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Information relevant to the identification of Critical Habitats of North Pacific Humpback Whales (*Megaptera novaeangliae*) in British Columbia

Renseignements pertinents en vue de la désignation des habitats essentiels pour les rorquals à bosse (*Megaptera novaeangliae*) du Pacifique Nord en Colombie-Britannique

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ABSTRACT

This report presents a synthesis of published and unpublished information on the occurrence and distribution of Humpback Whales in British Columbia waters, and particularly in four areas of the coast; 1) the waters surrounding Langara Island; 2) coastal waters along the south eastern side of Moresby Island and Kunghit Island; 3) the mainland channels around Gil Island and Gribbel Island: and 4) waters off southwest Vancouver Island including Barkley Sound, La Perouse Bank, Swiftsure Banks and Barkley Canyon. The annual seasonal occurrence of Humpback Whales observed in these four areas over more than a decade, disproportionate number of sightings in these areas compared to other coastal areas and the historic occurrence of Humpback Whales evident from whaling records indicate that Critical Habitat designation is warranted. Waters off Langara and southeast Moresby islands appear to support over half of the British Columbia population, while the area off southwest Vancouver Island may support a distinct sub-group occurring primarily in southern British Columbia and Washington State. The Gil Island area is the only fjord habitat identified as candidate Critical Habitat. Although it is not yet possible to quantify habitat characteristics that are important to Humpback Whales, it is most likely that important attributes of these areas for Humpback Whales are oceanographic processes that concentrate prey. These processes include tidal mixing, eddies, upwelling, wind- and wave- driven currents and bathymetric features that aggregate euphausiids and forage fish. Considering the precautionary approach is required to address recovery of threatened species, and that analysis of data from these four areas utilized the best information currently available, it appears that all four candidate areas meet the criteria for designation as Critical Habitat under Canada's *Species at Risk Act*. It is expected that the candidate areas of Critical Habitat identified in this document comprise a portion of total Critical Habitat for the species, and that in future additional regions of critical and important habitat may be identified both in Canada and in other jurisdictions.

RÉSUMÉ

Ce rapport présente une synthèse des données publiées et non publiées sur l'occurrence et la répartition des rorquals à bosse dans les eaux de la Colombie-Britannique et particulièrement dans quatre régions de la côte soit 1) les eaux voisines de Langara Island; 2) les eaux côtières le long du sud-est de l'île Moresby et de Kunghit Island; 3) les passages continentaux avoisinants Gil Island et Gribbel Island 4) les eaux au large du sud-ouest de l'île de Vancouver, y compris le bassin de Barkley, le banc La Perouse, les hauts fonds Swiftsure et le Canyon Barkley. L'occurrence saisonnière annuelle du rorqual à bosse relevée dans ces quatre zones depuis plus d'une décennie, le nombre disproportionné d'observations dans ces zones comparativement aux autres zones côtières et l'historique de l'occurrence des rorquals à bosse confirmé par les relevés de pêche à la baleine indiquent que la désignation d'habitat essentiel est justifiée. Il appert que les eaux au large de Langara et du sud-est des îles Moresby abritent plus de la moitié de la population de la Colombie-Britannique, tandis que la zone au sud-ouest de l'île de Vancouver pourrait abriter un sous-groupe distinct que l'on rencontre principalement vers le sud de la Colombie-Britannique et dans l'état de Washington. La zone de Gil Island est le seul habitat de fjord proposé pour la désignation comme habitat essentiel. Bien qu'il ne soit pas encore possible de quantifier les caractéristiques de l'habitat qui soient importantes pour le rorqual à bosse, il est fort probable que les attributs importants de ces zones pour le rorqual à bosse soient des processus océanographiques qui concentrent les proies. Ces processus sont, entre autres, le mélange tidal, les remous, les remontées d'eau, les courants causés par le vent et par les vagues et les caractéristiques bathymétriques qui favorisent l'agrégation des euphausiacés et des poissons-proies. Étant donné qu'une approche de précaution s'impose pour aborder le rétablissement des espèces menacées et que l'analyse des données de ces quatre zones s'appuie sur les meilleurs renseignements disponibles à l'heure actuelle, il semble que les quatre zones candidates répondent aux critères de désignation comme habitat essentiel au titre de la *Loi sur les espèces en péril* du Canada. On s'attend à ce que les zones candidates pour la désignation d'habitat essentiel définies dans ce document constituent une part de l'habitat essentiel de cette espèce et qu'éventuellement d'autres zones d'habitat essentiel et important pourront être désignées, tant au Canada que dans d'autres pays.

INTRODUCTION

In 2005, North Pacific Humpback Whales were listed as Threatened under Canada's newly formed *Species at Risk Act* (SARA). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended this listing as the population appeared to be well below historic levels and had not re-occupied its entire British Columbia (B.C.) range. Additional rationale included the low numbers of animals using B.C. waters, high site fidelity, and risk of entanglement (Baird 2003).

Under SARA, a recovery strategy must be developed for extirpated, endangered or threatened species, and development of a Recovery Strategy for North Pacific Humpback Whales (Fisheries and Oceans Canada (DFO) 2009) is underway. Additionally, the Critical Habitat of SARA listed species, defined as '*habitat necessary for survival and recovery of a listed wildlife species...'* , must be identified, to the extent possible, in a recovery strategy or action plan for extirpated, endangered or threatened SARA-listed species[1].

In January 2009, a meeting of experts in the field of Humpback Whale research was convened to critique information presented in the draft Recovery Strategy (e.g., species information, key threats) and to ensure it incorporated all available knowledge and addressed priority research, management and other actions to promote recovery of North Pacific humpbacks in Canadian waters. Discussions on the available data and potential Critical Habitat designations were also conducted. Based on weight of evidence from the data and information presented, it was clear that there are predictable, seasonal aggregations of Humpback Whales in B.C. and four areas were identified as candidates for Critical Habitat designation (Fisheries and Oceans Canada Humpback Whale Recovery Planning Workshop, Nanaimo, B.C., January 12-14, 2009).

The objectives of this report are (1) to evaluate data and literature pertaining to patterns of Humpback Whale occurrence within these areas (2) to describe the oceanographic and biological features of these areas, based on a literature review, particularly with reference to the manner in which they may support Humpback Whale foraging needs in order to recommend Critical Habitat designation in support of the recovery goals and objectives as set out in the draft Humpback Whale Recovery Strategy.

HUMPBACK WHALE ECOLOGY

Humpback Whales are a migratory species spending their winters on low-latitude subtropical and tropical breeding grounds, and spring through fall on higher latitude foraging grounds. Waters off the coast of B.C. represent part of these higher latitude feeding areas for North Pacific Humpback Whales. Humpback Whales feed on dense patches of zooplankton, euphausiids in particular, and on small fish. They do so by lunging through these patches and engulfing large volumes of water mixed with prey. The Humpback Whale's expandable throat pleats allow it to maximize the volume of water and prey it can take in. Prey is trapped inside the mouth as the water is expelled through the baleen plates. Dense patches of prey are sought but prey densities are also enhanced by concentrating prey using techniques such as "flicking feeding" and "co-operative bubble-net feeding".

[1] Species at Risk Section 41 (1)

Euphausiids were the most common prey reported in B.C. from stomach contents collected between 1949 and 1965 from Humpback Whales taken by commercial whalers (Cetacean Research Program (CRP) - DFO unpubl. data). Of 287 stomachs that contained food remains, 263 (92%) contained only euphausiids, 12 (4%) contained only copepods, and 2 (0.7%) contained only fish. The remaining stomachs contained mixtures of these prey types and one was full of small (2 inch) squid. Two species of euphausiids were reported, *Euphausia pacifica* and *Thysanoessa spinifera*. The high proportion of stomachs containing euphausiids and the comparatively small proportion containing fish likely reflects the predominantly offshore focus of whaling activity. During this period, whaling in B.C. focused on large rorqual species and thus hunting occurred from 10 to over 100 kilometres from shore (Gregr et al. 2000). Therefore these data likely under represent the diet of Humpback Whales that occurred nearshore in B.C. during this period.

Recent observations and prey sampling from feeding Humpback Whales during 2002-2007 indicate euphausiids are the primary prey species in most coastal areas of B.C. (CRP-DFO, unpubl. data). However, feeding on schooling fish was considerably more common than demonstrated in the whaling records, particularly in nearshore waters. Fish species observed to be taken by humpbacks in coastal waters include Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus*), and Pacific sardine (*Sardinops sagax*). However, no recent studies have yet been undertaken to document the degree of whale foraging on these prey species in BC waters. Ecological links between Humpback Whales and Pacific herring have been studied in Prince William Sound, Alaska, and substantial predation has been estimated from observations (J. Rice, U.S. National Oceanic and Atmospheric Administration, pers. comm.).

Off Canada's west coast, Humpback Whales are considered one population under the *Species at Risk Act* (www.sararegistry.gc.ca). The most recent population estimate for Humpback Whales in the North Pacific from mark-recaptures models using extensive photo-identification data is 18,302 individuals (excluding calves) with a population growth rate of 4.9 to 6.8% per year (Calambokidis et al. 2008). The most recent population estimate for B.C. waters is 2,145 (1,970-2,331) whales in 2006, estimated using a Jolly-Seber mark-recapture model and photo-identification data (Ford et al. 2009). The number of humpbacks in B.C. waters is estimated to be increasing at 4.1% (95% confidence limits 3.9 – 5.1%) per year (Ford et al. 2009).

Within the North Pacific, Humpback Whales can be segregated into regional stocks based on differences in mitochondrial DNA haplotype frequencies, although there is significant mixing (Baker et al. 1998). Under the U.S. *Marine Mammal Protection Act*, three stocks are recognized in the North Pacific. These U.S. classifications are 1) California/Oregon/Washington stock or eastern stock, which feeds off the west coast of the U.S. mainland, 2) the Central North Pacific stock, with feeding areas from Southeast Alaska to the Alaska Peninsula, and 3) the Western Pacific stock, with feeding areas around the Aleutian Islands, Bering Sea and Russia (Angliss and Outlaw 2007; Carretta et al. 2007). The population in B.C. has not formally been assigned to any of these stocks.

Humpback Whale Habitat in British Columbia

The important characteristics of habitat to Humpback Whales in B.C. are most likely those related to prey abundance and the physical and biological processes that sustain and concentrate prey resources. This is because foraging is the primary activity observed and because Humpback Whales experience relatively low rates of predation and are thus primarily limited by "bottom-up" ecological processes such as prey abundance (Ford and Reeves 2008). Yet it is difficult to quantify the habitat characteristics that are associated with Humpback Whale occurrence in B.C. because these animals feed on a wide variety of species and do so in a variety of habitat types, from nearshore coastal features (e.g. channels and inlets) to offshore waters.

In general, it is understood that seasonal variations in biotic productivity are linked to fluxes in nutrients and daylight in the North Pacific. Zooplankton, which feed on phytoplankton, increase in abundance as phytoplankton availability increases in spring and summer with lengthened daylight hours and increased nutrient availability. Simard and Mackas (1989) report that in addition to phytoplankton, euphausiid distribution (e.g., *Euphasia pacifica* and *Thysanoessa spinifera*) is also governed by underwater light intensity, temperature and salinity. The interactions of water movements with bathymetric features can increase the availability of zooplankton to vertebrate predators by bringing zooplankton closer to the surface, concentrating them at converging water masses or in eddies, or by attracting zooplankton to regions of higher productivity (Simard and Mackas 1989, Perry and Waddell 1997, Lu et al 2003). Physical forcing mechanisms that drive water movements include wind, tidal currents, buoyancy fluxes (e.g., effects of freshwater runoff), and seasonal downwelling and upwelling processes.

There are many species of fish and invertebrates in B.C. waters which could be food for Humpback Whales but information on their distribution, abundance and even life history may be limited or non existent. In general, where a fishery occurs or has been considered, there is more information about a fish populations and much of the information on Pacific herring, Pacific sardine and eulachon stocks has been collected for such purposes. However the lack of information on other fish and invertebrate species should not be interpreted as evidence of lesser importance of these as potential prey to Humpback whales, but rather as a knowledge gap.

Many forage species have distinct life history patterns that influence their seasonal availability to Humpback Whales as prey. These patterns are better known for some species than for others. Life history examples of Pacific herring and Pacific sardine are briefly described below. Adult Pacific herring migrate into nearshore waters from late fall to early winter. They then spawn nearshore from late winter to early summer and after spawning migrate offshore to feed in biologically productive waters, such as near oceanic shelves and basins (Tanasichuk 2000, 2001; Therriault 2003). Juvenile Pacific herring, which are herring up to two years of age, remain feeding in sheltered nearshore waters relatively near to where they have hatched (Thompson and Therriault, 2006, 2007). This suggests that herring of different life stages may be available to predators including Humpback Whales through much of the year. Adult Pacific sardine typically migrate into B.C. waters from their southern spawning distribution in early summer to feed on zooplankton and phytoplankton through the summer and fall months (MacFarlane and Beamish 2001; Schweigert et al 2009). Thus Pacific sardine are available to predators including Humpback Whales during summer and fall.

METHODS

Identification of Candidate Critical Habitats

Potential Critical Habitat areas for humpbacks in B.C. were identified by assessing various sources. Distribution data were collected from: photo-identification and visual surveys and incidental sightings collected over the past two decades and B.C. historical whaling data. Discussions were also held among experts at the "Humpback Whale Recovery Planning Meeting" held in Nanaimo in January, 2009, regarding areas of consistent occupation as well as longevity of occupation (Calambokidis et al. 2004; Rambeau 2008: Williams and Thomas 2007, Sandilands 2008; Ford et al. 2009; CRP-DFO unpubl. data). Figures 1 and 2 illustrate the widespread occurrence of these animals on the B.C. coast, and depict where relatively high concentrations have been observed. Four areas with particularly high and persistent seasonal abundance of whales were identified as candidates for SARA Critical Habitat. The boundaries to delineate these areas were drawn to include the majority of sightings and traditionally used areas. To some extent, the four areas collectively represent the breadth of habitat types occupied by humpbacks in B.C. The four areas are: (a) waters surrounding Langara Island, (b) waters along the southeastern side of Moresby Island and Kunghit Island, (c) mainland channels around Gil and Gribbell Islands, and (d) waters off southwest Vancouver (Figure 3 and 4.). These four areas will here after be referred to as Langara Island, Southeast Moresby Island, Gil Island and Southwest Vancouver Island.

Literature Review

For each of the four areas, a literature review was also undertaken to compile a description of the physical and biological processes in or near each area that may concentrate or support prey making these areas productive for Humpback Whales.

Humpback Whale Datasets and Analysis

Humpback Whale data sets were used to examine patterns of occurrence, both seasonally and inter-annually. Data were also used to examine abundance within each of the four areas and rates of interchange among the four areas.

Photo-identification Data

Photo-identification surveys provide the most comprehensive dataset with data available from each area and dating back to the early 1990s. Photographs and digital images have been compiled and are maintained in a database at the Pacific Biological Station. The database up to 2007 contains 6,401 photo images of 1,871 individual animals and there are additional photo images from 2008 for the Gil Island area. Photo-identification data are comprised of a photo or digital image, the date and location of the encounter and a unique alpha-numeric code recorded for each individual whale not previously encountered in B.C.

