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Information in Support of the Identification of Habitat of Special Importance to Fin Whales (*Balaenoptera physalus*) in Canadian Pacific Waters

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The Fin Whale is the second largest whale species in the world and occurs in Canadian Pacific waters. Fin Whales in the Pacific were listed as Threatened under Canada's Species at Risk Act (SARA) in 2006. As required by the SARA, research has focussed on studies to support identification of critical habitat for the species. In this report, we draw on recent research to describe distribution, abundance and behaviour of Fin Whales to provide information about important habitat to assist the identification of critical habitat. Following synthesis of the research findings one region was identified that meets the criteria for important habitat to support survival and recovery of Fin Whales under the SARA. The region includes most of the waters of Hecate Strait and Queen Charlotte Sound, and Greater Caamaño Sound. Ship-based surveys, acoustic monitoring, photo-identification studies and satellite tagging studies in the region demonstrate that Fin Whales are present year-round, and that they forage extensively throughout the area. Male mating calls in fall and winter months, and the presence of calves accompanying females observed during surveys, indicate Fin Whales carry out most if not all life processes in the area. The biophysical functions, features and attributes of this habitat of special importance are described, and examples of activities likely to result in the destruction of these components of the habitat are summarized. The identified habitat, however, represents only part of the total habitat of special importance for this species. Fin Whales also occur elsewhere in Canadian Pacific waters but most research effort to date has occurred in the inshore region. The relationship between Fin Whales in the inshore region and the offshore region is not clear. Photo-identification results, as well as acoustic studies, suggest that animals occupying Hecate Strait, Queen Charlotte Sound, Greater Caamaño Sound do not move readily between this region and the offshore of Vancouver Island and Haida Gwaii. Continued research will be needed to fully identify all habitats of special importance that are necessary for the survival and recovery of the species throughout Canadian Pacific waters.

1. INTRODUCTION

In 2006, Fin Whales in the Canadian Pacific were listed as Threatened under Canada's *Species at Risk Act* (SARA). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended this listing because sightings of Fin Whales are uncommon in British Columbia (BC) as a result of severe population depletion from commercial whaling in the 20th century. Oshumi and Wada (1974) estimated that pre-exploitation abundance in the North Pacific was 40,000 – 45,000 animals. Mizroch *et al.* (2009) presented a summary of kills from the North Pacific indicating that at minimum 40,650 animals were taken in the North Pacific (1911-1985). In the Northeast Pacific alone, 7,605 Fin Whales were killed and processed at coastal whaling stations in British Columbia between 1908 and 1967 (Ford 2014; Gregr *et al.* 2000), and thousands more were processed at coastal whaling stations in Alaska in the early part of the 20th Century. In addition, thousands were also killed during pelagic whaling operations in the Northeast Pacific that continued through the 1970s (Mizroch *et al.* 2009; COSEWIC 2005). Whaling reduced the number of Fin Whales in the North Pacific to an estimated 13,000 – 19,000 by 1973, of which 8500 – 11,000 were assumed to be from the eastern North Pacific (Oshumi and Wada 1974). These estimates, however, were made before it had been demonstrated that the former Soviet Union's whaling industry systematically under reported their catches during the 1960s. In the Northeast Pacific, the population is thought to be less than 50% of what it was before commercial whaling (COSEWIC 2005).

As required under the SARA, a recovery strategy was completed in 2006 and a partial action plan in 2013 for Fin Whales in Canadian Pacific waters (DFO 2013; Gregr *et al.* 2006). The stated goal of the recovery strategy is to '*attain a long-term viable population of Fin Whales that use Pacific Canadian waters'*. The population and distribution objectives stated in the recovery strategy were to '*identify the population to which Fin Whales in British Columbia belong*, and *to maintain or increase the proportion of Fin Whales in BC waters relative to the whole population by 2016'*. Further abundance and distribution objectives were '*to estimate the number of Fin Whales in BC waters'*, and to '*determine the extent of migration* and *determine seasonal distribution in BC waters'.*

It is a legal requirement under SARA to identify critical habitat for species that are listed as Threatened or Endangered. Critical habitat under SARA is defined "*as habitat necessary for survival or recovery of a listed wildlife species...".* SARA further defines habitat for aquatic species as areas for rearing, food supply, migration or any other areas upon which aquatic species depend directly or indirectly to carry out life processes (DF0 2015). In cases where information is insufficient to identify critical habitat, the recovery strategy must include a schedule of studies to obtain such information. At the time the Recovery Strategy was prepared in 2006, the technical team concluded that existing information was inadequate to identify critical habitat, and a schedule of studies was included in the document. A schedule of studies was also included in the partial action plan (DFO 2013), because in 2011 science advice, based on a synthesis of the best information available at that time, indicated that there was insufficient information with which to identify critical habitat in BC waters (Nichol and Ford 2012).

In this report, we present a synthesis of the results of several quantitative analyses that arose from the schedule of study for critical habitat. In particular, we draw upon data presented in Koot (2015), Nichol *et al.* (2018) and Pilkington *et al.* (2018). With this synthesis we identify habitat of special importance for the species that would contributes to the population and distribution recovery objectives for Fin Whales in the Canadian Pacific waters. This information will assist in the identification and designation of critical habitat for Fin Whales.

2. FIN WHALE ECOLOGY

The Fin Whale occurs almost worldwide from polar regions to the equator. In the North Pacific, Fin Whales are found from the Southern Chukchi Sea to the Tropic of Cancer (Mizroch *et al.* 2009). A distinct seasonal migration between high-latitude summer feeding grounds and low-latitude breeding grounds, a characteristic of many baleen whale species (e.g. Grey Whale, Humpback Whale), is not apparent in Fin Whale in the North Pacific. Historical catch data and acoustic data demonstrate that the species is regularly found north of 40° N in winter months. There is also potentially a complex population structure underlying the more diffuse migration patterns and also evidence of discrete eastern Pacific and western Pacific populations (Archer *et al.* 2013; Mizroch *et al.* 2009). Acoustic studies also suggest that Fin Whales are breeding as well as feeding in northern latitudes (Archer *et al.* 2013; Simon *et al.* 2010; Mizroch *et al.* 2009; Stafford *et al.* 2007).

Fin whales are the second largest whale species attaining lengths of 17.8m and 19.8m in males and females respectively in the North Pacific (Ford 2014). Studies of Fin Whale life history indicate that they reach sexual maturity at 5 to 15 years. The life span of a Fin Whale is thought be about 80 years. Females calve every 2 years and give birth after an 11-12 month gestation period. Calves are born at 6 m and weaned at approximately 11.5m in length (Ford 2014).

Fin Whales are large-bodied filter-feeding grazers that prey on dense aggregations of tiny prey organisms, including euphausiids, copepods, and a variety of schooling fish that they obtain by lunging feeding at depth and near the surface (Ford 2014). In BC, diet information is inferred from whale carcasses processed at the Coal Harbour whaling station from 1955 to 1967. Of 959 Fin Whales with food in their stomachs, 96% contained euphausiids and 4% copepods, whereas squid and fish (likely herring) made up less than 1% of diet (Ford 2014; Flinn *et al.* 2002).

3. ANALYSIS AND DISCUSSION

3.1. DISTRIBUTION IN BRITISH COLUMBIA

Current distribution

The distribution of Fin Whales based on data from ship surveys (2002 - 2014), photo-identification studies (2002 - 2015), and aerial surveys (2012-2015) indicates that Fin Whales are found seaward of the continental shelf off west of Vancouver Island and Haida Gwaii but also in Hecate Strait, Queen Charlotte Sound, Dixon Entrance, and Greater Caamaño Sound which are on the continental shelf (Ford et al. 2010a; Nichol et al 2018) (Figure. 1, 2). Greater Caamaño Sound includes Caamaño Sound, Campania Sound, Squally Channel and Whale Channel which together comprise Gil Basin (MacDonald *et al.* 1983;

While the distribution of sightings in Figure 1 illustrates the geographic extent of Fin Whale sightings in BC since 2002, most of the ship survey and photo-identification effort, and all of the satellite telemetry effort, has taken place in the inshore region of Hecate Strait, Queen Charlotte Sound, Greater Caamaño Sound, and to some extent, Dixon Entrance. This area is demarcated to the west by the continental margin between Cape Scott on Vancouver Island and Cape St. James in Haida Gwaii, to the east by the BC mainland inlets and channels, and to the north by the Canada-US border in Dixon Entrance (Figure 3). Aerial survey data confirm that Fin Whales do occur seaward of the continental shelf, but there has been much less survey effort in offshore areas, despite the apparent historical importance of this area suggested by whaling catch records.

Occupation of both oceanic waters and near coast waters has been reported elsewhere as well. In the central Bering Sea, Fin Whales were found clustered along a 200m isobath of the Bering

Sea shelf break but large aggregations of animals were also encountered in depths less than 200m (Moore *et al.* 2000). In western Alaska, Fin Whales were often found close to shore, and regularly entered narrow deep inlets and bays around Kodiak Island (Witteveen *et al.* 2015).

Historical distribution

Information about the historical distribution of Fin Whales is inferred largely from whaling catch records (1908 to 1967). Fin Whales in BC were killed mostly offshore in Canadian Pacific waters, seaward of the continental shelf, but a smaller portion of the catch was taken in Hecate Strait, Queen Charlotte Sound, Greater Caamaño Sound and Dixon Entrance. Most Fin Whales killed in BC during 1948-1967 were taken in depths of 1800-1900 m, representing offshore waters, whereas animals hunted inshore were taken in depths of < 1000m (Pike and MacAskie 1969; Gregr 2000; Gregr *et al.* 2000) (Figure 4). The distribution of kills in Hecate Strait and Greater Caamaño Sound are very similar to the distribution of sightings from recent ship surveys.

Habitat modelling

Fin Whale sightings and effort from the region of Hecate Strait, Queen Charlotte Sound, Greater Caamaño Sound obtained from 37 ship surveys (2003 – 2014), were modelled as a function of depth, slope and latitude. The analysis did not include sightings and effort from Dixon Entrance or offshore waters because of heterogeneity of survey effort in these areas (Nichol et al 2018). The model predicted distribution of Fin Whales in Hecate Strait, Queen Charlotte Sound, and Greater Caamaño Sound, and demonstrated an association with some particular areas. These include Moresby Trough, a deep-water gully that extends northeast from the shelf break south of Haida Gwaii to Caamaño Sound, heads of submarine canyons near the 1000m depth contour between Cape Scott and Cape St James, and areas along the mainland coast, particularly Greater Caamaño Sound (Nichol et al. 2018) (Figure 5). The model distribution of Fin Whales agrees closely with the predicted distribution of Fin Whales reported in other studies. In all cases, the bathymetric feature, Moresby Trough, was highlighted. Gregr and Trites (2001) used historical whaling data (1948-67) Williams and O'Hara (2009) used data from line transect surveys (2004-2005), Best *et al.* (2015) used Williams and Thomas (2007)'s 2004 and 2005 data as well as additional line transect data collected 2006 to 2008. It is likely that features captured by depth, slope and latitude have an important role in enrichment processes which may serve to concentrate and/or retain zooplankton creating productive feeding areas (Dalla Rosa *et al.* 2012).

