NOAA Technical Memorandum NMFS-AFSC-385

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

January 2019

NOAA Technical Memorandum NMFS

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This document should be cited as follows:

Jefferson, T. A., M. E. Dahlheim, A. N. Zerbini, J. M. Waite, and A. S. Kennedy. 2019. Abundance and seasonality of Dall's porpoise (*Phocoenoides dalli*) in Southeast Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-385, 45 p.

Document available: http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-385.pdf

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Abundance and Seasonality of Dall's Porpoise (*Phocoenoides dalli*) in Southeast Alaska

T. A. Jefferson[1], M. E. Dahlheim[2*], A. N. Zerbini[2,3,4],
J. M. Waite[2], and A. S. Kennedy[2,5]

[1]Clymene Enterprises
Yerba Valley Way
Lakeside, CA 92040
email: sclymene@aol.com

[2]National Marine Fisheries Service
Alaska Fisheries Science Center
Marine Mammal Laboratory
7600 Sand Point Way N.E
Seattle, WA 98115
*retired

[3]Cascadia Research Collective
218½ 4th Ave W
Olympia, WA 98501

[4]Marine Ecology and Telemetry Research
2468 Camp McKenzie Tr. NW
Seabeck, WA 98380

[5]Joint Institute for the Study of Atmosphere and Ocean
University of Washington
3737 Brooklyn Ave NE
Seattle, WA 98105

www.afsc.noaa.gov

U.S. DEPARTMENT OF COMMERCE
Wilbur L. Ross Jr., Secretary
National Oceanic and Atmospheric Administration
RDML Timothy Gallaudet (ret.), Acting Under Secretary and Administrator
National Marine Fisheries Service
Chris Oliver, Assistant Administrator for Fisheries

January 2019

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ABSTRACT

Little is known about Dall's porpoise (*Phocoenoides dalli*) population biology in Southeast Alaska. Here we present the first abundance estimates for Dall's porpoise in the waters of Southeast Alaska. We studied the density and abundance of Dall's porpoise during 19 line-transect vessel surveys covering the major inland waters of Southeast Alaska between the months of April and September, from 1991 to 2012. Dall's porpoise was the most frequently encountered odontocete (toothed cetacean) within the study area and abundance was estimated with multiple-covariate distance sampling methods. Highest abundance was recorded in spring months (N = 5,381, CV = 25.4%), with lower numbers in summer (N = 2,680, CV = 19.6%), and lowest in fall (N = 1,637, CV = 23.3%). Peak density in spring months (31.6 porpoises/100 km^2) was the highest ever reliably recorded for inshore areas of the species' range. Estimates of abundance for comparable areas (i.e., those surveyed consistently in each study year) showed strong yearly fluctuations, and demonstrate that this species is a common inhabitant of these waters from at least spring to early fall.

CONTENTS

INTRODUCTION

Dall's porpoise (*Phocoenoides dalli*) is well known as an endemic species in the North Pacific Ocean (Houck and Jefferson 1999) and is considered one of the most common cetaceans found in Alaska waters, with a preference for both deep pelagic and inland waters, such as Prince William Sound (Hall 1981) and Southeast Alaska (Dahlheim et al. 2009). Although frequently seen throughout temperate waters in the North Pacific, they are notably absent in the high-Arctic waters of the Beaufort Sea, shallower parts of the Gulf of Alaska, and some smaller shallow bays, channels, and passes (see Nichols 1926, Scheffer 1949, Hall 1981, Hobbs and Lerczak 1993, Lowry and Bodkin 2005, Dahlheim et al. 2009).

Because of its susceptibility to entanglement in fishing gear, in particular set gillnets and driftnets (see Jefferson and Curry 1994), management efforts by the National Marine Fisheries Service (NMFS, National Oceanic and Atmospheric Administration) have been directed at this species since the 1980s. Several range-wide estimates of Dall's porpoise abundance suggest that there are likely between 1 and 2 million individuals in the global population found throughout the North Pacific Ocean (Bouchet 1981, Kato 1983, Jones et al. 1987, Buckland et al. 1993, Friday et al. 2012, 2013, Hobbs and Lerczak 1993, Moore et al. 2002). Hobbs and Lerczak (1993) used data from NMFS observers on fishery vessels and platforms of opportunity collected between 1987 and 1991 and estimated that there were 106,000 (CV = 20%) Dall's porpoises in the Gulf of Alaska, 9,000 (CV = 91%) in the northern Bering Sea, and 302,000 (CV = 11%) in the Aleutian Islands region, yielding an overall estimate of 417,000 Dall's porpoises for Alaska waters. Unfortunately, population structure in the eastern North Pacific is not well understood, and NMFS currently recognizes a single stock in Alaska waters (Muto et al. 2018). An estimate of 83,400 Dall's porpoises (CV = 10%) is used by NMFS for the entire stock (the large reduction in abundance results from a ‘correction’ for vessel attraction), though this estimate does not include the coastal or inland waters of Southeast Alaska (Muto et al. 2018). None of these abundance estimates are based on dedicated surveys, and they are all outdated for management by NMFS.

