surveys in the Strait of Georgia was established to assess the early marine growth and survival of Pacific salmon, particularly for Chinook and coho salmon which, in the 1990s, had declined dramatically from earlier levels. As well, we investigated the timing of migration away from these nearshore nursery areas in the Strait of Georgia and Puget Sound to the overwintering areas (west coast of Vancouver Island for coho and Chinook stocks; North Pacific for chum, pink and sockeye salmon). Data from these juvenile surveys have also been successfully used in forecasting adult returns, and that for coho salmon has been included in the regional forecast documents (PSARC/CSAP) for several years.

Two surveys have been planned for the Strait of Georgia program for 2012: a summer survey, running from June 19 – July 16, 2012, and an early fall survey from September 11 – October 1, 2012. The primary objectives of these surveys will be to (1) collect biological information on juvenile Pacific salmon (*Oncorhynchus* spp.) and the associated fish community, (2) collect information on ambient oceanographic conditions, and (3) collect DNA samples for stock identification purposes. Recent research by our group has shown strong seasonality in location and abundance of Chinook stocks within the Strait of Georgia. This variability appears to be related to types of life history strategies, ie., ocean-type vs stream-type. A similar strategy appears to be promoting the higher survival exhibited by Harrison River sockeye, one of the few North American stock that enters the ocean as fry rather than smolts

2.2.1. GENERAL SURVEY INFORMATION

Both the summer and fall surveys will conduct scientific operations primarily in three main areas. First, both surveys will begin and end with 3 day surveys of the Gulf Islands region, an area bounded by Vancouver Island on the west side and an archipelago of islands on the east side, separating these water from the Strait of Georgia proper (Figure 3). The second stage is our normal survey of the Strait of Georgia, typically requiring 9-10 days. In addition to the strait itself, we typically sample some of the major mainland inlets – Bute/Toba Inlet to the north, Jervis Inlet in the mid-strait area and Howe Sound in the southern portion. Note that there are no major inlets on the western side of the Strait of Georgia (Vancouver Island). The third stage is in the Puget Sound area. This generally involves fishing both north and south of Seattle, but not in the South Sound area on a regular basis. We have done some work in Hood Canal the past three years, but are not planning to do so this year. We are, however, hoping to fish down the mainland side of Boundary Bay (Figure 3) and into Saratoga Passage/Port Susan areas north of Seattle. Both the summer and fall surveys will then conduct 2-3 days fishing in Juan de Fuca strait, on both US and Canadian sides. Traffic in both Puget Sound and Juan de Fuca limits these surveys to relatively near shore areas.

Both the summer and fall surveys will be conducted using the *CCGS W.E. Ricker*. As noted earlier, these surveys follow track lines that have been established for at least ten years. As noted for the High Seas salmon surveys, additional scientists are encouraged for these surveys, pending security clearance, which generally requires several months advance effort.

2.2.2. FISHING GEAR, OPERATIONS AND SAMPLING PROCEDURES

The research vessel W. E. Ricker will tow a modified mid-water diamond trawl, originally manufactured by Cantrawl Nets Ltd., Richmond, BC, and later modified to a model 240 trawl by the fishing crew. Sets in the Strait of Georgia, in Juan de Fuca Strait and on the west coast are 30 minutes in duration. Sets in the Gulf Islands and in Puget Sound may be as short as 10 minutes, dependent on densities and/or catch limits established for these areas. Many Chinook stocks in Puget Sound are on the endangered list and some coho and summer chum stocks are currently be assessed for inclusion as well. Work in the Gulf Islands is focussed on Cowichan Bay Chinook, and catches can be high in this restricted area. Furthermore, the average CPUE for chum, coho and Chinook in Puget Sound is often 10-50x that observed in the Strait of Georgia mere days earlier. In the summer surveys, fishing begins at 0600 and continues until 1800, generating 12-14 sets per day (depending on location and size of catch per set). In September, due to the later sunrise timing, fishing begins at 0700 and continues until darkness (1700-1800), generating 10-12 sets per day.

