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Information relevant to the assessment of critical habitat for Blue, Fin, Sei and North Pacific Right Whales in British Columbia

Information relative à l'évaluation de l'habitat essentiel du rorqual bleu, du rorqual commun, du rorqual boréal et de la baleine noire du Pacifique Nord en Colombie-Britannique

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ABSTRACT

Blue, Fin, Sei and North Pacific Right Whales in Canadian Pacific waters are listed as Endangered or Threatened under the Species at Risk Act, which requires the identification and protection of Critical Habitat. Available data on current distribution and habitat use by these species is reviewed and assessed with respect to its adequacy for the identification of Critical Habitat. Information was obtained from Fisheries and Oceans Canada ship-based surveys, remote passive acoustic monitoring and photo-identification studies. In addition, opportunistic sightings databases and published literature were reviewed. Descriptions of physiographic and oceanographic features that may influence prey density in various regions of the coast are included as these are likely important characteristics of habitat for these species. As there is insufficient information and significant gaps in survey coverage, particularly of historically occupied habitat, future research is described that will be necessary to support identification of Critical Habitat for these species.

RÉSUMÉ

Le rorqual bleu, le rorqual commun, le rorqual boréal et la baleine noire du Pacifique Nord vivant dans les eaux canadiennes du Pacifique sont désignées en tant qu’espèces en voie de disparition ou menacées en vertu de la *Loi sur les espèces en péril*, qui prescrit la désignation et la protection de leur habitat essentiel. On évalue si les données disponibles sur la répartition actuelle de ces espèces et l’utilisation de l’habitat par celles-ci permettent la désignation de l’habitat essentiel. L’information provient de relevés par navire réalisés par Pêches et Océans Canada, de la télésurveillance acoustique passive et d’études par photo-identification. En outre, on a passé en revue des bases de données d’observations opportunistes ainsi que des documents publiés. On a inclus des descriptions des caractéristiques physiographiques et océanographiques qui peuvent avoir une incidence sur la densité des proies dans différentes régions de la côte, car il s’agit vraisemblablement d’importantes caractéristiques de l’habitat de ces espèces. Comme l’information est insuffisante et qu’il existe d’importantes lacunes dans la couverture des relevés, particulièrement en ce qui concerne l’habitat historique, on décrit les recherches qui devront être effectuées pour soutenir la désignation de l’habitat essentiel de ces espèces.

INTRODUCTION

Seven species of baleen whales occur in the northeastern Pacific and in Canadian Pacific waters. With the exception of the Minke Whale, which is considered not at risk, and the Grey Whale, listed as Special Concern, the remaining five species are listed as Threatened or Endangered under the Canadian Species-at-Risk Act (SARA). SARA requires a Recovery Strategy and identification of habitat that is critical to the survival or recovery of species listed as Threatened or Endangered. For baleen whales, Critical Habitat has thus far only been identified for the Humpback Whale in the Pacific. However, a re-assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2011 has resulted in a recommendation to change the listing of Humpback Whales from Threatened to Special Concern which, if accepted, would obviate the requirement for Critical Habitat designation (Nichol *et al.* 2010; COSEWIC 2011).

When SARA came into effect in 2003, the Blue Whale was already listed as Endangered in the Pacific and that status was reaffirmed by COSEWIC in 2005. The designation was recommended because the population had been severely reduced by whaling and because of the rarity of sightings suggesting the population is still critically low (COSEWIC 2002). Fin Whales in the Pacific were listed as Threatened under SARA in 2006. COSEWIC recommended this listing because Fin Whale sightings are uncommon in British Columbia (BC) and because large numbers were removed by coastal and pelagic whaling. The population today is likely less than 50% of what it was 60 to 90 years ago (COSEWIC 2005). The Sei Whale was listed as Endangered in the Pacific under SARA in 2005. COSEWIC recommended this listing because although the species had been one of the most abundant species sought by BC whalers, sightings are currently extremely rare. Few if any mature animals have been seen in BC since whaling ended. There is evidence of a severe decline from whaling with no sign of recovery (COSEWIC 2003). The North Pacific Right Whale was listed as Endangered in 2006 under SARA. COSEWIC recommended maintaining this listing because the species has not been sighted in BC waters for 60 years but there have been sightings in adjacent waters, therefore the species should not be considered extirpated (COSEWIC 2004).

A Recovery Strategy was completed in 2006 for the Blue, Fin, and Sei Whales (Gregr *et al.* 2006) and a draft Recovery Strategy has been developed for the North Pacific Right Whale (DFO 2010a). A draft Action Plan for all of these species has also been prepared but Critical Habitats have not yet been identified. Critical Habitat under SARA is defined "*as habitat necessary for survival or recovery of a listed wildlife species...".* SARA defines habitat for aquatic species as areas for rearing, food supply, migration or any other areas on which aquatic species depend directly or indirectly to carry out life processes (DF0 2010b).

Critical Habitat should be identified spatially and temporally and the description of the habitat must include characterization of the biophysical features and attributes which together support the functions that have been identified (Environment Canada 2004; DFO 2010b; Environment Canada 2004). To date there has been limited effort to relate whale distribution to habitat features in BC waters (Gregr and Trites 2001; Dalla Rosa 2010). Gregr and Trites (2001) used six independent oceanographic processes as predictor variables in a generalized linear model to predict habitat they termed critical for Blue, Fin, Sei and Humpback Whales. Their work is an important development in the area of methods for constructing and exploring predictive habitat models for cetaceans, but the habitat prediction results are considered preliminary by the authors (Gregr and Trites 2001; Redfern *et al.* 2006).

Part of identifying Critical Habitat also includes providing examples of the types of anthropogenic activities that would be likely to destroy the habitat. Furthermore, the Critical Habitat that is identified should support the population and distribution objectives that are set out in the Action Plan for the species in question (DFO 2010b). For Blue, Fin, Sei and North Pacific Right Whales, the objectives in the draft Action Plan are:

- Estimate the abundance of Blue, Fin, and Sei Whales using Pacific Canadian waters.
- Confirm the presence of North Pacific Right Whales in Pacific Canadian waters.
- Determine the extent of migrations and identify the populations to which Blue, Fin, and Sei Whales using Pacific Canadian waters belong.
- Determine the relative seasonal distribution and habitat use in Pacific Canadian waters of Blue, Fin, and Sei Whales.

In many instances it may not be possible to identified Critical Habitat at the time the Recovery Strategy or Action Plan is being developed. If this is the case, SARA requires a schedule of studies in the Recovery Strategy and Action Plan that will address the knowledge gaps and lead to identification of Critical Habitat. As a result of knowledge gaps, Schedules of Studies are included in the Recovery Strategies for Blue, Fin, and Sei and for North Pacific Right Whales. The Action Plan development process requires, in addition to a Schedule of Studies, an in-depth understanding of the state of knowledge and documentation of the effort thus far to identify Critical Habitat (DFO 2010b). This document addresses this requirement and presents the available information and current state of knowledge regarding habitat(s) for these species which can then be incorporated into the draft Action Plan for Blue, Fin, Sei, and North Pacific Right Whales as required under SARA S. 49(1)(a). The terms of reference for this report are:

> Identify, if possible, Critical Habitat for Fin, Blue, Sei and North Pacific Right Whales in British Columbia or provide a rationale as to why Critical Habitat cannot be identified for these species at this time. What additional information and studies, if any, are required for Science to identify Critical Habitat for these species?
>
> Identification of Critical Habitat is requested for these species, or a statement from Science Branch describing what additional studies or information is required to identify Critical Habitat for these four whale species and a rationale explaining why the best available information is not sufficient to identify Critical Habitat for these species at this time.

Here we present information regarding the distribution and seasonal occurrence of each species based on information collected since 2002 by the Cetacean Research Program (CRP) Pacific Biological Station, Fisheries and Oceans Canada, as well as information from published literature, incidental sightings databases and from the BC Historical Whaling Database (Nichol *et al.* 2002). Knowledge gaps that pertain to Critical Habitat are highlighted. We also describe physical and biological oceanographic features of ocean areas in BC where whales have been encountered during contemporary surveys and/or where whales were killed during the commercial whaling era (1908 to 1967). The conclusions re-iterate knowledge gaps about the species and list the additional information and studies that are needed to identify Critical Habitat for these species

BALEEN WHALE DISTRIBUTION AND OCEANOGRAPHIC PROCESSES

Blue, Fin, Sei and North Pacific Right Whales feed on zooplankton and small fish and have evolved to efficiently consume large volumes of prey to support their metabolic needs. These species are highly mobile and adapted to locating ephemeral and shifting prey patches at various scales in the ocean (Whitehead and Carscadden 1985; Kenney *et al.* 2001). The formation of prey patches, which occur at mesoscales of less than 10 to 100s of km and for periods of 1 to 10 days, are the result of dynamic oceanographic processes such as fronts, eddies and upwelling that help to concentrate prey. Marine mammals are often strongly associated with prey patches at these scales (Piatt and Methven 1992; Redfern *et al.* 2006; Doniol-Valcroze *et al.* 2007).

Baleen whale (Fin Whales, Humpback Whales, Minke Whales and Sei Whales) density correlated positively with krill abundance off the West Greenland shelf, but the relationship was only significant when there was close spatial and temporal proximity of less than a few days between whale sightings and krill acoustic backscatter volume measurements (Laidre *et al.* 2010). Slope was also a predictor of whale presence, presumably because slope influenced oceanographic processes which affected prey density. In the Antarctic, whale distribution was tightly coupled with zooplankton acoustic backscatter volume and was also correlated with distance to the ice edge and bathymetric slope (Friedlander *et al.* 2006). Along the continental slope off California, satellite-tagged Blue Whales were associated with areas of strong upwelling (Irvine 2007). These areas sustain high concentrations of zooplankton because of enhanced productivity associated with upwelling and topographic breaks in the continental shelf (Fiedler *et al.* 1998; Croll *et al.* 1999).

In the Gulf of St Lawrence, distribution of Blue, Fin and Humpback Whales was associated with the formation of sea surface temperature (SST) gradients (Doniol-Valcroze *et al.* 2007). SST fronts are dynamic and change over periods of hours or days and the association was demonstrated at this fine temporal scale (Doniol-Valcroze *et al.* 2007). Thermal fronts are created by tide or wind-induced upwelling which may increase productivity, or the temperature gradient itself may have a herding effect on krill (Doniol-Valcroze *et al.* 2007).

Humpback whale distribution in 2004 to 2006 in BC and adjacent waters were positively associated with SST fronts in most years but more strongly associated with latitude and bathymetry. Although latitude and bathymetry are likely very general proxies for prey availability, interactions between whales and prey fields and oceanography needs to be studied at finer spatial and temporal scales to provide input to habitat models at the population level (Dalla Rosa 2010).

Concentration features alone though are not sufficient to ensure patch formation. Gregr and Coyle (2009) point out that the occurrence of zooplankton will depend on life history of the constituent species and on the availability of food to support zooplankton growth. The variable nature of the processes responsible for zooplankton growth, survival, and concentration together make marine habitats ephemeral, and their location and timing challenging to predict (Gregr and Coyle 2009).

Gregr and Trites (2001) used six independent oceanographic processes as predictor variables in a generalized linear model with BC historical whaling data and compared relationships on average annual and monthly time scales to predict habitat in BC waters for Blue, Fin, Sei and Humpback Whales. Problems with lack of concurrency of datasets, autocorrelation and bias in the whaling data were acknowledged by the authors to limit interpretation of the habitat model predictions but they suggested these only raise the question of the relative importance of the habitats described for each species (Gregr and Trites 2001).

METHODS

Current understanding of distribution, abundance, and seasonal occurrence of Blue, Fin, Sei and North Pacific Right Whales in BC is based primarily on data collected by DFO’s Cetacean Research Program (CRP), Pacific Biological Station. These data are from ship-based visual surveys, remote acoustic monitoring, and photo-identification studies. In addition to these current data sources, data from the BC historical whaling database and incidental sightings from the British Columbia Cetacean Sightings Network (BCCSN) and the US National Oceanic and

Atmospheric Administration's Platforms of Opportunity Program (NOAA POP) as well as published literature were reviewed.