Seasonal habitat use

Fin Whales were sighted in all seasons, including winter, during ship and aerial surveys, which is consistent with observations noted by Mizroch *et al.* (2009) of a year-round occurrence at high latitudes in the North Pacific. Analysis of acoustic data from remote monitoring sites in BC has demonstrated that Fin Whale songs, produced by males and associated with reproduction, are detected throughout fall and winter months in BC and provide further confirmation that Fin Whales are present year-round. The presence of calling males also suggests that breeding occurs in Canadian Pacific waters (Pilkington *et al.* 2018; Koot 2015; Ford *et al.* 2010b; Stafford *et al.* 2005; Watkins *et al.* 2000).

Acoustic monitoring sites in Hecate Strait, Queen Charlotte Sound and Greater Caamaño Sound had the greatest and most sustained acoustic activity of all monitoring sites in BC that were analysed, after accounting for among-site differences in detectability (Figure 6,7). In Hecate Strait and Queen Charlotte Sound, peak periods of song (November to January) were offset seasonally from peak periods of singing elsewhere in BC waters (Figure 8), suggesting a seasonal movement of Fin Whales into the region in late fall and winter could be occurring, coinciding with the climax of the breeding season. Details of Fin Whale kills in the BC historical whaling records, reveal that an estimated 75% of births in the Fin Whale population in British Columbia would have occurred between mid-November and mid-March with a peak in January (Pike 1956 Unpublished data[1]; Koot 2015). These insights combined with high levels of calling and the offset peak of calling from everywhere else suggest that courtship and mating occur during the period October to February (Pilkington *et al.* 2018). Whether pregnant females also remain in the region to give birth is unknown. Rearing also appears to occur in this region indicated by the presence of Fin Whales with dependent calves, although it may occur widely as well but is not known because most survey effort has occurred in the inshore (Table 1).

3.2. CURRENT ABUNDANCE

The size of the Fin Whale population throughout Canadian Pacific waters is not known, but extensive photo-identification effort to support a mark-recapture abundance analysis was undertaken primarily in the inshore region of Hecate Strait, Queen Charlotte Sound and Greater Caamaño Sound (2009-2015) (Nichol et al 2018). Based on mark-recapture modelling of 283 photo-identified individuals, an estimated 405 whales (%CV 6, 95% CI: 363-469), had occurred in the study area and were available for capture at any time during the period of 2009 to 2014, whether or not they were all present in the study area at any given time (Nichol et al 2018). This estimate is called the super population abundance estimate. There are two other abundance estimates for this region that are based on line transect survey data (Williams and Thomas 2007; Best *et al.* 2015). Abundance estimates derived from line-transect surveys represent estimates of the number of animals present in a study area at the time of the surveys. Williams and Thomas (2007) reported an abundance estimate of 496 (%CV 46, 95% CI 202 – 1218) in the region (although including Dixon Entrance) based on line transect surveys made in 2004 and 2005. This number can be interpreted to represent the estimated average number of Fin Whales present in the study area at any time during the given survey years. Best *et al.* (2015) reported an abundance estimate of 329 Fin Whales in the same region with narrower confidence intervals (95% CI 274-395), using the Williams and Thomas (2007) dataset plus additional line transect surveys made 2006-2008. Abundance estimates from mark-recapture and line transect surveys are not directly comparable. Nonetheless the two estimates suggest that on average during a line transect year a high proportion of the super population occupied the Hecate Strait, Queen Charlotte Sound, and Greater Caamaño Sound region (Calambokidis and Barlow 2004). Whaling catch records provide some indication of the historic population size and importance of this area, in a 15-year period (1952-66), 240 Fin Whales comprised of both males and females were killed in Hecate Strait and Queen Charlotte Sound, of which 47 were killed in Greater Caamaño Sound.

3.3. MOVEMENTS AND SITE FIDELITY

Analysis of photo-ID data also provided insight into movements of Fin Whales in BC waters over the entire photo-ID time series (1995-2015). Although there was comparatively less photo-identification effort offshore compared to the inshore region, very few photographed Fin Whales moved back and forth from inshore (Hecate Strait, Queen Charlotte Sound, and Greater Caamaño Sound) to offshore (seaward of the continental shelf) (Figure 3). Specifically, among 177 Fin Whales that were each photographed again in at least one subsequent year, there were

[1] Pike, G. C. 1956. Age, growth and maturity studies on fin whales from the coast of British Columbia. Fisheries Research Board of Canada. Unpublished Manuscript.

only 5 instances in which an animal moved between the inshore and the offshore region (Figure 9). Although greater effort inshore compared to offshore may, at least in part, drive this result, there may be real population differences between the inshore and the offshore as well. Other published studies report that distinct populations exist in the Northeast Pacific, distinguishable by genetics and by geographic variation in Fin Whale songs (Archer *et al.* 2013; Mellinger and Barlow 2003). Of particular relevance to BC is the discovery of two song types identified during analysis of acoustic data from autonomous recorders deployed off the BC coast (Koot 2015). Fin Whales that produced song Type 2 were detected throughout coastal British Columbia, in coastal inlets and along the shelf edge, but also offshore at Bowie Seamount. The Type 1 song was only heard at offshore and shelf break recording locations. This suggests that there may be two populations whose distributions include BC waters, with one population using coastal waters more often the other distributed offshore (Koot 2015).

Photo-identifications were also used to examine movements of Fin Whales within the inshore region. The results suggest that Fin Whales move between locations within Hecate Strait and Queen Charlotte Sound. Greater Caamaño Sound was the only area where there appeared to be relatively strong site fidelity from year to year. This is demonstrated by the leveling off of the discovery curve which would be expected if the area were occupied by animals exhibiting fidelity to the area (Figure 10).

3.4. BEHAVIOUR AND MOVEMENTS INFERRED FROM SATELLITE-LINKED TAGS

A Bayesian state-space switching model was used to analyse satellite tag data from 19 animals tagged in Hecate Strait and Greater Caamaño Sound (August to October 2011-2014). The model categorizes movement into two states; transiting and area-restricted-search (ARS). The latter state is characterized by frequent changes in direction and speed, and is inferred to represent foraging behaviour, but may also include any other localized behavioural state such as socializing (Jonsen *et al.* 2005). Modelling results indicated that the tagged whales undertake long directional movements throughout the area, stopping to engage in ARS type behaviours in locations for days or weeks at a time. Although most of the animals were tagged in Greater Caamaño Sound, which would tend to bias the sample toward animals that had already selected Greater Caamaño Sound, several animals travelled from Greater Caamaño Sound into Hecate Strait and followed the edge of Moresby Trough as it runs north parallel to Banks Island, or they moved across Hecate Strait following Moresby Trough and initiated ARS type behaviours near southeast Moresby Island and Cape St. James (Figure 11). These movements are consistent with observations during photo-identification focused field work of large aggregations of Fin Whales that appeared to be foraging (Ford 2014). The Fin Whale distribution model based on ship surveys (2003-2014) also predicted relatively higher Fin Whale densities in these locations where tagged animals exhibited foraging behaviour.

Dive profiles associated with ARS behaviour illustrated a significant diurnal pattern in diving behaviour in Greater Caamaño Sound. Longer and deeper dives occurred during day-light hours whereas dives were shorter and shallower during night hours, a behaviour that would be consistent with whales foraging on dense layers of diel vertically migrating zooplankton that would be aggregated at depth during the day (Figure 12). The intensive and consistent ARS behaviour and associated dive behaviour recorded in Greater Caamaño Sound suggests Fin Whales were feeding in this sub-region, in particular, and that it is an important feeding area for Fin Whales.

3.5. SIGNIFICANCE OF HECATE STRAIT, QUEEN CHARLOTTE SOUND, AND GREATER CAAMAÑO SOUND

Our analyses reveal important information about the behaviour of Fin Whales in Hecate Strait, Queen Charlotte Sound, and Greater Caamaño Sound, and indicate that these areas are occupied year-round by Fin Whales. Whaling catch also confirms that the region was occupied historically. There is not sufficient data and survey effort with which to assess the significance of Dixon Entrance, and offshore regions of west coast Haida Gwaii and west coast Vancouver Island. However, within Hecate Strait, Queen Charlotte Sound, and Greater Caamaño Sound Fin Whales forage, rear young, and potentially mate. Large aggregations of feeding whales have been observed in Hecate Strait and Queen Charlotte Sound (Ford 2014). State-space modelling of tag data provides considerable quantitative evidence that Fin Whales exhibit ARS movement throughout the region, and field observations suggest this ARS type movement is likely foraging behaviour. Tagged Fin Whales travelled back and forth across Hecate Strait, particularly following the long axis of Moresby Trough. Areas where ARS movement occurred and where field observations suggest foraging behaviour, included Greater Caamaño Sound, west of Banks Island along the 200m depth contour, in Moresby Trough at the southwest end near Moresby Island, and along the mainland side of Hecate Strait. Observations of females with calves during ship surveys and from photo-identification efforts, and the increase in singing behaviour that occurs November to January, suggest that mating and rearing take place in the region. Acoustic analyses suggest that a movement of Fin Whales into the region in winter could account for a peak calling period in Hecate Strait that is 1-2 months later than all other areas examined (Pilkington *et al.* 2018). If true, this could indicate that the abundance of animals estimated by mark-recapture represents a pre-breeding season population size in the region.

Fin Whales feed on dense aggregations of diel vertically migrating zooplankton. Diel partitioning of singing behaviour is commonly reported and it is thought that animals may be more vocal during the portion of the 24-hr cycle when prey are not profitable to exploit, and then are less vocal because they are engaged in foraging activity when prey are profitable to exploit (Simon *et al.* 2010; Stafford *et al.* 2005; Watkins *et al.* 1987). In Hecate Strait and Queen Charlotte Sound, no diel pattern to call activity was evident (Pilkington *et al.* 2018). One possible explanation is that oceanographic conditions and complex bathymetric features create foraging areas throughout the Hecate Strait and Queen Charlotte Sound that are profitable at different times and for varying lengths of time during the 24-hr cycle which could enhance the profitability of the region for Fin Whales.

Within Greater Caamaño Sound itself, satellite-linked tag data, coupled with photo-ID data, demonstrate that animals foraged at depth during the day most likely on dense patches of zooplankton, and further that individuals exhibit fidelity to this area, returning or remaining in the area such that the same individuals were photographed in multiple years. This area appears to have been of historical importance to Fin Whales as well, based on the reported Fin Whale catch from Greater Caamaño Sound.