There is very little information on abundance of Dall’s porpoise in inland waters of Southeast Alaska. Scheffer (1949) reported that this species was most abundant in Clarence Strait, Dixon Entrance, and Icy Strait. Dahlheim et al. (2009) summarized the overall seasonal distribution and occurrence of Dall’s porpoise within the inland waters of Southeast Alaska, based on 17 years of line-transect surveys. Since 1991, the Marine Mammal Laboratory (MML) has conducted annual vessel surveys for cetaceans within the inland waters of Southeast Alaska with studies primarily focused on harbor porpoises (*Phocoena phocoena*) and killer whales (*Orcinus orca*) (see Dahlheim et al. 1997, 2009, 2015; Hoelzel et al. 1998, 2002; Dahlheim and White 2010). Seasonal distribution information for all cetaceans encountered during this 17-year effort (1991 through 2007; representing 38 cruises) was presented in Dahlheim et al. (2009). During this study, Dall’s porpoises were found throughout the inland waters of Southeast Alaska, with most sightings occurring in spring (April/May), fewer animals observed during summer periods (June/July/August), and the lowest number of porpoises occurring during fall months (September/October) (Dahlheim et al. 2009). For the current study, line-transect data collected in Southeast Alaska during the years 1991-1993, 2006-2007, and 2010-2012 were used to 1) obtain estimates of Dall’s porpoise density and abundance and 2) profile seasonal trends in abundance.

MATERIALS AND METHODS

Study Area

Southeast Alaska is a complex system of rugged mountains, glaciers, and marine waterways (mostly glacially-carved fjords, channels, bays, and passes) between 55-59° N and 131-

137° W (Fig. 1). The continental shelf is narrow, with deep marine connections to the outer coast of the Gulf of Alaska. The complex geological setting results in a high diversity of marine biological habitats, heavily influenced by winds, freshwater input, and strong tidal currents (Weingartner et al. 2009).

The study area (17,666 km^2) included all major channels and bays in Southeast Alaska from Juneau to Ketchikan (i.e., Lynn Canal, Icy Strait, Glacier Bay, Cross Sound, Chatham Strait, Stephens Passage, Frederick Sound, Sumner Strait, Clarence Strait, and Dixon Entrance) (Fig. 1). When time permitted or weather precluded the surveying of major channels, many smaller bodies of water (bays, inlets, and passages) adjacent to these major inland channels were also surveyed. However, the coverage of these smaller areas varied considerably among surveys and across years.

Survey Methods (1991-1993)

A total of 19 surveys were conducted in Southeast Alaska during the study period from 1991 to 2012, between the months of April and September (Table 1). During the early 1990s (i.e., 1991-1993) surveys were carried out aboard the NOAA vessel *John N. Cobb.* The ship was 28.36 m (93 ft) long with a combined bridge and average observer height of 5.9 m. Line-transect methodology was employed following pre-determined tracklines. At the start of this study, distribution, habitat preferences, and seasonal occurrence of Dall's porpoise within the study area were unknown. Tracklines were designed throughout the study area using either a zig-zag or straight-line path, depending upon the size of the different areas. The survey was designed to include all major waterways and a selection of the smaller bays and inlets to examine both deep water and near-shore habitats throughout the entire study area. The same tracklines were used for the nine surveys throughout 1991–1993, although alterations were made during each survey, depending on weather and other unforeseen circumstances (e.g., mechanical breakdowns, rescue operations).

During line-transect surveys, sighting data were collected by three observers (1 starboard, 1 port, and 1 recorder). A full observer rotation took 2 hours, spending 40 minutes at each station. A 2-hour rest period occurred for each observer after each full-watch rotation. A complement of six biologists was required for the survey. Observer rotational schedules were randomly selected.

Port and starboard observers used 7 × 50 Fujinon binoculars to search from 0 degrees (ship's bow) to 90 degrees. Scanning techniques were standardized with nearly 32 minutes (or 80%) of the 40-minute watch spent scanning with the binoculars and about 8 minutes scanning with the naked eye. To reduce fatigue, binoculars were supported by adjustable metal poles, which were either hand-held or rested on the observer’s hips. The recorder searched for porpoises by scanning both sides of the ship from the bridge with the naked eye. Binoculars were used by the recorder to confirm sighting identifications and numbers. Sightings made by the officers, crew, and off-watch observers were recorded as "off-effort" and were not used to estimate density.

A GPS unit was connected directly to a portable computer on the bridge. The date, time, and position of the ship were automatically entered into a data file every 10 minutes and whenever data were entered by the recorder. Search effort was recorded on the computer by marking the beginning and end of each transect. The Beaufort sea state, weather description (rain and fog), visibility index, and observer positions (port, recorder, and starboard) were also entered. A new entry was made whenever a course, weather, or personnel change occurred.

When a sighting was made, the recorder entered the following data: sighting angle, number of reticles to the sighting, radar distance (nm) to the shoreline at the same angle of the sighting, species, number seen (best, high, and low counts), and direction of travel of the animal(s). The sighting angle was obtained from peloruses mounted on the port and starboard bridge. Dall’s porpoises have two main types of surfacing behavior – rooster-tailing when moving fast, and slow-rolling when moving more slowly (Fig. 2). They are more easily seen at greater distances or in higher sea states when rooster-tailing. To obtain distance to a sighting, Fujinon 7 × 50 binoculars equipped with internal reticles were used. The top reticle was placed on the horizon or shoreline and the number of reticles down to the location of the sighting was counted, to the nearest tenth of a reticle. The reticle binoculars were calibrated using the ship's radar to objects of known distance.