The trawl used in our surveys is essentially the same as described earlier for the High Seas program and both are used as backup nets for each program. The net is towed at the surface at 5 knots (2.6 m s^{-1}) in good sea conditions, typically achieving an opening approximately 32 m wide by 14 m deep (measured acoustically by a Scanmar trawl eye mounted on the headrope). Differences in net sizes between the two programs are due to slight variations in gear structure. Unlike the High Seas program, the Nearshore program routinely fishes at multiple depths throughout the day, although effort is generally weighted to surface tows. As the general net depth at 5 knots is 14-16 meters, we fish in 15m increments: 0, 15m, 30m, 45m, and occasion deeper sets. While the majority of our catch of all species of Pacific salmon is taken at the surface (Beamish et al. 2007), significant numbers (and CPUE) are seen at deeper depths and there are strong species-specific and seasonal trends.

Once the catch is brought aboard, fish are sorted by species into individual totes. A random subsample of 15-20 salmon are immediately measured for fork length (to nearest mm), and weight (to nearest gram, if weather conditions permit), and otoliths removed. If scale samples are required, they are also taken at this time. Stomachs are then opened (from cardiac to pyloric constrictions) and the stomach contents emptied into a Petri dish. Estimates of % fullness, total volume and degree of overall digestion are then made. Finally, the entire stomach contents are broken down into percent contribution by individual prey groups. Dependent on particular items, the level of prey identification is at least to family, but often to the genus level (eg., Sweeting and Beamish 2009, Duffy et al. 2010).

This procedure is repeated for all five species of salmon, if present in the net and if time permits. Fork lengths are then take on the remainder the salmon in the catch. If the catches are too large to measure all the fish, then random subsamples of 60-200 fish are measured. Counts (or volumetric estimates of large catches, N > 500) are then made for the rest of the salmon catch. In this manner, all diets are analyzed within 30 minutes of retrieval. Higher number of coho and Chinook stomachs is examined, but significant numbers of stomachs of all five species of Pacific salmon are examined during the course of any survey. When time permits, stomach of certain bycatch species are also examined (eg., hake, dogfish, Pollock), mainly for the presence of salmon in the stomachs. The diet analyst has been the same trained, qualified person for all of the surveys and is the same individual that performs diet analysis in the laboratory at the Pacific Biological Station (PBS). All bycatch species are identified and lengths recorded. For larger catches of common pelagics (eg., herring), subsamples of fork lengths will be taken and either counts or volumetric estimates made of the rest of the catch. These numbers are critical for understanding the ecosystem as a whole, and how climate changes may impact other species as well as salmonids.

All coho and Chinook salmon are individually scanned for presence of coded-wire tags, and examined for presence or absence of adipose fins. If coded-wire tags are present, then the head/nose is removed, tagged and bagged and brought back for decoding. In Puget Sound, CWTs are retained and decoded by WDFW personnel. Clips of pelvic and pectoral fins, while not as prevalent as in years past, are also recorded. Samples (tail clips) are taken and preserved in 95% ethanol for determination of stock origin using microsatellite DNA (Beacham et al. 2001, 2005, 2006). For gene expression studies in Pacific salmon, in conjunction with K. Miller-Saunders at PBS, a subsample of 5-10 salmon are taken immediately upon retrieval of the catch, with emphasis on the liveliest fish and tissue samples (muscle, brain, liver etc) are then immediately frozen in liquid nitrogen. As with the High Seas program, small independent or university research is also conducted during these surveys, as these surveys provide platforms of opportunity for these non-DFO projects (eg., Beachamp lab in Puget Sound, Lucas Brotz in SoG and WCVI).

2.2.3. OCEANOGRAPHIC AND PLANKTON SAMPLING

Oceanographic data collected during the Coastal Salmon surveys currently consists of CTD data. Our procedure is to conduct three casts per day: prior to fishing, at noon, and at the end of day. The oceanographic data (temperature, salinity, conductivity, oxygen) collected in these surveys are stored on a database maintained at the Institute of Ocean Sciences (Sidney, British Columbia).

We do have archived data collections of plankton catches from bongo tows (both vertical and towed) from selected sites within the Strait of Georgia and Juan de Fuca strait, but personnel and financial restraints have limited this collection in recent years. The bongo sampling procedures are essentially as outlined above for the High Seas program, but without fractionation – the entire collection samples are preserved in 10% formalin. Species classification and enumeration were conducted at the Pacific Biological Station.

The zooplankton data collected during our Strait of Georgia surveys resides at a database at PBS. Chlorophyll data was also collected in the 1990s, but not since 2002.

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Table 1. Tentative summer survey itinerary for the June 15 – July 3, 2012, DFO High Seas Salmon research survey.