Ship-Based Visual Surveys

Between 2002 and 2010, over 2,000 hours of dedicated survey effort covering almost 40,000 km were completed to collect sightings of large whales using a line transect observation and data collection protocol from large vessel platforms (Ford *et al.* 2010a: CRP-DFO unpubl.). Four surveys were conducted in winter (January to March), seven surveys in spring (April to June), 12 surveys in summer (July to September) and five surveys in fall (October to December). Observations were recorded when (1) the ship travelled along a designated transect, (2) sea state according to the Beaufort scale of wind force was < 5, (3) visibility was ≥ 3 nautical miles (5.5 kilometres), and (4) two dedicated observers were stationed (one to port and the other to starboard) on the observation deck or bridge of the ship. A data recorder was also stationed on the bridge to record environmental conditions and sightings of whales reported to them by the observers. The observers used either Fujinon 7x50 binoculars with reticles, or Fujinon 25x150 MTM military binoculars with reticles ("Big Eyes") that were pedestal-mounted on the vessel's observation deck.

Survey coverage was determined by cruise length, weather and sea conditions encountered, and at times, by the range restrictions of the ship. Survey effort was not distributed systematically over the coast and only portions of the coast were surveyed on each vessel cruise. Surveys had multiple objectives including studies of species likely to be encountered inshore and on the continental shelf (e.g. killer whales and humpback whales). Thus surveys were not typically dedicated to study of large oceanic baleen whale species. The coverage presented in **Figure 1** is the composite of all surveys from 2002 to 2010. It is clear that there was limited effort in waters more than 50 km of the west coasts of Vancouver Island and Haida Gwaii and less survey effort on and west of the continental shelf off southwest Vancouver Island.

Passive Acoustic Monitoring

Underwater acoustic monitoring is a valuable tool for determining relative abundance and seasonal occurrence of cetaceans by detecting their distinctive vocalizations. Remote passive acoustic stations allow monitoring of broad ocean areas for extended periods and during sea and weather conditions when visual surveys would not be possible. **Figure 2** illustrates the locations of acoustic monitoring sites along the BC coast established by CRP since 2005. In 2006 and 2007, acoustic recorders were deployed at Union Seamount and La Pérouse Bank respectively. Data from these recorders have been analyzed (Ford *et al.* 2010b). At Cape St James, Haida Gwaii (formerly the Queen Charlotte Islands) acoustic recorders have been deployed for two years, July 2009-July 2011. The recordings are currently being analyzed. An acoustic recorder was deployed in July 2010 at Brooks Peninsula, west coast Vancouver Island and was retrieved for analysis in spring 2011. Another recorder was deployed at this location and will be recovered in 2012. The Barkley Canyon node of the NEPTUNE Project became operational in December 2009 and is intended to collect acoustic data continuously (http://www.neptunecanada.ca/). An acoustic recording device was first installed at Langara Island in 2005. Two acoustic recorders were deployed at Bowie Seamount and another near Triangle Island in July 2011. These will collect data for up to one year, with subsequent redeployment planned for an additional year of sampling.

Photo-identification

Photo-identification is a method to identify individual whales of a species by documenting unique scars, nicks, pigmentation patterns evident on a prominent area of the body that can be reliably photographed (e.g. tail fluke, dorsal fin). Photo-identified individuals can be tracked between years and within years and season. Photo-identification data can be used in mark-recapture analysis to estimate population abundance as well as in studies of movement patterns and site fidelity. (e.g. Humpback Whales, Rambeau 2008; Ford *et al.* 2009). Photo-identification of Blue Whales and Fin Whales were obtained during DFO ship surveys, usually from small skiffs deployed in areas of whale concentration. The photo-ID databases for these two species are still small compared to the large database of compiled images for Humpback Whales (Ford *et al.* 2009). Blue whale photo-IDs are shared with Cascadia Research Collective, Washington USA, which conducts population studies using photo-identification of Blue Whales off California (Calambokidis *et al.* 2009). Fin whale photo images collected during DFO surveys are being analysed to investigate site fidelity and movements of individuals, and will be used in future mark-recapture analyses to estimate abundance (CRP-DFO unpubl.). A similar photo-identification effort involving Fin Whales is underway in Washington and California (Falcone *et al.* 2011).

BC Historical Whaling Database

Six whaling stations were established along the BC coast and operated at various times between 1905 and 1967. No records were located corresponding to the first three years of whaling and no records have been located from the station that was located in the Strait of Georgia (Page's Lagoon) that operated briefly from 1907 to 1909. Aside from Page's Lagoon, whaling records from 1908 to 1967 have been located and compiled from archival company documents and from the database of the International Whaling Commission (IWC) (Nichol *et al.* 2002). Where information was available, the database includes specific data on each whale captured such as, date and location of capture, species, length, sex, and reproductive status. However, about half of the 24,000 kills recorded in the database were taken before 1948 when little more than catch by species by week or month was recorded from each whaling station. Consequently the geographic distribution of catch and effort are largely unknown for the whaling period prior to 1948.

BC Cetacean Sightings Network (BCCSN)

The BCCSN is a collaborative program between the Vancouver Aquarium and DFO. The BCCSN maintains a database of opportunistic sightings reported by mariners, fisheries observers, researchers, Canadian Coast Guard, and tour operators. These data provide evidence of presence but not absence. The database was queried for relevant sightings.

National Oceanic and Atmospheric Administration, Platforms of Opportunity Program (NOAA, POP)

The POP is a US marine mammal sightings program. Data are obtained through both opportunistic sightings and dedicated US marine mammal surveys from a number of sources including: NOAA vessels, US Coast Guard vessels, US Fish and Wildlife Service vessels, various research vessels, and the National Marine Fisheries Service (NMFS) North Pacific Groundfish Observer Program. The database was queried for relevant sightings.

RESULTS AND DISCUSSION

BLUE WHALE

In the northeastern Pacific, Blue Whales winter in the Sea of Cortes, along the Pacific coast of the Baja Peninsula and over the Costa Rica Dome, but other wintering areas may also exist (Reilly and Thayer 1990; Mate *et al.* 1999; Bailey *et al.* 2009). Productive waters of the northeastern Pacific represent feeding habitat for this species. In summer, 2,800 individuals inhabit waters off California, based on a photo-identification mark-recapture estimate, however some of these animals appear to move between southern California and northern feeding grounds (Calambokidis and Barlow 2004; Calambokidis et al. 2009). Three of ten Blue Whales individually photo-identified off BC matched to southern California and one of three Blue Whales photo-identified in the northern Gulf of Alaska also matched to southern California (Calambokidis et al. 2009). These sightings in BC and the Gulf of Alaska indicate potential re-establishment of historic feeding grounds (Calambokidis *et al.* 2009). With the exception of one sighting from June 1997, the remaining nine whales identified in BC were encountered in August (Calambokidis *et al.* 2009). Blue Whales satellite tagged off southern California that moved northward into Washington and BC waters and demonstrated area-restricted movements suggestive of foraging behaviour, did so primarily in late summer and fall (Irvine 2007; Bailey *et al.* 2009).

Similar seasonality is revealed by acoustic data in BC. Blue Whale calls were recorded in September 2007 from La Pérouse Bank but not from Union Seamount, where acoustic monitoring occurred from February to July of 2006 (**Figure 3**) (Ford *et al.* 2010b). The results from La Pérouse Bank are consistent with findings over a broader region of the northeastern Pacific in which the majority of calls occurred August to December with a peak in October – November, 1996 to 2002 (Stafford *et al.* 2009). Based on analysis of remote acoustic monitoring data from 1996 to 2000, Burtenshaw *et al.* (2004) suggested that calling Blue Whales primarily aggregate offshore of central and southern California in the mid-summer and fall and also in a region offshore of Vancouver Island from late summer through winter.

BC historical whaling records account for 1,378 Blue Whales killed from 1908 through 1965. The catch of Blue Whales peaked in August and September (Gregr *et al.* 2000; Nichol *et al.* 2002). Through the season, which commenced in April and ended in mid to late September, there was a slight increase in the proportion of males in the catch. The catch was mostly dominated by immature animals (based on reported lengths). Slightly larger animals were caught at the beginning of the season (Gregr *et al.* 2000).

During DFO ship surveys May 2002 and August, 2005 and 2007, Blue Whales were sighted on six occasions (Ford *et al.* 2010a). No Blue Whales were observed during 24 ship surveys during 2002-2010 (Ford et al. 2010a; CRP-DFO unpubl.). Blue Whales were encountered near the continental shelf break between Vancouver Island and Haida Gwaii, in about 1,000 m of water, west of Kunghit Island along the shelf break 10-11 km from shore, and in approximately 2,200 to 2,500 m of water 40 to 60 km southwest of Cape St. James (**Figure 4; Figure 6**). Blue Whales were hunted in these areas in the 1920s and between 1948 and 1965, although most were also taken west of the continental shelf off northwest Vancouver Island and in western Dixon Entrance. A few were also taken in western Moresby Trough (**Figure 5**) (Nichol and Heise 1992; Gregr and Trites 2001). There are a further four incidental sightings recorded in the BCCSN database. One in Dixon Entrance, one west of the continental shelf off southern Haida Gwaii and two very nearshore of southern Haida Gwaii. In the NOAA Platforms of Opportunity database there is one sighting on the continental shelf off southwest Vancouver Island from 1965 which was the last year Blue Whales were legally hunted in the Canadian Pacific (Nichol *et al.* 2002).

Blue Whales feed almost exclusively on euphausiid crustaceans (Croll *et al.* 1998). In BC waters, the only diet information comes from a subset of historic whaling records (1963 and 1965). Of 41 Blue Whales examined, 22 contained prey remains which were identified as krill (Flinn *et al.* 2002; Nichol *et al.* 2002; CRP-DFO unpubl.). Animals observed in BC in 2005 and 2006 appeared to be foraging, based upon their milling behaviour in one area and because of a zooplankton prey layer evident on the 200 kHz echosounder (Calambokidis *et al.* 2009). In the Monterey Submarine canyon off California, satellite-tagged Blue Whales dove consistently to

150 to 200 m prey layers and then made vertical excursion up through these layers to feed (Croll *et al.* 2001). During the 2005 encounter in BC, the prey layer was evident as acoustic backscatter at 100 to 160 m. A Blue whale was detectable on the tracing as it dove to as much as 200 m and then swam up through the prey layer in the same manner as the lunge feeding tagged Blue Whales observed off California (Calambokidis *et al.* 2009).

The distribution of Blue Whales in higher latitudes is strongly correlated with the occurrence of dense patches of euphausiids, which are linked to the timing of primary production (Benson *et al.* 2002, Burtenshaw *et al.* 2004). Numerous small-scale studies of whale presence and habitat covariates have shown a close association between these animals and eddies, fronts and SST gradients (Woodley and Gaskin 1996; Doniol-Valcroze *et al.* 2007; Irvine 2007). Calambokidis *et al.* (2009) suggest a relationship between the timing of cool phase Pacific Decadal Oscillation (PDO) and Blue whale occurrence in BC and Alaskan waters. A cool PDO, which may create conditions favourable to zooplankton production, occurred 1890 to 1924, 1947 to 1976 and again beginning in 1998 (Mantua and Hare 2002). Most of the Blue Whales (75%) taken during the BC whaling era were caught from 1908 to 1924, during a cool PDO cycle. Conversely, kills of just under 1,000 Blue Whales took place off the west coast of Baja California, primarily in the spring and summer 1926 to 1935 which was during a warm PDO cycle (Calambokidis et al. 2009). Comparatively few (5%) Blue Whales were taken in BC during these years (Nichol *et al.* 2002).

Knowledge of the current spatial and seasonal distribution of Blue Whales in Canadian Pacific waters is poor. There has been little DFO ship survey effort west of the continental shelf break where Blue Whales were primarily hunted and where they were sighted during those occasions on DFO surveys when it was possible to move further offshore. With very few sightings and photo-IDs and large areas of their historic distribution not surveyed, it is not possible at this time to document the extent of seasonal habitat use and inter-annual variation, and, therefore, identify Critical Habitat. Although acoustic monitoring suggests a late summer and fall occurrence off southwest Vancouver Island more extensive acoustic monitoring and ship surveys are required to better define this seasonal and spatial distribution pattern.