Effort increased over time, particularly after 2002 coinciding with the SPLASH project ('Structure of Populations, Level of Abundance and Status of Humpbacks' (Calambokidis et al. 2008)). The Langara Island area is an exception as this area has

received consistent survey effort twice annually since 1992. Spatially, effort has also been unevenly distributed as it was focused to some extent in areas of known occurrence (Figure 2).

Around Gil Island, a greater emphasis on the collection of Humpback Whale observations commenced in 2004 with the establishment of the North Coast Cetacean Society (NCCS) research station on Gil Island (http://www.whaleresearch.ca) and collaborative research efforts with the Gitga'at Lands and Resources Stewardship Society (GLRSS).

Photo-identification data were used to summarize the number of whales that have been identified in each candidate area and to determine inter-matches (movements of individuals) between areas and to examine inter-annual variation in occurrence. The percentage of inter-matches between two areas was calculated using Dice's Index.

Percent inter-matches = $(2n_t/(n_x + n_y)) *100$

Where n_t = the number of individuals photo-identified in both areas, n_x = the number of individuals photo-identified in area x, and n_y = the number of individuals photo-identified in area y

Photo-identification data were also used to estimate abundance in each candidate area using the "Minimum Number Alive" method. Ford et al. (2009) used this approach to predict the number of individually identified whales alive in 2006, by calculating the total number of unique whales identified in B.C. between 1992 and 2006. The method only considers the component of the population that had been 'previously seen', and is therefore considered a minimum estimate. Although it is calculated under the assumption of a closed population, estimates were made using a value of 0.98 for survival over the time series (Ford et al. 2009). Ford et al. (2009) provided a B.C. coast-wide Minimum Number Alive estimate (MNA) for 2006 of 1,620 Humpback Whales, which is the minimum number of Humpback Whales that have used B.C. waters over the past 15 years (Ford et al. 2009). We used this same approach to calculate the MNA in 2006 in each candidate area to examine the percent of the coast-wide estimate that has been observed in each candidate area over the past 15 years.

Sightings From Ship-Based Line Transect Surveys

Sightings of Humpback Whales obtained during DFO ship-based line transect surveys were available from 2002 to 2008. Observations were recorded when (1) the ship traveled along a designated transect, (2) sea state according to the Beaufort scale of wind force was ≤ 5, (3) swell height was less than four metres, (4) visibility was ≥ 3 nautical miles (5.55 kilometres), and (5) two dedicated observers were stationed (one to port 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 effort was not distributed equally over the coast and only portions of the coast were surveyed on each cruise. Survey coverage was dependent on the cruise length, weather and sea conditions encountered, and at times, range restrictions of the ship.

The coverage presented in Figure 1 is the composite of 26 surveys. Despite these limitations, sighting data from these surveys were used to compare sighting densities in a candidate area to sighting density encountered over all areas surveyed. To compare with coastwide observations, sufficient survey data for this analysis were only available for the Gil Island and Southeast Moresby Island areas.

The number of individuals sighted per 100km of survey effort within the Southeast Moresby area, Gil Island candidate area, and for all coastal areas surveyed was calculated for each survey. The Student's t-test was used to test for significant differences between densities within area and over the whole coast. The analyses were made separately for 'spring' (April through June), 'summer' (July through September), and 'fall' (October through December) surveys although there were no fall surveys in the Southeast Moresby area.

Gitga'at Sightings Data

The Gitga'at Lands and Resources Stewardship Society has undertaken small vessel marine mammal surveys annually since 2005 in the waters around Gil and Gribbell Islands. These surveys provided additional sightings and effort data with which to estimate individuals per 100km in the Gil Island candidate area and compare sighting densities within the area among seasons. Sightings were recorded as a small boat traveled through the area following one of three survey routes. Route length was determined in GIS. Individuals per 100km were calculated for each survey. Surveys were then grouped by season and compared using one-way ANOVA and Scheffe post hoc test. Seasons were defined as follows, 'spring' (April through June), summer (July through September), fall (October through December), and winter (January through March).

British Columbia Cetacean Sightings Network data

The B.C. Cetacean Sightings Network (BCCSN) is a collaborative program between the Vancouver Aquarium and Fisheries and Oceans Canada. The BCCSN maintains a database of sightings reported by mariners, researchers, tour operators etc. Observers report their sightings via website (http://wildwhales.org), e-mail, phone, mail and their logbook program. Sightings of Humpback Whales from each of the four candidate areas were summarized by month and year. These sightings were used to ascertain the earliest year of reported Humpback Whale occurrence in each area and to determine if there were sightings in winter months when there were no other data sources.

Acoustic Data

Acoustic data were available for the Langara Island area and the Gil Island area only. A shore-based hydrophone installation was installed in 2003 to record the presence of killer whales and other cetaceans during fall, early winter and spring in the Langara Island area. Acoustic data from the spring and fall months of 2003 to 2008 have been analysed to determine the presence of Humpback Whales in this area (CRP-DFO unpublished data). A summary of the acoustic presence of Humpback Whales during 2008 from three hydrophone stations in the Gil Island area were also made available for this assessment (North Coast Cetacean Society, unpubl. data).

Acoustic data provide information on the presence of Humpback Whales in a broad area. It is not possible to estimate the number of animals present since not all animals present may be vocalizing and there could be some bias with seasonal vocalizations such as singing. It is also not possible to ascertain the location of the calling animals. In this regard these data confirm presence of individuals over a broad area, but not absence. Humpback Whale calls and songs are likely audible at a range of not more than ten kilometres, thus animals detected acoustically at Langara and at two of the Gil Island hydrophones were most likely within the boundaries of the candidate areas.

Prey and Behavioural Observations

Observations of foraging behaviour (e.g., lunge feeding, flick feeding and co-operative bubble-net feeding) were often, though not consistently, recorded with photo-identifications in the DFO Humpback Whale photo-identification database. These observations were recorded opportunistically and are qualitative. They may confirm a type of feeding behaviour and prey in an area, but provide no indication of the prevalence of this behaviour or of the importance of a particular prey-type in the area. Furthermore, the absence of observations does not indicate that foraging does not occur in an area.

RESULTS AND DISCUSSION

Humpback Whales show considerable fidelity to feeding areas and this may be maternally driven with whales returning to the feeding areas they first visited with their mothers as calves (Whitehead and Carscadden 1985, Piatt *et al.* 1989). This characteristic would therefore be expected to influence the pattern and even rate of habitat re-occupation because animals would select habitat areas based not only on favourable habitat characteristics but also on previous experience. The median distance between initial and subsequent year sightings of photo-identified individual Humpback Whales in B.C. was 75 km, which indicates very high site fidelity to feeding areas (Rambeau 2008; Ford et al. 2009). The photo-identification data also show that there were only low rates of movements between these areas and very few whales were encountered in more than two of the areas. Between areas, the highest percentage of photo-identification inter-matches was between Langara Island and southeast Moresby Island; the lowest percentages were with southwest Vancouver Island which is the greatest distance away from the other three candidate areas (Figure 5). Low rates of inter-matches between areas suggest the four areas support, to a large extent, different parts of the population.

The contemporary data sets used in this analysis show that these areas have been used by Humpback Whales for more than a decade. B.C. whaling catch records indicate that Humpback Whales were found in each of these areas at least as early as the 1920s and as late as the 1950s and ‘60s (Nichol et al. 2002; CRP-DFO unpubl. data). The re-occupation of these areas suggests that the habitat characteristics that make them favourable to Humpback Whales are relatively stable over long periods of time.

Langara Island

The earliest reported incidental sighting in the Langara Island area since the end of whaling dates from 1984 (BCCSN unpubl. data). Of the four candidate areas, this area has the most consistent time series of survey effort because there have been bi-annual small boat surveys and photo-identification effort in June/July and in September since 1992.

Humpback Whales in this areas have frequently been observed flick feeding, a foraging behaviour typically associated with feeding on zooplankton. A limited number of prey samples obtained in the vicinity of foraging humpbacks indicate that the euphausiid species *T. spinifera* and crab zoea may be targeted and foraging on Pacific herring and Pacific sand lance has also been observed (CRP-DFO unpubl. data). Cooperative bubble-net feeding has also been observed in the Langara area (CRP-DFO unpubl. data). This behaviour, which is associated with feeding on schooling fish, is observed frequently in parts of Alaska but much less often in B.C.

Photo-identification data demonstrate that Humpback Whales were present in every year (1992 to 2007) and were encountered on an average of 86% of effort days (range, 54% to 100% of effort days, n = 16 years) (Figure 6). Although Humpback Whales were present each year, there was considerable inter-annual variation in the number of animals encountered. The number of individuals photographed ranged from as few as 14 in 1992 to as many as 199 in 1999 (Figure 7). A total of 629 individual whales were identified in this area (1992 to 2007). The number of new animals not previously photographed in the area continues to increase annually (Figure 8). The MNA estimate of abundance for the area for 2006 was 597 individuals. This represents approximately 37% of the coast-wide MNA of 1,620 for 2006, given by Ford et al. (2009).

Acoustic monitoring of the region from a shore-based hydrophone installation revealed that Humpback Whales continued to be present through the fall with numbers dropping off dramatically in February (Figure 9), likely corresponding to the migration of Humpback Whales to breeding grounds in lower latitudes. Vocalizations heard on the recordings included Humpback Whale songs, typically associated with courtship/breeding behaviour observed on breeding grounds.

Habitat

The Langara Island area encompasses 721.7 km^2 (Figure 9) and is on the south side of Dixon Entrance, the body of water separating the Queen Charlotte Islands from southeast Alaska. Dominant oceanographic influences include water transport through Dixon Entrance and downwelling effects from the Alaskan Coastal Current (Lucas et al. 2007). The western side of this area includes portions of the continental shelf which slopes steeply to depths greater than 400m. Nearby shelf breaks and Learmonth Bank to the north also contribute to biological productivity in the area (Crawford et al. 2007).

Satellite images of the area depict high levels of late spring and summer phytoplankton with relatively low levels in March and September (Mackas et al. 2007). Waters in Dixon Entrance and in canyons and troughs of the continental shelf seasonally support aggregations of zooplankton, with peaks in abundance generally occurring mid summer, but spring periods are also very productive (Perry and Waddell, 1997). Although

euphausiids are part of the Dixon Entrance zooplankton community, sampling has shown a predominance of chaetognaths and copepods (Perry and Waddell, 1997).

Data representing Pacific herring spawner abundance for nearby sheltered waters off the west side of Graham Island suggest some increases in abundance in the last 10 years with recent estimates ranging from approximately 2000 to 5000 tonnes (Schweigert and Haist 2008). Other forage species estimates of abundance for this area are not available.

Southeast Moresby Island

The earliest reported incidental sighting since the end of whaling dates from 1984 (BCCSN unpubl. data). Humpbacks were sighted infrequently during dedicated whale surveys conducted off southeast Moresby Island, including Juan Perez Sound, in the summers of 1991-1993 (Ford et al. 1994). Most survey effort in this area has occurred since 2002, led by DFO and Parks Canada.

Sightings from line-transect surveys (2002 to 2008) suggest that this area has been a hotspot for large numbers of Humpback Whales (Figures 1 and 2), particularly off Juan Perez Sound (Figure 3). A comparison of individuals per 100 km of survey effort indicates that densities of Humpback Whales were significantly higher in the candidate area during spring surveys than over all areas surveyed ($t_{(0.05, 6,)} = -4.000$, $p = 0.007$), and though not significantly so, were still higher in summer surveys than over all surveyed areas of the B.C. coast ($t_{(0.05,5)} = -1.545$, $p = 0.1534$) (Figure 11).

Photo-identification data also suggest high densities of Humpback Whales in the area. During 1992- 2007, 531 whales were identified in only 89 photo-encounter days. Examined annually, however, it is also clear that there has been considerable inter- and intra-annual variation in the number of whales present. The photo-identification data show that the highest total numbers of Humpback Whales encountered annually occurred in 2004 and 2007 (Figure 12). The maximum number of individuals photographed on a single day during 2002-2007 ranged from 23 in 2002 to 94 individuals in both of 2003 and 2007. Most survey and photo-identification effort has occurred from May to August, but incidental sightings indicate that Humpback Whales have been encountered in this area in all months of the year (BCCSN unpubl. data)

Figure 13 presents the cumulative number of individuals photographed in this area since 1992. As an estimate of abundance in the area, the MNA indicates that by 2006 there were a minimum of 403 animals in the B.C. population identified in the Southeast Moresby Island area. This represents approximately 25% of the B.C. coast-wide MNA of 1,620 for 2006 (Ford et al. 2009).

Humpback Whales have been observed flick feeding and lunge feeding in this area (CRP-DFO unpubl. data). Prey samples obtained near foraging humpbacks in most years from 2002 to 2008 indicate a predominance of euphausiid species *T. spinifera* and *E. pacifica* (CRP-DFO unpubl. data).

Habitat

The Southeast Moresby Island area includes the waters off the southeastern side of Moresby Island and Kunghit Island in the Queen Charlotte Islands and encompasses 4,544.9 km^2 (Figure 14). This area is comprised of islands, channels, oceanic shelves and gullies, and areas influenced by shallow banks. The area includes a large portion of the proposed Gwaii Haanas National Conservation Area Reserve (Sloan 2006; http://www.pc.gc.ca/progs/amnc-nmca/cnamnc-cnnmca/gwaiihaanas) and the waters off Cape St. James have previously been identified by Clark and Jamieson (2006) as biologically and ecologically important due to high concentrations of whales.

Oceanographic modelling (based on oceanographic properties of water depth, bottom type and local tidal currents) suggests that intermediate to high levels of nutrient mixing occur in the water column of the candidate area (Jardine et al. 1993). In addition, Robinson et al. (2004) reported satellite-derived observations representing phytoplankton blooms occurring in spring, late summer and early fall periods, caused by inshore nutrient loads possibly in combination with tidal fronts and ocean upwelling. They also reported extensive dispersion of a large bloom stemming from shoreward sources in Juan Perez Sound in June.

Tidal fronts coupled with water displacement through Moresby Trough (a large deepwater gully extending from the southeast coast of Banks Island in eastern Hecate Strait to Cape St James) appear to concentrate both nutrient rich and relatively warm waters towards southeast Moresby and Kunghit Islands (Jardine et al 1993; Crawford 1997). Based on these and other oceanographic processes, Perry and Waddell (1997) identified the waters extending from the Moresby Trough towards Moresby and Kunghit Islands as having favourable conditions to support substantial zooplankton aggregations.

Limited information on several forage species has been collected from catch observations (e.g Therriault 2003; Sloan 2006) but overall, no interannual information on abundance and distribution is available for most species. Pacific Sand lance has been identified as an ecologically important forage fish in the area but little is known about the species' distribution, abundance, spawning and foraging habitat in the region (Sloan 2006). Pacific herring use these waters for spawning, rearing, migrating and foraging (Therriault 2003; Thompson and Therriault 2007; Schweigert and Haist 2008). Annual biomass estimates of spawning Pacific herring from 1999-2009 are less than 10,000 tonnes, whereas substantially higher estimates of approximately 90,000 tonnes were recorded during the period 1980 to 1998. Recent low abundance of spawning herring has been attributed to consecutive years of high natural mortality and poor recruitment (Schweigert and Haist 2008).