Date	General area of operations
June 15	PBS Nanaimo, loading
June 16-23	West coast of Vancouver Island
June 24	Triangle Island
June 25-27	Hecate Strait
June 28-29	Dixon Entrance
June 30 - July 1	West coast of Queen Charlotte Islands
July 2	Travel
July 3	PBS Nanaimo, off loading

Table 2. Tentative fall survey itinerary for the October 1 – November 3, 2012, DFO High Seas Salmon research survey.

Date	General area of operations
October 1	PBS Nanaimo, loading
October 2-4	Queen Charlotte Strait/Triangle Island
October 5-6	Hecate Strait
October 7	Dixon Entrance
October 8-9	Prince Rupert – Crew Chance
October 10 - 13	Southeast Alaska
October 14 - 16	Central Coast of British Columbia
October 17-19	Northern Vancouver Island
October 20-21	Travel
October 22 - 26	Coast Guard Training Week - No sampling
October 27 – November 2	West coast of Vancouver Island
November 3	Victoria, off loading

Table 3. Tentative winter survey itinerary for the February 28 – March 24, 2013, DFO High Seas Salmon research survey.

Date	General area of operations
February 28	PBS Nanaimo, loading
March 1-10	Strait of Georgia
March 11-20	West coast of Vancouver Island
March 21	Triangle Island
March 22	Queen Charlotte Strait
March 23	Travel
March 24	PBS Nanaimo, off loading

Table 4. Tentative summer itinerary for the June 19 – July 16, 2012 DFO Coastal Salmon Investigations survey.

Date	General area of operations
June 19	PBS Nanaimo, loading
June 21-23	Gulf Islands
June 24 – July 3	Strait of Georgia
July 4-7	Queen Charlotte Strait
July 8-9	Juan de Fuca Strait (US and Canadian sides)
July 9-10	Puget Sound
July 11-15	Gulf Islands/Inlet
July 16	PBS Nanaimo, off loading

Table 5. Tentative fall itinerary for the Sept 9 – Oct 1, 2012 DFO Coastal Salmon Investigations survey.

Date	**General area of operations**
Sept 9	PBS Nanaimo, loading
Sept 10 – 12	Gulf Islands
Sept 13 - 22	Strait of Georgia, Howe Sound
Sept 23 – 26	Puget Sound
Sept 27 – 28	Juan de Fuca Strait (US and Canadian sides)
Sept 29 – 30	Gulf Islands, Howe Sound
Oct 1	Off loading, Nanaimo