4. CRITICAL HABITAT: BIOPHYSICAL FUNCTIONS, FEATURES AND THEIR ATTRIBUTES

DFO's guidelines for the identification of critical habitat (DFO 2015[2]) require that a description of the habitat includes a description of its biophysical functions, features and attributes. This descriptive exercise serves to explain as clearly as possible, given the extent of knowledge, how Fin Whales use the habitat and what aspects of the habitat are important to support them. Biophysical functions describe how the habitat is used by the species to support specific life processes. Table 2 summarizes the following description of functions, features and attributes. Our surveys indicate that Fin Whales are present on the coast year-round in all months during which we have surveyed by ship, plane, and remote acoustic monitoring. Male courtship and **mating** calls are detected in fall and winter in BC with increased activity November to January in Hecate Strait, Queen Charlotte Sound and Greater Caamaño Sound (Pilkington *et al.* 2018; Koot 2015). This period overlaps the time frame of mid-November to mid-March (with a peak in January) when Fin Whale calving occurs (based on estimates from BC whaling data) (Pike 1956 Unpublished data[1]; Koot 2015). Gestation in this species is 11-12 months, placing births in the same seasonal time frame as male calling activity. Calves are weaned at 6 to 8 months. Therefore, calves observed during surveys in winter (February, March) are likely young of the year. Calves observed in July may be near weaning suggesting that **rearing** of young takes place in BC waters. **Foraging** is the main activity observed during ship surveys and photo-identification studies,and inferred from State-space modeling and analysis of dive tag data. Therefore, it should be presumed that habitat in Canada supports all life processes of Fin Whales.

The biophysical features of critical habit are defined as the components of the habitat that support the functions described (DFO 2015[2]). To support the function of foraging, food availability is important. In general, it is understood that profitable aggregations of prey are the result of oceanographic conditions, in conjunction with favourable bathymetric features, that help to aggregate prey into sufficient densities for optimal foraging. Castellote *et al.* (2012) demonstrated that Fin Whale calling behaviour changed under increasing levels of background noise, and that when exposed to conditions associated with seismic airgun activity, Fin Whales left the area for an extended period of time. Fin Whales may, therefore, require an underwater acoustic environment in which background noise does not interfere with foraging, or with acoustic communication during breeding and rearing. Table 2 also lists two additional features, "physical space" to maneuver and "water quality" of sufficient quality, to support all the functions identified.

The biophysical attributes of critical habitat can be defined as the components of the features that together allow those features to support the function of the habitat (DFO 2015[3]). For example, for there to be sufficient food available, important prey species must not only be abundant enough to support the Fin Whale population, they must be available in sufficiently dense aggregations for them to be energetically profitable to exploit, and to be at a depth range that is also optimal for foraging (Hazen et al 2015). Laidre *et al.* (2010) found that prey patches below 150m depth were predictors of Fin Whale sightings in West Greenland suggesting there was a threshold depth above which foraging was not profitable. It is not known what densities of prey are required for foraging to be energetically profitable for Fin Whales. Studies of Blue Whales may provide some insight, although Blue Whales are obligate euphausiid feeders,

[2] DFO. 2015. Species at Risk Act (SARA) Guidelines for the Identification of Critical Habitat for Aquatic Species at Risk. April, 2015, 43p.Unpublished report.

whereas Fin Whales have a broader diet. Densities of less than 100 krill m^3 are predicted to be suboptimal for foraging Blue Whales (Hazen *et al.* 2015; Goldbogen *et al.* 2011).

Attributes that are important for the acoustic quality of habitat are difficult to quantitatively. There is concern about the effects of both chronic and acute anthropogenic noise on cetaceans (Castellote *et al.* 2012; Nowacek *et al.* 2007). Despite this, it is currently not possible to define quantitatively the specific attribute thresholds that contribute to the features of the acoustic environment that facilitate critical habitat functions. It is also not known what threshold of space is needed to carry out life processes nor what specific thresholds of water quality are needed. Presumably loss of space and water quality might arise from an anthropogenic development project, resulting in an increase in shipping activity in an area.

5. IDENTIFICATION OF HABITAT NECESSARY TO MEET RECOVERY OBJECTIVES

Following recommendations provided in DFO's operational guidelines for the identification of critical habitat, we used the *bounding box* approach to identify habitat necessary to meet population and distribution recovery objectives for Fin Whales (DFO 2015[3]). This approach is proposed when the exact location of important habitat features and their attributes are not well known, even though the features that are essential to the survival or recovery of the species are understood. A map showing the boundaries of this important habitat area in Hecate Strait and Queen Charlotte Sound is provided in Figure 13. This encompasses locations that our studies have shown to be occupied for much of the year by high densities of Fin Whales and that are undoubtedly important for feeding and other life processes. Dixon Entrance is not included in this area, for several reasons. It is separated from the bounded area by a shallow area which forms a natural boundary. More research in Dixon Entrance is needed because there were few photo-identification matches between Dixon Entrance and the bounded area suggesting little movement and there was also no movement of satellite tagged animals into that area. The bounded area should be considered as habitat necessary to meet population and distribution recovery objectives as defined by the SARA and provided in the recovery strategy for Fin Whales. However, it should be noted that this constitutes only part of the habitat needed for Fin Whales to meet population and distribution recovery objectives in Canadian Pacific waters. It does not include important habitats that may exist in the outer region, which, based on our photo-ID studies and analyses of song structure (Koot 2015), is likely occupied mostly by whales that do not frequent the inner coast region. Also, insufficient information was available to assess inner region waters off the west coast of Vancouver Island, as well as Dixon Entrance. Further studies will be needed to identify important habitat in these other areas.

5.1. OCEANOGRAPHIC DESCRIPTION OF HECATE STRAIT, QUEEN CHARLOTTE SOUND AND GREATER CAAMAÑO SOUND

Hecate Strait is situated at the inshore transition zone between two large-scale North Pacific circulating Gyres: the Alaskan and East Pacific Gyres. The Alaskan Gyre transports cold waters from offshore towards the coast of BC where it turns northward becoming the Alaska Current. The East Pacific Gyre brings warm waters towards the coast of BC and develops into the southbound California Current (Crawford *et al.* 2007). During summer months, this transition zone encompasses all of southern Hecate Strait and northern Queen Charlotte Sound, though position, strength, and size, of the gyres are influenced by atmospheric pressure systems and varies seasonally. Down-welling caused by the northbound Alaska Current being directed inshore by coriolis forces, pushes dense, nutrient rich waters to deeper depths along the coast of northern BC, and is strongest in winter months. In contrast, the southbound California Current causes upwelling in summer bringing nutrient rich waters to the surface along the complex coastline (Crawford *et al.* 2007).

The bathymetric complexity of Hecate Strait and Queen Charlotte Sound plays a significant role in the variable patterns of water circulation and dynamic ocean productivity. Deep-water troughs extend into Queen Charlotte Sound and southern Hecate Strait, divided by shallow banks. The extensive, deep and irregular Moresby Trough extends from canyons south of Cape St. James to the northeast, coming to a head off Banks Island in eastern Hecate Strait. Mitchell's Trough extends from canyons south of Cape St. James to the east shoaling in Queen Charlotte Sound up to Goose Island. The troughs are divided by Middle Bank (Figure 2). The strong, cold-water outflows and vertical mixing within the deep troughs coupled with the retaining effect of the neighbouring warm shallow banks appear to concentrate both nutrient rich waters towards southeast Moresby Islands (Jardine *et al.* 1993; Crawford 1997; Perry and Waddell 1997) creating favourable conditions for zooplankton aggregation.

Enhanced productivity can also be concentrated by cold water plumes created by wind-driven upwelling. The Aristazabal Island Plume off the southeastern side of Hecate Strait extends towards Mitchell Trough, creating a clockwise flow around Middle Bank, in July and August (Crawford *et al.* 2007). The Greater Caamaño Sound sub-region is composed of deep, narrow, glacial carved fjords that have steep sides with flat bottoms, multiple islets and shoals, and ledges where fjords meet the coast. These physical features likely contribute significantly to flow and retention of zooplankton within the area, as it experiences mild to moderate degrees of mixing with nutrient rich waters of Hecate Strait. Freshwater input is also critical in controlling circulation and plankton distributions properties in this region (Pickard and Stanton 1980, Crawford 2001, Crawford *et al.* 2007, Lucas *et al.* 2007).

6. ACTIVITIES LIKELY TO DESTROY

When critical habitat is identified, SARA requires that "examples of activities that are likely to result in its destruction will be provided". Threats to Fin Whales and their habitat are described in the recovery strategy (Gregr *et al.* 2006) and re-iterated in the partial action plan. The following provides a description of those threats and some additional threats that should be considered as examples of "activities likely to result in the destruction of critical habitat", as outlined in DFO (2015[3]). Table 3 summarizes the descriptions provided below.

6.1. Examples and Descriptions of Activities Likely to Destroy Critical Habitat

6.1.1. Acoustic Disturbance from Human Activities

There has been increasing concern in recent years about the potential effects of underwater noise on cetaceans. Noise associated with commercial shipping, coastal port developments, oil and gas extraction, and seismic surveys increase the amount of noise in the habitat which could impede the ability of Fin Whales to forage and to communicate during breeding and during rearing. Acoustic disturbance can be of two types: chronic and acute. Chronic noise is primarily associated with motorized vessel traffic, and particularly from commercial shipping. In the northern hemisphere, shipping noise is the dominant source of background noise between 10 to 200 Hz (NRC 2003). It is estimated that background underwater noise levels had increased an average of 15 dB by 2003 compared to 50 years earlier throughout the world's oceans (NRC 2003). One result is that in certain parts of Northern Hemisphere oceans, the area over which a Fin Whale can hear a conspecific has decreased by four orders of magnitude (Payne 2004). Functional models indicate that hearing in large marine mammals extends to 20 Hz and may extend to frequencies as low as 10-15 Hz in several species, including Fin Whales. The upper range of mysticete hearing is predicted to extend to 20-30 kHz (Ketten 2004). Chronic noise can result in masking of communication signals used for social contact, including reproductive behaviour (Castellote *et al.* 2012). Masking effects of increasing background noise could reduce foraging efficiency, and the distance over which Fin Whales can communicate, thus degrading the foraging and the breeding functions of important habitat. The degree to which such acoustic pollution may, or already has, degraded habitat for Fin Whales has not been determined.

Sources of acute noise in the marine environment include military and commercial sonars, airguns used in seismic surveys, and underwater explosions usually associated with construction and military exercises. These sounds can be extremely intense and may travel large distances underwater. Loud acute noises have the potential to cause a variety of effects in cetaceans, including hearing threshold shifts, production of stress hormones, and tissue damage, as well as a variety of behavioural responses. Acute noise that results in displacement of Fin Whales from habitat needed for foraging, rearing or breeding would be a threat to critical habitat.

6.1.2. Hydrocarbon Spills

Although catastrophic oil spills in the marine environment are rare events, they are known to result in mortality to marine mammals and to have sub-lethal impacts through impacts on prey resources. Given that significant volumes of oil are transported through inside passages along the BC coast each year, catastrophic oil spills should be considered as a potential cause of destruction of critical habitat through reduced availability of prey to Fin Whales. A catastrophic oil spill, were it to occur, would likely result in destruction of critical habitat. Spills of other types of hydrocarbons are less clear but proposed transport of significant volumes of hydrocarbon through Douglas Channel, Greater Caamaño Sound, eastern Hecate Strait and Dixon Entrance, which are areas that overlap with important habitat for Fin Whales, the activity that could lead to such an event (e.g. marine transportation of hydrocarbons) should be considered a threat to critical habitat.