Gil Island

The earliest reported humpback sighting in the Gil Island area since the end of the whaling era dates from 1992 (BCCSN unpubl. data). Since 2002, there has been a significant increase in data collection and monitoring efforts in this area as a result of DFO ship-based surveys, the presence of the Northcoast Cetacean Society (NCCS) on Gil Island, and Gitga'at Lands and Resources Stewardship Society (GLRSS) small boat surveys.

There were four DFO ship-based line transect surveys during 2003-2007 that included the Gil Island area as well as other regions of the coast. Humpback whales were observed in the Gil Island area during each of these surveys which occurred in the fall. The density of sightings encountered in the Gil Island area compared to all other parts of the coast surveyed were not, however, significantly different ($t_{(0.05, 3,6)}$ = -.116, p = 0.911) (Figure 15).

The GLRSS completed 42 small boat surveys, one to three per month, during 2005-2008: seven winter surveys, 12 spring surveys, 13 summer surveys, and 12 fall surveys. No Humpback Whales were encountered during winter surveys. Figure 16 shows that the mean number of individuals encountered per 100km increased from spring through fall ($F_{(0.05, 2, 34)}$ = 6.331, p = 0.005). A Scheffe post hoc test indicated that spring was significantly different from fall (p = 0.006). The mean density of individuals in fall surveys was 11.26/100km compared to the DFO fall surveys (14.23/100km). DFO ships provide a substantially higher platform for observations which likely accounts for the higher sighting rate compared to the GLRSS surveys.

The first Humpback Whales photographically identified from this region date from August and October 1997. During 1997-2008, there were a total of 303 encounter days and 172 different whales identified in the area (Figure 17). The mean number of encounter days over the eight years was 30.3 per year, the highest of the four candidate areas. This is probably because of the NCCS presence in the area almost year round. Figure 18 presents the number of different whales that have been photo-identified per month (1997 to 2008) and the number of encounter days. More photo-IDs per encounter day have been obtained July through October than in other months. Ford et al. (2009) noted that in general the presence of whales in the mainland inlets in B.C. is greatest from late summer through fall.

From the three shore-based acoustic monitoring stations established by NCCS, data were available from 2008. Two stations, Taylor Bight and Bear Point, monitor sections of Whale Channel in the Gil Island area. The third station, Ulric Point monitors portions of the entrance to Caamano Sound and the northern part of Laredo Channel at the southern boundary of Gil Island. In 2008, these stations operated for variable periods of time, including some periods with all three operating simultaneously (Figure 19). The Taylor Bight hydrophone operated throughout the year, the Bear Point station began monitoring in April and thus the two stations provided greater coverage of part of Whale Channel from April through December. The vocalizations detected were feeding calls. No Humpback Whales were detected acoustically in Whale Channel until June. During the months of June through September all three stations were operating. Figure 19 indicates that Humpback Whales were heard more often on the Ulric station hydrophone during the summer months than on the two stations monitoring Whale Channel. Although the Ulric station ceased functioning after September, the number of monitoring days on which Humpback Whales were detected in Whale Channel was highest in the months of October through December.

Figure 20 presents the cumulative number of individuals photographed in this area since 1997. The MNA in the Gil Island candidate area up to 2006 was 116 animals. This represents approximately 7% of the coast-wide MNA of 1,620 for 2006, given by Ford et al. (2009). While this is a relatively low percentage of the coast-wide estimate, the area is significant as it represents a fairly distinctive type of Humpback Whale habitat occurring well inshore, within steep inlets and channels. Use of this area appears to be

more strongly seasonal than the other candidate areas. Williams and Thomas (2007) show more sightings of Humpback Whales in this area than in other inlets and channels they surveyed in 2004 and 2005. Also, Humpback Whales were taken in this area at least as far back as the 1920's (CRP-DFO unpubl. data). Cooperative bubble-net feeding has been observed in the Gil Island area, a foraging technique associated with foraging on schooling fish (Sharpe 2001).

Habitat

The Gil Island area includes Campania Sound, and the channels surrounding Gil Island (Squally and Whale Channels) and Gribbell Island (Ursula Channel), encompassing 765.7 km^2 of waterways (Figure 21). This area is comprised of deep, narrow, glacial-carved fjords that have steep sides with flat bottoms, with sills or ledges where fjords meet the coast. The area is subject to low to moderate degrees of tidal action and mixing with nutrient rich waters of Hecate Strait. Consequently, freshwater input is critical in controlling circulation and water properties in this fjord habitat (Pickard and Stanton 1980, Crawford 2001, Crawford et al. 2007, Lucas et al. 2007). Surface concentrations of chlorophyll are generally maintained by estuarine circulation driven by freshwater runoff and differentials in salinity along inlets and sheltered waters (Lucas et al. 2007). In addition to freshwater inputs, shoals and islets to the north of the area likely contribute to flow and retention of zooplankton within the area.

Maximum freshwater input is typically in late spring and summer when snowmelt and freshets are highest (Lucas et al. 2007, Crawford et al. 2007). Autumn and winter rainfall also significantly affects water chemistry in the region (Crawford et al. 2007). As the less dense freshwater at the surface flows outwards, a compensatory inward (landward) flow of more saline water at depth occurs (Crawford et al. 2007). This is a common pattern in B.C. fjords which influences plankton distributions.

There has been little quantitative sampling and species identification of zooplankton in B.C. mainland inlets and fjords and the spatial resolution of satellite remote sensing data is too coarse to infer information about zooplankton biomass in the area. A considerable amount of information is available on spawning herring populations to the north and south of this candidate area in the Prince Rupert and Central Coast Stock Herring Assessment regions, respectively, and there has been relatively low herring abundance in these areas since 2006 (Schweigert and Haist 2008). Several rivers draining into nearby waters of the area historically supported spawning eulachon, a small schooling fish, like Pacific herring, that may be preyed on by Humpback Whales (Hay and McCarter 2000).

Southwest Vancouver Island

The earliest reported incidental sighting in the Southwest Vancouver Island area since the end of whaling is from 1986 (BCCSN unpubl. data). An examination of DFO's photo-identification data indicates that during 1992-2007, there were 196 photo-encounter days and 247 whales identified. Most photo-identification effort has occurred since 1998. The highest numbers of Humpback Whales photo-identified occurred in 2005 and 2007 (83 and 67 whales respectively) (Figure 22). The maximum number of individuals photographed on a single day during 1998- 2007 ranged from 5 in 1999 and 2001 to 22 individuals in 2007. Figure 23 presents the cumulative number of individuals photographed in this area since 1992 and shows that the number of new animals

photographed annually continues to increase. By 2006, the MNA was 208 animals in this candidate area. This represents approximately 13% of the 2006 coast-wide MNA (Ford et al. 2009).

The southwest portion of this area has been included in U.S.-led line-transect and small boat photo-identification surveys from the Washington coast over the past two decades (Calambokidis et al. 2004). Based on their data from ship surveys (1995-2002) and small boat surveys (1989-2002), consistent small-scale concentrations of Humpback Whales have been present near the mouth of Barkley Canyon and over Swiftsure Bank. They also found that approximately 44% of photo-identified animals were re-sighted in their study area in more than one year.

Photo-identification matches and genetic analysis suggest that the Humpback Whales in this area may be part of a sub-population distinct from the Humpback Whales found along the B.C. coast north of Vancouver Island. In the mid 1990's, it was suggested that this area represented a demographic break between Humpback Whales that fed in waters off southern B.C. , Washington, Oregon and California, and Humpback Whales that fed to the north in B.C. and Alaska (Calambokidis et al. 1996). Recent genetic and photo-identification research provides further evidence for two sub-populations of humpbacks in B.C. (Urbán R. et al. 2000, Calambokidis et al. 2008, Ford et al. 2009). While a clear boundary or demographic break has not been demonstrated, it has recently been shown from photo-identification matches that 87% of Humpback Whales in areas of B.C. north of the southwest Vancouver Island return to winter breeding grounds in Hawaii, whereas whales encountered off the southwest coast of Vancouver Island are equally likely to be destined for breeding grounds in Mexico or Hawaii (Urbán R. et al. 2000, Rambeau 2008). Although there is unlikely to be a clear geographic demarcation, preliminary data suggest, a diffuse sub-population division may exist somewhere off northern Vancouver Island (Ford et al. 2009).

Although Humpback Whales in Canada's Pacific waters are considered one population under SARA, there is compelling evidence to suggest that there are two subpopulations (Baird 2003). The SPLASH project estimated a regional abundance of 200 to 400 Humpback Whales for southern B.C. - northern Washington and our MNA estimate for the Southwest Vancouver Island candidate area of 208 animals is consistent with this estimate (Calambokidis et al. 2008). It is possible that Humpback Whales off southern B.C. are part of an eastern stock that occupies feeding grounds off Washington, Oregon and California, whereas Humpback Whales observed elsewhere in B.C. are part of a central Pacific population (Calambokidis et al 1996; Calambokidis et al, 2004; Rambeau 2008).

Humpback Whales in this area have been observed lunge feeding. Prey samples obtained near foraging humpbacks in 2000 and 2002 were of euphausiids of both *T. spinifera* and *E. pacifica* (CRP-DFO unpubl. data). Since the mid 1990s, there appears to have been a shoreward shift in distribution of whales (J. Calambokidis, Cascadia Research Collective, pers. comm.), and photo-identification records suggest that Humpback Whales have made more frequent use of Barkley Sound in recent years, coincident with an increased presence of Pacific sardine and observations of foraging on sardine (CRP-DFO unpubl. data).

Habitat

The area includes nearshore waters of Barkley Sound and waters extending offshore to encompass sections of the continental shelf, with a total area of 6,188.3 km^2 (Figure 24). The southern marine boundary of the area is delineated by the Canada-U.S. border. Several oceanographic processes circulate water and affect patterns in nutrient and plankton availability off the west coast of Vancouver Island. The width of the continental shelf off Vancouver Island is greatest in this southern region (~75 km wide) and it contains or is influenced by several basins and canyons that affect the local hydrography (e.g. La Perouse Bank, Nitinat Canyon, Swiftsure Bank and Barkley Canyon (Thomson et al. 1989). Nutrient rich waters brought onto the shelf by recurrent upwelling driven by the interaction of currents and bottom topography, by wind-driven coastal upwelling, and by the tidally-mixed outflow of Juan de Fuca Strait have a substantial impact on local biology, making this a nutrient rich and biologically productive oceanographic area even during El-Niño-Southern-Oscillation (ENSO) events (Freeland et al 1984; Thomson et al 1989; Ware and Thomson, 2005; Harris et al 2009).

This area supports large amounts of euphausiids including *E. pacifica* and *T. spinifera,* found in highly localized and relatively dense distributions conducive to Humpback Whale foraging habits (Bryant et al. 1981; Dolphin 1987a; 1987b; Simard and Mackas 1989, Tanasichuk 1998 a,b; Lu et al 2003). Mackas et al (2007) reported that this area generally supports 1.5 to 3 times more total zooplankton biomass than Hecate Strait. From surveys conducted in June and August, Simard and Mackas (1989) reported particularly high euphausiid concentrations continuously distributed in bands from 2-30km wide in regions near or over the 200m depth contour and in scattered layers within or over deep basins from La Perouse Bank to the Juan de Fuca Canyon. Euphausiid aggregations show diel vertical migration, reaching surface waters at dusk and descending to their day depths by dawn (Simard and Mackas, 1989). Simard and Mackas (1989) also report that day time depths of euphausiid aggregations at both the shelf break and over the shelf corresponded to water properties characteristic of the California Undercurrent, and that adjacent regions assist in supplying euphausiids to the region. In nearshore waters of Barkley Sound, euphausiids can also be particularly abundant, thus contributing forage to several fish and marine mammal populations (Tanasichuk, 1998 a,b).

Information on zooplankton species composition and relative abundance has been collected in the area since 1979 (Mackas et al 2004; Crawford and Irvine 2009). In the vicinity of Barkley Sound and further off the southwest coast of Vancouver Island, a large proportion of southern B.C. spawning herring feed during spring to fall periods (Tanasichuk 2000, 2001). It is estimated that 50,000 to 100,000 tonnes of Pacific herring annually feed primarily on euphausiids in this region from late spring to autumn (Tanasichuk 2000, 2001; Schweigert and Haist 2008). Adult Pacific sardine migrate northwards into the candidate area in summer to feed on phytoplankton and zooplankton (McFarlane and Beamish 2001). Annual estimates of Pacific sardine abundance from 1997 to 2008 in an area approximately encompassing the Southwest Vancouver Island candidate area, exceed 15,000 tonnes and range to over 70,000 tonnes (McFarlane and Beamish 2001; Schweigert et al 2009). Sexually mature and juvenile sardine have only occasionally been observed in B.C., which suggests low level winter presence of the species in the area (McFarlane and Beamish 2001). Annual spring bottom trawl surveys that target shrimp have been conducted in this area eastward of the break in the continental shelf since 1975. Estimates of shrimp abundance (mostly *Pandalus jordani*)

from these trawls show considerable variability between years, ranging from approximately 2,000-16,000 tonnes during 1975-2008. Associated with the shrimp survey are eulachon abundance data, which also show considerable annual variability ranging from approximately 500-6,000 tonnes. (DFO 2009b).

CONCLUSIONS

Recurrent annual occupation of these four areas and the disproportionate number of sightings within these four areas compared to the whole B.C. coast are the primary reasons they are recommended as potential Critical Habitat. In addition, historical whaling records show that Humpback Whales were encountered in these areas at least as far back as the 1920's, which suggests these areas historically supported foraging humpbacks. To better understand the processes that support concentrations of Humpback Whale prey species in these areas, we reviewed the literature to characterize their physical and oceanographic features.

Based on conservative estimates representing "Minimum Number Alive" for all areas of the B.C. coast (Ford et al. 2009), over half of all Humpback Whales photo-identified in B.C. have been encountered in the Langara and Southeast Moresby candidate areas. As such, factors influencing either of these two areas have the potential to affect a large proportion of the Canadian humpback population. Additionally, cooperative bubble-net feeding behaviour has been observed in the Langara area and this foraging technique is infrequently observed in B.C.

The Southwest Vancouver Island area is recommended based on information from genetics and photo-identification matches that local sub-populations of humpbacks may occur in B.C. waters. This information increases the relative importance of this candidate area as a precautionary protection measure under SARA because it identifies habitat that a subpopulation of Humpback Whales may preferentially occupy in southern B.C. and northern Washington.

Humpback Whales appear to use the Gil Island area predominantly in the late summer and fall. This area is quite distinctive as the only fjord-like habitat area recommended for as Critical Habitat. During surveys of mainland inlets and channels in 2004 and 2005, this area had the most sightings among inlet/channel areas surveyed. Humpback Whales also occurred in this area during the whaling era. Finally, this is one of only a few areas in B.C. where co-operative bubble-net feeding has been observed.