FIN WHALE

Fin Whales in the northeastern Pacific are distributed in latitudes from Hawaii to the Baja California peninsula and the Sea of Cortes in winter but may also be distributed in higher latitude habitats during winter and summer. Re-examination of historical catch data and acoustic data suggests the species is regularly found north of 40° N in winter months, suggesting a less distinct migratory pattern than previously thought and possibly a more complex population structure (Mizroch *et al.* 2009). In addition to foraging, Fin Whales may be breeding in northern latitudes. In Davis Strait between Greenland and eastern Canada, the presence of calling Fin Whales in November and December coincides with the period of peak conception in this species (Simon *et al.* 2010).

Fin Whales were encountered during spring, summer and winter during DFO ship surveys between 2002 and 2010 (Ford *et al.* 2010a; CRP-DFO unpubl.). Fin Whale calls were detected in acoustic recordings from Union Seamount, February to September of 2006 and at La Pérouse Bank, May to September 2007 (**Figure 3**) suggesting that Fin Whales occupy Canadian Pacific waters for a protracted period or may even remain year round. Both the male mating call and another less distinctive call type were recorded (Ford et al 2010b). In a study of broad oceanic regions, Fin Whale calls were heard throughout the year from an array of US Navy Sound Surveillance System (SOSUS) sites that monitor the west coast of Washington, Oregon and Vancouver Island (Moore *et al.* 1998). The received calls were from Fin Whales occupying continental shelf and slope waters as well as seamounts. Continued acoustic monitoring in BC by CRP from additional acoustic sites and during all months of the year will help confirm that the species is present year round.

BC historical whaling records indicate that the length of whales changed over the whaling season (April to October) suggesting an age-structured migration with larger animals arriving in BC waters first (Gregr *et al.* 2000). Catch records also show an increase in the number of whales killed over the season as well as a decrease in distance from shore, suggesting movement of Fin Whales into BC waters from spring through summer (Gregr *et al.* 2000). At the same time, length data suggest that much of the catch was of immature animals (Nichol and Heise 1992; Gregr *et al.* 2000) which led Pike and MacAskie (1969) to suggest that BC waters provided feeding grounds for subadult animals that stayed to feed during the summer months.

Fin Whale diet in the North Pacific is dominated by euphausiids (70%), copepods (25%) and some fish and squid (Kawamura 1980). Stomach contents from Fin Whales taken in BC waters from 1963 through 1967 indicated that euphausiids were primarily consumed although there was some annual variation with a higher percentage of copepods, fish and squid in 1964 and 1965 samples than in the other years (Flinn *et al.* 2002).

Fin Whales were considered the most abundant large whale species on the BC coast during the whaling era and 7,520 were taken from 1908 to 1967 (Pike and MacAskie 1969; Nichol *et al.* 2002). In contrast, they were the third most frequently encountered species during 28 DFO ship surveys from 2002 to 2010 with 346 sightings recorded (Ford *et al.* 2010a; CRP-DFO unpubl. data). The encounter rate during DFO ship surveys from 2002 to 2008 was 1.61 individuals per 100 km, considerably less than for Humpback Whales, which were encountered at a rate of 10.58 individuals per 100 km (Ford *et al.* 2010a).

Fin Whale sightings made during DFO ship surveys were distributed widely over the continental shelf west of Vancouver Island and Haida Gwaii, in Queen Charlotte Sound, southern Hecate Strait, and Dixon Entrance. In addition to these open ocean areas, Fin Whales were also encountered in the confined waterways of Caamano Sound and Squally Channel on the northern mainland coast (**Figure 6; Figure 7**) (Ford *et al.* 2010a; CRP-DFO unpubl,). There are 154 incidental sightings recorded of Fin Whales in the BCCSN database from the same areas including the confined waterways. Of these sightings, only 17 come from the previous decade (1990s) and these were reported from vessels operating west of the continental shelf off Vancouver Island. There are 16 sightings in the NOAA Platforms of Opportunity Program database with the first sighting made in 1958 on the continental shelf off southwest Vancouver Island. The remaining 15 sightings are from 1968 to 1992 and all are recorded west of the continental shelf off Vancouver Island, southern Haida Gwaii and in western Dixon Entrance.

Moresby Trough, which extends from the northern mainland coast near Caamano Sound across southern Hecate Strait and Queen Charlotte Sound, is an inshore area where Fin Whales (and other baleen species) have been encountered during DFO surveys and where whales were hunted historically (**Figure 6**). In 2010, a systematic line transect survey of Moresby Trough was undertaken to estimate density and abundance of Fin Whales (**Figure 8**). Survey data were analysed using conventional Distance Sampling (Buckland *et al.* 2001) with the program Distance (version 6.0 Release 2.0) to obtain an estimate of abundance in Moresby Trough. A half-normal detection function was selected and fitted to the 25 Fin whale sightings obtained along 260 km of transect line. The resulting estimate was 176 Fin Whales (95% CI: 85-363, CV = 0.35) with a corresponding density estimate of 0.035 Fin Whales per km^2 in Moresby Trough on July 14^{th} and 15^{th}, 2010 (CRP-DFO unpubl. data). Williams and Thomas (2007) reported an abundance estimate of 496 (95% CI: 201-1222, CV = 0.46) Fin Whales in Dixon Entrance, Hecate Strait and Queen Charlotte Sound based on 35 sightings obtained during line transect surveys in 2004 and 2005.

Fin Whales were sighted during at least one ship survey annually from 2002 to 2010 but survey effort was not spatially or temporally consistent enough to facilitate identification of critical or important habitats and large portions of their historic range in BC waters have not been surveyed. The areas in which they were recorded including the confined waterways, were occupied during the whaling era (based on catch locations), but substantial numbers of Fin Whales were also taken in oceanic waters west of the continental shelf, an area that has received limited ship survey effort (**Figure 9**). Acoustic monitoring should be continued and expanded to improve understanding of seasonality and distribution of Fin Whales year-round in BC waters. Ship survey effort should focus on historic whaling grounds. In inshore areas, research efforts should focus on identifying areas of relatively consistent usage through ship surveys, photo-ID studies and satellite tagging to document fine scale habitat use, site fidelity, and inter-annual variation. Comparisons of photo-identifications should be undertaken with Fin Whale catalogues being compiled off the US west coast and Alaska to determine broad movement patterns and stock identity.

SEI WHALES

Like the Blue Whale, the Sei Whale occupies pelagic habitats and rarely ventures into inshore waters, although whaling records show a few whales taken in Moresby Trough and over Goose Bank in Hecate Strait and Queen Charlotte Sound. Less than 0.5% of the catch for which geographic coordinates were recorded were distributed on the continental shelf (Gregr 2002) (**Figure 10**). As with most other baleen whale species, Sei Whales are thought to move to lower latitudes during winter months to breed and move to higher latitudes in spring and summer to feed, but little is known about the distribution of this species in the northeastern Pacific. Gregr *et al.* (2000) compared catches from BC with those from whaling stations in Alaska and suggested there may be a northern limit of about 55° N for this species in the northeastern Pacific. Nemoto and Kawamura (1977) suggested Sei Whales expanded northward following the depletion of Blue Whales and Fin Whales from whaling in the mid part of the last century. Rice (1974) suggested that Sei Whales in the northeast Pacific move further offshore into the Pacific to winter.

During the BC whaling era, 3,779 Sei Whales were taken offshore of west coast Vancouver Island, mostly during the 1960s (Gregr *et al.* 2000; Nichol *et al.* 2002), but since the cessation of commercial whaling in Canada, only two Sei Whale sightings have been recorded in Canadian Pacific waters, one sighting off southeastern Haida Gwaii in 2004 and one Sei Whale was sighted near Learmonth Bank in Dixon Entrance in 2008 (CRP-DFO unpubl. data; Williams and Thomas 2007). However there has been little DFO survey effort west of the continental shelf off Vancouver Island, which is where the majority of Sei Whales were taken. Off the coast of Washington, Oregon and California, where extensive line transect surveys have been undertaken (1991 to 2005) only five sightings of Sei Whales were recorded. The estimate of abundance from these sightings is 46 (CV = 0.61) animals but there is considerable uncertainty in this estimate given the very small sample size (Carretta *et al.* 2011). In contrast Sei Whales were the fourth most common whale species harvested off California during the 1950s and 1960s (Rice 1974).

Like other baleen species, Sei Whales are often associated with ocean fronts and eddies but may be more dynamic and respond more rapidly to changes in prey availability than other baleen species. Sei Whales are often observed in the same foraging area for many years and then disappear for prolonged periods of time (Jonsgård and Darling 1977; Schilling *et al.* 1992). The large number of Sei Whales taken off BC mainly during the 1960s suggests such a phenomenon may have taken place in BC waters (Gregr *et al.* 2000). Rice (1974) reported that Sei Whales were abundant off California in late summer and early fall. BC whaling records indicate peak catches were in July and that over the course of the summer the distribution moved further offshore (Gregr *at al.* 2000).

Sei Whale calls are not always distinctive and readily identifiable, but possible Sei Whale calls were detected intermittently throughout the monitoring periods at Union Seamount (February to September 2006) and La Pérouse Bank (May to July 2007) (Ford *et al.* 2010b). Further acoustic monitoring is needed to ascertain Sei Whales vocalizations in BC waters.

Sei Whales use both “skimming” and “engulfing” (or gulping) feeding strategies (Nemoto and Kawamura 1977) and feed primarily on calanoid copepods. Although Fin Whales and Blue Whales usually feed at depth, Sei Whales feed near the surface. The diet of Sei Whales may have considerable inter-annual variation. Stomach contents from Sei Whales taken off BC during 1963 to 1967 show a predominance of copepods (85 to 90.5% frequency of occurrence) in 1963 to 1965 but euphausiids and saury in 1966 (65.4% and 23.6% respectively) and various fish (81.8%) in 1967 (Flinn *et al.* 2002). There were also within-season differences suggesting this species responds readily to seasonal and annual changes in prey species abundance and diversity.

With little survey effort where Sei Whales were historically hunted and only two recent sighting records, little can be said about the distribution of Sei Whales and potential Critical Habitats in BC waters. Research should focus on increased acoustic monitoring and ship survey effort of historic whaling grounds.

NORTH PACIFIC RIGHT WHALE

The North Pacific Right Whale is the most critically endangered whale species and relatively little is known of its distribution in the North Pacific. Six were taken in BC waters between 1914 and 1929. The species was first protected from whaling in 1937*,* but a seventh animal was taken in BC in 1951 (Nichol *et al* 2002). There have been no confirmed sightings in Canadian Pacific waters since 1951, although there have been a few sightings in adjacent waters. Historical whaling data from the 19th century indicate that Right Whales were present in Canadian Pacific waters from April to October although most were taken west of the continental shelf and primarily north of 52°N (Townsend 1935, Clapham *et al.* 2004, Josephson *et al*. 2008) (**Figure 11**). **Figure 12** illustrates the distribution North Pacific Right Whales taken during the BC whaling era in the 20th century. Minimal DFO ship survey effort since 2002 has occurred west of the continental shelf. No North Pacific Right Whale calls were detected on recordings from Union Seamount or La Pérouse Bank. Acoustic monitoring in the southeastern Bering Sea where North Pacific Right Whales have been sighted recently suggests Right Whales are present from May until December, with a peak in mid-summer through early fall (Munger *et al*. 2008).

Right Whales feed entirely on zooplankton, primarily copepods. However, North Pacific Right Whales feed on several different species of copepods suggesting that they may have a more diverse diet than North Atlantic Right Whales, which feed primarily on a single species (Gregr and Coyle 2009). The size of the eastern population of North Pacific Right Whales is thought to be well below 100 individuals (Clapham *et al.* 2005). A recent estimate from the Bering Sea based on mark-recapture techniques using photo-identification from images collected 1997 to 2008 suggests a population of 31 (95% CI 23-54) animals. This may be a sub-population with strong site fidelity to the southeastern Bering Sea (Wade *et al.* 2011). Intensive historic whaling of this species in the mid 19th century followed by illegal Soviet pelagic whaling during the 1960s are considered the main causes of an extremely reduced population in the North Pacific.

With limited ship survey effort and acoustic monitoring in offshore areas and a very small population, it is clear that there is not yet information with which to consider Critical Habitat for this species. Research should focus on increased acoustic monitoring in offshore areas followed by dedicated ship surveys once North Pacific Right Whales have been detected.