Survey Methods (2006, 2007, 2010-2012)

When line-transect surveys resumed in 2006, it was recognized that there was considerable variation in the density of both Dall's porpoise and harbor porpoise (*Phocoena phocoena*) that occur in Southeast Alaska, such that extrapolating one density to the whole region was not appropriate. By creating smaller regions (strata), porpoise density could be determined for these regions, allowing for an abundance estimate that incorporated the patchiness of porpoise distribution. These strata were created using bodies of water that were characterized by different geographical features (i.e., bays, inlets, deep-water narrow channels such as Icy Strait and Chatham Strait, and large areas of exposed waters such as Frederick Sound). Stratum-specific effort allocation by region was based on harbor porpoise densities derived from the 1991-1993 surveys. Regions with higher porpoise density in the early 1990s were given greater trackline effort. As in the early years, both zig-zag and straight-line tracklines were used in an effort to include as many different habitats as possible.

The NOAA vessel *John N. Cobb* was used in the 2006 and 2007 surveys but was decommissioned in 2008. Therefore, from 2010 through 2012, the following four charter vessels were used to conduct our surveys: July 2010, the FV *Steller* (21.3 m commercial fishing vessel with a combined bridge and observer height of 4.78 m); September 2010, the FV *Northwest*

Explorer (43.8 m research/fishing vessel with a combined bridge and observer height of 5.64 m); June and September 2011, the Alaska Department of Fish and Game's RV *Medeia* (33.5 m research vessel with a combined bridge height and observer height of 7.4 m); and July 2012, the RV *Aquila* (50 m commercial fishing vessel with a combined bridge and observer height of 7.2 m).

During all line-transect surveys, a team of three researchers (1 recorder and 2 observers) were on effort. However, the total number of observers during a survey and the amount of time that a particular observer spent off effort varied throughout the years. For the 2006 and 2007 surveys, sighting data were collected by a team of four observers. A full observer rotation took 1.5 hours, with each observer spending 30 minutes at each station. In this case, the observer only had a rest period of 30 minutes between watches. To minimize fatigue, we also went off effort for meals, which provided observers with an additional rest period. In 2010, data were collected by a team of five observers. Similarly to the 2006 and 2007 surveys, a full observer rotation took 1.5 hours. A rest period of 1 hour occurred between watches. In 2011 and 2012, a team of six observers collected porpoise sighting data, spending 30 minutes at each station with a 90-minute rest period. As noted earlier, observer rotational schedules were randomly selected.

To gather positional and navigational information the data computer was either interfaced directly to the ship's GPS system (2006 and 2007) or connected to a portable GPS unit (2010-2012). The computer program *WinCruz* (R. Holland, Southwest Fisheries Science Center) was used to record all sighting and environmental data (e.g., cloud cover, wind strength, and direction, and sea conditions). All other data collection methods (i.e., scanning techniques, field equipment) were similar to those conducted in the early 1990s.

Group Size Estimation

Porpoises were considered to be in a group when animals were within several body lengths of each other. Group size has the potential to affect estimates of detection probability (P). If larger groups are easier to detect farther away from the trackline, use of average group size can bias estimates (Buckland et al. 2001). Exploratory analysis (regression of group size versus detection probability; Buckland et al. [2001]) suggested that detections were independent of group size. Therefore, stratum-specific simple means were used after truncation to estimate the expected group size for analysis conducted using Conventional Distance Sampling (CDS) models. For Multiple Covariate Distance Sampling (MCDS) models, estimates of the expected group sizes were obtained as proposed by Marques and Buckland (2003, Equation 16 on p. 928).

Analysis for Corrected Distances

In the inland waters of Southeast Alaska, there was often land behind a sighting rather than the horizon. In these cases, an observer positioned the top reticle on the shoreline and determined the reticle reading from that distance. During the 1991-1993 surveys, observers also recorded a distance to shore obtained from the ship's radar at the angle of the sighting. Sighting distances could then be calculated using the reticle reading and the distance to shore. For the 2006-2012 surveys, *Wincruz* was adopted for data collection. When calculating distance from the vessel to the animal *WinCruz* used the assumption that the reticle given by the observer was taken from the horizon. But for sightings where the observer used the shoreline as the "horizon", the distance to the sighting needed to be recalculated. Sightings were recorded in *WinCruz* as the position of the observer (vessel) at the time of a sighting. All sightings were plotted in ArcMap and a line representing the distance to the real horizon, at the correct sighting angle, was drawn. The horizon line was truncated wherever it crossed land. The length of this new line, representing the distance from the observer to the shore at the angle of the sighting, was then converted to “reticles to land” using *DistRet* (Geofunc[1]), which accounted for the corresponding observer height and radians per reticle for 7 × 50 binoculars. “Reticles to land” was added to the original observer reticle to calculate the actual reticle reading of the animal from the vessel. Final distance from the observer to the animal was then calculated from this new reticle value using the *DistRet* function.