Humpback Whales have occupied these four areas annually over long periods and we conclude that prey availability and abundance to some degree directs Humpback Whale occurrence patterns, However, Humpback Whales also demonstrate onsiderable site fidelity to specific feeding grounds and this has been shown to be maternally driven, with animals returning to the feeding areas they first visited as calves with their mothers. Low rates of inter-matches between candidate areas indicate that each area largely supports different components of the population. Collectively these areas support a substantial portion of B.C.'s current Humpback Whale population.

The process leading to designation of Critical Habitat under SARA requires that areas not only be described spatially and temporally, but also that potential or existing threats to these habitats be identified (Environment Canada 2004). Detailed descriptions of

threats to humpbacks are provided in both the Humpback Whale Recovery Potential Assessment (Ford et al. 2009) and the draft Humpback Whale Recovery Strategy (DFO 2009b). Anthropogenic activities that would affect prey occurrence and abundance, disrupt habitat use (shown here to be predominantly for foraging), or displace whales are threats to Humpback Whale habitat in B.C. Examples of threats include, but are not limited to, oil spills, fishing, seismic surveys, pile driving and sonar or other alterations of acoustic environment that impact communication or foraging. The draft Recovery Strategy also notes disturbance and/or displacement due to underwater noise, vessel strikes and entanglement as threats to humpbacks (DFO 2009).

Habitat use by Humpback Whales in B.C is widely understood to be primarily for the purposes of foraging. Functional attributes of the four areas include oceanographic processes which annually and seasonally promote high levels of primary biological productivity. These processes vary between each of the areas and include, but are not limited to; tidal mixing, eddies, upwelling, wind- and wave- driven currents and bathymetric features (e.g. shelf breaks, sills, canyons and troughs). Direct links between these processes and the annual presence of humpbacks within each candidate area have yet to be clarified.

Considering that the precautionary approach is required to address recovery of threatened species, and that analysis of the four candidate areas utilized the best available information at this time, it appears that all four areas analysed in this document meet the criteria for designation as Critical Habitat under Canada's *Species at Risk Act*. It is expected that the areas presented in this document comprise only a portion of total Critical Habitat for the population, and as data gaps are addressed, additional habitat areas of critical or high importance may be identified both within Canada and in other jurisdictions.

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FIGURES

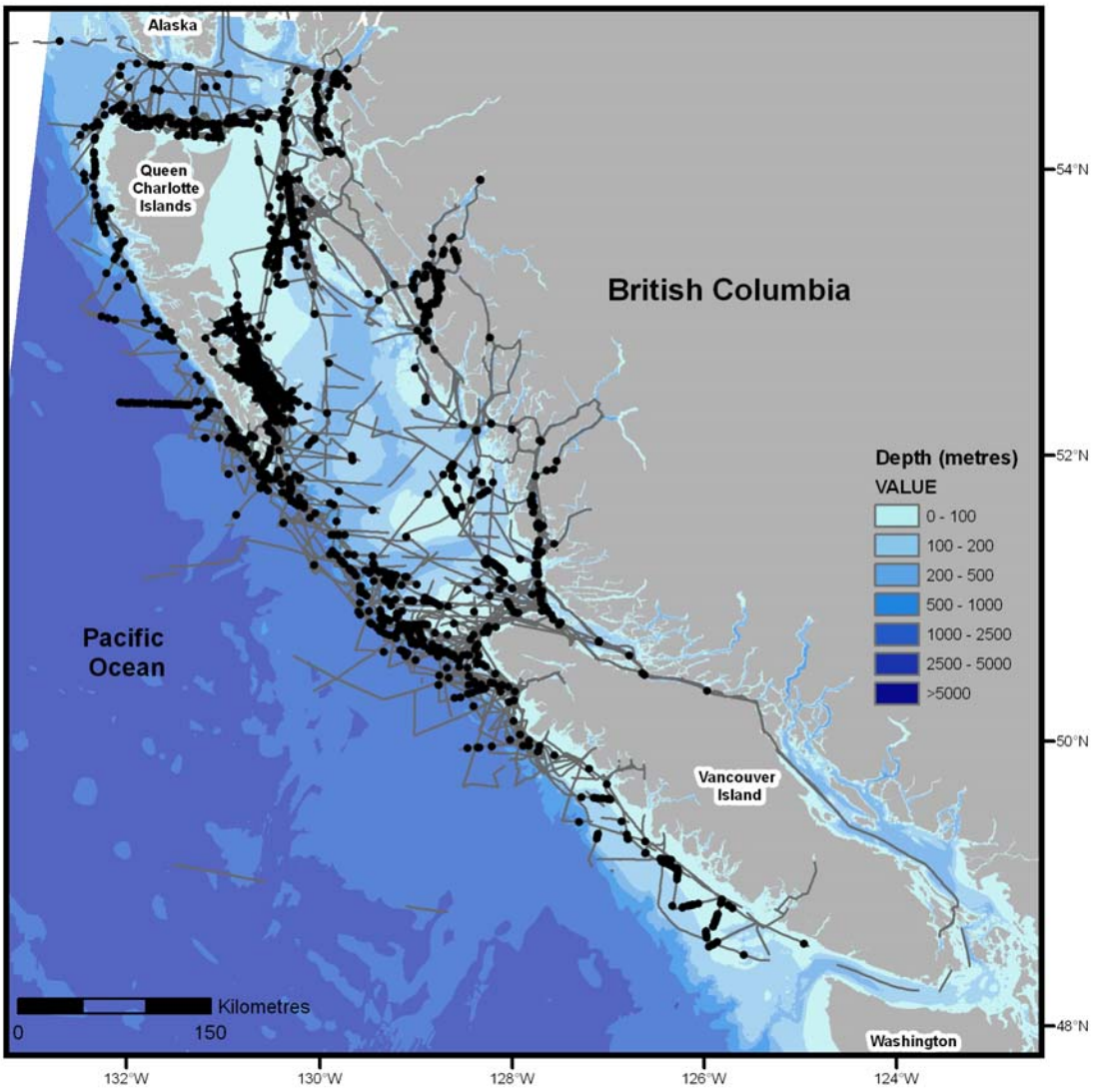

Figure 1. Locations of 1,906 Humpback Whale sightings made during 26 DFO shipboard cetacean surveys, 2002-2007. Black dots indicate locations where one or more Humpback Whales were sighted and grey lines indicate on-effort survey tracks (Ford et al. 2009).

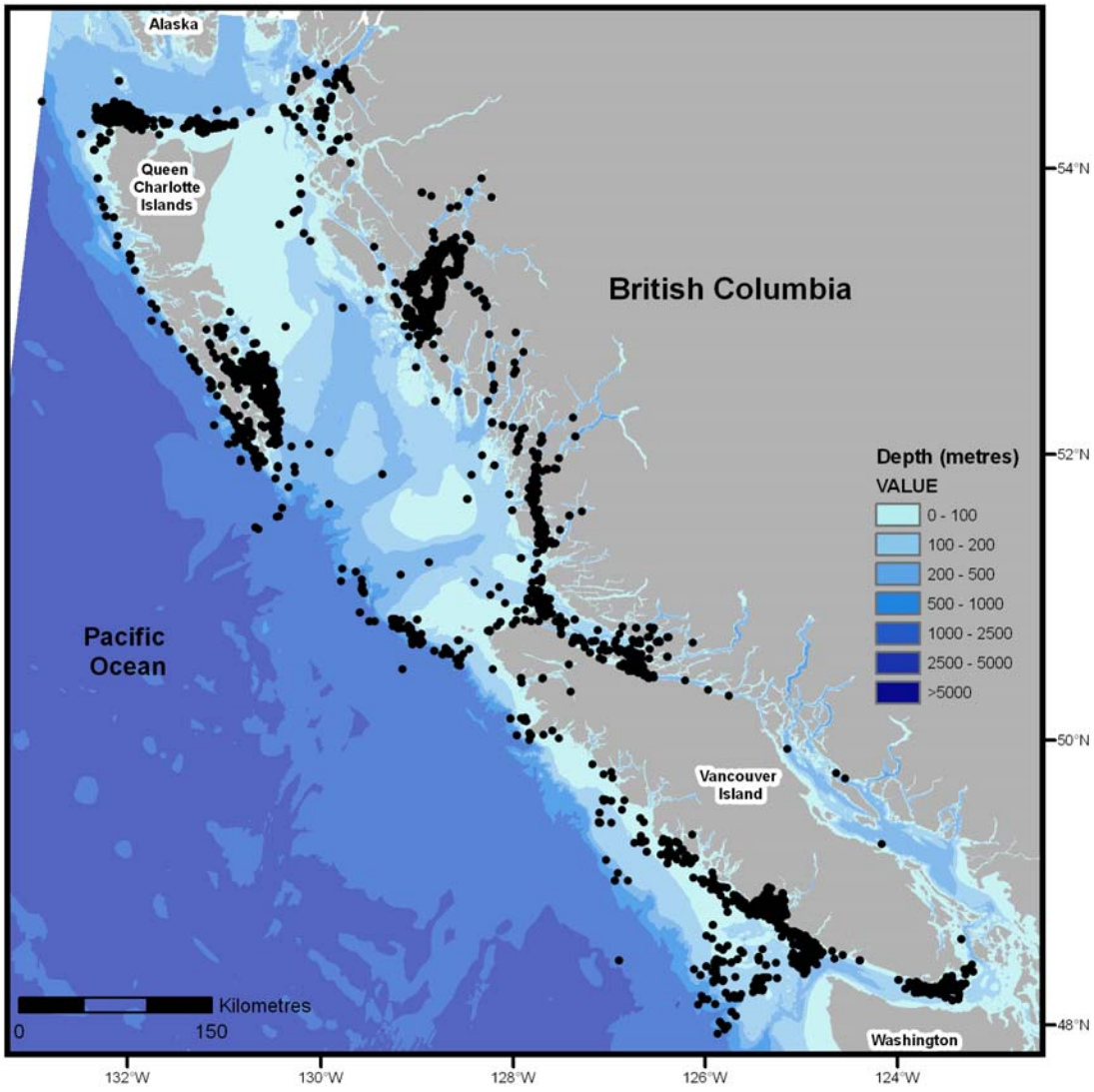

Figure 2. Locations of 6,401 Humpback Whale photo-identifications in BC waters, collected during 1984-2007 (from Ford et al. 2009).

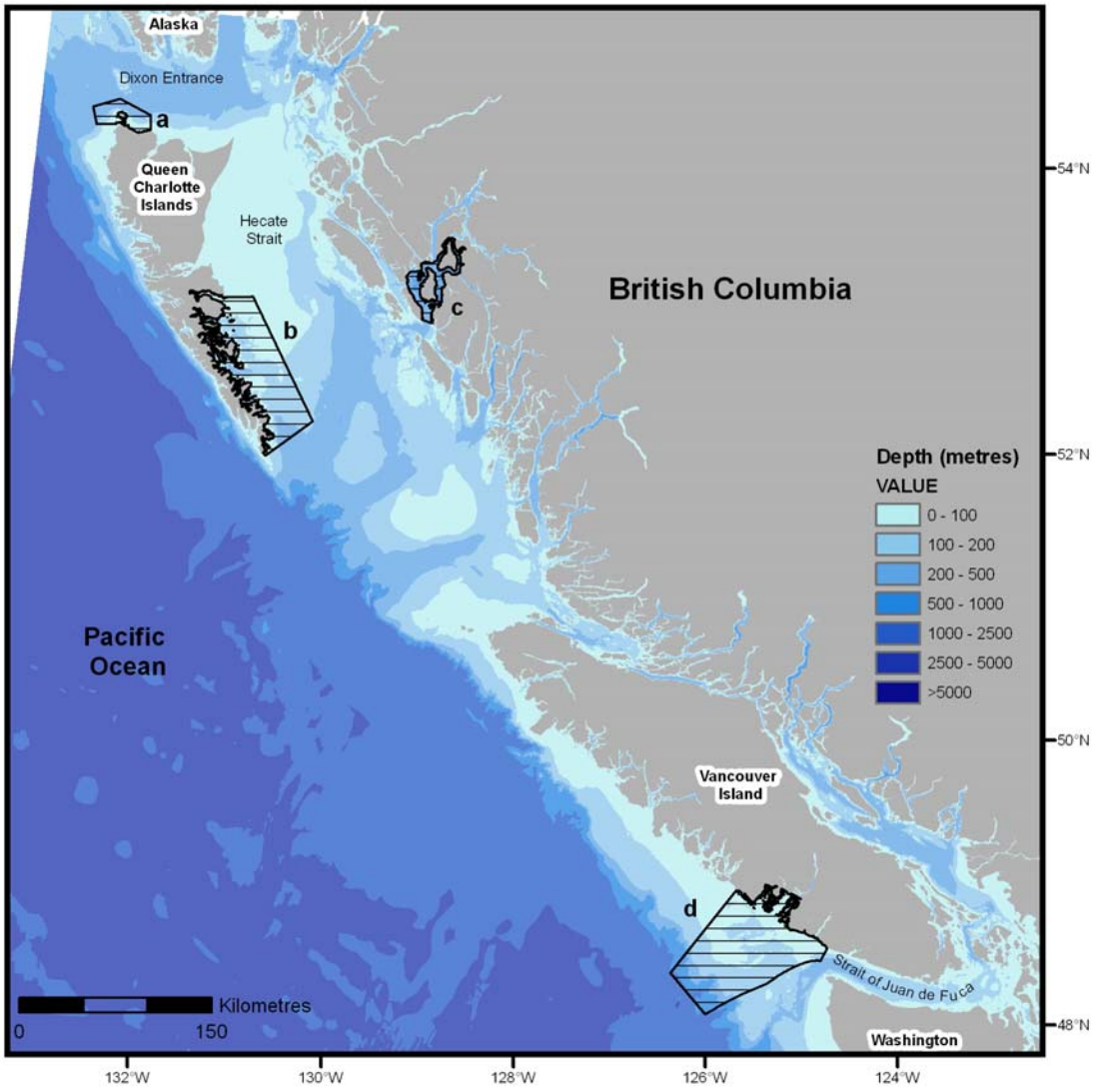

Figure 3. Locations of the four candidate Critical Habitat areas, a. Langara Island, b. Southeast Moresby Island, c. Gil Island, d. Southwest Vancouver Island.