HABITAT DESCRIPTIONS

Several regions of the Canadian Pacific waters overlap the distribution of catches from the historical whaling era and also sightings obtained during contemporary ship surveys. These regions are western Dixon Entrance, Queen Charlotte Sound, southern Hecate Strait, and west coast Haida Gwaii and west coast Vancouver Island. The following is a synthesis of physical and biological oceanographic information obtained from the literature. Our objective is to describe patterns and processes which may be the features that support the primary function (foraging) of BC habitat for these species.

West coast Vancouver Island

The main input to this region is the outflow of nutrient rich surface waters through the Strait of Juan de Fuca, which pumps nutrients onto the continental shelf year-round regardless of seasonal winds. It is primarily this phenomenon that makes this a nutrient rich and biologically productive oceanographic area even during El-Nińo-Southern-Oscillation (ENSO) events. Seaward of the continental shelf, as well as near the shelf break, a mid-summer euphausiid bloom remains concentrated over the shelf with strong late-summer to fall peak occurrences of the two dominant euphausiid species, *Euphausia pacifica* and *Thysanoessa spinifera* (Mackas *et al.* 1980; Mackas 1992). However the spatial distribution of zooplankton within this region can vary by one or more orders of magnitude of biomass over a few kilometres. Canyon features in particular support or entrain dense patches (Mackas *et al.* 1997).

Queen Charlotte Sound and Hecate Strait

Three deep-water troughs extend into Queen Charlotte Sound and southern Hecate Strait and are important to the pattern of inflow and outflow in the region (**Figure 6**). The mouth of Moresby Trough has the most turbulent waters of the continental shelf along Canada's Pacific coast (Crawford *et al.* 1995). High euphausiid biomass is often found over steep sea floor slopes, which include the continental slope and margins of these deep troughs leading from the outer coast into Queen Charlotte Sound (Simard and Mackas 1989; Mackas *et al*. 1997; Lu *et al*. 2003). Although there have not been zooplankton drift or accumulation studies near these margins, it is possible that strong outflows from Moresby Trough have eddies that form near slopes and help to concentrate plankton (Sinclair *et al.* 2005). Within Hecate Strait, strong outflow and vertical mixing in Moresby Trough may move nutrient rich waters towards southern Haida Gwaii creating conditions favourable to zooplankton aggregations in the trough (Jardine *et al.* 1993; Crawford 1997; Perry and Waddell 1997) (**Figure 13**). Sightings of Fin Whales in Moresby Trough during ship surveys and kills of Fin Whales, Blue Whales and Sei Whales during the whaling era suggest this area may warrant more focused study in the future (Ford *et al.* 2010a; Williams and Thomas 2007).

Studies describing how Haida eddies form and their role in transporting coastal zooplankton species into offshore areas may shed light on why large whales have been encountered on the western edge of Queen Charlotte Sound and west of the continental shelf (Crawford and Batten 2005; Mackas and Galbraith 2002).

To the south in Queen Charlotte Sound northerly winds push surface water west of Cook Bank (**Figure 13**). This flow passes the Scott Islands into the Pacific and a branch moves south along northwest Vancouver Island. The returning flow moves through Goose Island Trough, carrying nutrient rich waters and likely phytoplankton and zooplankton along the north slope of Cook Bank (Crawford *et al.* 1997; Sinclair *et al.* 2005).

Off Aristazabal Island on the east side of southern Hecate Strait, a cold water plume originating from wind driven upwelling develops in July and persists through August. The plume flows southward from Aristazabal Island and then southwest through Mitchell Trough (Crawford *et al.* 1997). Enhanced productivity from this plume in summer may make the region off Laredo Sound and Caamano Sound attractive to Fin Whales, which have been encountered during recent summer DFO ship surveys and were hunted there historically.

Dixon Entrance

Waters of Dixon Entrance and adjacent canyons and troughs on the continental shelf seasonally support aggregations of zooplankton with peaks in abundance in summer as well as in spring (Perry and Waddell 1997). The pattern of estuarine flow in Dixon Entrance likely allows vertically migrating zooplankton to remain in the entrance (Sinclair *et al.* 2005) (**Figure 13**). There is little detailed oceanographic information available for western Dixon Entrance and it is less clear why this area would be productive, although Learmonth Bank may support dense prey patches by trapping food along the sloping bottom (Sinclair *et al.* 2005).

THREATS TO POTENTIAL CRITICAL HABITAT

Anthropogenic activities that would affect prey occurrence and abundance and/or displace or disrupt whales should be considered threats to Blue, Fin, Sei, and North Pacific Right Whale habitat in BC. Activities that may result in threats to habitat, would include, but are not limited to, oil spills, vessel traffic, fishing, seismic surveys, pile driving and sonar or other acoustic alterations of the environment that impact communication or foraging and mating.

CONCLUSION

Since 2002, the occurrence of Fin Whales, Blue Whales and Sei Whales has been confirmed in BC waters. The current presence of North Pacific Right Whales has not yet been confirmed. Ship survey effort, remote acoustic monitoring and photo-identification techniques have been used to understand the seasonal distribution, site fidelity, habitat use and population structure of these species. Historical whaling records suggest these species were largely distributed in oceanic waters west of the continental shelf and for North Pacific Right Whales, primarily north of 52°N. However, there has been minimal survey effort in these offshore areas. Although catch locations are lacking for most of the whale catch prior to 1948, it is probable that most whaling effort associated with the two whaling stations that operated on west coast Vancouver Island prior to 1948 would have been focused off the west coast of Vancouver Island. Whaling effort from the two stations that were located on Haida Gwaii would have been focused in Hecate Strait, Queen Charlotte Sound as well as off west coast Haida Gwaii and in Dixon Entrance (Nichol and Heise 1992; Nichol *et al.* 2002).

More information in the form of sightings from dedicated line transect surveys, acoustic monitoring and photo-ID studies in offshore areas is required to better understand the current distribution of these species in order to identify Critical Habitat. Further systematic survey coverage in key inshore areas such as Caamano Sound is also needed. BC waters support foraging whales of these species where habitat features contribute to concentrating and sustaining prey, although the occurrence of Fin Whales year-round and the detection of male mating calls underscore the need to better understand the function of BC habitat for Fin Whales.

Oceanographic mesoscale processes that concentrate prey (e.g., fronts, eddies and upwelling) are likely the features that support a foraging function. The most common approach to identify species' habitats involve correlations between a sizeable sample of whale survey data and concurrent environmental observations (Gregr and Coyle 2009; Dalla Rosa 2010). As there are insufficient whale sighting data over the study area to link with concurrent oceanographic information, such approaches can not yet be applied for BC waters.

There are comparatively more data available for Fin Whales than for the other three species but they are still not sufficient to model habitat associations or to identify areas of persistent occurrence (Nichol *et al*. 2010). The occurrence of Fin Whales in Caamano Sound and adjoining waterways on the northern mainland coast is intriguing as it is one of few inshore areas where Fin Whales are found in BC and where they were encountered historically as well.

The following are recommended research approaches needed to obtain an understanding of habitat use and future identification of Critical habitat.

- There is insufficient information on the seasonal distribution of Fin Whales in BC waters and the life processes that this region supports (e.g., foraging, migrating, calving). *Continued and expanded passive acoustic monitoring is needed to clarify the seasonal occurrence of this species in BC.*
- There is insufficient information about habitat features with which Fin Whales and their prey are associated. *Expanded survey effort is needed in areas of Fin Whale occurrence, particularly in Hecate Strait and Caamano Sound. Study approaches should include systematic visual surveys, photo-identification, satellite tagging and collection of hydroacoustic data to document potential prey.*
- There has been little systematic survey effort west of the continental shelf where most Blue, Fin and Sei Whales were taken during the BC whaling era. *Focus ship survey effort further offshore on historic whaling grounds. Collect hydroacoustic data during ship surveys to investigate association between whales and prey biomass densities. Continue to expand the passive acoustic monitoring network to monitor offshore areas.*
- The current occurrence of the North Pacific Right Whale in Canadian Pacific waters remains to be confirmed, and once confirmed survey effort will be needed to determine abundance and distribution. *Continue and expand the passive acoustic recording network to more effectively monitor offshore areas for the presence of Right Whales.*
- Concurrent data on whale distribution and oceanographic processes at appropriate spatial and temporal scales are lacking. *As sufficient survey sighting data become available, investigate the association between oceanographic processes and whale distribution.*

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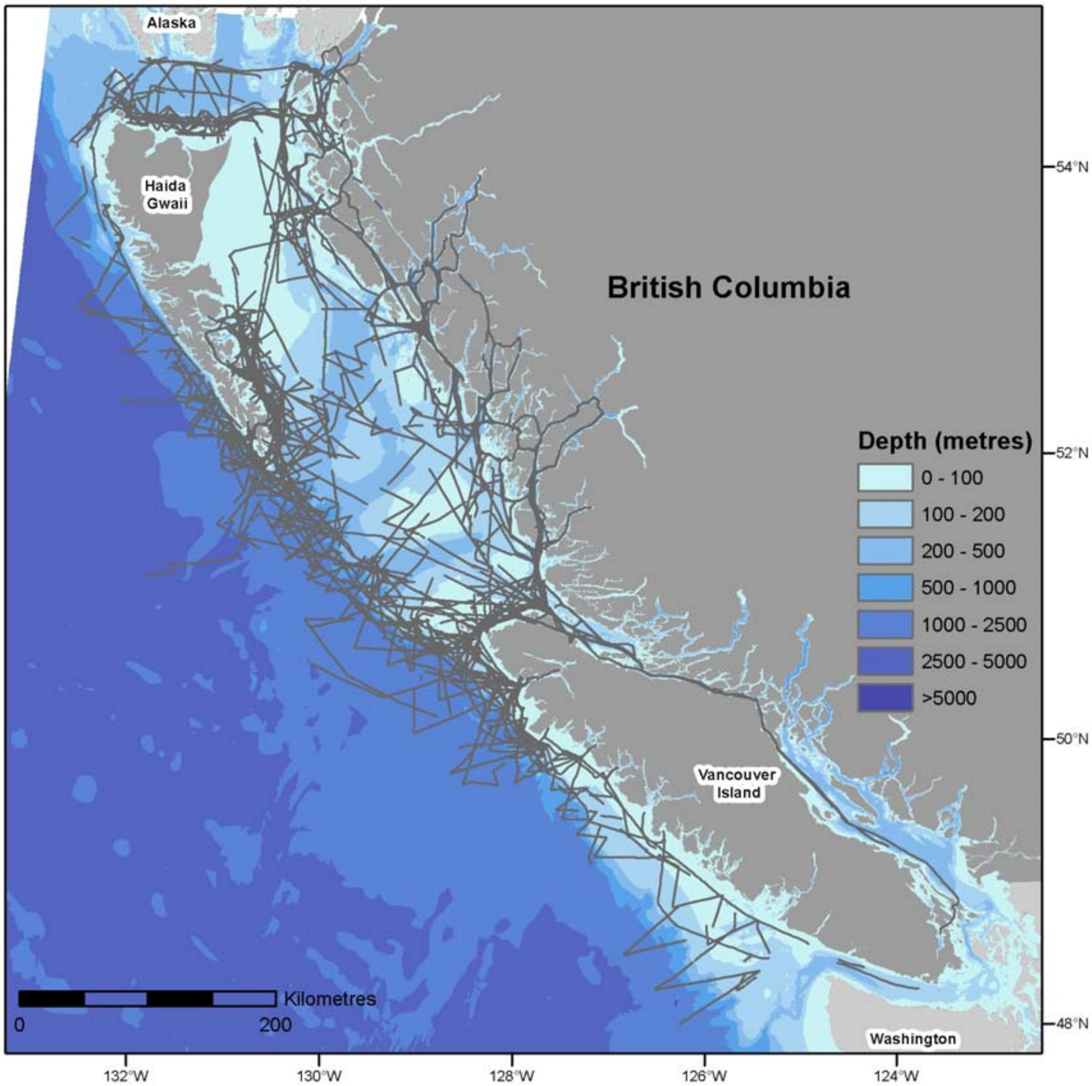


Figure 1. Tracklines showing DFO ship survey effort, 2002 to 2010 (Ford et al 2010a; CRP-DFO unpubl. data).