6.1.3. Physical Disturbance

Ships travelling at speeds above 10 knots in close proximity to Fin Whales have a relatively high probability of colliding with whales (Vanderlaan and Taggart 2007). Although it is difficult to quantify the frequency with which ship strikes involving Fin Whales occur, evidence (in the form of dead carcasses) confirms this species is struck by fast moving ocean going vessels. It is not known whether the possibility of being struck affects the behaviour of Fin Whales, but it is possible that expending energy to avoid ships displaces Fin Whales from important life activities of foraging and breeding (McKenna *et al.* 2015). Shipping traffic that results in a loss of foraging opportunities and mating opportunities in otherwise important habitat, should be considered a reduction in the area available for foraging and mating in the critical habitat.

7. FURTHER STUDIES

The following are research approaches needed to support further identification of important habitat for Fin Whales in Canadian Pacific waters.

- Continue ship-based or aerial survey effort in offshore regions including off west coast Vancouver Island.
- Undertake satellite tagging studies in offshore regions including west coast Vancouver Island
- Continue and expand photo-identification effort particularly into offshore regions
- Continue and expand the acoustic monitoring network in offshore regions

The following are research approaches needed to support refinement and understanding of biophysical features and attributes of identified important habitat

- Dive tags studies and use of drop cameras or other technology to quantify foraging behaviour and associated prey aggregation densities
- Conduct winter surveys in Hecate Strait, Queen Charlotte Strait, and Greater Caamaño Sound to investigate behaviour and distribution to refine understanding of biophysical function of critical habitat

8. ACKNOWLEDGEMENTS

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9. REFERENCES

Archer, F. I., P. A. Morin, B. L. Hancock-Hanser, K. M. Robertson, M. S. Leslie, M. Bérubé, S. Panigada, and Taylor, B. L. 2013. Mitogenomic phylogenetics of fin whales (*Balaenoptera physalus* spp.): genetic evidence for revision of subspecies. PloS ONE 8(5):e63396.

Best B.D., Fox, C.H., Williams, R., Halpin, P.N., and Paquet, P.C. 2015. Updated marine mammal distribution and abundance estimates in British Columbia. J. Cetacean Res. Manage. 15: 9-26.

Calambokidis J. and Barlow J. 2004. Abundance of blue and humpback whales in the eastern North Pacific estimated by capture-recapture and line-transect methods. Marine Mammal Science. 20(1):63-85.

Castellote, M., Clark, C.W., M.O. Lammers. 2012. Acoustic and behavioural changes by fin whales (*Balaenoptera physalus*) in response to shipping and airgun noise. Biological Conservation. 147: 115-122.

COSEWIC 2005. COSEWIC assessment and update status report on the fin whale *Balaenoptera physalus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. ix + 37 pp. (Accessed 1 May, 2018)

Crawford, W., Johannessen, D., Whitney, F., Birch, R., Borg, K., Fissel, D., and Vagle, S. 2007. Appendix C: Physical and chemical oceanography. In: Ecosystem overview: Pacific North Coast Integrated Management Area (PNCIMA). Edited by Lucas, B.G., Verrin, S., and Brown, R. Can. Tech. Rep. Fish. Aquat. Sci. 2667: vii + 77p.

Crawford, W.R. 2001. Oceans of the Queen Charlotte Islands. Can. Tech. Rep. Fish. Aquat. Sci. 2383. Canadian Hydrographic Service, Institute of Ocean Science.

Crawford, W.R. 1997. Physical oceanography of the waters around the Queen Charlotte Islands, p. 8-17 In: Ecology, status and conservation of marine and shoreline birds of the Queen Charlotte Islands, Edited by K. Vermeer, and K.H. Morgan, Occasional Paper Number 93, Canadian Wildlife Service, Environment Canada, Institute of Ocean Sciences, 150 p.

Dalla Rosa, L., J. K. B. Ford and A. W. Trites. 2012. Distribution and relative abundance of humpback whales in relation to environmental variables in coastal British Columbia and adjacent waters. Continental Shelf Research 36:89-104.

DFO. 2013. Partial Action Plan for Blue, Fin, Sei and North Pacific Right Whales *(Balaenoptera musculus*, *B. physalus*, *B. borealis*, and *Eubalaena japonica*) in Pacific Canadian Waters. Species at Risk Act Action Plan Series. Fisheries and Oceans Canada, Ottawa, ON. iv + 23 pp.

Flinn, R.D., Trites, A.W. and Gregr, E.J. 2002. Diets of fin, sei and sperm whales in British Columbia: An analysis of commercial whaling records, 1963-1967. Mar. Mamm. Sci., 18(3): 663-679.

Ford, J. K. B. 2014. Marine Mammals of British Columbia. Royal BC Museum, Victoria, BC.

Ford, J.K.B., Abernethy, R.M., Phillips, A.V., Calambokidis, J., Ellis, G.M. and. Nichol, L.M. 2010a. Distribution and relative abundance of cetaceans in western Canadian waters from ship surveys, 2002-2008. Can. Tech. Rep. Fish. Aquat. Sci. 2913: v + 51 p.

Ford, J.K.B, Koot, B., Vagle, S., Hall-Patch, N., Kamitakahara, G. 2010b. Passive acoustic monitoring of large whales in offshore waters of British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2898: v + 30 p.

Goldbogen JA, Calambokidis J, Oleson E, Potvin J, Pyenson ND, Schorr G, Shadwick RE. 2011. Mechanics, hydrodynamics and energetics of blue whale lunge feeding: efficiency dependence on krill density. The Journal of experimental biology. 214(1):131-46.

Gregr E.J. 2000. An analysis of historic (1908-1967) whaling records from British Columbia, Canada. M.Sc. Thesis, University of British Columbia, Vancouver, BC. 104 pp.

Gregr, E. J. and A. W. Trites. 2001. Predictions of critical habitat for five whale species in the waters of coastal British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 58:1265-1285.

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

Gregr, E. J., Nichol, L., Ford, J. K. B., Ellis, G. and Trites, A. W. 2000. Migration and population structure of northeastern Pacific whales off coastal British Columbia: An analysis of commercial whaling records from 1908-1967. Mar. Mamm. Sci. 16(4):699-727.

Hazen E.L., Friedlaender, A.S., J.A. Goldbogen. 2015. Blue whales (*Balaenoptera musculus*) optimize foraging efficiency by balancing oxygen use and energy gain as a function of prey density. Sci. Adv. 1:e1500469

Jardine, I.D, Thomson, Keith A., Foreman, Michael G., and LeBlond, P. H. 1993. Remote Sensing of Coastal Sea-Surface Features off Northern British Columbia. Remote Sensing of Environment. 45: 73-84.

Jonsen, I. D., J. M. Flemming, and R. A. Myers. 2005. Robust state-space modeling of animal movement data. Ecology 86(11):2874-2880.

Ketten, D. R. 2004. Marine Mammal Auditory systems: A summary of audiometric and anatomical data and implications for underwater acoustic impacts. International Whaling Commission. 27-31

Koot, B. 2015. Winter behaviour and population structure of fin whales (*Balaenoptera physalus)* in British Volumbia inferred from passive acoustic data. M.Sc. thesis, University of British Columbia, BC. 111pp

Laidre, K.L., Heide-Jorgensen, M.P., Heagerty, P., Cossio, A., Berdström, and Simon, M. 2010. Spatial associations between large baleen whales and their prey in West Greenland. Mar. Ecol. Prog. Ser. 402: 269-284.

Lucas, B.G., Verrin, S., and Brown, R. 2007. Ecosystem Overview: Pacific North Coast Integrated Management Area (PNCIMA). Can. Tech. Rep. Fish. Aquat. Sci. 2667.

Macdonald, R.W., B.D. Bornhold, and I. Webster. 1983. The Kitimat fjord system: An introduction. Can. Tech. Rep. Hydrogr. Ocean Sci. 18, 2-13.

McKenna, M. F., Calambokidis, J., Oleson, E. M., and Goldbogen, J. A. 2015. Simultaneous tracking of blue whales and large ships demonstrated limited behavioural responses for avoiding collision. Endang. Spec. Res. 27:219-232.

Mellinger, D., and J. Barlow. 2003. Future directions for acoustic marine mammal surveys: stock assessment and habitat use. Report of a workshop held in La Jolla, CA, 20-22 November 2002. NOAA OAR Special Report, NOAA/PMEL Contribution No. 2557:1–38.

Mizroch, S.A., Rice, D.W., Zwiefelhofer, D., Waite J. and Perryman, W.L. 2009. Distribution and movements of fin whales in the North Pacific Ocean. Mammal. Rev. 39(3): 193-227.

Moore, S.E, Waite, J.M., Mazzuca, L.L., R.C. Hobbs. 2000. Mysticete whale abundance and observations of prey associations on the central Bering Sea shelf. J. Cetacean Res. Manage. 2(3): 227-234

Nichol, L.M., Abernethy, R.M., Wright, B.M., Heaslip, S., Spaven, L.D., Towers, J.R., Pilkington J.F., Stredulinsky, E.H., and Ford, J.K.B. 2018. Distribution, movements and habitat fidelity patterns of Fin Whales (*Balaenoptera physalus*) in Canadian Pacific Waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/004. vii + 52 p.

Nichol, L. M. and J. K. B. Ford. 2012. Information relevant to the assessment of critical habitat for Blue, Fin, Sei and North Pacific Right Whales in British Columbia. DFO Can. Sci. Advis. Sec. Res .Doc. 2011/137. vi + 31 p.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mammal Review 37:81-115.

NRC (National Research Council). 2003. Ocean Noise and Marine Mammals. in N. R. Council, editor. National Academies Press, Washington, D.C.

Oshumi, S., and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. Report of the International Whaling Commission 25:114-126.

Payne, R. S. 2004. Long-range communication in large whales, ocean noise and synergistic impacts. International Whaling Commission. 22-23

Perry, I. R. and Waddell , B. J. 1997. Zooplankton in Queen Charlotte Islands waters: distribution and availability to marine birds, p. 18-28 in: Ecology, status and conservation of marine and shoreline birds of the Queen Charlotte Islands, Ed. By K. Vermeer, and K.H. Morgan, Occasional Paper Number 93, Canadian Wildlife Service, Environment Canada, Institute of Ocean Sciences, 150 p.

Pickard, G.L. and B.R. Stanton. 1980. Pacific fjords – a review of their water characteristics. In: Fjord Oceanography (1980) H.J. Freeland, D.M. Farmer and C.D. Levings (eds). 1-51p.

Pike, G.C. and MacAskie, I.B. 1969. Marine Mammals of British Columbia. Bulletin 171, Fish. Res. Bd. Can., Ottawa, 55 pp.

Pilkington, J.F., Stredulinsky, E.H., Abernethy, R.M., and Ford, J.K.B. 2018. Patterns of Fin whale (*Balaenoptera physalus*) Seasonality and Relative Distribution in Canadian Pacific Waters Inferred from Passive Acoustic Monitoring. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/032. vi + 26 p.