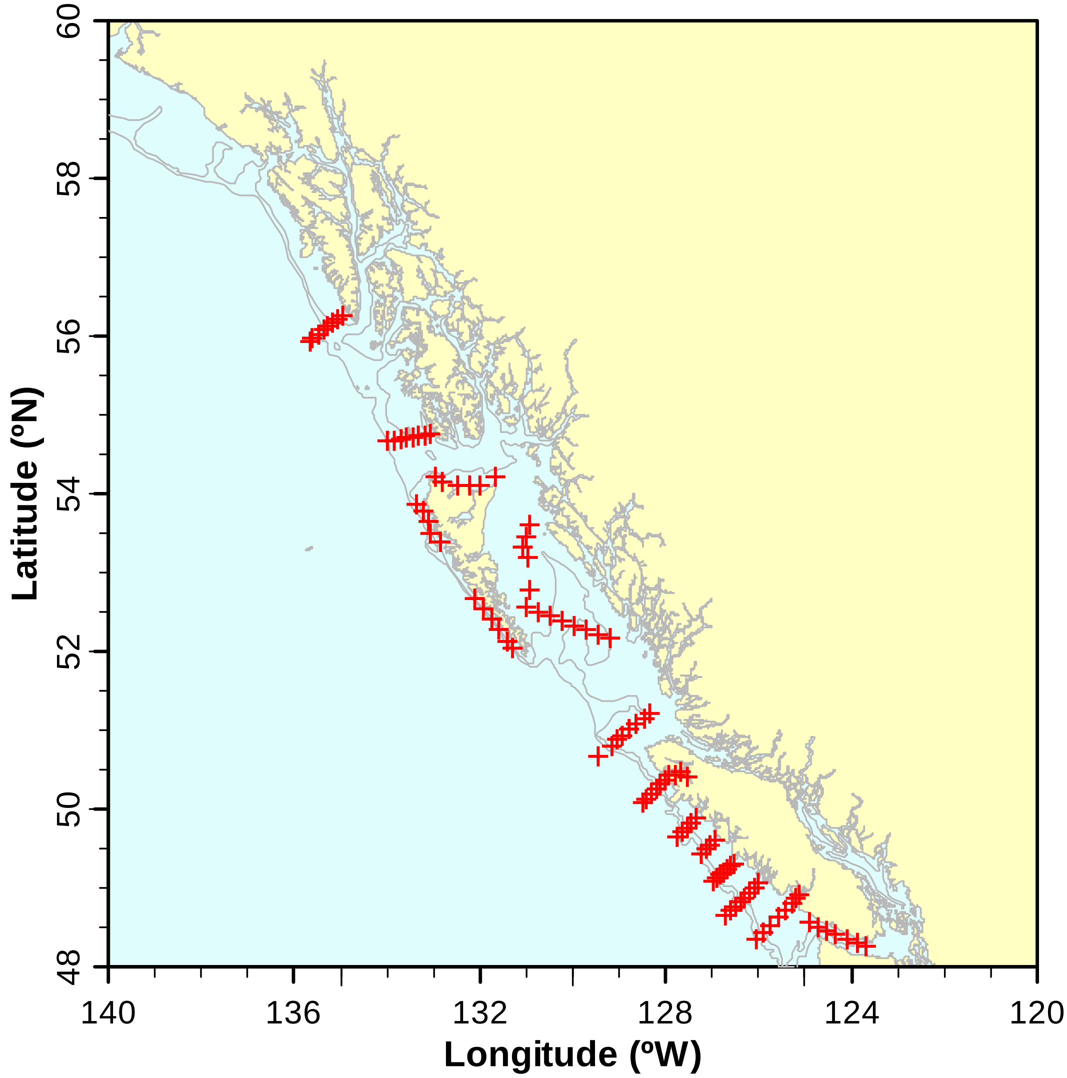

Figure 1. Tentative survey stations for the High Seas Salmon summer survey (June 16 – July 4, 2012).