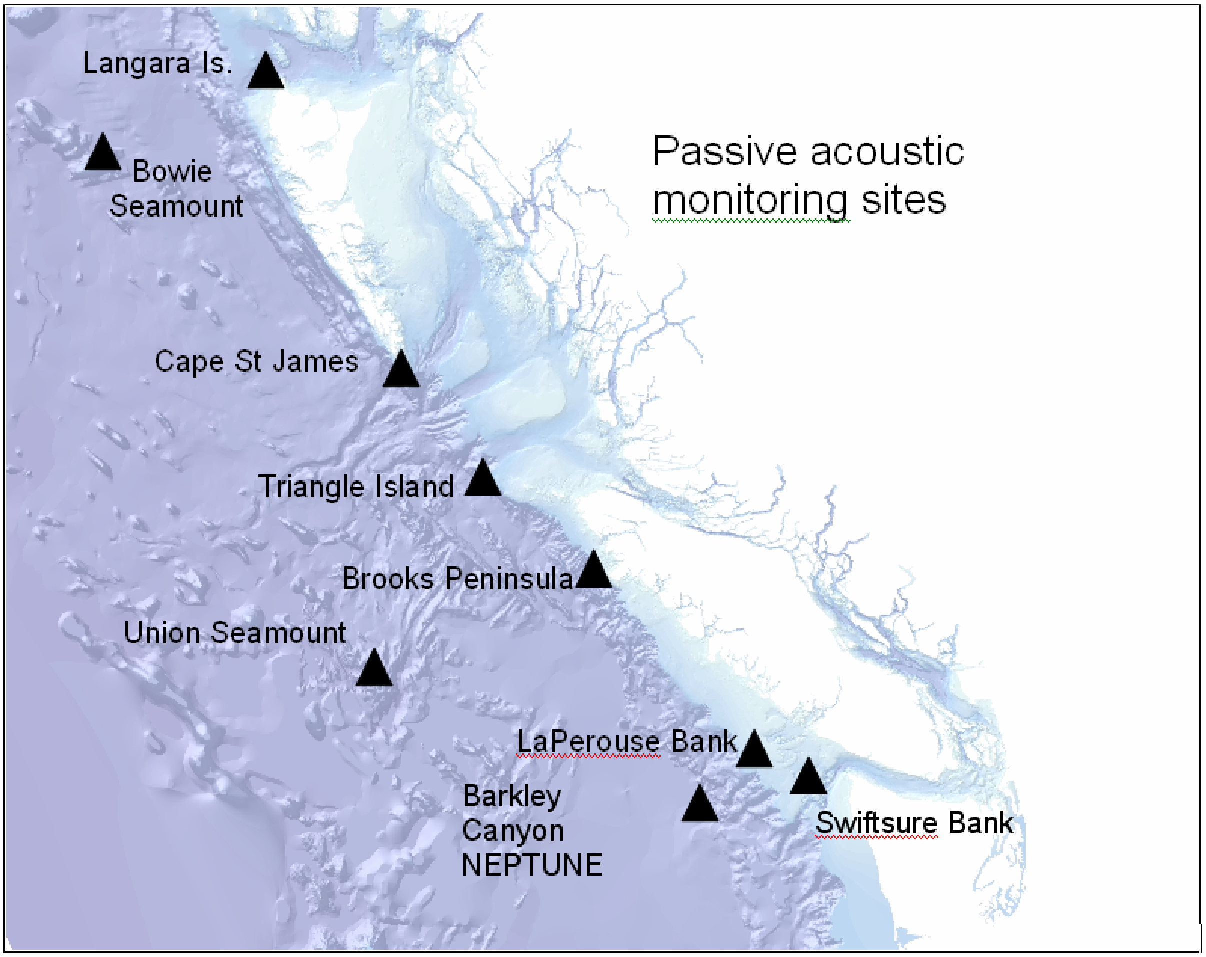
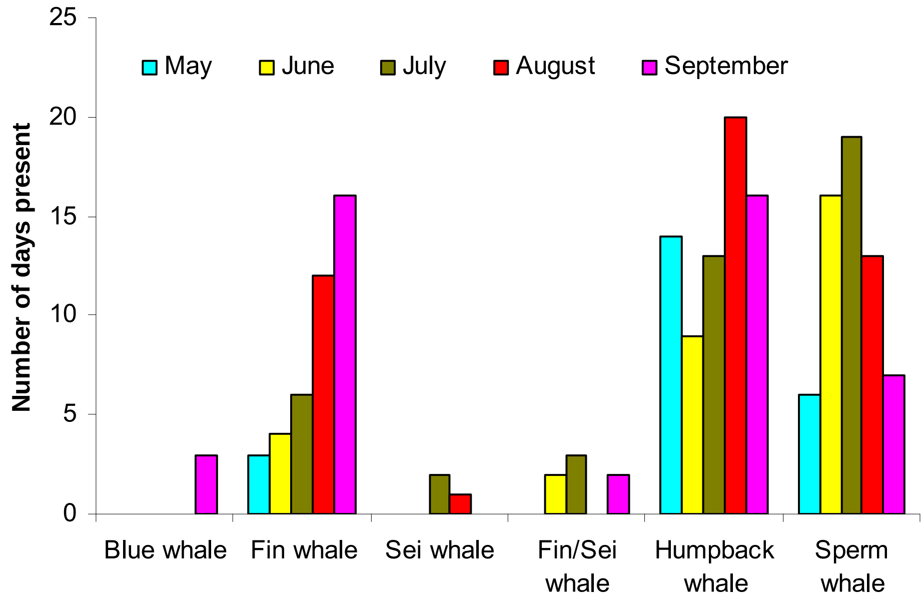


Figure 2. Passive acoustic monitoring sites. Langara Is.: winters 2005 to 2009, year-round 2009 to 2011; Bowie Seamount: deployed July 2011; Cape St. James: May 2008 to May 2011; Triangle Island: deployed May 2011; Brooks Peninsula: deployed July 2010; Union Seamount: February to June 2006; LaPérouse Bank: May to September 2007; Barkley Canyon NEPTUNE: operational December 2009; Swiftsure Bank: May 2009 to May 2011.

a)



b)

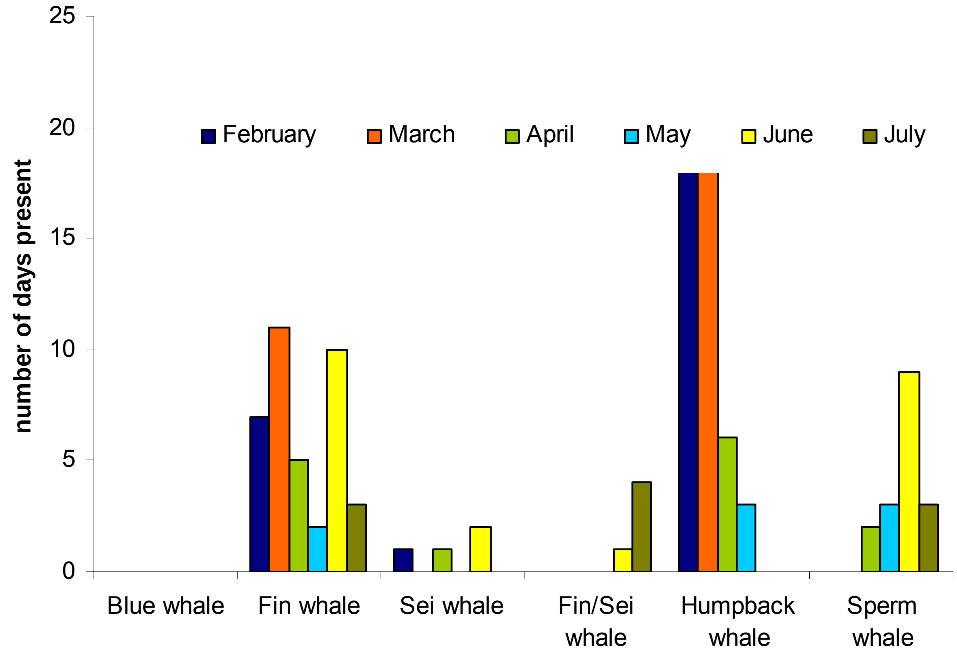


Figure 3. Number of monitoring days per month whales detected acoustically, a) La Perouse Bank 2007, b) Union Seamount 2006.

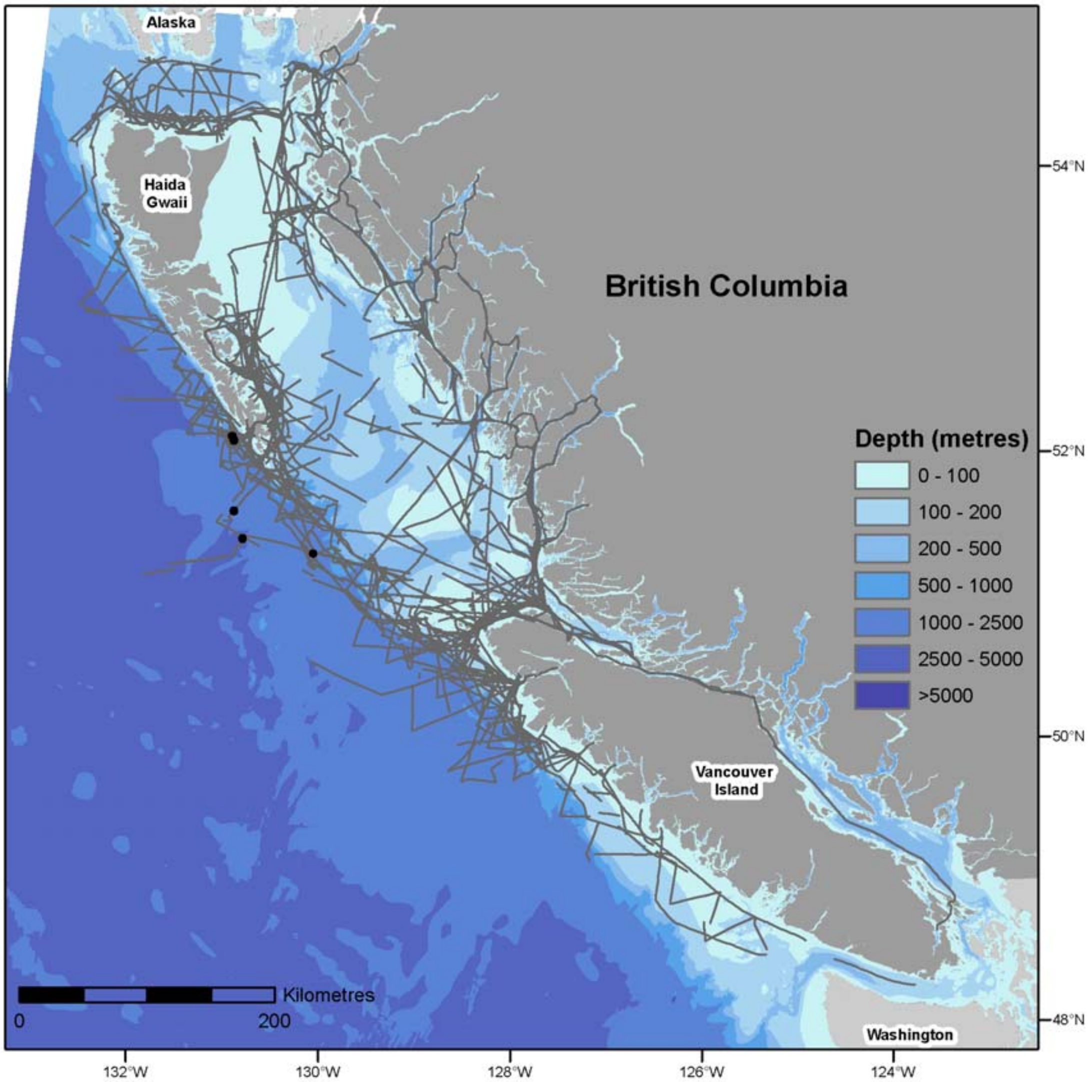


Figure 4. Blue whale sightings during DFO ship surveys 2002 to 2008 (Ford et al. 2010a).