Simon, S., Stafford, K. M., Beedholm, K., Lee, C.M., and P.T. Madsen. 2010. Singing behavior of fin whales in the Davis Strait with implications for mating, migration and foraging. J. Acoust. Soc. Am. 128(5): 3200-3210.

Stafford, K. M., D. K. Mellinger, S. E. Moore, and C. G. Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999-2002. J. Acoust. Soc. Am. 122:3378–3390.

Stafford, K. M., S. E. Moore, and C. G. Fox. 2005. Diel variation in blue whale calls recorded in the eastern tropical Pacific. Animal Behaviour 69:951–958.

Vanderlaan, A. S. M., and Taggart, C. T. 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. Mar. Mamm. Sci. 23:144-156.

Watkins, W. A., M. A. Daher, G. M. Reppucci, J. E. George, D. L. Martin, N. A. DiMarzio, and D. P. Gannon. 2000. Seasonality and distribution of whale calls in the North Pacific. Oceanography 13:62–67.

Watkins, W. A., P. Tyack, K. E. Moore, and J. E. Bird. 1987. The 20-Hz signals of finback whales (*Balaenoptera physalus*). J. Acoust. Soc. Am. 82:1901–1912.

Williams, R. and P. O'Hara. 2009. Modelling ship strike risk to fin, humpback and killer whales in British Columbia, Canada. J. Cetacean Res. Manage. 11:1-10.

Williams, R. and Thomas, L. 2007. Distribution and abundance of marine mammals in the coastal waters of British Columbia, Canada. J. Cetacean Res. Manage. 9(1):15-28.

Witteveen, B.H., De Robertis, A., Guo, L. and Wynne, K.M. 2015. Using dive behavior and active acoustics to assess prey use and partitioning by fin and humpback whales near Kodiak Island, Alaska. *Marine Mammal Science*, *31*:255-278.

10. TABLES

Table 1: Summary of Fin Whale calf photo-identifications in BC waters

Date	Whale ID	Location
13/08/2006	FW0143	Hecate Strait
09/08/2010	FW0024	Hecate Strait
2011/07/09 - 2011/07/19	FW0089	Greater Caamaño Sound
21/06/2012	FW0161	Hecate Strait
22/08/2012	FW0211	Hecate Strait
17/08/2012	FW0213	Greater Caamaño Sound
23/08/2012	FW0234	Hecate Strait
2012/08/22-2012/08/23	FW0256	Hecate Strait
25/08/2012	FW0259	Hecate Strait
2013/07/02-2012/07/14	FW0335	Greater Caamaño Sound
17/07/2013	FW0371	Hecate Strait
04/09/2013	FW0379	Hecate Strait
05/09/2013	FW0391	Hecate Strait
2014/08/12-2014/09/30	FW0417	Greater Caamaño Sound
2014/08/18-2014/09/11	FW0418	Greater Caamaño Sound
2014/08/18-2014/09/10	FW0420	Greater Caamaño Sound
2014/09/08-2014/09/12	FW0422	Greater Caamaño Sound
2014/08/08-2014/09/11	FW0423	Greater Caamaño Sound & Hecate Strait
04/03/2015	FW0604	Offshore
10/07/2015	FW0699	Hecate Strait
21/09/2015	FW0707	Hecate Strait

Table 2: Biophysical functions, features, attributes of habitat considered important for survival and recovery of Fin Whales in Canadian Pacific waters.

Function	**Feature(s)**	**Attribute(s)**
Feeding/Foraging Rearing Courtship/mating	Prey. Features contributing to prey aggregations and primary productivity, such as spatiotemporal variability of water circulation, including surface currents, topography and prey swimming behaviour	Prey densities and quality to support efficient foraging, life cycle and population growth.
Feeding/Foraging Rearing Courtship/mating	Acoustic environment	Ambient noise levels below a level that would impede communication associated with courtship/mating and rearing, foraging
Feeding/Foraging Rearing Courtship/mating	Physical space	Enough space to maneuver in vertical and horizontal planes, and not alter normal behaviour at and below the surface
Feeding/Foraging Rearing Courtship/mating	Water column	Water quality of a sufficient level to support identified function and to support sufficient prey densities.

Table 3: Activities likely to destroy the functions, features and attributes of important habitat considered necessary for the survival and recovery of Fin Whales in Canadian Pacific waters.

Threat	**Activity**	**Effect Pathway**	**Function Affected**	**Feature Affected**	**Attribute Affected**
Acoustic disturbance	Shipping and cruise ships Seismic surveys, military and commercial sonars Pile driving, underwater explosions	Acoustic disturbance resulting in disruption of behaviour or displacement from habitat Acoustic disturbance resulting in loss of habitat availability or function	Feeding and foraging Rearing Courtship/mating	Acoustic environment	Ambient noise levels below a level that would impede communication associated with courtship/mating and rearing, foraging
Release of environmental contaminants	Transportation by vessel of deleterious substances (e.g. petroleum, other contaminants)	Displacement or avoidance of habitat, resulting in reduced foraging efficiency Loss of water quality in habitat resulting in a decrease in foraging opportunities	Feeding and foraging Rearing Courtship/mating	Prey Water column	Prey densities and quality to support efficient foraging, life cycle and population growth Water quality of a sufficient level to support identified function and to support sufficient prey densities.
Physical Disturbance	Vessel traffic in close proximity to whales	Reduction of physical space available to whales	Feeding and foraging Rearing Courtship/mating	Physical space	Enough space to maneuver in vertical and horizontal planes, and not alter normal behaviour at and below the surface

11. FIGURES

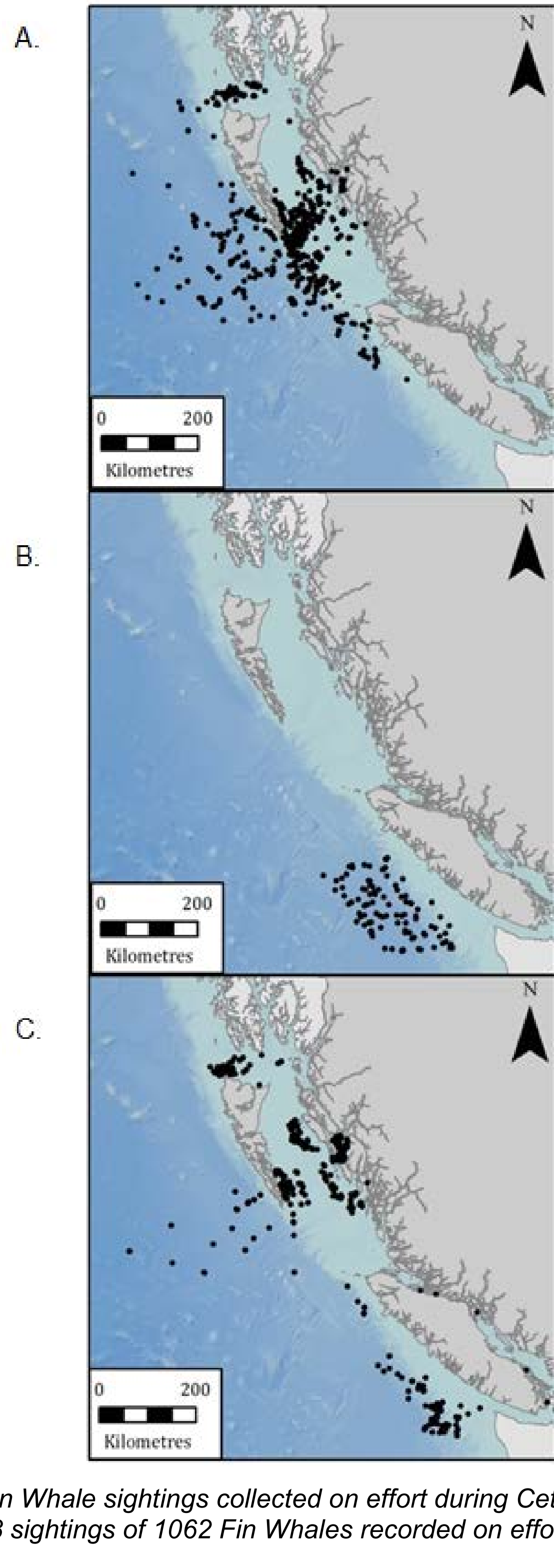

Figure 1: Distribution of all Fin Whale sightings collected on effort during Cetacean Research Program led surveys (2002-2015). A. 598 sightings of 1062 Fin Whales recorded on effort during 42 (1-3wk/survey) ship surveys (2002 -2014). B. 74 sightings of 120 Fin Whales recorded on effort during 34 (~ 2h/ survey) aerial surveys (2012-2015), C. Locations of 1549 Photo IDs (1995-2015).

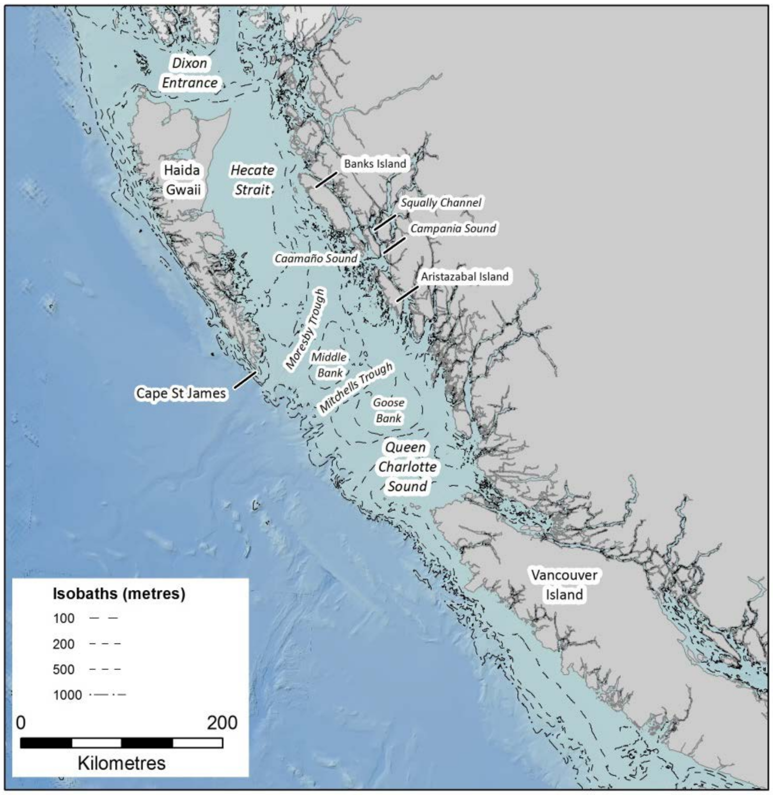

Figure 2: Pacific coast of Canada showing troughs and banks of Hecate Strait and Queen Charlotte Sound described in the text.