Detection Probability Estimation

Often, when sighting data collection is consistent across years and/or strata in visual line-transect surveys, perpendicular distance data are pooled to obtain a single detection function for the whole study period/area, which is then used to compute year- or season-specific abundance estimates (e.g., Hammond et al. 2002, Barlow 2006, Zerbini et al. 2006). In the present analysis, this approach was adopted and detection probability (P) was estimated using CDS (Buckland et al. 2001) and MCDS (Marques and Buckland 2003). MCDS methods differ from CDS in that they allow for the inclusion of environmental covariates in the estimation of detection probability (Innes et al. 2002, Marques and Buckland 2003).

Perpendicular distance was grouped into eight bins of 250 m (implying truncation of the data at 2 km). Half normal and hazard rate functions were used to model perpendicular distance data. Four categorical covariates and one continuous covariate were proposed to investigate their effects on the estimation of P (Table 2).

The Beaufort category had two levels: a “low” sea state (Beaufort 0-2) and a “high” sea state (Beaufort >3). In addition, a “ship” covariate was proposed for the period 2010-2012 to assess

[1] Geofunc (http://www.afsc.noaa.gov/nmml/software/excelgeo.php) is a Microsoft Excel© Add-in file that performs trigonometric calculations for plane and spherical geometry pertinent to marine mammal survey sighting methods. The appropriate formulas are described in Lerczak and Hobbs (1998).

if the use of ships with different height platforms had an effect on detection probability. This covariate had four levels, one for each ship used during the summer surveys.

For each year, covariates were tested singly or in additive combination. It is expected that *P* is positively correlated with group size and platform height (ship), but negatively correlated with Beaufort sea state. If proposed models were inconsistent with these expectations, models were deleted from the analysis before model selection was performed (e.g., Zerbini et al. 2006). The model with the lowest Akaike's Information Criterion (AIC) score was used for inference (Burnham and Anderson 2002). In the estimates provided here, the probability of detecting porpoises on the trackline was assumed to be unity (i.e., $g(0) = 1$; see Discussion).

Abundance Estimation

Density and abundance of Dall's porpoise were estimated separately for each season and each year using the most-supported detection probability model in each of the six regions (strata) described in Dahlheim et al. (2015). Total abundance in the study area was computed by summing across the estimates of each individual stratum. Abundance and variance were estimated as in Innes et al. (2002) and Marques and Buckland (2003) and log-normal 95% confidence intervals were computed as proposed by Buckland et al. (2001)

RESULTS

Distribution

Sighting data provided insights on the distribution patterns of Dall's porpoise in Southeast Alaska. Patterns were broadly similar among the three seasons, with Dall's porpoise being common in most of the larger, deeper channels. Sightings were generally rare in most narrow waterways, especially those that are relatively shallow and/or with no outlets (Figs. 3-5). Some geographic regions within the study area were either not used by Dall's porpoise (i.e., Wrangell Narrows and Gastineau Channel), or were used only sporadically with very low densities (i.e., Cross Sound, Glacier Bay, Excursion Inlet, Port Frederick, and Sumner Strait). These general patterns were consistent across all three seasons assessed.

Effort, Sightings, and Group Size

Surveys covered a total of 239 days over the study period, with 27,979.6 km of survey effort completed in total, and they recorded 2,422 on-effort Dall's porpoise sightings. On some days, inclement weather prevented formal survey effort, but on such days an observer was usually stationed on the bridge to record off-effort sightings. The total amount of survey effort and number of Dall's porpoise sightings used in the analyses are presented by year and season in Table 3. Group size was generally small, usually less than five individuals, but there was some seasonal variation in average group size, with overall smaller average group sizes in summer months (mean = 2.6, s.d. = 1.84, n = 1,247) vs. spring (3.5, s.d. = 2.75, n = 923) or fall (mean = 3.3, s.d. = 2.08, n = 412) (ANOVA, t-value = -7.274, d.f. = 2,579, $p < 0.001$; Fig. 6).

Estimation of Detection Probability

Dall's porpoise sightings occurred at perpendicular distances of up to 8 km, but most sightings were within 2 km of the vessel (Fig. 7). Parameter estimates for the most-supported detection probability model, which included year, season and Beaufort category as covariates, are presented in Table 4, and the resulting detection function is illustrated in Figure 8. This model received significantly more support than the second-best model, given the delta AIC difference between them was 7.78. The average detection probability (P) was estimated at 0.37 (CV = 3%).

Estimates of Abundance

Yearly and seasonal estimates of abundance ranged from a low of 819 porpoises (CV = 29%) in fall 1992 to a high of 6,180 (CV = 33%) in spring 1991 (Table 5). Overall, the highest seasonal estimates were for the spring season (mean = 5,381.6, CV = 25.4%), and the lowest were in the fall (mean = 1,636.8, CV = 23.3%), with summer estimates in between (mean = 2,679.9, CV = 19.6%). Point estimates (with 95% confidence intervals) of abundance for all years and seasons are plotted in Figure 9. Average Dall's porpoise densities for the study area were 31.60 porpoises/100 km^2 for spring, 15.18 porpoises/100 km^2 for summer, and 9.85 porpoises/100 km^2 for fall. There was a general tendency toward lower abundance in the later years of the study for spring and summer estimates, but not for fall (Fig. 9).