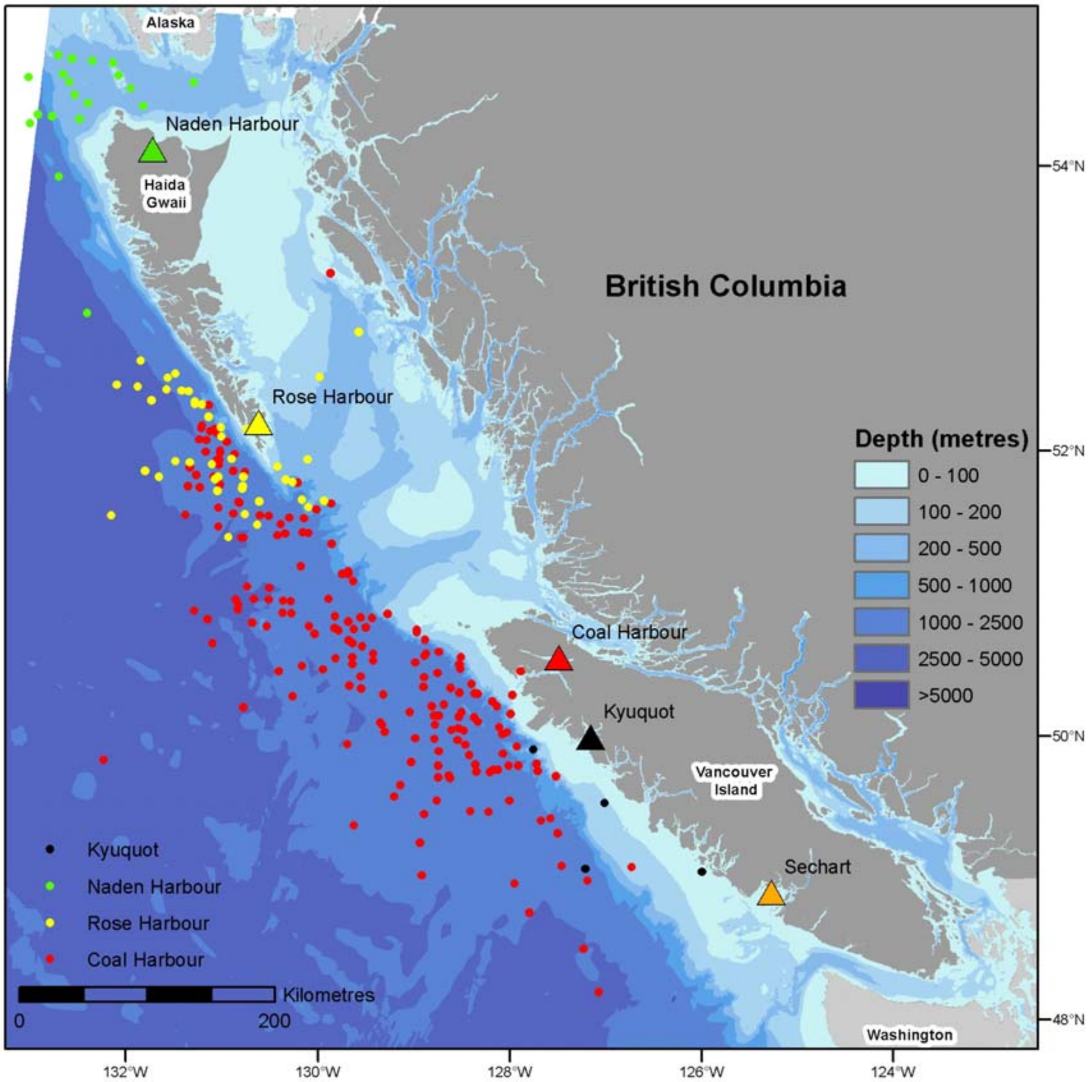


Figure 5. Distribution of geo-referenced Blue Whale catch. Naden Harbour (green symbols) operated 1911-1941 geo-referenced catch 1924-1928, Rose Harbour (yellow symbols) operated 1910-1943 geo-referenced catch 1924-1928, Coal Harbour (red symbols) operated 1948-1967, all catch geo-referenced, Kyuquot (black symbols) operated 1907-1925 geo-referenced catch 1924-1928, Sechart (orange symbol) operated 1905-1917 no catch geo-referenced (BC Historical Whaling database DFO; Nichol et al. 2002).

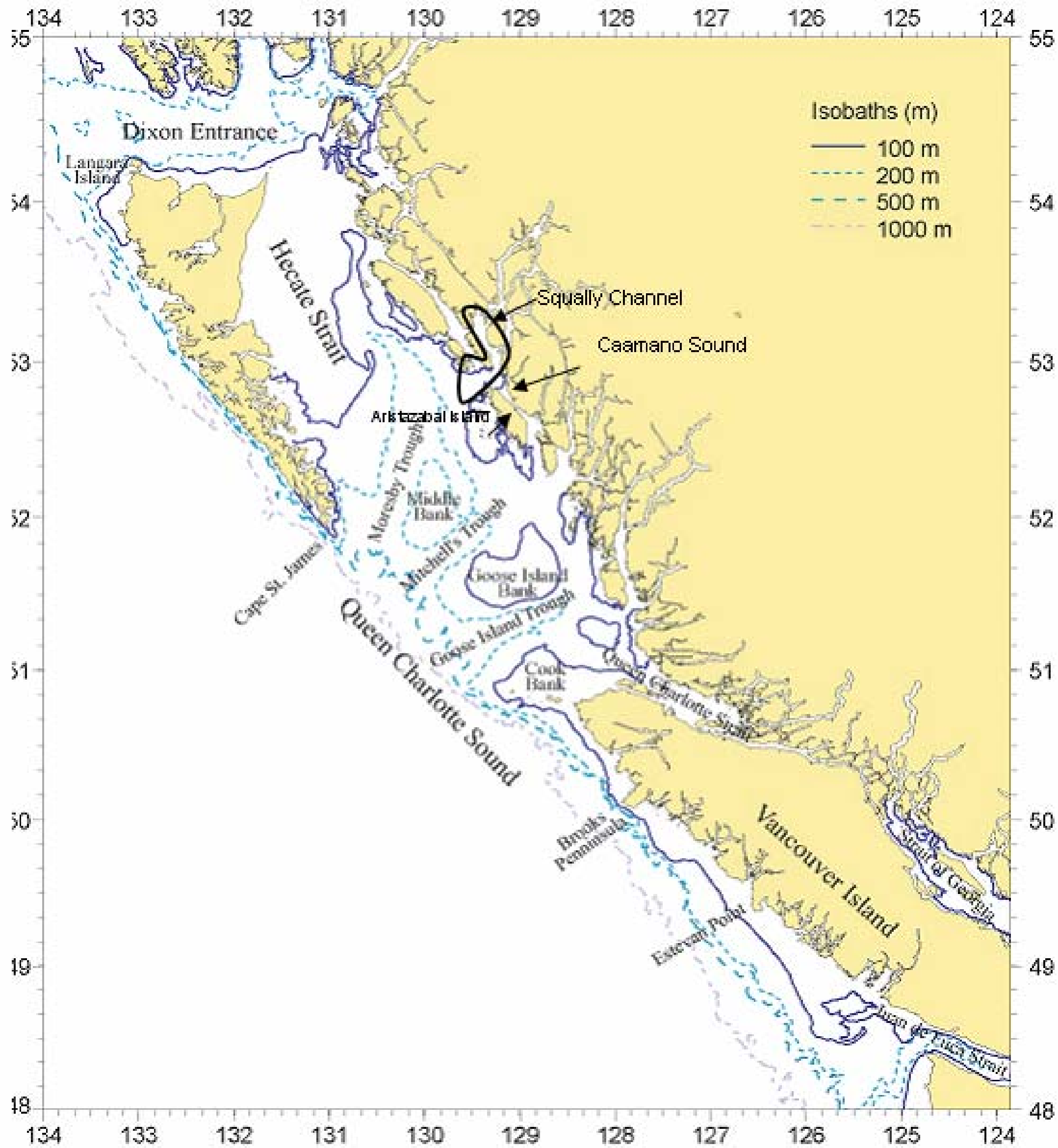


Figure 6. Pacific coast of Canada showing water bodies and oceanographic troughs mentioned in the text (Sinclair et al. 2005).

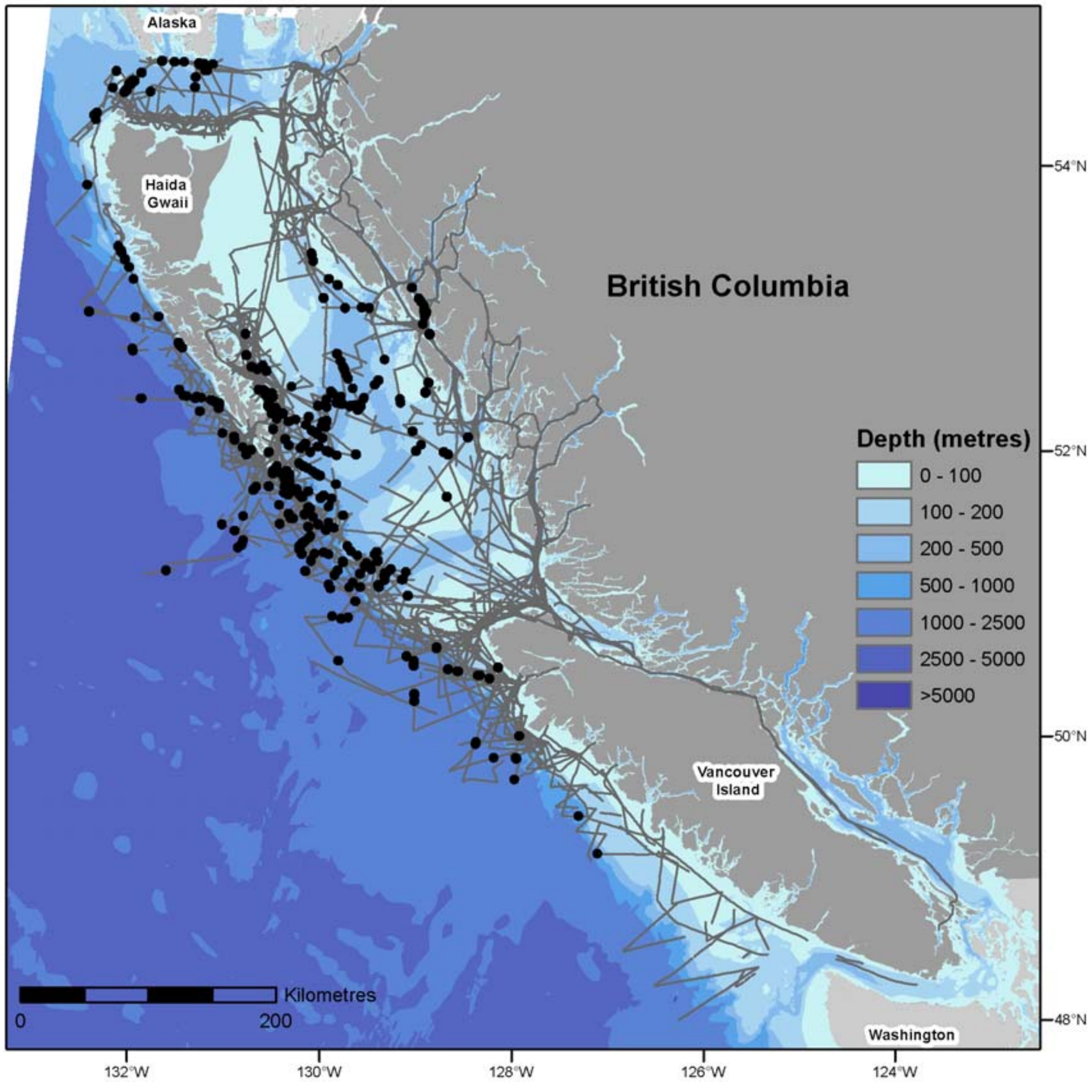


Figure 7. Fin Whales sightings, DFO surveys, 2002 to 2010 (Ford et al. 2010a; CRP-DFO unpubl. data).