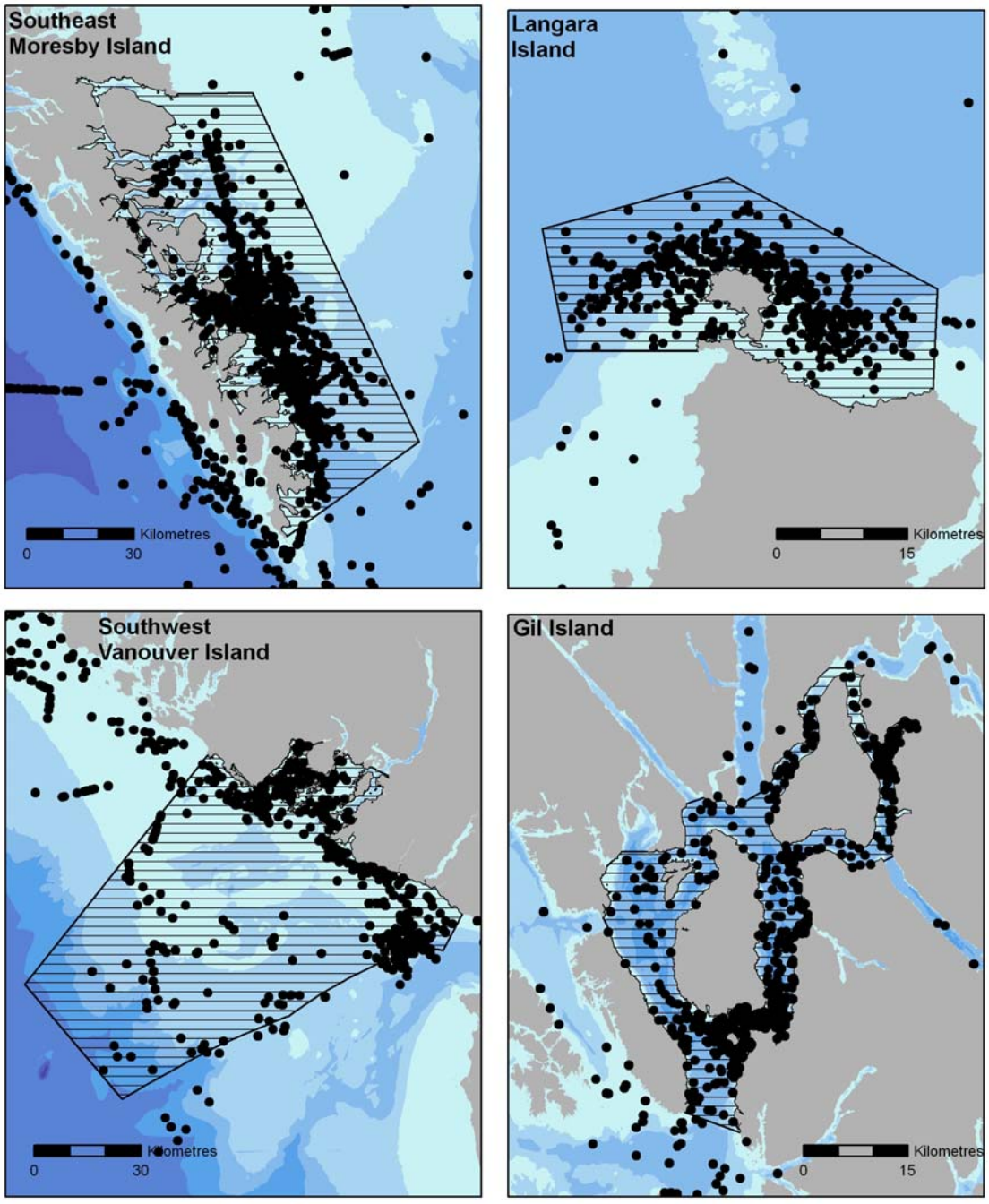

Figure 4. Each of the four candidate Critical Habitat areas showing the distribution of sightings from line transect surveys and photo-identifications in relation to area boundaries.

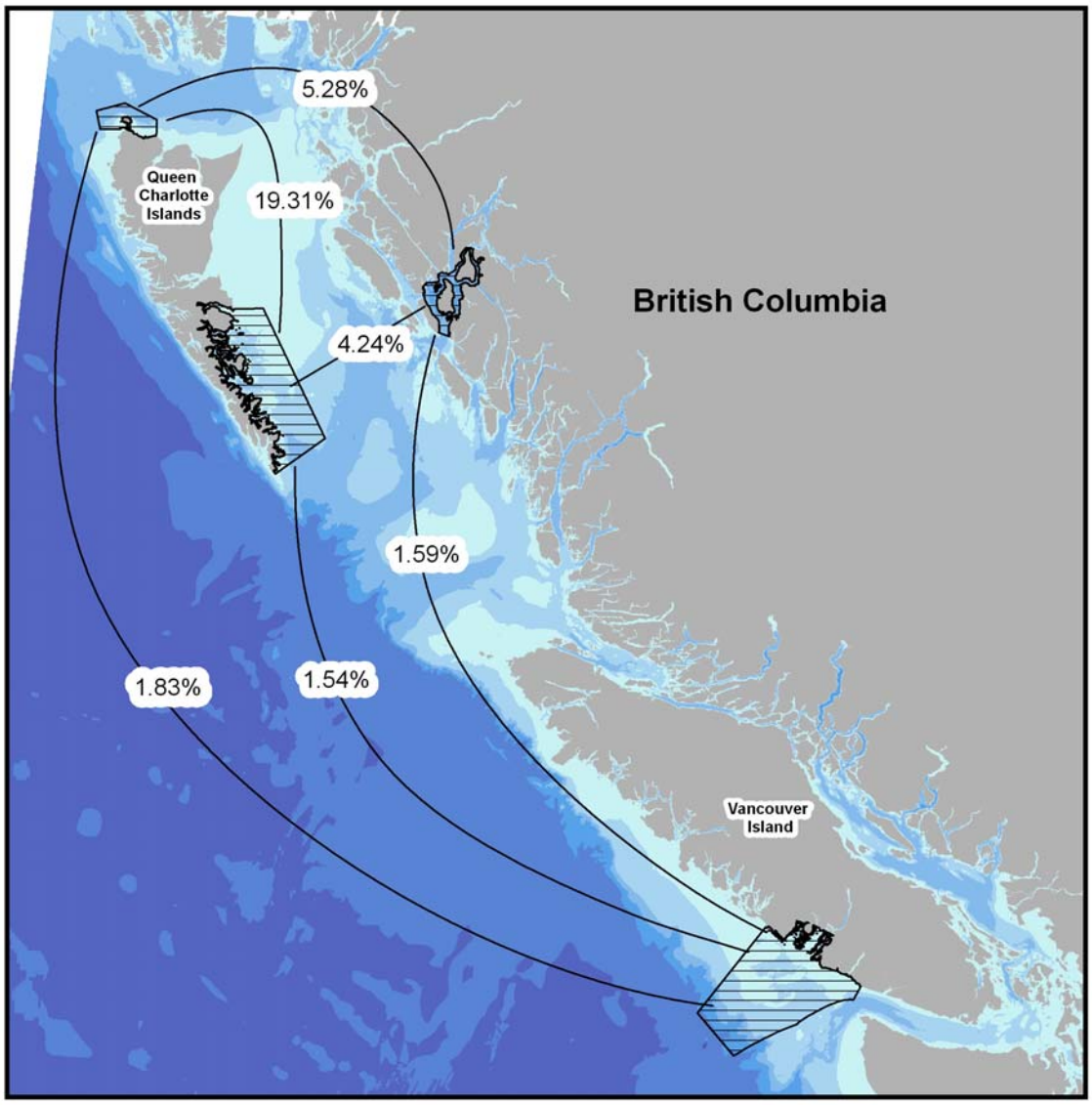

Figure 5. Percentage of inter-matches between candidate areas.

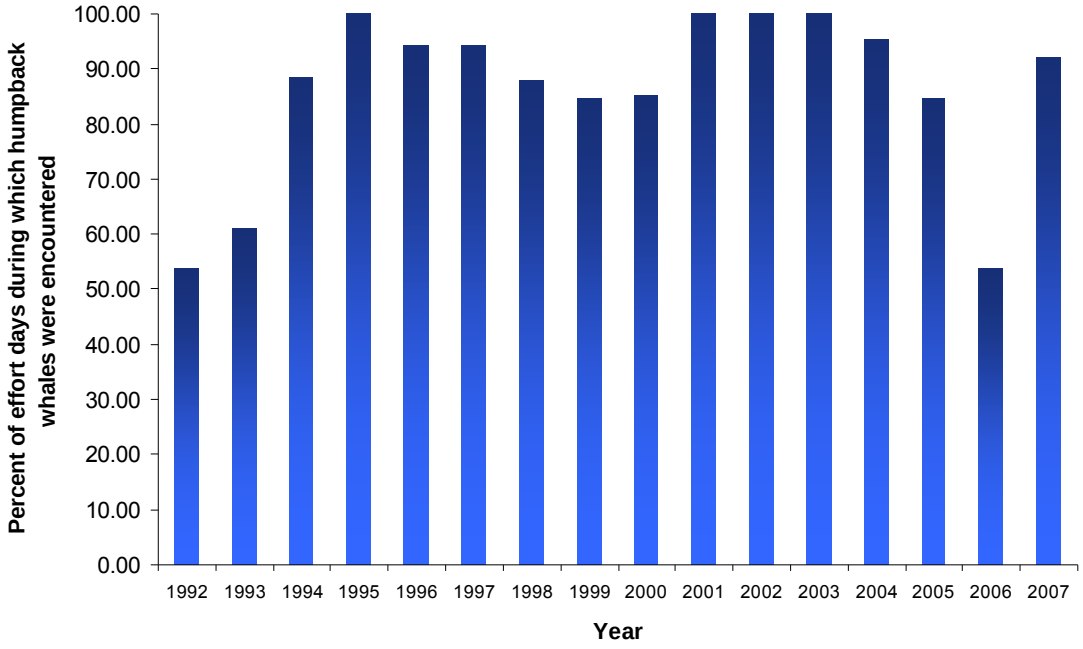

Figure 6. Percent of effort days during bi-annual dedicated small boat surveys in which Humpback Whales were encountered in the Langara Island area (1992-2007). There were 165.5 encounter days and 193.5 effort days. Average annual encounter/effort days (%) is 85.95, SE = 3.96, n = 16 years.

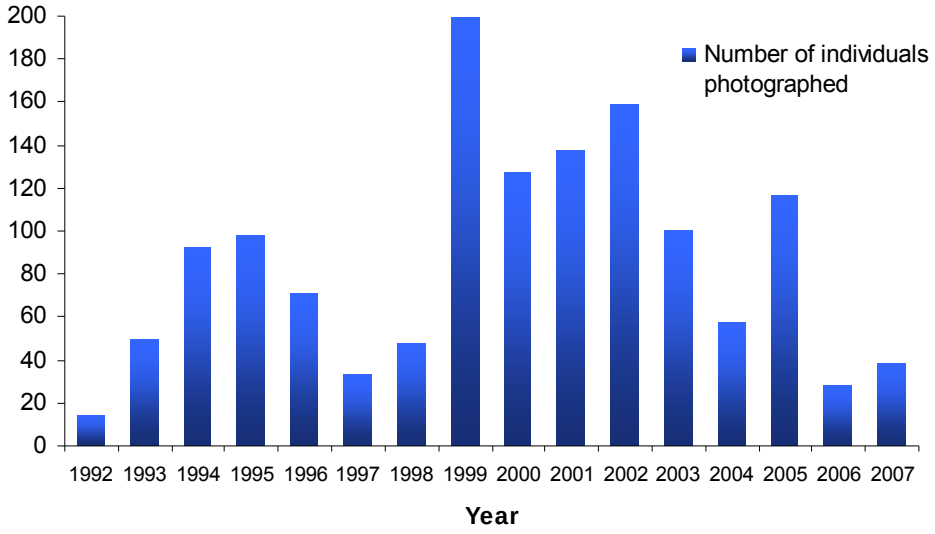

Figure 7. Number of individuals photographed in the Langara Island area each year, 1992 to 2007.

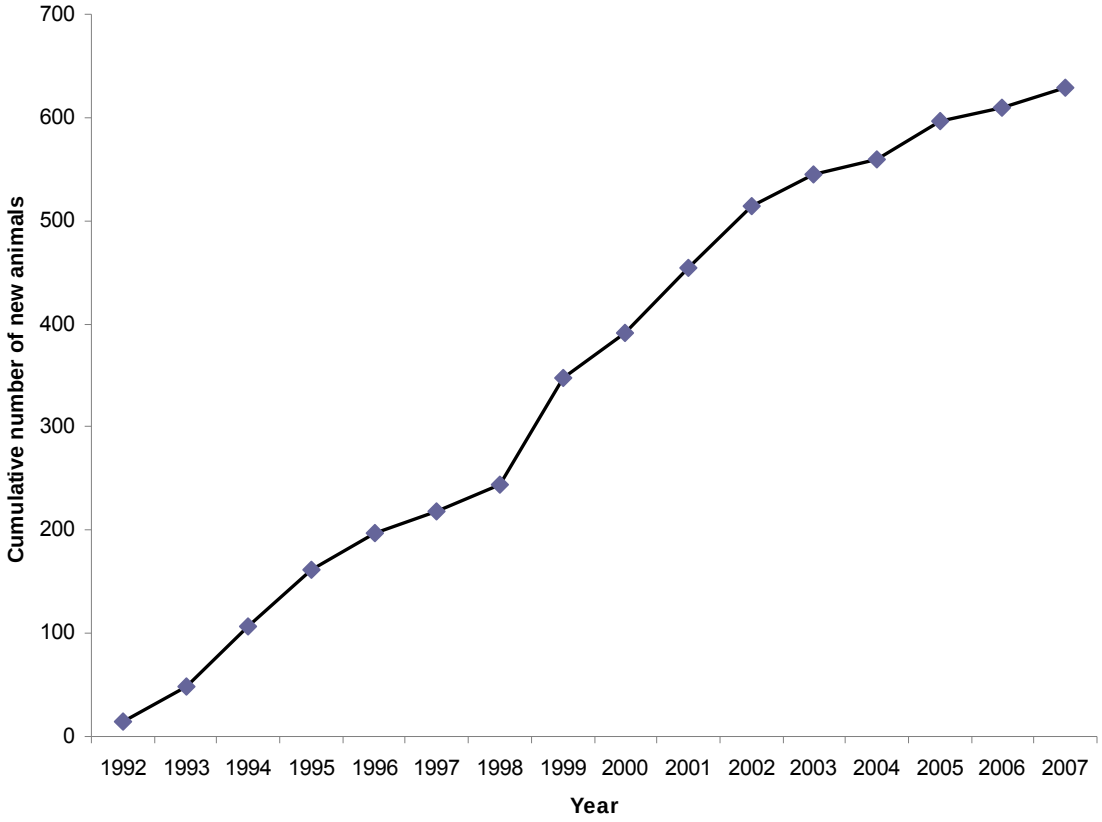

Figure 8. The cumulative number of new individuals photo-identified in the Langara Island area.