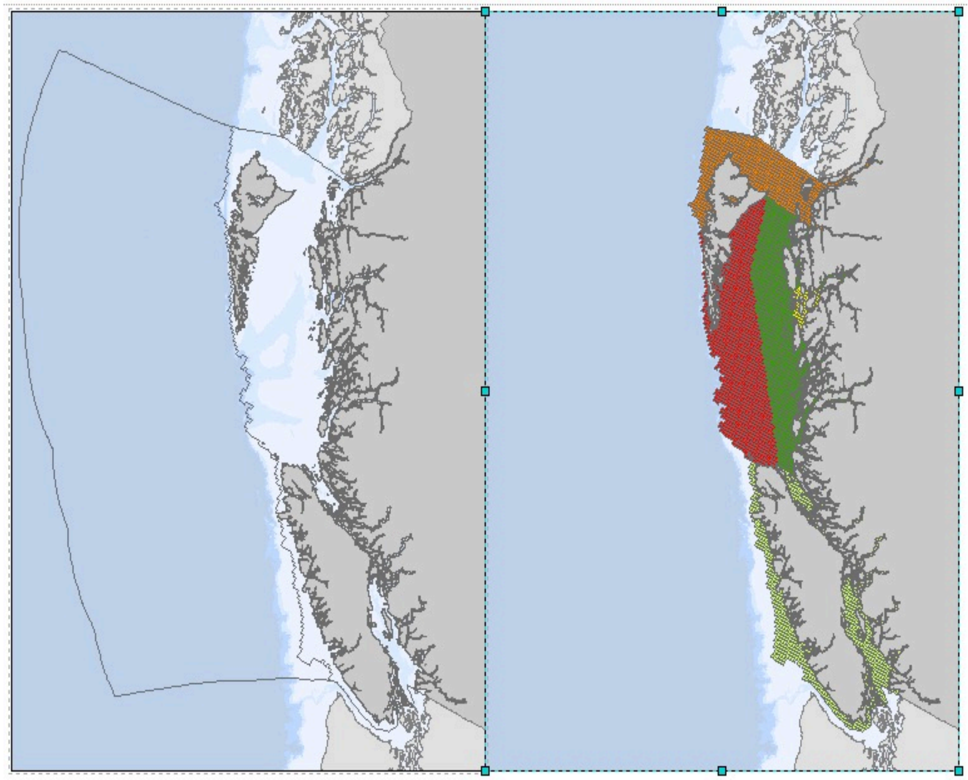

Figure 3: Map of Canadian Pacific waters and study area regions. A. Boundaries of the offshore and the inshore regions. Boundary between is the 1000m depth contour from north to the northern tip of Vancouver Island after which it follows the 100m depth contour. B. the inshore, Orange: Dixon Entrance, Green and Red: Hecate Strait and Queen Charlotte Sound, Yellow: Greater Caamaño Sound, Pale Yellow: coastal areas around Vancouver Island.

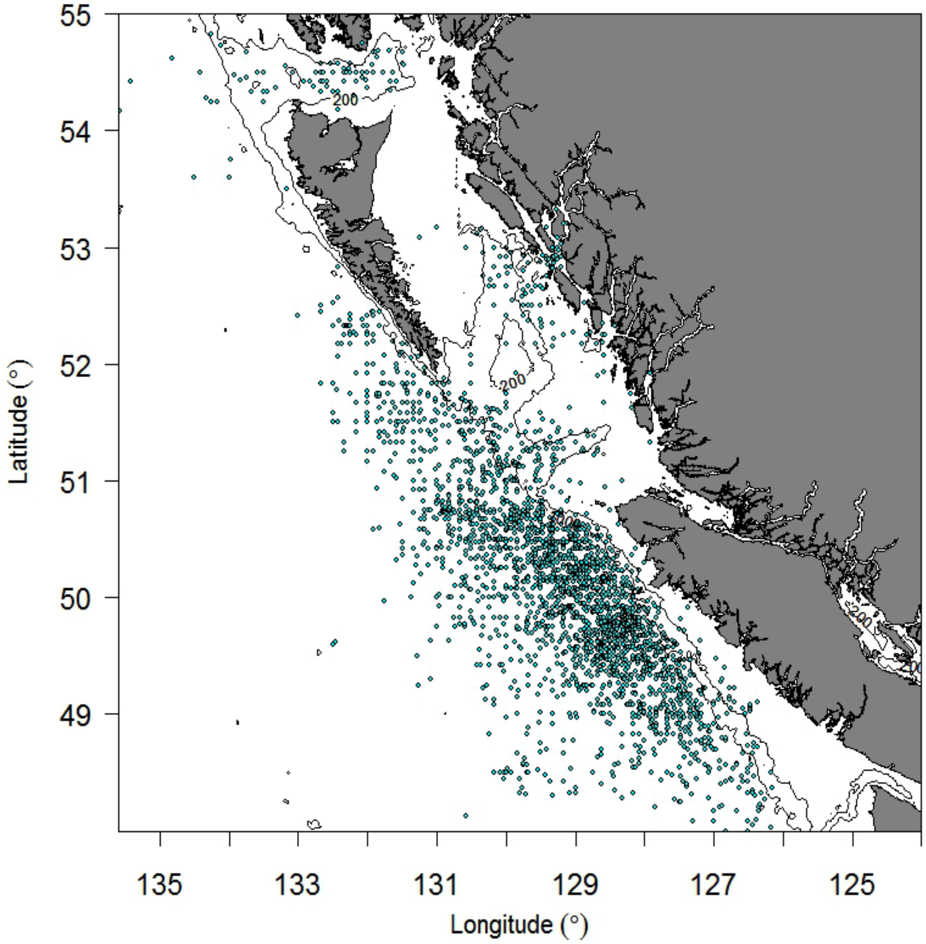

Figure 4: Distribution of 3,412 Fin Whales killed in years 1924-1928, and 1948-67. Although 7,605 Fin Whales were killed in BC during the commercial whaling years 1908 to 1967. Logbooks, documenting where whales were killed are not available for all of the catch. The 200m isobaths and the 1000m isobaths are displayed.

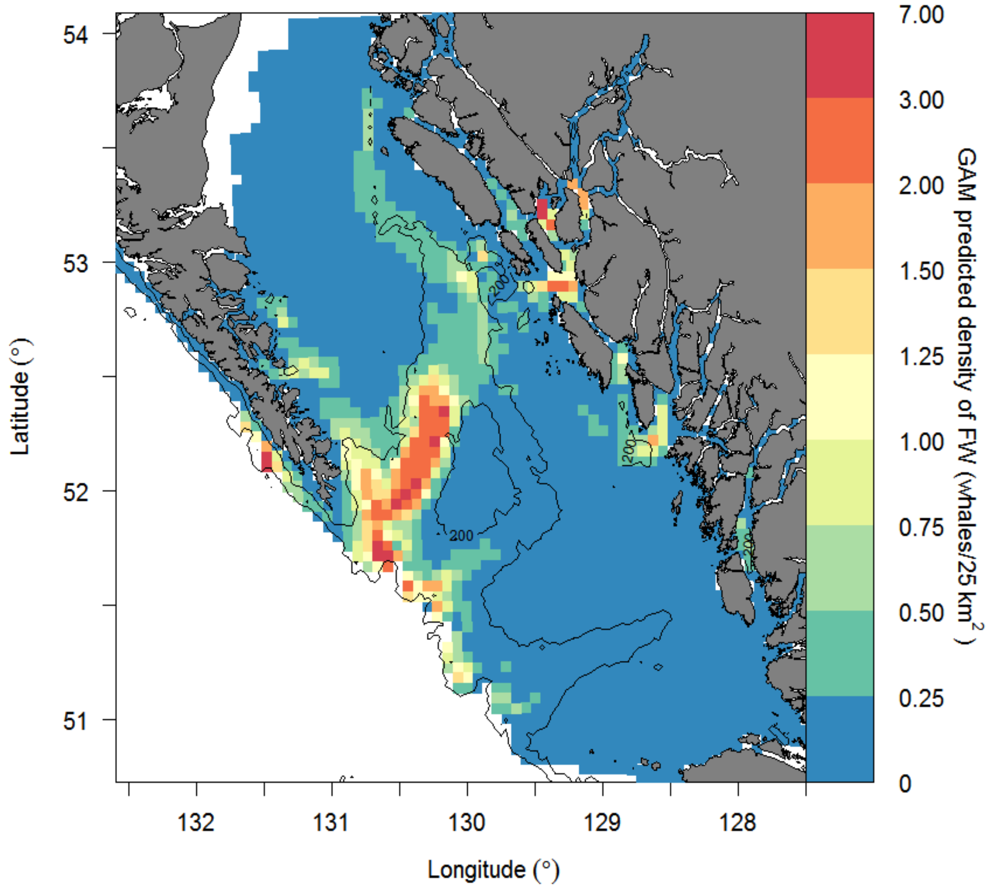

Figure 5: Model predicted distribution of Fin Whales in the Hecate Strait and Queen Charlotte Sound, based on ship-based surveys, (2003-2014) and habitat covariates (from Nichol et al. 2018).

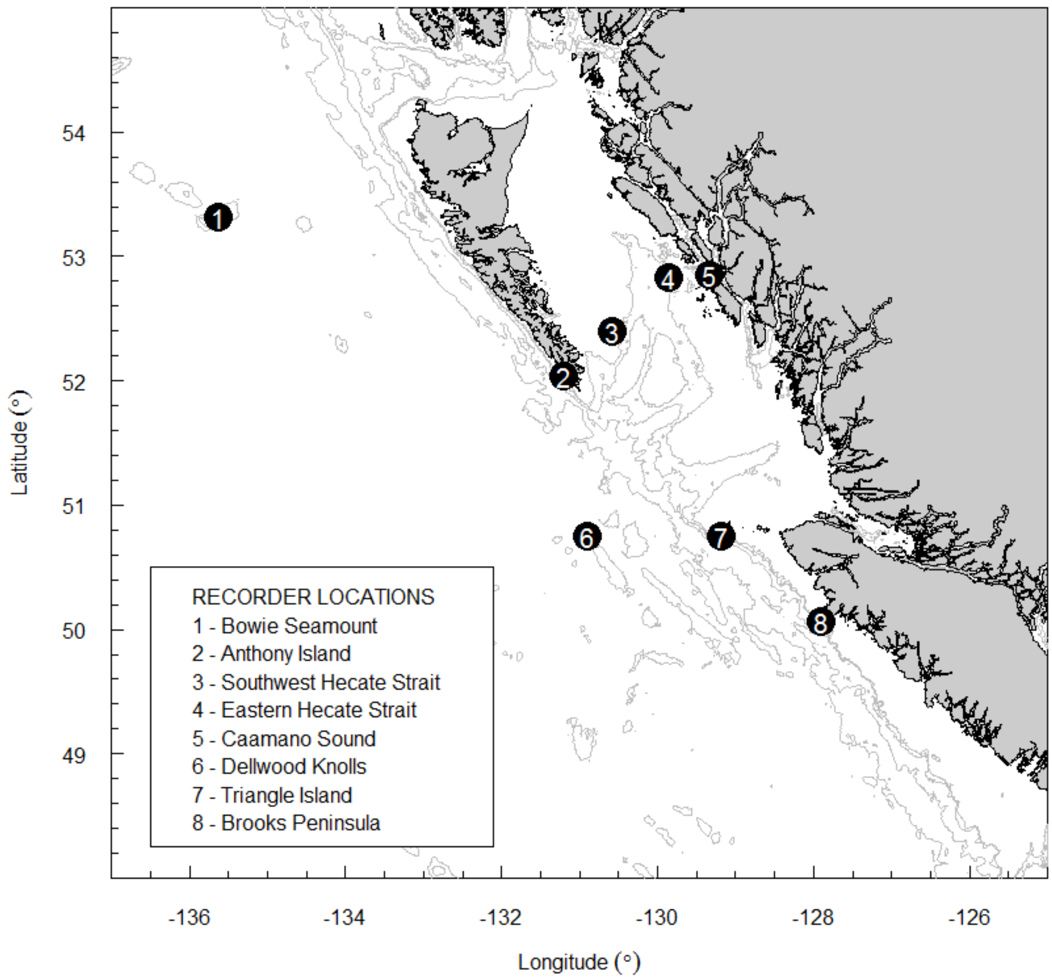

Figure 6: Map of the British Columbia coast showing the locations of autonomous acoustic recorder deployment sites for this study (2009 to 2015). The 200, 300, 1000, 1500m isobaths are shown (from Pilkington et al. 2018).