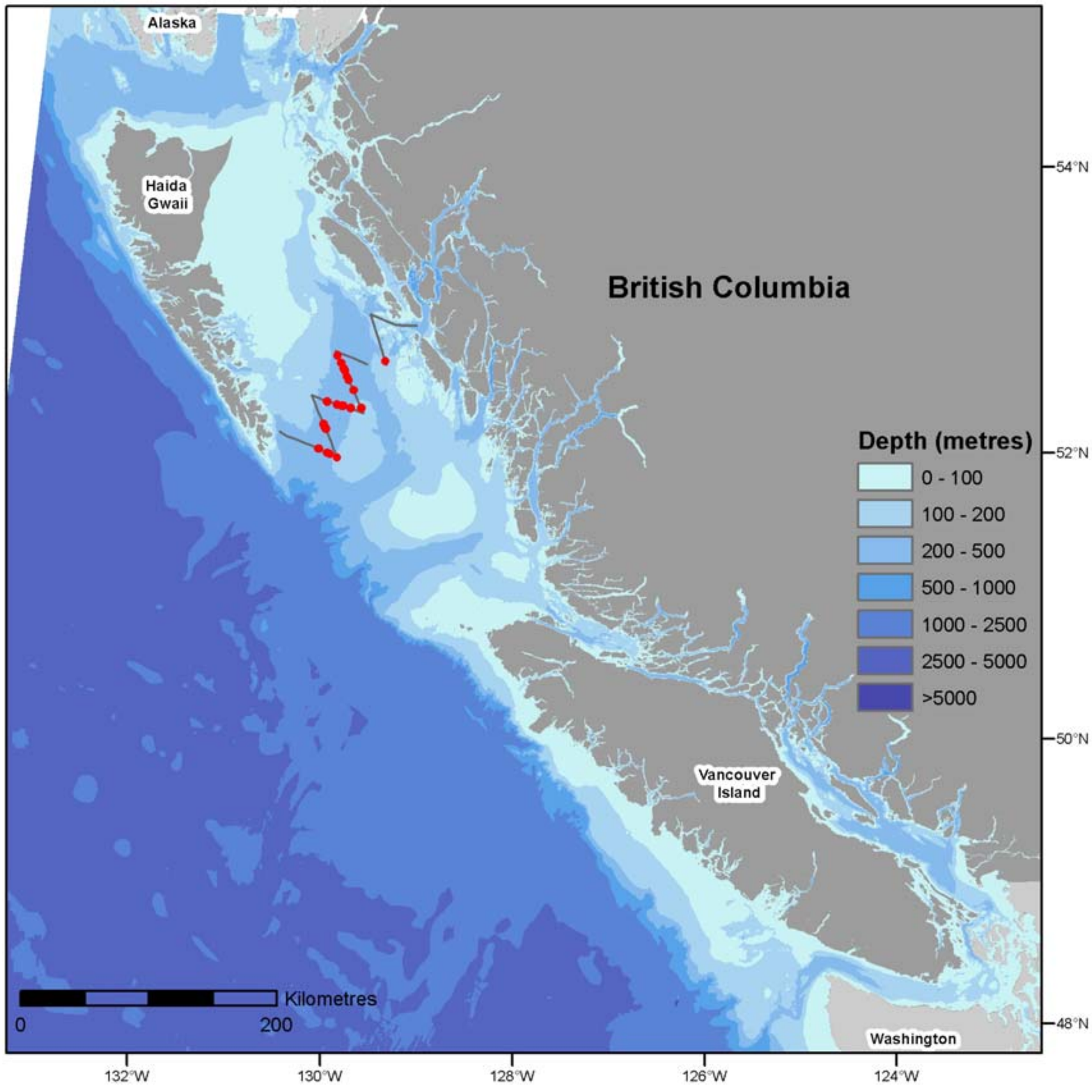


Figure 8. Moresby Trough survey area. July 2010. Total survey area 5098 km², survey transects lines (blue line), Fin whale sightings, (red dots) (CRP-DFO unpubl. data).

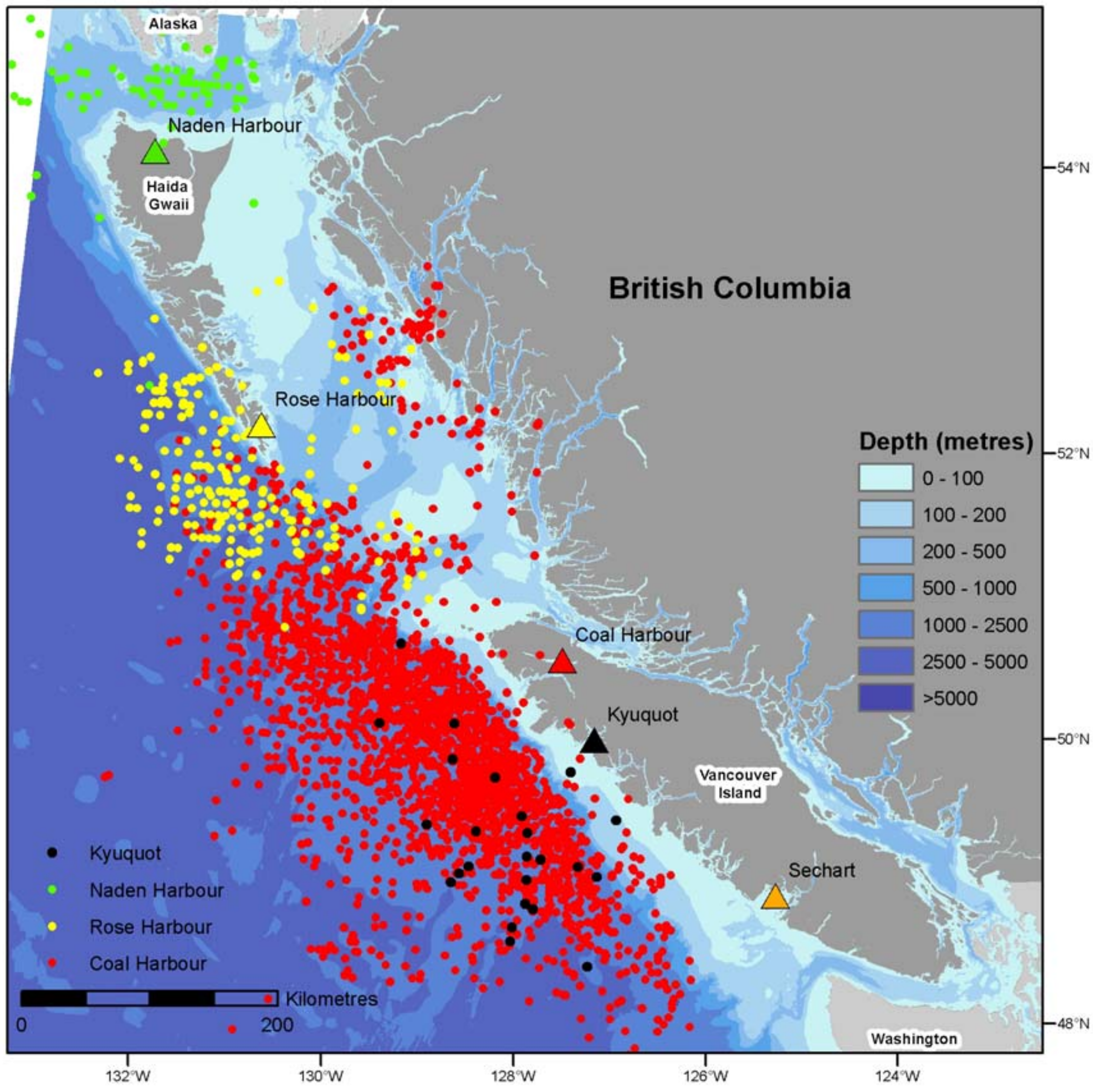


Figure 9. Distribution of geo-referenced Fin Whale catch. Naden Harbour (green symbols) operated 1911-1941 geo-referenced catch 1924-1928, Rose Harbour (yellow symbols) operated 1910-1943 geo-referenced catch 1924-1928, Coal Harbour (red symbols) operated 1948-1967, all catch geo-referenced, Kyuquot (black symbols) operated 1907-1925 geo-referenced catch 1924-1928, Sechart (orange symbol) operated 1905-1917 no catch geo-referenced (BC Historical Whaling database DFO; Nichol et al. 2002).

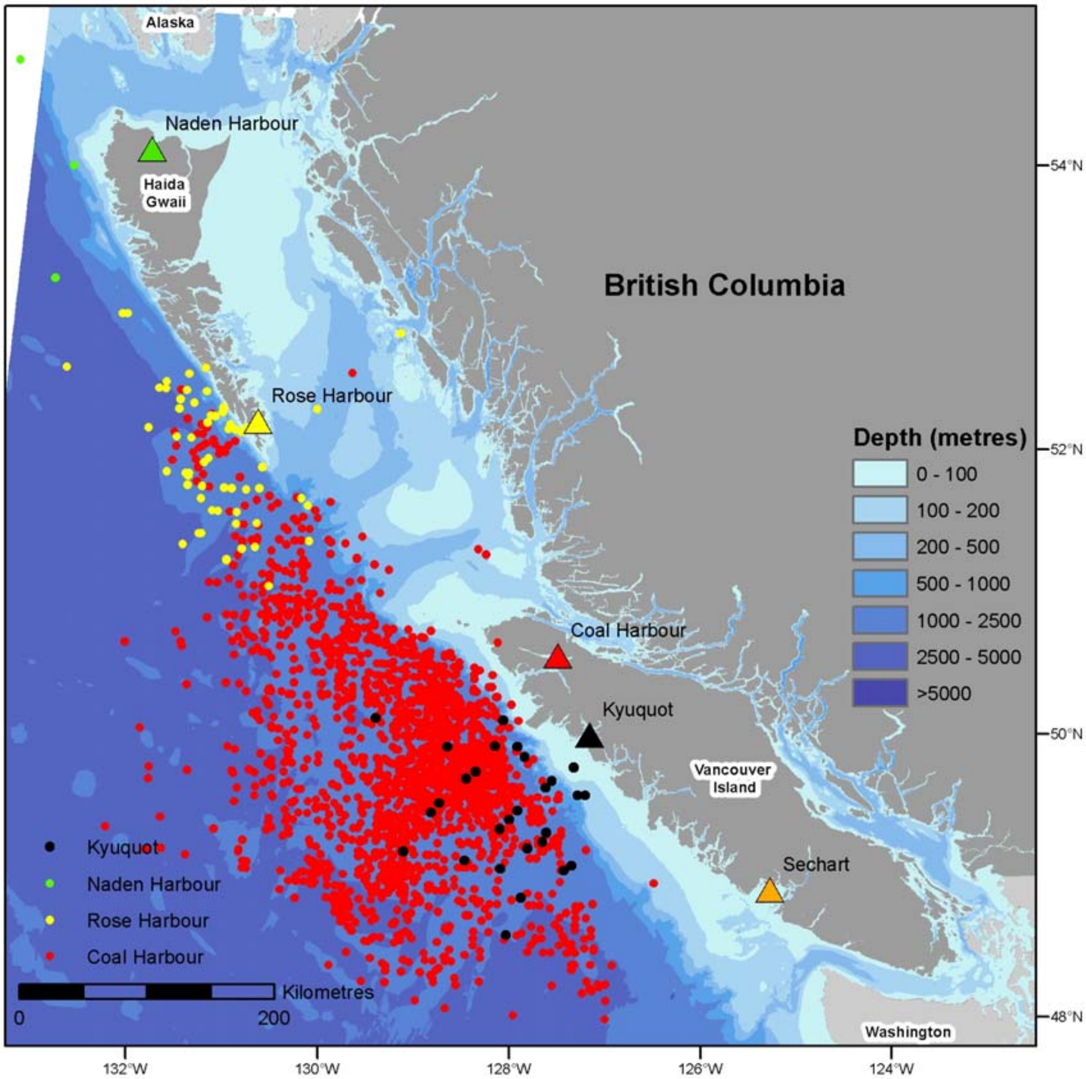


Figure 10. Distribution of geo-referenced Sei Whale catch. Naden Harbour (green symbols) operated 1911-1941 geo-referenced catch 1924-1928, Rose Harbour (yellow symbols) operated 1910-1943 geo-referenced catch 1924-1928, Coal Harbour (red symbols) operated 1948-1967, all catch geo-referenced, Kyuquot (black symbols) operated 1907-1925 geo-referenced catch 1924-1928, Sechart (orange symbol) operated 1905-1917 no catch geo-referenced (BC Historical Whaling database DFO; Nichol et al. 2002).