DISCUSSION

Potential Bias in the Estimates

Dall's porpoises are known to be attracted to vessels to ride bow and stern waves, and this can cause a serious positive bias in the resulting abundance estimates. The above estimates of abundance were not corrected for vessel attraction. Turnock and Quinn (1991) found that, if left uncorrected, such estimates could in some cases be biased upwards by as much as a factor of five, and in fact the correction factor used by Turnock et al. (1995) was to divide their estimated abundance by 5.44. This issue is complicated by the observation that not all Dall's porpoise groups are vessel-attracted and there is extensive geographic variation in the proportion of groups that ride bow waves (Kasuya and Jones 1984, Jefferson[2]).

[2] Unpubl. data

Since no corrections were made in this study for Dall's porpoises being attracted to the vessel, potential upward bias from vessel attraction behavior must be considered (see Turnock and Quinn 1991, Turnock et al. 1995). In the open-ocean regions of the North Pacific Ocean, where the vast majority of the data analyzed by Turnock and Quinn (1991) were collected, a large proportion of Dall's porpoise groups approached the vessel to bowride. In offshore areas, proportions of sighted groups that approached the ship to bowride have generally been high (e.g., 53% for Monterey Bay [Jefferson 1991] and 30-100% for the northwestern North Pacific [Kasuya and Jones 1984]). This does not appear to be the case within the inland waters of Southeast Alaska. Our histograms of perpendicular sighting distances (Figs. 7, 8) do show some evidence of a moderate spike near the origin, which could often be indicative of vessel attraction (such a spike is apparent in the histogram from surveys of the offshore Bering Sea shelf by Friday et al. 2013: Fig. 8d on p. 251). Indeed, vessel attraction has been observed in Southeast Alaska, and thus we cannot discount vessel attraction as a possible factor leading to some overestimation of abundance.

Based on our observations during this study, bowriding behavior of Dall's porpoise appears to be less common in the inland waters of Southeast Alaska than in oceanic waters. There is a recollection among observers that participated in many surveys over a long temporal scale that bowriding occurred more frequently in the earlier years. However, quantitative data on bowriding behavior were not collected over time so it is difficult to quantify whether temporal changes did occur. The lower rate of bowriding animals in later years appears to be consistent with studies conducted in other inland areas. Miller (1989) found that 22% of the groups encountered during studies conducted in Puget Sound (Washington State) were observed bowriding. However, this proportion may have been biased upwards by her repeated approaches of porpoise groups in order to obtain identification photos. In a more appropriate comparison, Williams and Thomas (2007) reported that only 1.8% of Dall's porpoise groups in the inland waters of British Columbia approached the bow wave of their survey vessels (20-21 m in length, similar to the size of our vessels).

Another potential factor related to this is that the sighting conditions are frequently very poor in oceanic areas of the North Pacific (i.e., high Beaufort sea states and degraded visibility due to fog and mist). As a result, many Dall's porpoise groups may not be seen until they were already responding to the vessel, racing to the bow. In the relatively calm, protected inland waters of Southeast Alaska, conditions are typically much better, enhancing the opportunity for detecting porpoises prior to any vessel response. If bowriding behavior did indeed vary over time, then it could potentially affect our estimates, but for the reasons listed here, we do not think it is likely that bias from vessel attraction was a major factor in this study.

Potential downward bias from missed groups on and near the trackline may be an issue. Dall's porpoises are capable of relatively deep diving and although no diving data are available from the study area, studies from other inland areas indicated that these animals can stay submerged for periods of up to 4-7 minutes (Jefferson 1987, Miller 1988). When slow rolling, they are relatively cryptic and like all other phocoenids, they occur mostly in small groups. Thus, it is possible that a significant fraction of trackline groups may have been missed in the present survey. Most previous studies using vessel survey data to estimate abundance of Dall's porpoise have assumed that *g(0)* equals 1.0 (e.g., Miyashita and Kasuya 1988; Miyashita 1991; Hobbs and Lerczak 1993; Keple 2002; Moore et al. 2002; Calambokidis et al. 2004; Williams and Thomas 2007; Friday et al. 2012, 2013). For surveys along the west coast of North America, line-transect estimates have been corrected for missed trackline groups and the estimated value of *g(0)* used was 0.822 (Forney 2007, Barlow 2010). If the present study, which used broadly similar methods as those described in Forney (2007) and Barlow (2010), is indeed biased due to missed trackline groups, this suggests that the bias may be relatively low (0.822 translates to a 22% downward bias in the resulting density and abundance estimates). However, those studies used 25× binoculars, which may affect *g(0)* calculations, because with large binoculars a much broader area can be effectively surveyed.

There are several additional factors that could have caused bias in the resulting estimates. Slow-rolling Dall's porpoises may have been misidentified as harbor porpoises in some cases, and if so this could have caused a downward bias in the estimates. However, we emphasized the importance of accurate species identification and worked with observers to minimize this factor, and so we do not believe that it had a significant effect on the final estimates provided. Finally, hybrid porpoises (Dall's × harbor porpoise – see Willis et al. 2004) were not identified in this study, and while they may exist in the area, our data suggest that they are not common there.