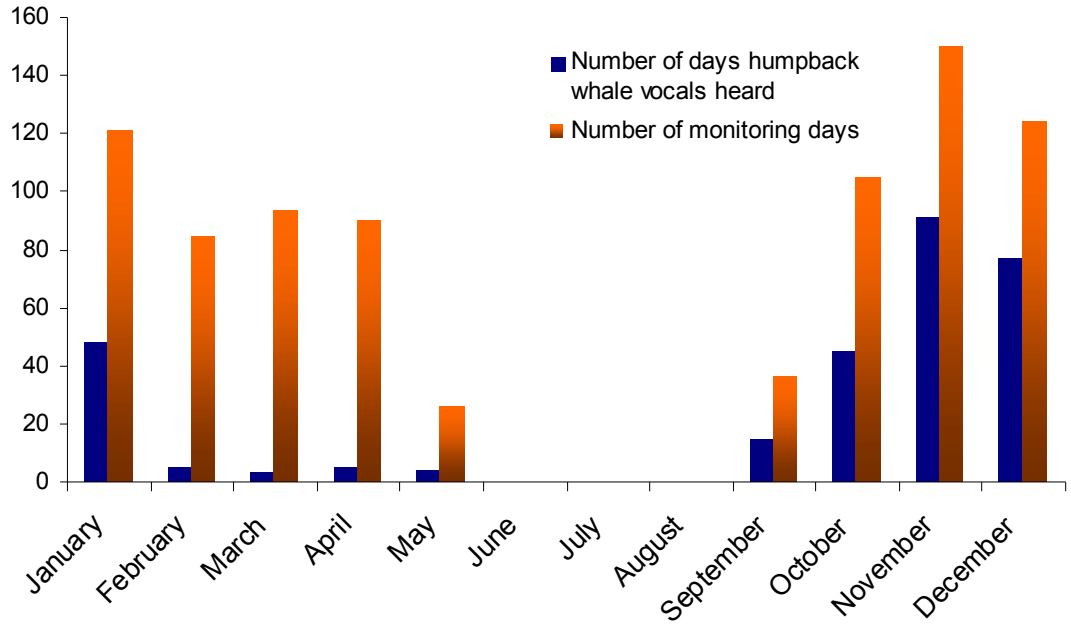

Figure 9. Number of days Humpback Whale vocalizations were heard, and the number of days of acoustic monitoring by month in the Langara Island area during 2003 -2008. Monitoring effort was not consistent among months and years: October and November where monitored annually; February through May were monitored in three years; September was monitored in two years; December and January were monitored in four years.

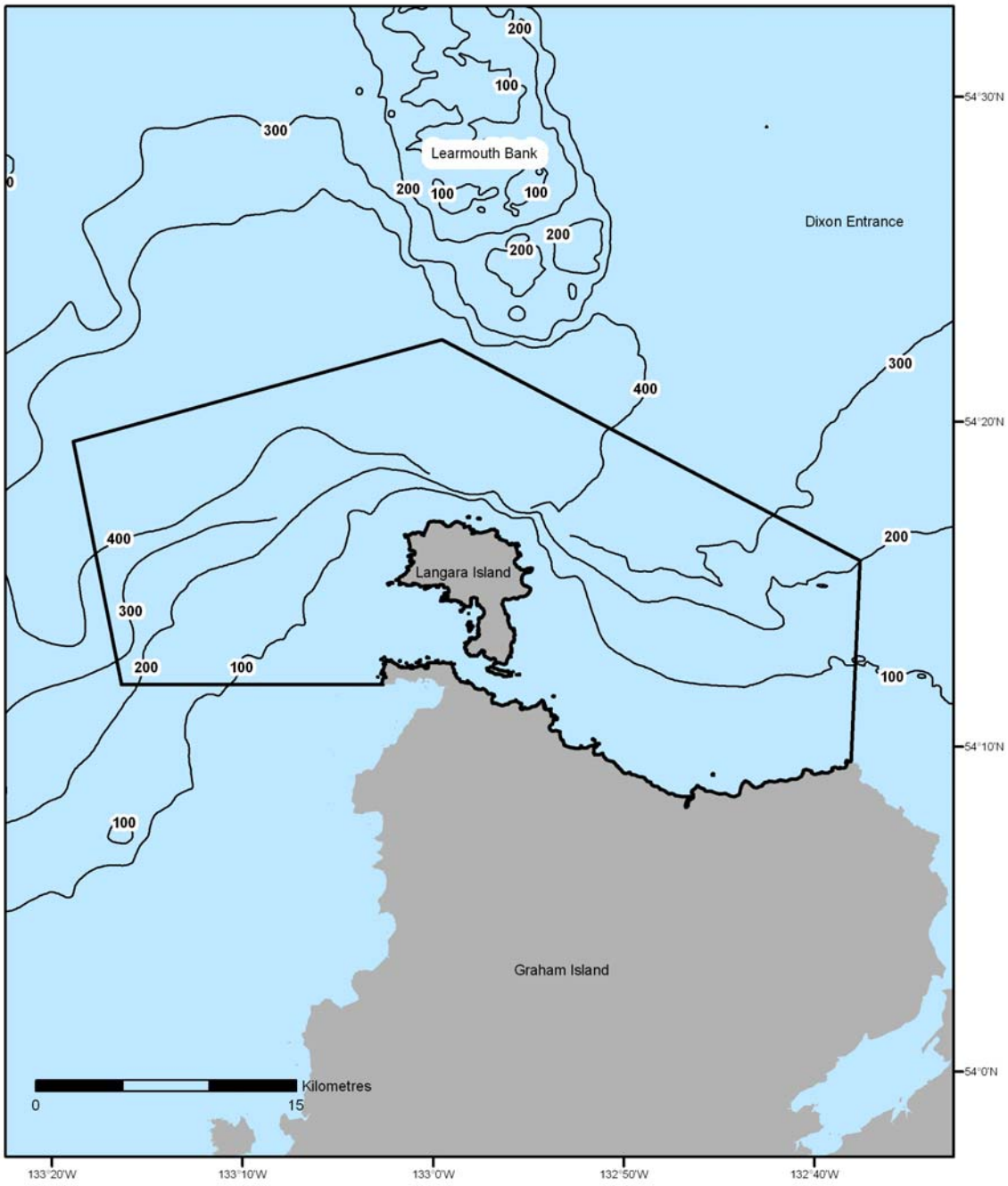

Figure 10. Bathymetry and other features in and near the Langara Island area (black-line polygon delineates area). Bathymetric contour depths are in metres. Langara Island area is 721.7 km^2.

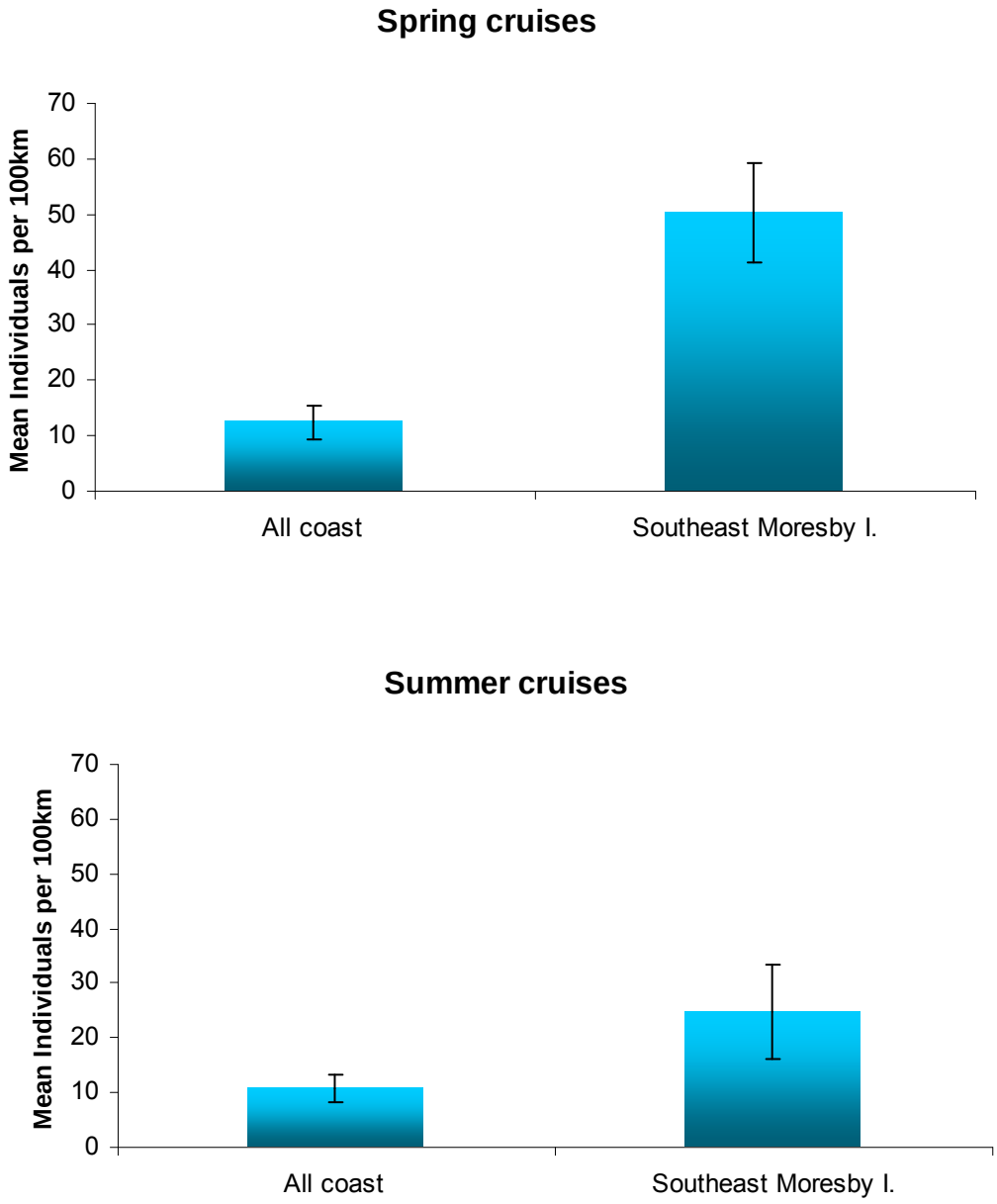

Figure 11. Mean number of individuals per 100 km on spring (n=7) and summer (n=6) cruises in the Southeast Moresby Island area and coast wide. Error bars represent plus/minus 1 standard error.

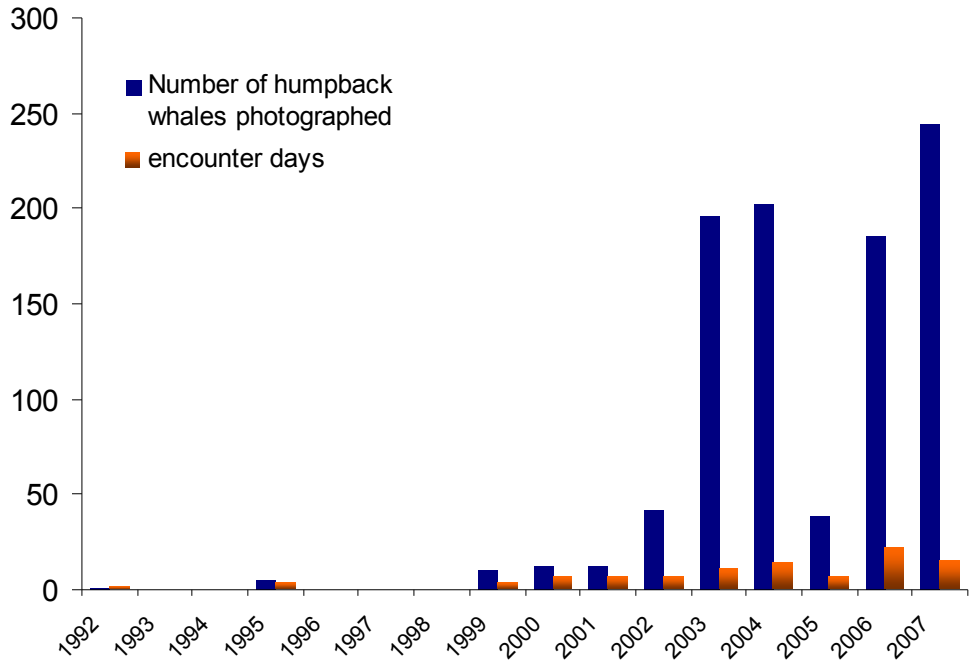

Figure 12. Number of whales photographed and the number of encounter days each year in the Southeast Moresby Island area.

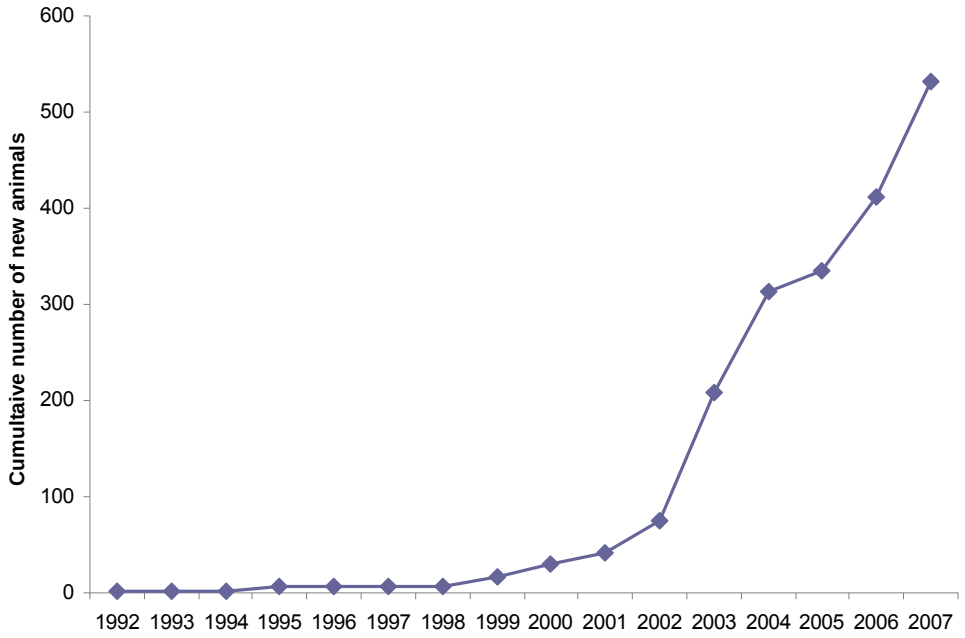

Figure 13. The cumulative number of new individuals photo-identified in the Southeast Moresby Island area.