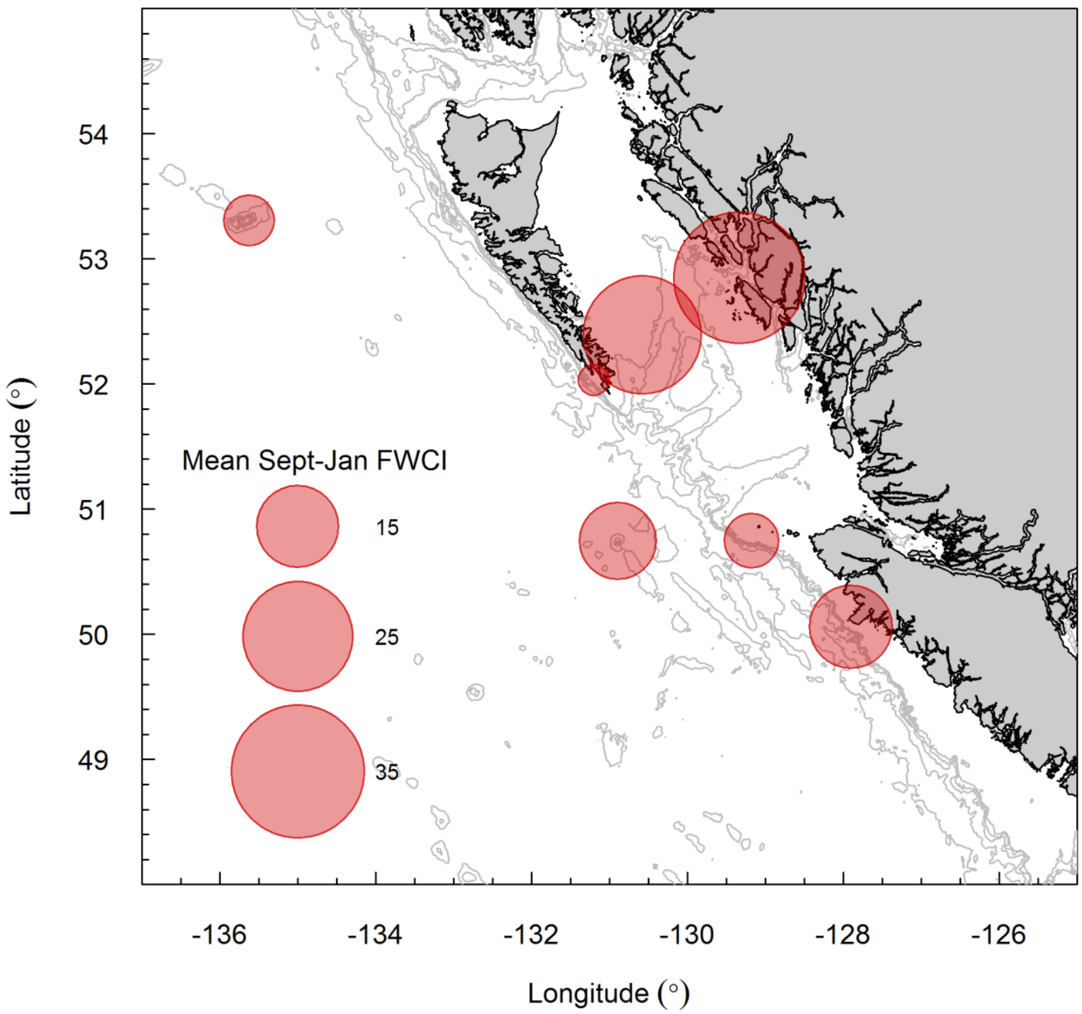

Figure 7: Map showing autonomous acoustic recorder locations (2009 to 2015). Size of red circles is proportional to the mean daily Fin Whale call index values (corrected for area and transmission loss) between September 1st and January 31st for all years available at each site, corrected for area-transmission loss. The 200, 300, 500, 1000, 2000 m isobaths are shown (from Pilkington et al. 2018).

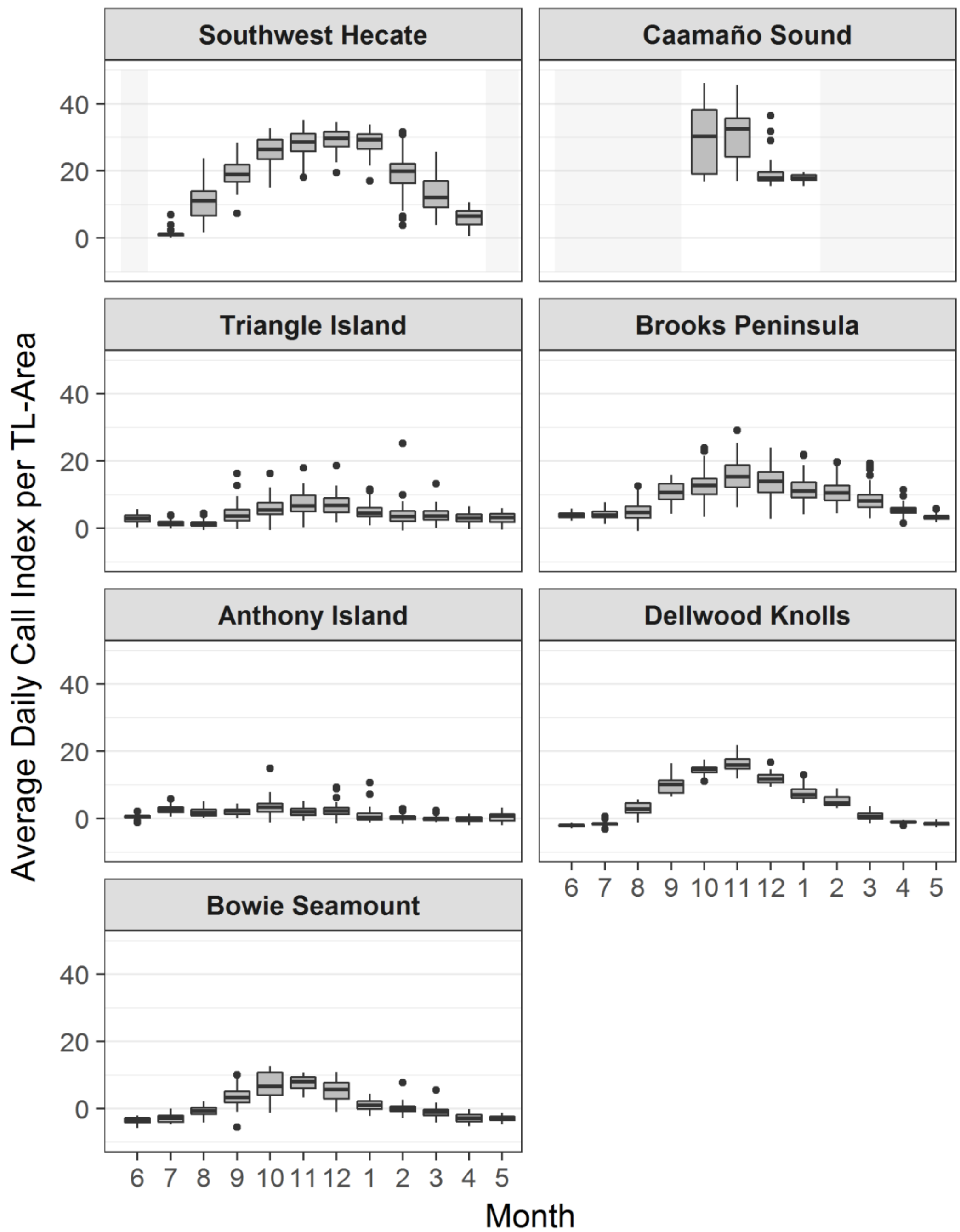

Figure 8: Boxplots showing corrected mean daily call index values by month for each recorder site, corrected for transmission loss-area. The black bar in the boxes represent the median, upper and lower limits of boxes represent 75th and 25th percentiles respectively, whiskers represent highest and lowest values within the 75th and 25th percentiles, and dots are outliers. Note the x-axis: plots have been centered on November (peak calling period). Light grey shaded regions represent months with no data. (from Pilkington et al. 2018). Data from 2009 to 2015.

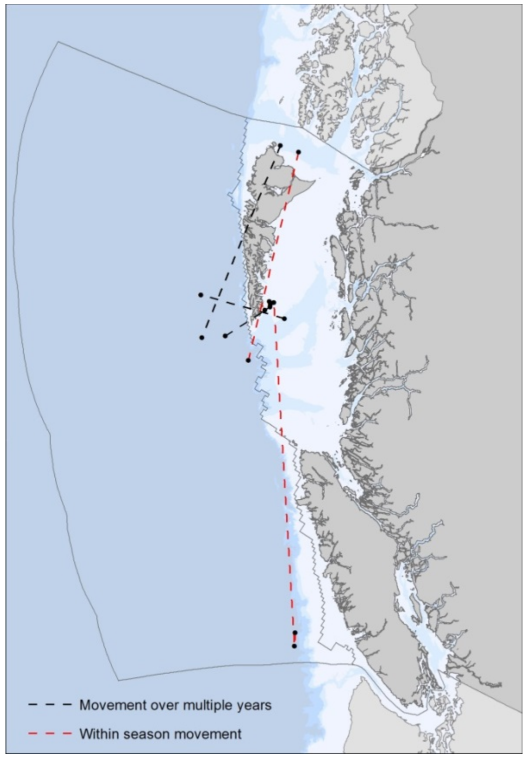

Figure 9: Individual Fin Whale Inshore-offshore movements among years (black dashed line) and within years (red dashed line) (n=5 individuals) (from Nichol et al. 2018).