The estimates provided here represent the first attempt to determine density, abundance, and population trends for Dall's porpoise in Southeast Alaska. They provide the average numbers of Dall's porpoises that typically inhabit the main waterways in the inland waters of Southeast Alaska. All of the large waterways were included in the survey and although smaller bays and passages were not part of the formal study area for the Dall's porpoise analysis, a selection of these were surveyed for the harbor porpoise study, especially in the early 1990s survey years (Dahlheim et al. 2015). In most of these areas, Dall's porpoises were not sighted (Tenakee Inlet (1991, 1992, and 1993), Peril Strait (1991, 1992, and 1993), Endicott Arm (1991, 2007, and 2011) Port Snettisham (1991), Keku Strait (1991 and 1993), Lisianski Inlet (1993), Duncan Canal (2007), and Taku Inlet (2006)). Dall's porpoise groups were sighted in several other areas (Cordova Bay (2011), Behm Canal (1991, 1992, and 1993), Seymour Canal (1993 and 2012), Eastern Passage/Bradfield Canal (1991, 1992, and 2011), and Port Houghton (1991)). Therefore, the exclusion of these latter areas from our analysis may result in a very slight underestimation of our total abundance for Southeast Alaska.

Comparison to Other Areas

Our average, seasonal density estimates for Southeast Alaska are consistent with information derived from other inland areas, in particular the waters of the northeastern North Pacific (see Appendix B). Reported densities for Dall's porpoise from the literature range up to 39.3 and 45.9 animals/100 km^2 (Hall 1979, 1981; Stewart et al. 1987), however, these high estimates are not considered reliable, as they are based on very small datasets or suffer from analysis problems. If we only consider reliably obtained estimates from inland waters, the range of reported densities is 0.6-21.8 animals/100 km^2 (see Appendix B). Our spring Southeast Alaska estimate from this study (D = 31.6 porpoises/100 km^2) is higher than any previously reported, which suggests that Southeast Alaska contains relatively high densities of Dall's porpoises, at least in spring (and to a lesser extent, summer) months.

The three seasonal estimates presented here show a clear pattern, with highest densities in spring, lowest in fall, with summer in between the two. Unfortunately there was no survey effort during the winter period in the study area; however, there are reports of Dall's porpoise sightings made during this season (Dahlheim[3]). In the only inland area where full seasonal estimates of Dall's porpoise density are available, (i.e., the Strait of Georgia in southern British Columbia), a similar seasonal pattern was found (Keple 2002). Keple's (2002) winter estimate was similar to, but slightly lower than, her spring estimate. Further study would be required to investigate this issue for our study area; however, due to inclement weather, marine mammal surveys in Alaska are challenging in winter months.

Conclusions and Recommendations

Our estimates provide a useful baseline against which to evaluate potential future

[3] Unpubl. data

abundance changes. Dall's porpoise in Alaska is not considered a strategic stock by NMFS and currently there are no major conservation issues known for this region. Dall's porpoises are known to be incidentally taken in some net fisheries that occur in the inland waters. Estimated mortality from the Southeast Alaska salmon drift gillnet fishery was 18 Dall's porpoises in 2012, but zero in 2013 (Muto et al. 2018). Even if Southeast Alaska is found to contain a distinct population of Dall's porpoise (which seems unlikely to us), these removals would likely not result in population-level impacts. If any management issues do arise, our estimates may be useful in assessing potential impacts.

When planning future studies, explicit data on the response of Dall's porpoises to the survey vessel at the time of sighting should be collected so that a quantitative evaluation of this issue can be made, and these data can be used as a covariate in the analysis. More important, however, may be the potential bias caused by missed groups on and near the trackline, which can cause a negative bias in resulting line-transect estimates. This issue can be addressed by conducting dedicated experiments designed to collect data for modeling of *g(0)*, the trackline detection probability, thereby allowing more accurate estimates of Dall's porpoise density and abundance.

ACKNOWLEDGMENTS

Our appreciation is extended to the various captains and crew of the NOAA vessel *John N. Cobb* FV *Steller*, FV *Northwest Explorer*, RV *Medeia*, and the RV *Aquila.* We thank our observers for their many hours of survey effort: Robyn Angliss, David Bain, Jason Baker, Stacey Buckelew, Jack Cesarone, Pierre Dawson, Robin DeLeuw, Dave Ellifrit, Candice Emmons, Danielle Frechette, Camille Goebel, Kim Goetz, Brad Hanson, the late John Heyning, Rod Hobbs, Juliana Houghton, Jerry Joyce, Tom Kieckefer, Kari Koski, Jeff Laake, Tom Loughlin, Beth Matthews, Dena Matkin, Mandy Merklein, R.V. Miller, Julie Mocklin, Paula Olson, Steve Osmek, Dave Potter, Rolf Ream, Bruce Robson, Brenda Rone, Richard Rowlett, Alisa Schulman-Janiger, Luciana Santos, Christy Sims, Kate Stafford, Jack Swenson, Jim Thomason, Rod Towell, Bill Walker, Daniel Webster, Paula White, and Anne York. We thank H. Braham, D. DeMaster, S. Moore, P. Wade, and P. Clapham for their unwavering support of this research. This manuscript was improved by comments from P. Clapham and two anonymous reviewers.