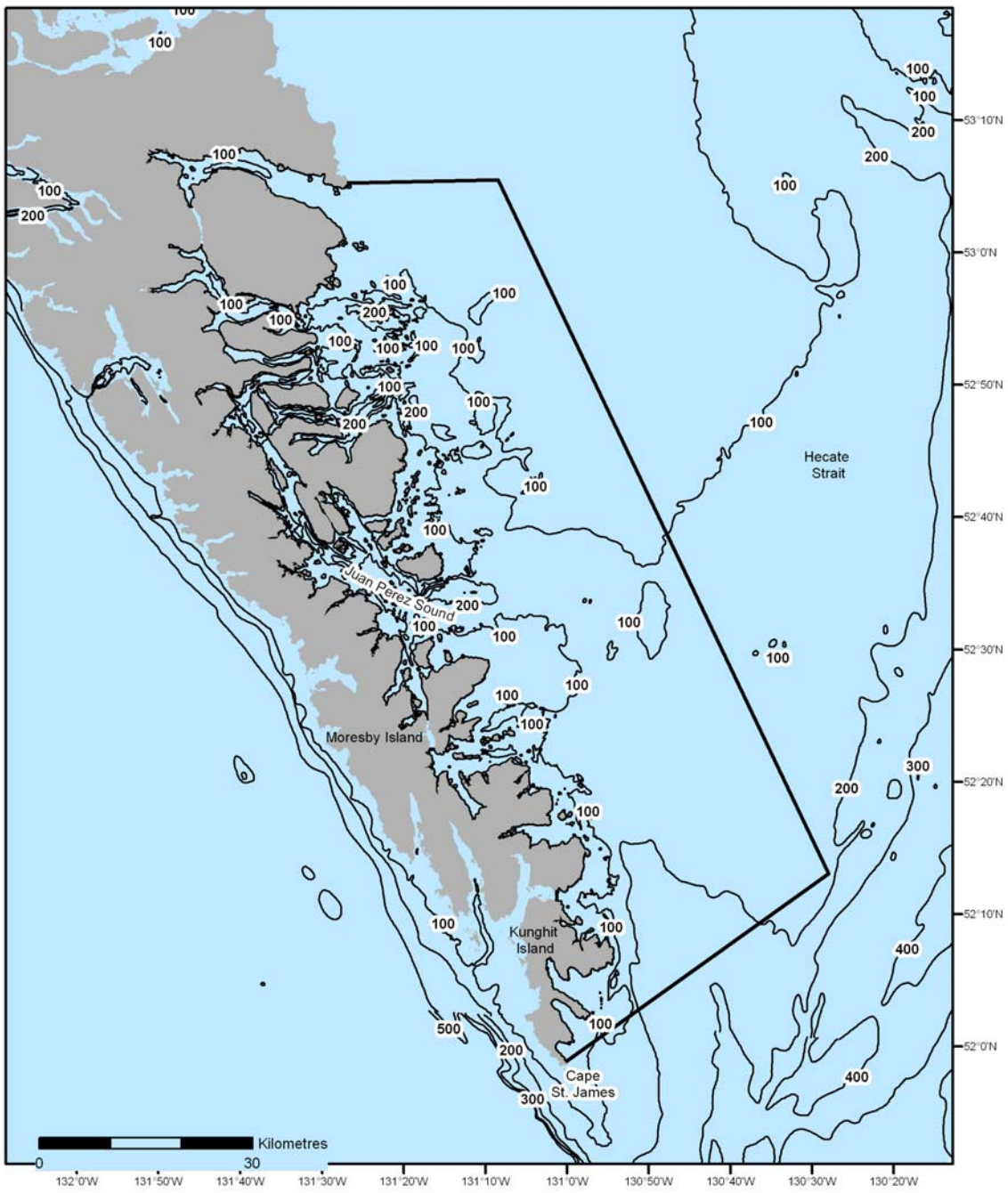

Figure 14. Bathymetry and other features in and near the Southeast Moresby Island area (black-line polygon delineates area). Bathymetric contour depths are in metres. Southeast Moresby Island area is 4,544.9 km^2.

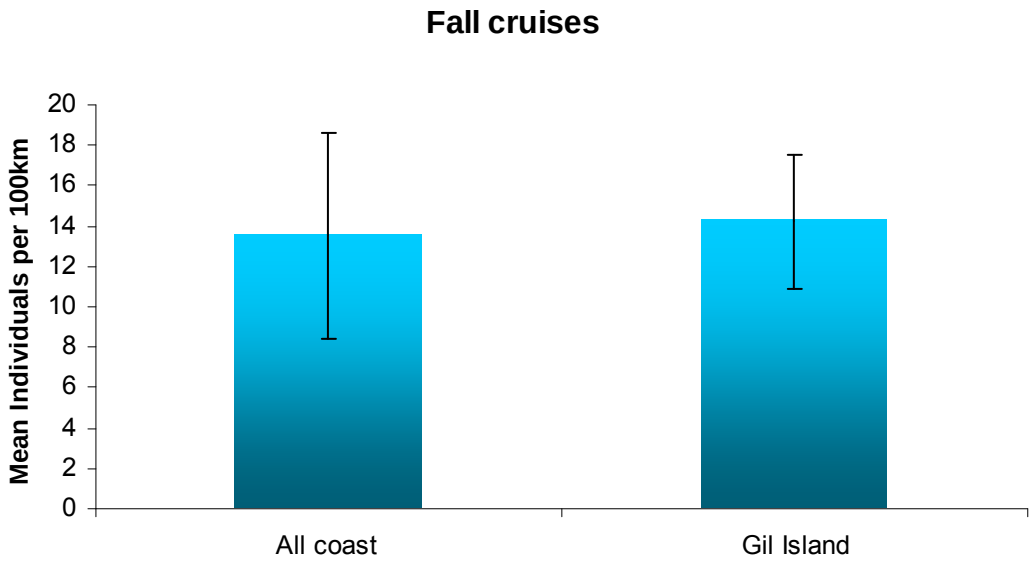

Figure 15. Mean number of individuals per 100 km sighted during fall cruises (n=4) in the Gil Island area and coast wide. Error bars represent plus/minus 1 standard error.

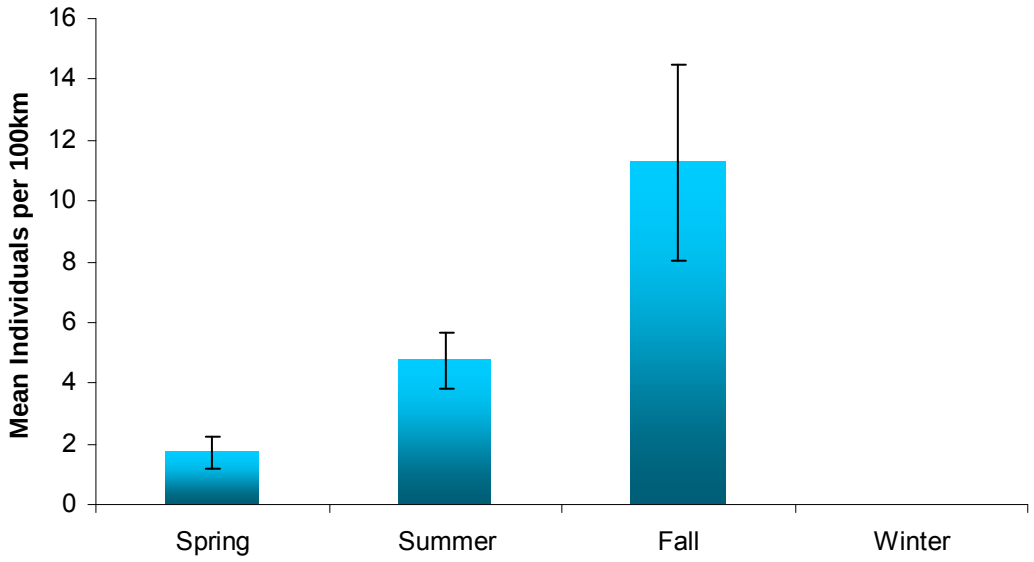

Figure 16. Mean number of individuals sighted per 100km during GLRSS small boat surveys 2005 to 2008 in the Gil Island area. Error bars represent plus/minus 1 standard error.

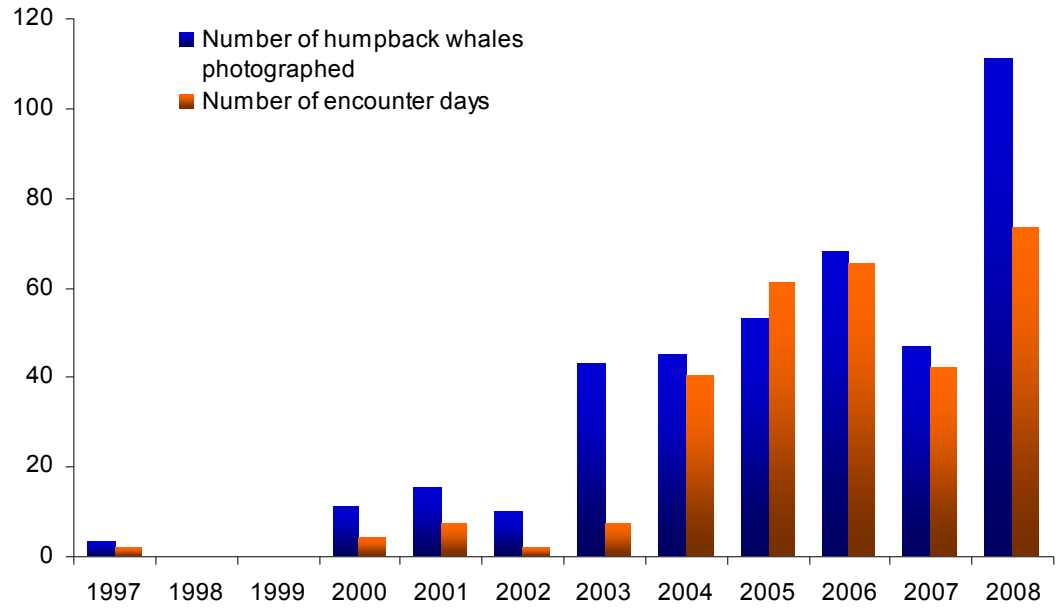

Figure 17. The number of individuals photo-identified and number of encounter days per year in the Gil Island area.

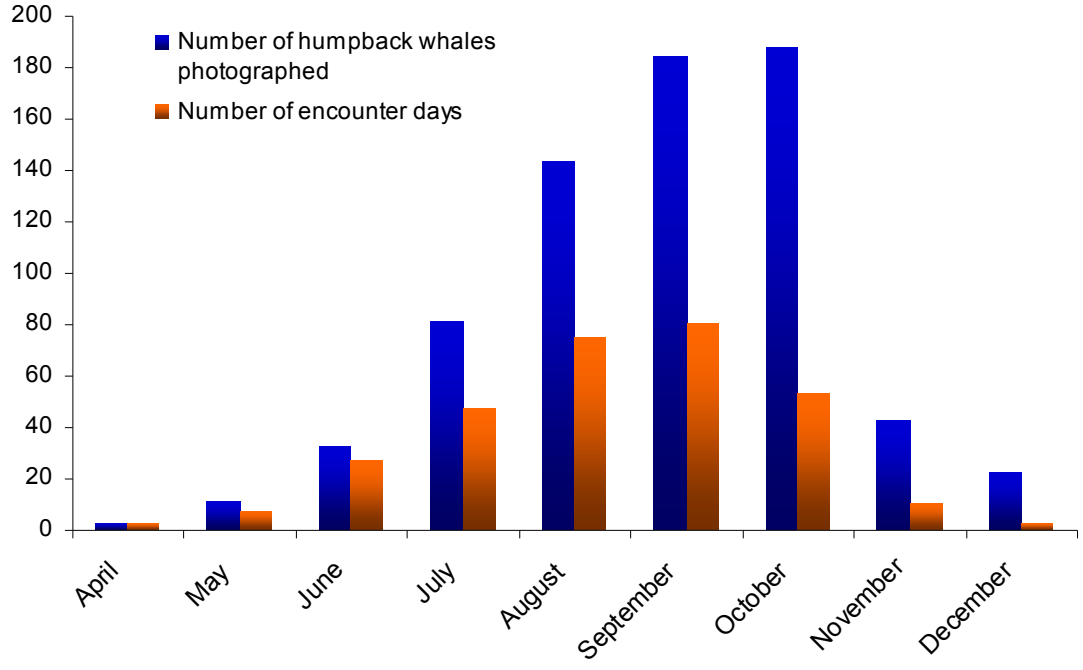

Figure 18. Number of individuals photo-identified by month and the total number of encounter days by month, 1997 to 2008 combined, in the Gil Island area.

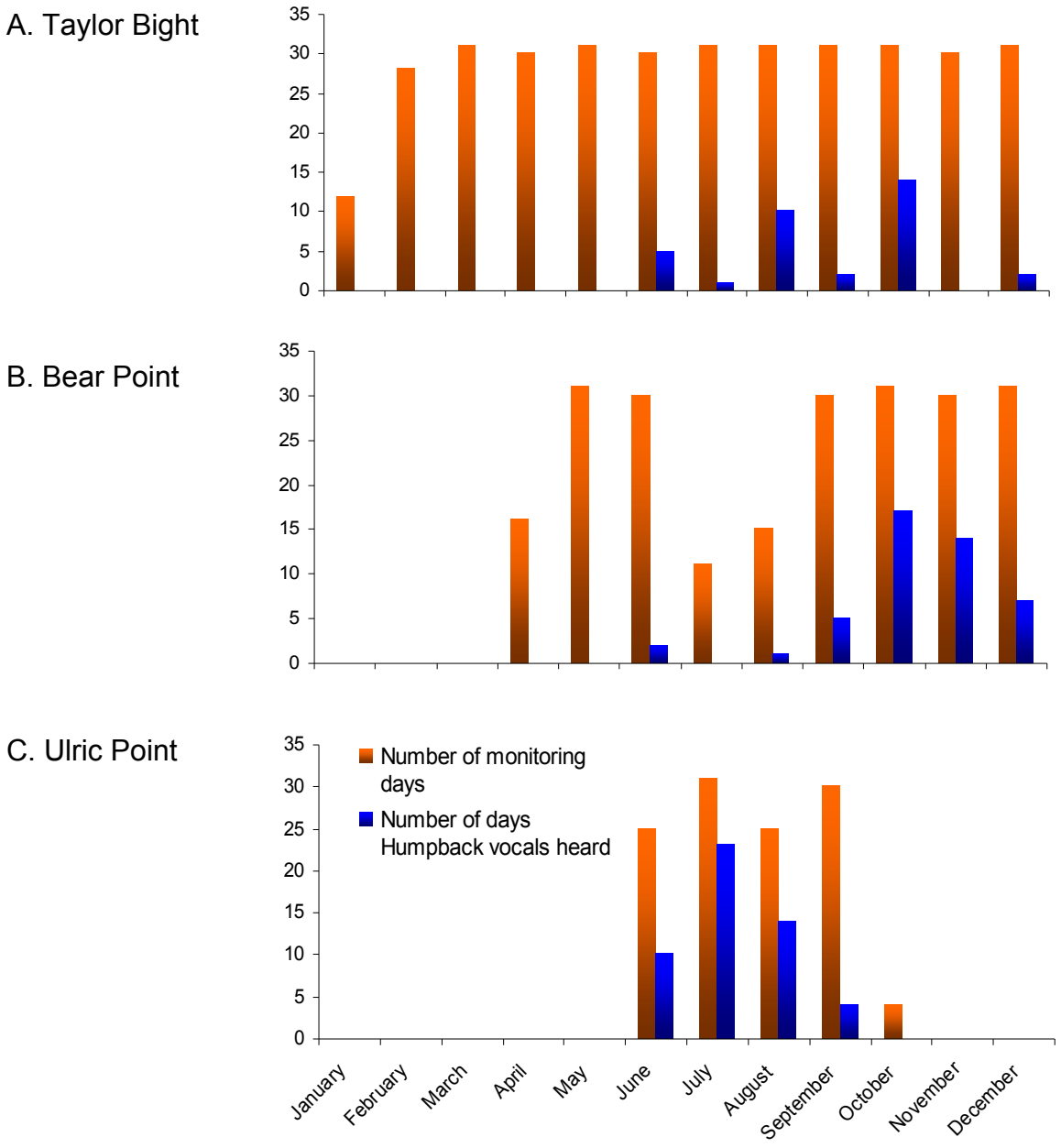

Figure 19. The number of days Humpback Whale feeding calls were heard and the number of monitoring days in 2008 at three shore-based monitoring stations. A. Taylor Bight station, which monitored Taylor Bight and a portion of Whale Channel. B. Bear Point station, which monitored additional portions of Whale Channel in the Gil Island area. C. Ulric Point station, which monitored part of Caamano Sound and Laredo Channel just south of the southern boundary of the Gil Island area.