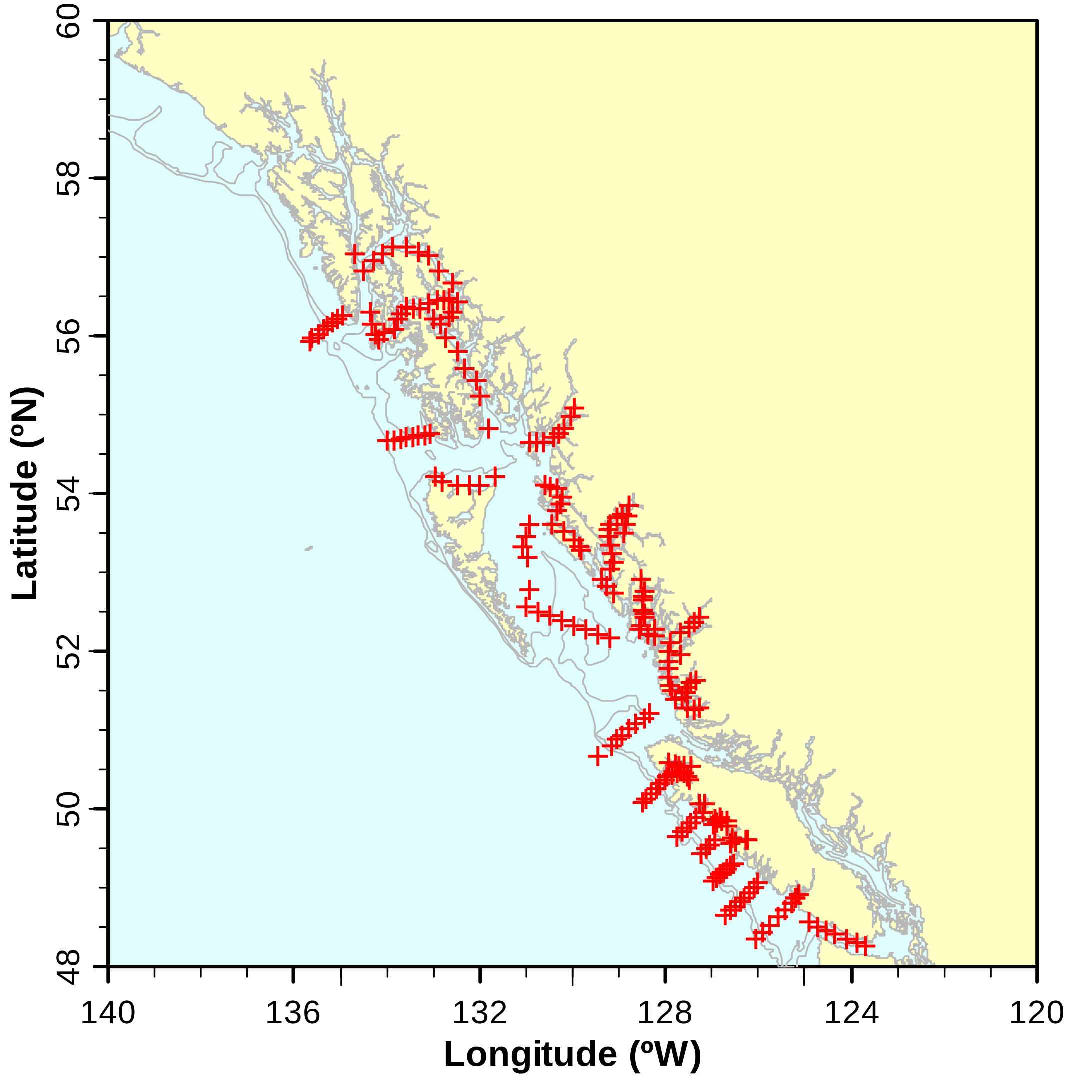

Figure 2. Tentative survey stations for the High Seas Salmon fall (October 1 – November 3, 2012) and winter surveys (February 28 – March 24, 2013).

Figure 3. Generalized map of Strait of Georgia, British Columbia. Track lines for the July and September surveys are shown in black. The Gulf Islands region is in the south-west portion of the strait, bounded by Vancouver Island on the western side. Boundary Bay extends south from Point Roberts along the eastern shoreline. Puget Sound set locations are not shown in this map. Juan de Fuca strait tracklines are essentially along either shoreline, as the middle areas are traffic lanes.

APPENDIX A. Data reports produced by the Canadian Program on High Seas Salmon.

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2. Welch, D. W., Morris, J. F. T., Ladouceur, A. R., Tucker, S., and Demers, E. 2002. CCGS W.E. Ricker Gulf of Alaska salmon surveys, 1999. Can. Data Rep. Fish. Aquat. Sci. 1104: 113p.
3. Welch, D. W., Morris, J. F. T., Thiess, M. E., Trudel, M., and Anderson, D. J. 2003. CCGS W.E. Ricker Gulf of Alaska salmon survey, June 27 to July 6, 2000. Can. Data Rep. Fish. Aquat. Sci. 1125: 110 p.
4. Welch, D. W., Morris, J. F. T., Thiess, M. E., Trudel, M., Ladouceur, A. R., Jacobs, M. C., Zubkowski, T. B., Demers, E., and Zamon, J. E. 2004. CCGS W.E. Ricker Gulf of Alaska salmon survey, June 14-24, 2001. Can. Data Rep. Fish. Aquat. Sci. 1135: 86 p.
5. Welch, D. W., Morris, J. F. T., Thiess, M. E., Trudel, M, Ladouceur, A. R., Zubkowski, T. B., MacLean, H. R., Jacobs, M. C., and Winchell, P. M. 2004. CCGS W.E. Ricker Gulf of Alaska salmon survey, October 9 to November 5, 2001. Can. Data Rep. Fish. Aquat. Sci. 1136: 145 p.
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8. Welch, D. W., Morris, J. F. T., Thiess, M. E., Trudel, M., Ladouceur, A. R., Zubkowski, T. B., Jacobs, M. C., Winchell, P. M., and MacLean, H. R. 2004. CCGS W.E. Ricker Gulf of Alaska salmon survey, February 14-26, 2003. Can. Data Rep. Fish. Aquat. Sci. 1139: 65 p.
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20. Morris, J. F. T., Trudel, M., Thiess, M. E., Zubkowski, T. B., and MacLean, H. R. 2007. CCGS W.E. Ricker Gulf of Alaska salmon survey, March 4-25, 2005. Can. Data Rep. Fish. Aquat. Sci. 1185: 83 p.
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