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Table 1. -- Line-transect surveys for Dall's porpoise in Southeast Alaska (1991-2012).

Year	Season	Survey Dates	#Days Surveyed	Methodology(# observers)
1991	Spring	20 April - 3 May	14	Line Transect (6)
	Summer	15 - 25 July	11	Line Transect (6)
	Fall	12 - 19 September	8	Line Transect (6)
1992	Spring	29 April - 12 May	14	Line Transect (6)
	Summer	11 - 24 June	14	Line Transect (6)
	Fall	10 - 24 September	15	Line Transect (6)
1993	Spring	30 April - 13 May	14	Line Transect (6)
	Summer	7 - 20 June	14	Line Transect (6)
	Autumn	23 Sep. - 3 Oct.	11	Line Transect (6)
2006	Spring	1 - 11 May	11	Line Transect (4)
	Summer	7 - 17 July	11	Line Transect (4)
2007	Spring	19 - 28 April	10	Line Transect (4)
	Summer	7 - 17 July	11	Line Transect (4)
	Fall	10 - 20 September	11	Line Transect (4)
2010	Summer	19 July - 1 August	14	Line Transect (5)
	Fall	9 - 22 September	14	Line Transect (5)
2011	Summer	1 - 14 June	14	Line Transect (6)
	Fall	25 Aug. - 7 Sept.	14	Line Transect (6)
2012	Summer	7 - 20 July	14	Line Transect (6)
		Total = 19 Cruises	**239**	

Table 2. -- Covariates selected to model detection probability of Dall's porpoise in Southeast Alaska.

Covariate	Covariate type	Observations
Year	Categorical	Survey years corresponded to each of eight levels (1991-1993, 2006, 2007, 2010-2012).
Season	Categorical	Survey seasons corresponded to each of three levels (spring, summer and fall).
Ship	Categorical	Each survey ship corresponded to one of five levels. Used as proxys for different platform heights.
Beaufort Category	Categorical	Two levels : " low" (Beaufort states 0-2), " high" (Beaufort sea state 3-5).
Group size	Continuous	Assumes a linear relationship between group size and detection probability.

Table 3. -- Amount of survey effort, number of sightings (#Stgs), average group size (E[s]), % area covered (%AC), and encounter rate (ER) of Dall's porpoise in Southeast Alaska, by year and season. CV is coefficient of variation.

Year	**Season**	**Effort (km)**	**#Stgs**	**E(s)**	**CV**	**%AC**	**ER**	**CV**
1991	Spring	1,572.8	148	3.8	0.09	35.6	0.094	0.18
	Summer	1,440.0	132	2.5	0.05	32.6	0.092	0.21
	Fall	520.4	29	2.9	0.07	16.7	0.056	0.34
1992	Spring	1,663.0	212	3.3	0.09	37.7	0.127	0.19
	Summer	1,777.9	172	2.8	0.06	40.3	0.097	0.16
	Fall	1,079.6	36	3.2	0.12	30.4	0.033	0.24
1993	Spring	2,117.2	228	2.9	0.10	47.9	0.108	0.28
	Summer	2,093.6	225	3.0	0.07	47.7	0.107	0.13
	Fall	1,207.4	61	3.3	0.04	28.8	0.048	0.18
2006	Spring	1,265.5	135	4.2	0.05	28.7	0.107	0.16
	Summer	1,429.6	106	2.7	0.10	32.4	0.074	0.15
2007	Spring	1,048.0	133	3.1	0.06	29.0	0.127	0.23
	Summer	980.6	110	2.8	0.04	22.2	0.112	0.23
	Fall	1,047.4	59	3.7	0.09	23.7	0.056	0.22
2010	Summer	1,610.4	76	2.3	0.06	36.5	0.047	0.00
	Fall	1,752.6	104	3.7	0.06	39.5	0.059	0.16
2011	Summer	1,903.6	229	2.3	0.05	43.1	0.120	0.16
	Fall	1,628.0	92	2.8	0.08	36.9	0.057	0.24
2012	Summer	1,842.0	135	2.1	0.05	41.7	0.073	0.18

After truncation.

Table 4. -- Parameter estimates for the most supported detection probability model.

Parameter	**Estimate**	**SE**
Shape	0.626	0.048
Intercept	-1.031	0.141
Beaufort Category: "Low"	0.427	0.081
Season: "Spring"	-0.515	0.106
Season: "Summer"	-0.175	0.097
Year: 1992	0.281	0.111
Year: 1993	0.112	0.108
Year: 2006	0.576	0.136
Year: 2007	0.348	0.120
Year: 2010	0.596	0.155
Year: 2011	0.119	0.124
Year: 2012	0.307	0.156

Table 5. -- Estimates of Dall's porpoise density (D) and abundance (N), and associated parameters, in Southeast Alaska, by year and season. Density is presented as porpoises/ 100 km^2. LCL and UCL are lower and upper 95% confidence levels.