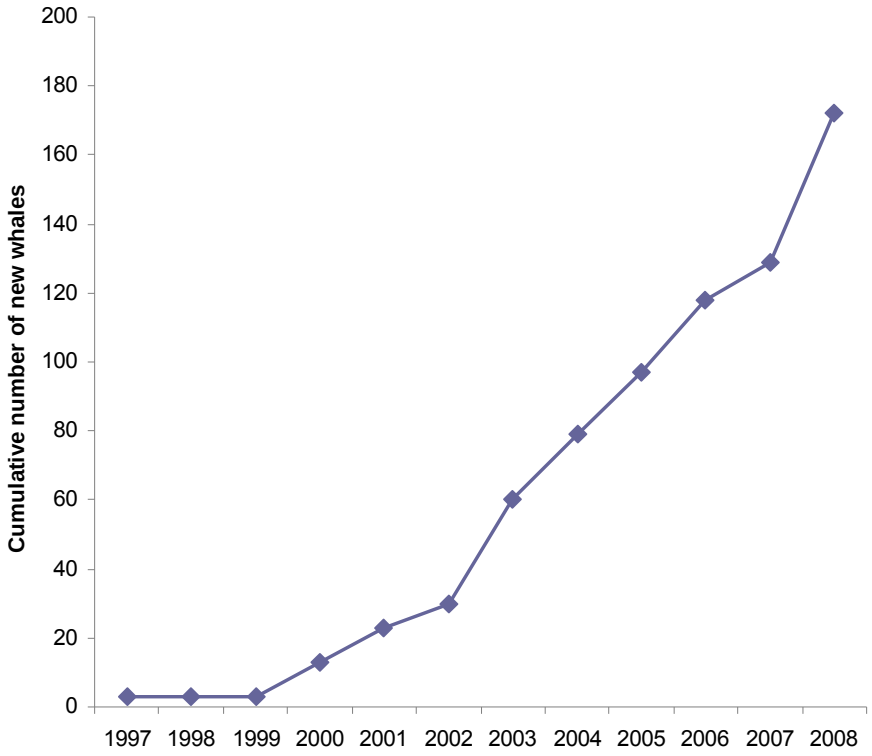

Figure 20. The cumulative number of new individuals photo-identified in the Gil Island area.

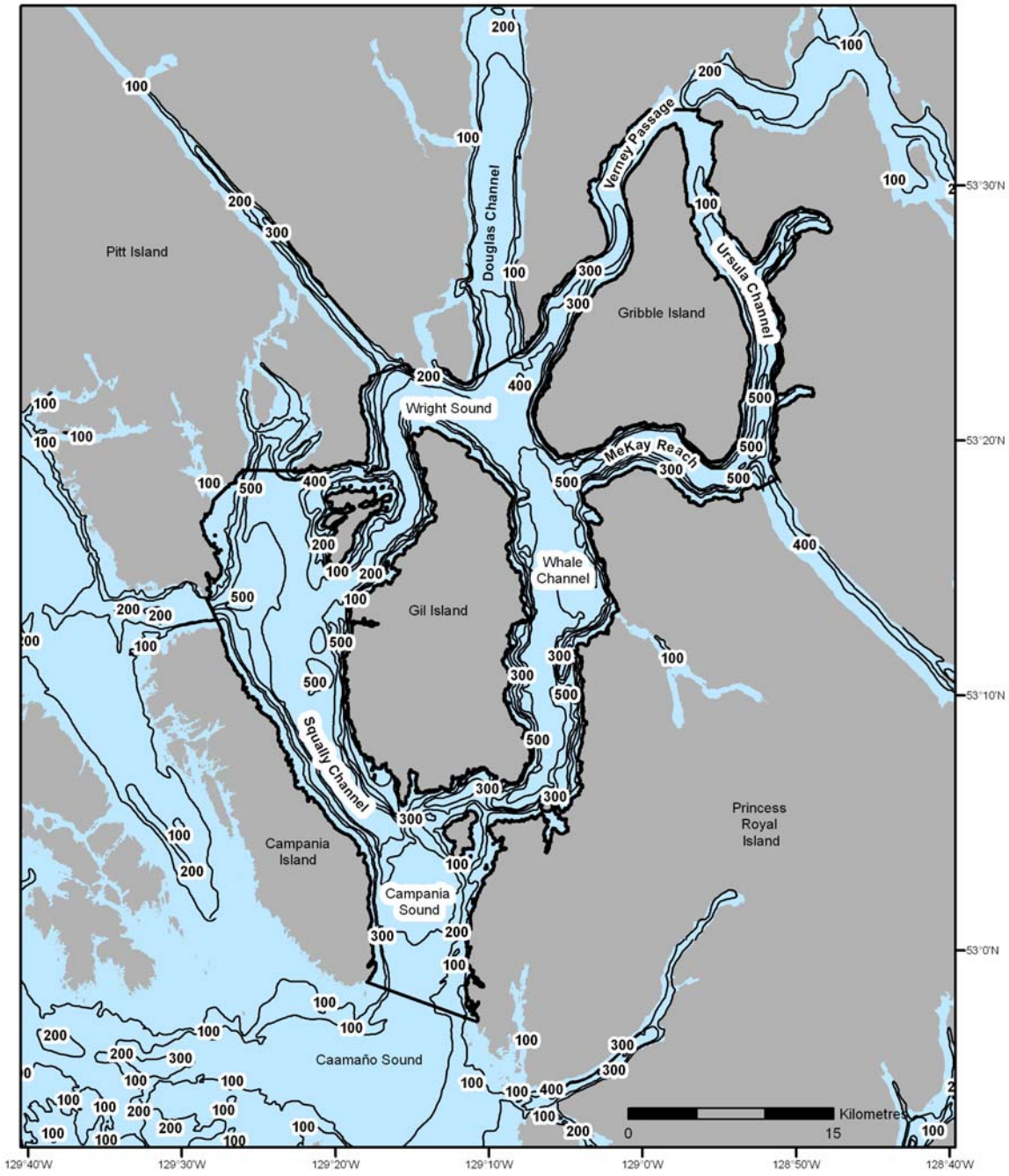

Figure 21. Bathymetry and other features in and near the Gil Island area (black-line polygon delineates area). Bathymetric contour depths are in metres. Gil Island area is 765.7 km^2.

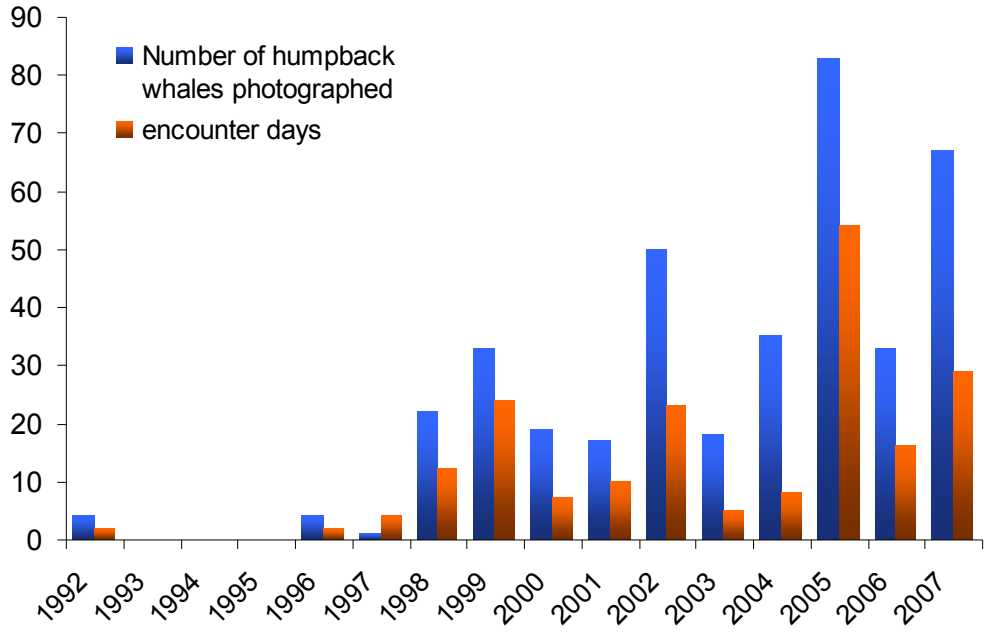

Figure 22. The number of Humpback Whales photo-identified and number of encounter days each year in the Southwest Vancouver Island area.

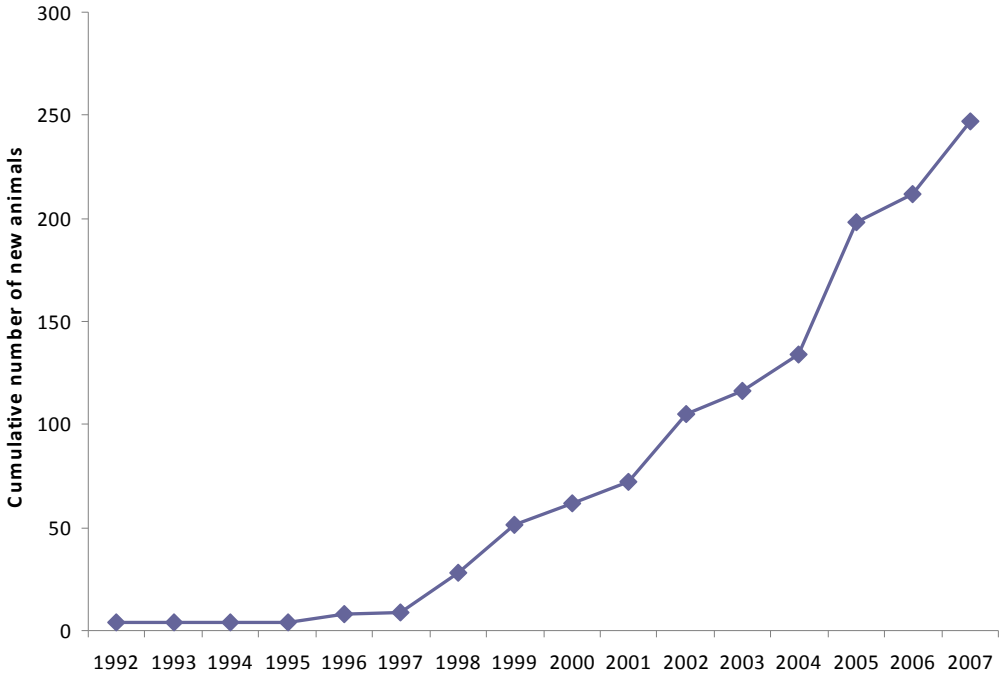

Figure 23. The cumulative number of Humpback Whales photo-identified in the Southwest Vancouver Island area.

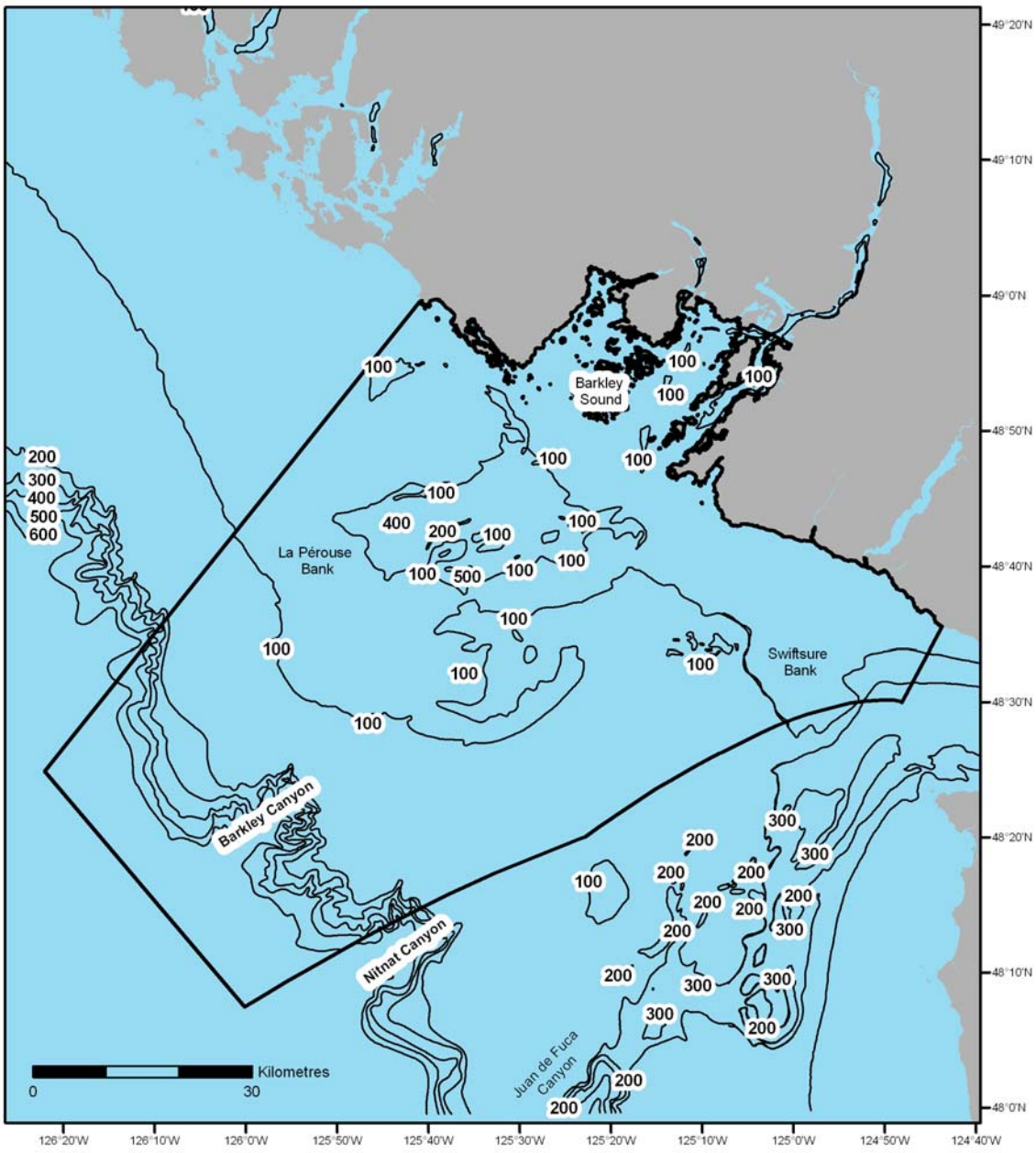

Figure 24. Bathymetry and other features in and near the Southwest Vancouver Island area (black-line polygon delineates area). Bathymetric contour depths are in metres. Southwest Vancouver Island area is 6,188.3 km^2.