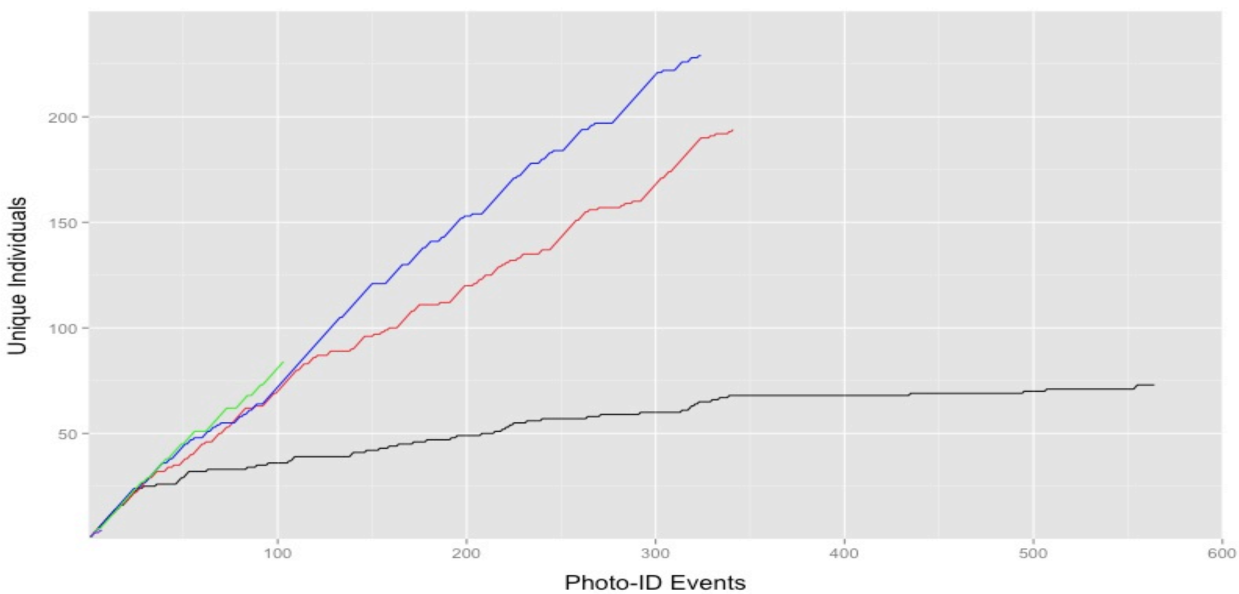

Figure10: Discovery curves of unique individual Fin Whales by Inshore sub-regions. Green – Dixon Entrance, Red – East Hecate Strait, Blue – West Hecate Strait, Black –Greater Caamaño Sound (from Nichol et al. 2018).

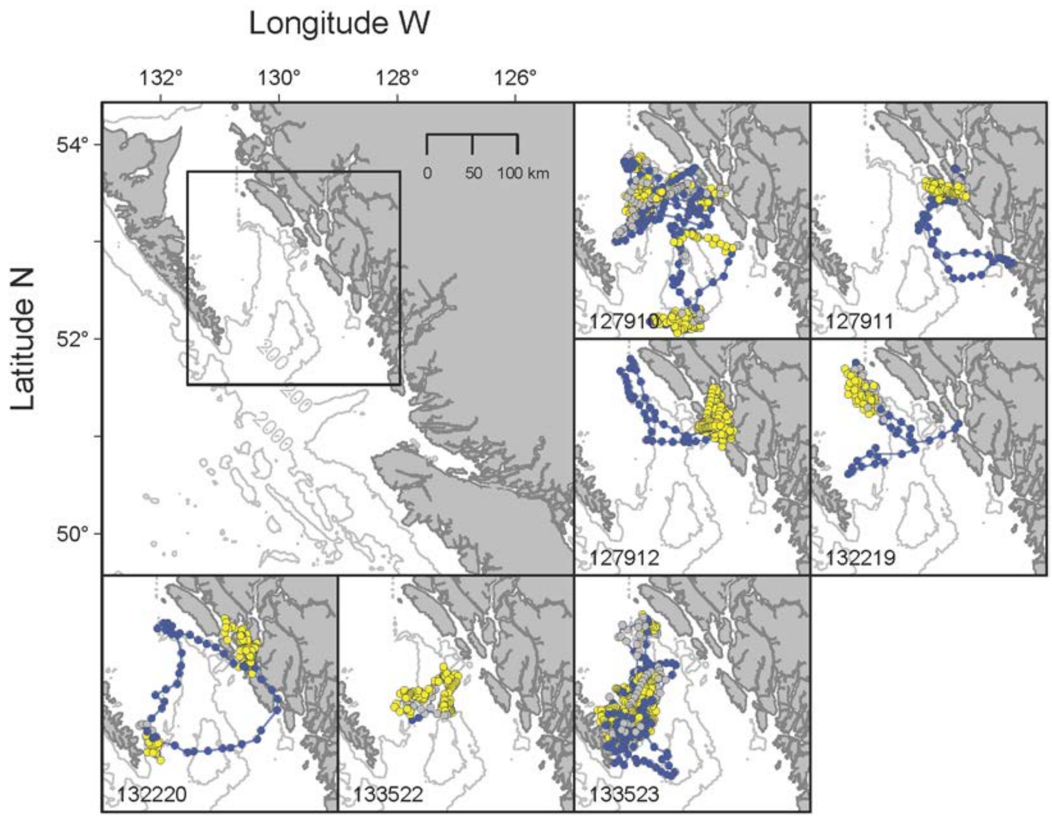

Figure 11: Fin Whale satellite tag tracks for 2013 deployments showing locations with inferred behavioural modes from hierarchical state-space modelling. Blue = transiting, grey = uncertain, and yellow = Area Restricted Search (ARS), which likely includes foraging behaviour.

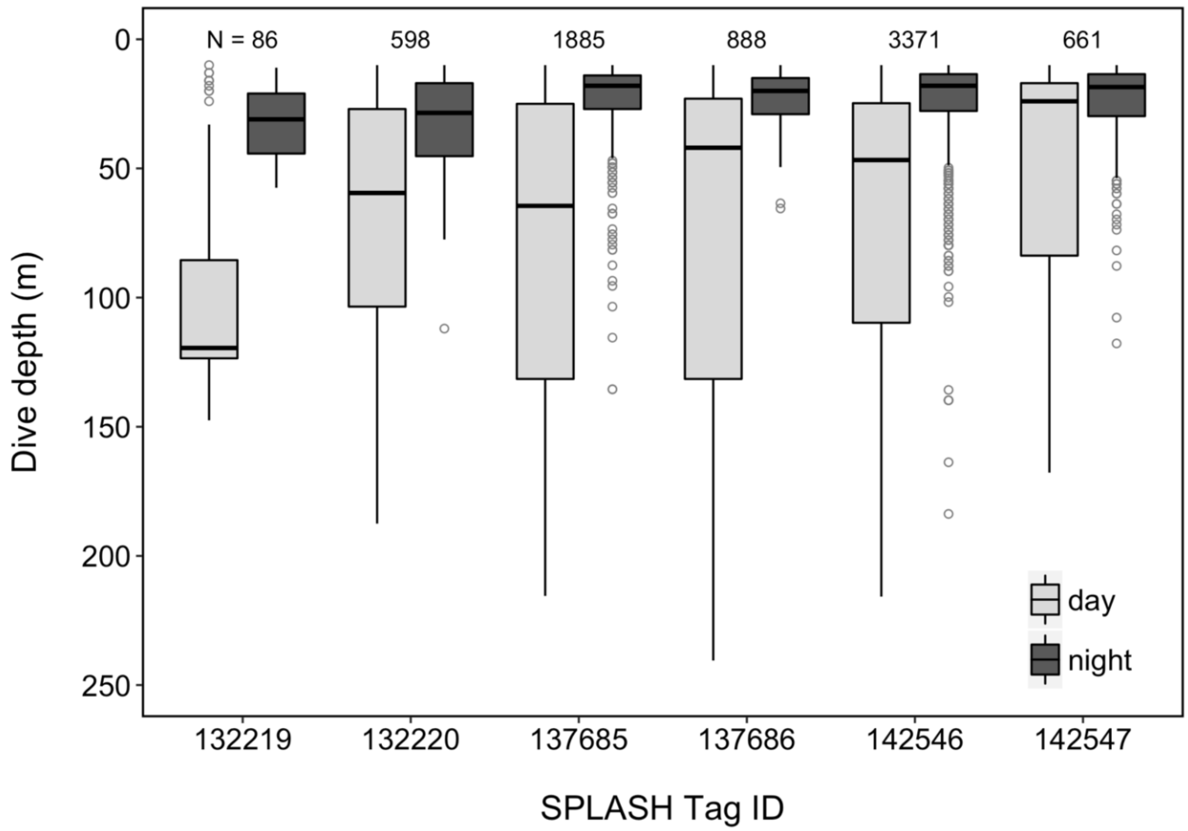

Figure 12: Maximum dive depths (m) recorded by SPLASH10 tags deployed on 6 individual Fin Whales during area restricted search (ARS) behaviour showing the difference in dive behaviour between day and night. Sample sizes (N, number of dives) recorded by each tag are displayed above the boxplots. Day and night periods were defined by times of nautical dawn (solar elevation < -12°) and dusk (solar elevation ≥ -12°) (from Nichol et al. 2018).

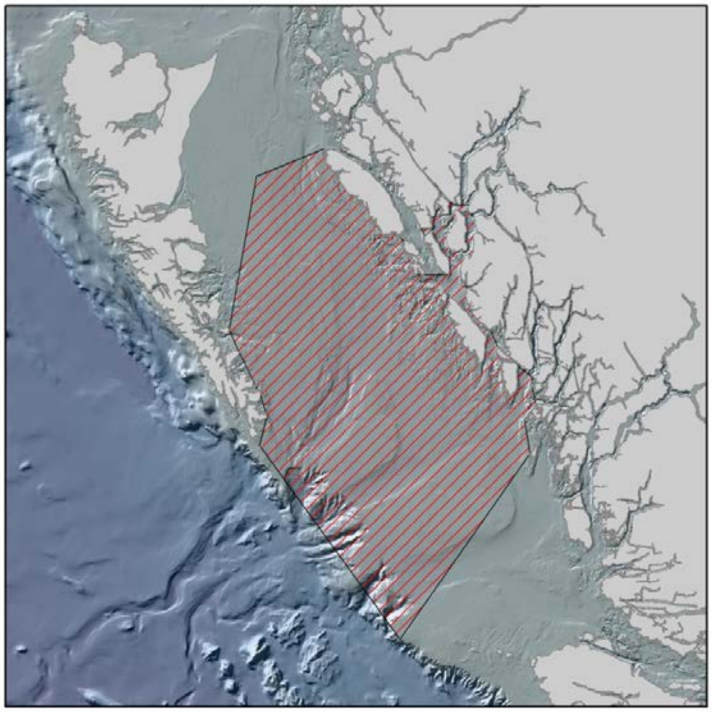

Figure 13: Map showing the bounded-box defined habitat considered important for the survival and recovery of Fin Whales in Hecate Strait and Queen Charlotte Sound.