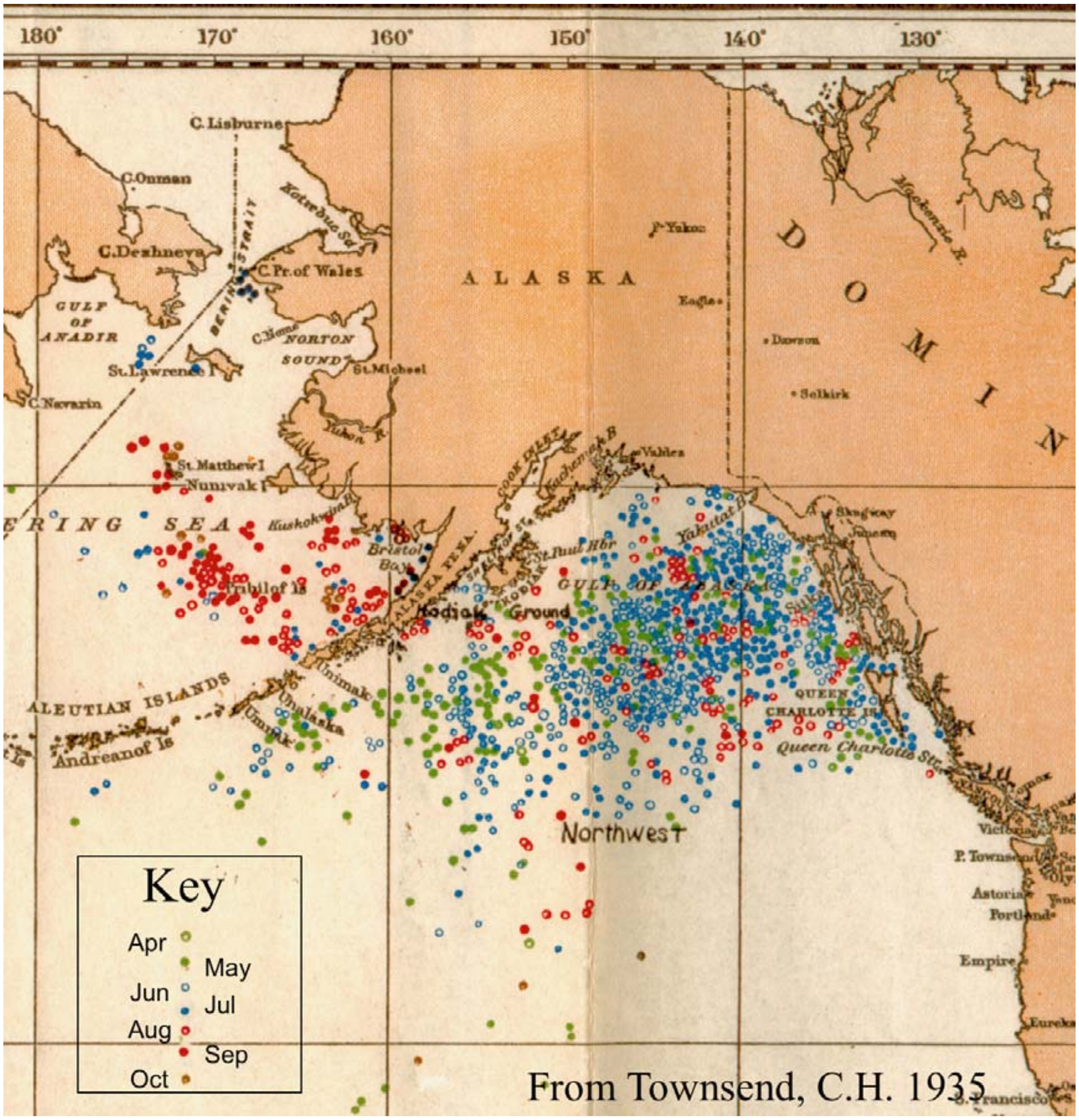


Figure 11. North Pacific Right whale catches from 1785-1913 in the eastern North Pacific from logbook records of American whaleships. The dot colour represents month of catch (Townsend 1935).

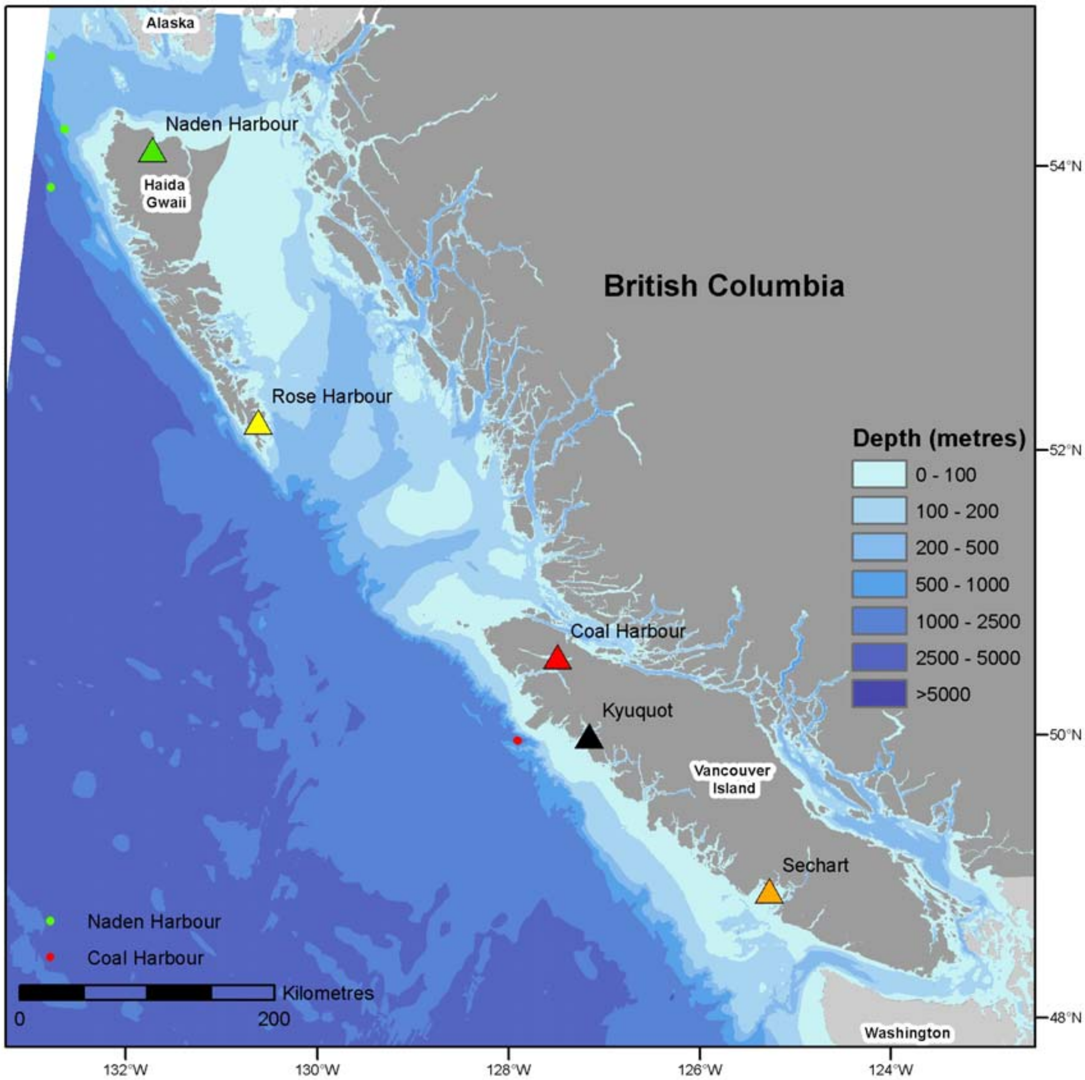


Figure 12. Distribution of geo-referenced North Pacific Right Whale catch. Naden Harbour (green symbols) operated 1911-1941 geo-referenced catch 1924-1928, Coal Harbour (red symbols) operated 1948-1967, all catch geo-referenced, Rose Harbour (yellow symbol) operated 1910-1943 no catch, Kyuquot (black symbol) operated 1907-1925 no catch, Sechart (orange symbol) operated 1905-1917 no catch (BC Historical Whaling database DFO; Nichol et al. 2002).

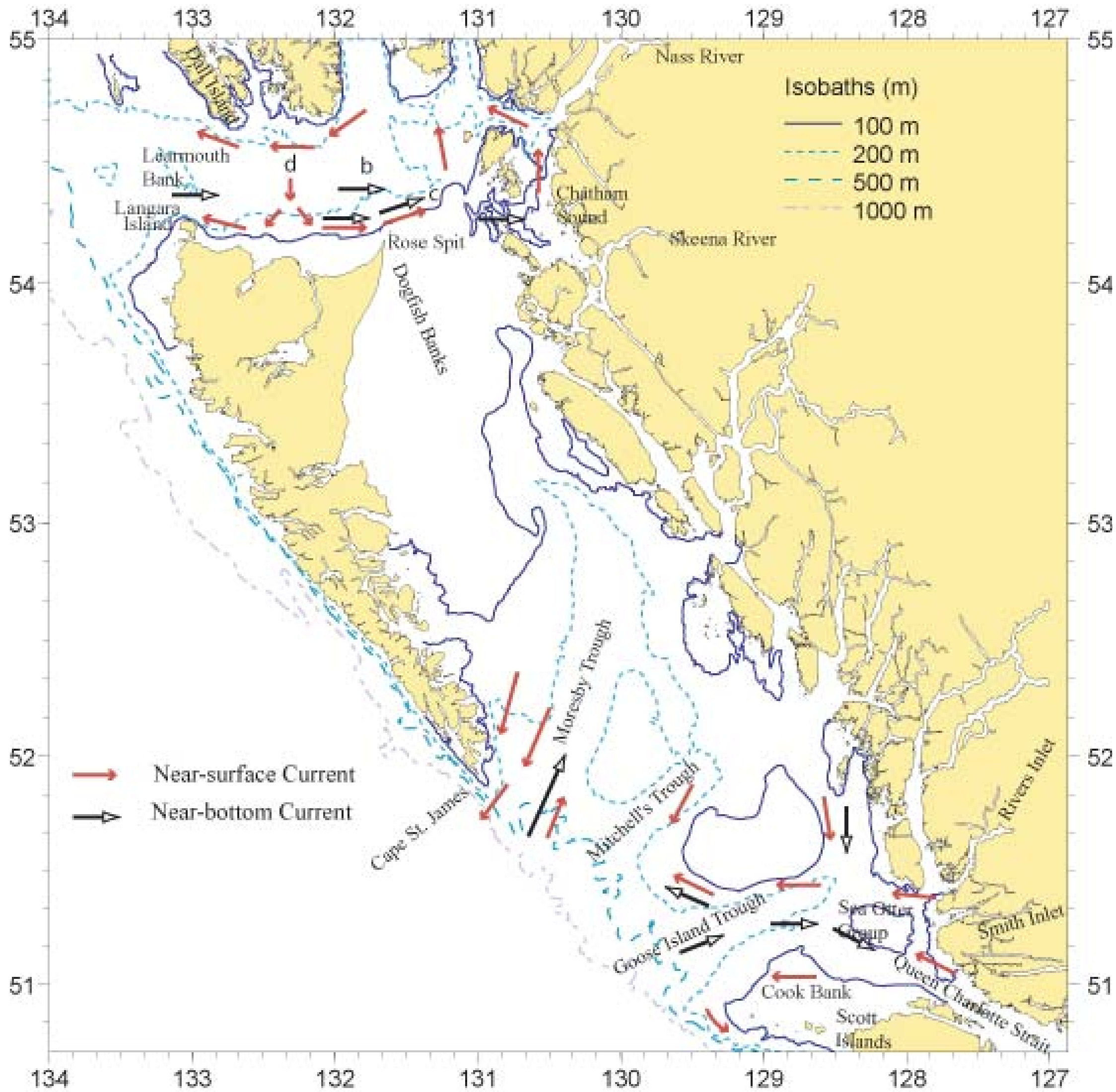


Figure 13. Troughs, banks and currents in Queen Charlotte Sound, Hecate Strait and Dixon Entrance (Sinclair et al. 2005).