Year	Season	D	N	CV(N)	LCL	UCL
1991	Spring	35.0	6,180	0.33	3,123	12,231
	Summer	18.5	3,262	0.22	2,094	5,083
	Fall	8.2	1,018	0.27	573	1,811
1992	Spring	31.6	5,573	0.20	3,729	8,329
	Summer	14.3	2,519	0.19	1,705	3,720
	Fall	5.7	819	0.29	462	1,452
1993	Spring	32.6	5,755	0.31	3,116	10,629
	Summer	24.4	4,302	0.16	3,155	5,866
	Fall	14.3	2,528	0.15	1,892	3,376
2006	Spring	28.1	4,689	0.18	3,481	7,091
	Summer	9.0	1,595	0.23	1,008	2,525
2007	Spring	30.7	4,432	0.25	2,710	7,246
	Summer	17.8	3,145	0.23	2,006	4,930
	Fall	11.1	1,955	0.27	1,114	3,344
2010	Summer	6.0	1,053	0.16	764	1,451
	Autumn	9.9	1,746	0.19	1,202	2,537
2011	Summer	20.2	3,572	0.19	2,474	5,157
	Fall	9.9	1,755	0.23	1,110	2,775
2012	Summer	11.3	1,991	0.19	1,371	2,893

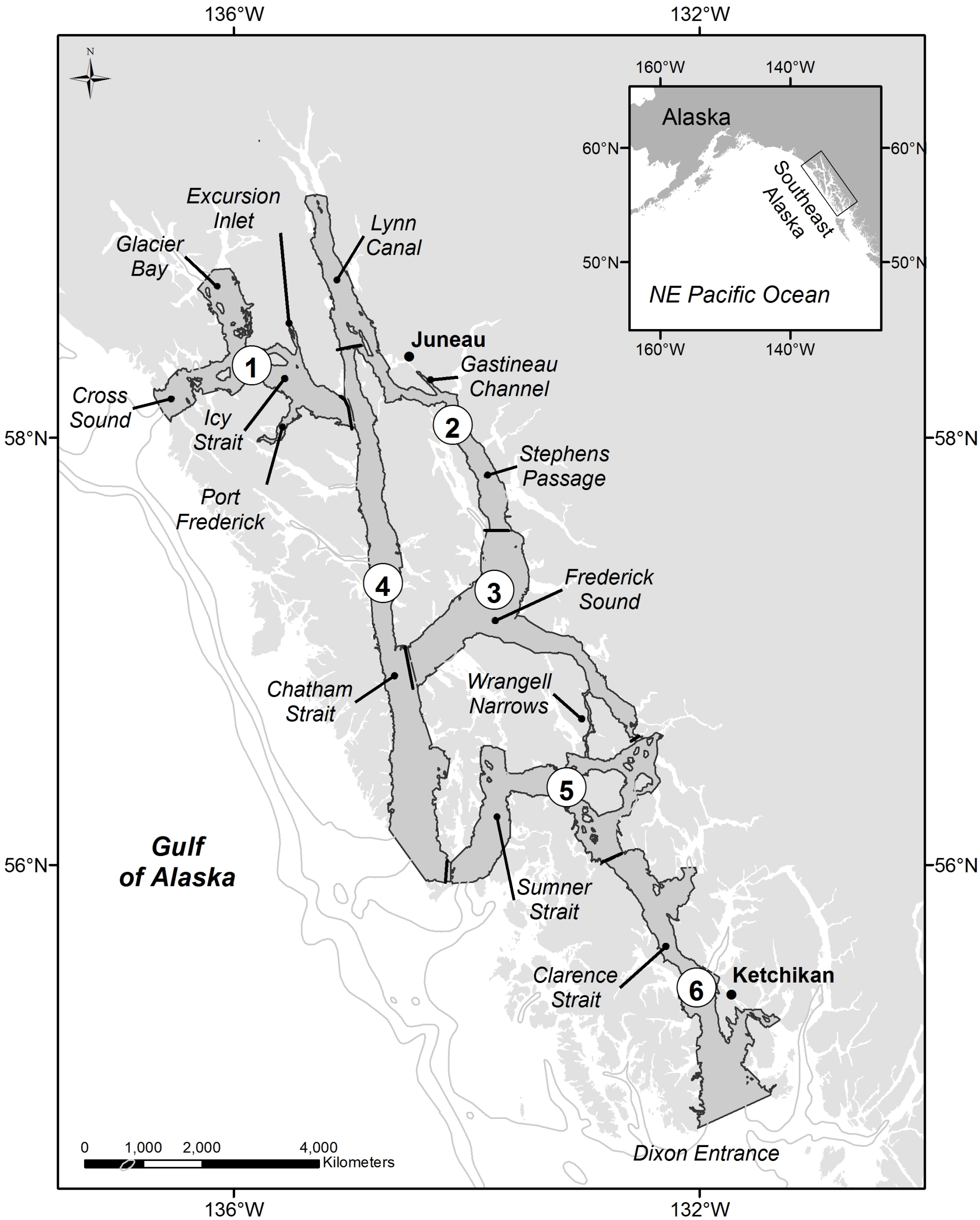

Figure 1. -- Map of the study area, showing the major bodies of water surveyed. See Appendix Table A for names of numbered regions.

Figure 2. -- Different surfacing behaviors of Dall's porpoise (which correspond to differential sightability during surveys): rooster-tailing (upper) and slow-rolling (lower).

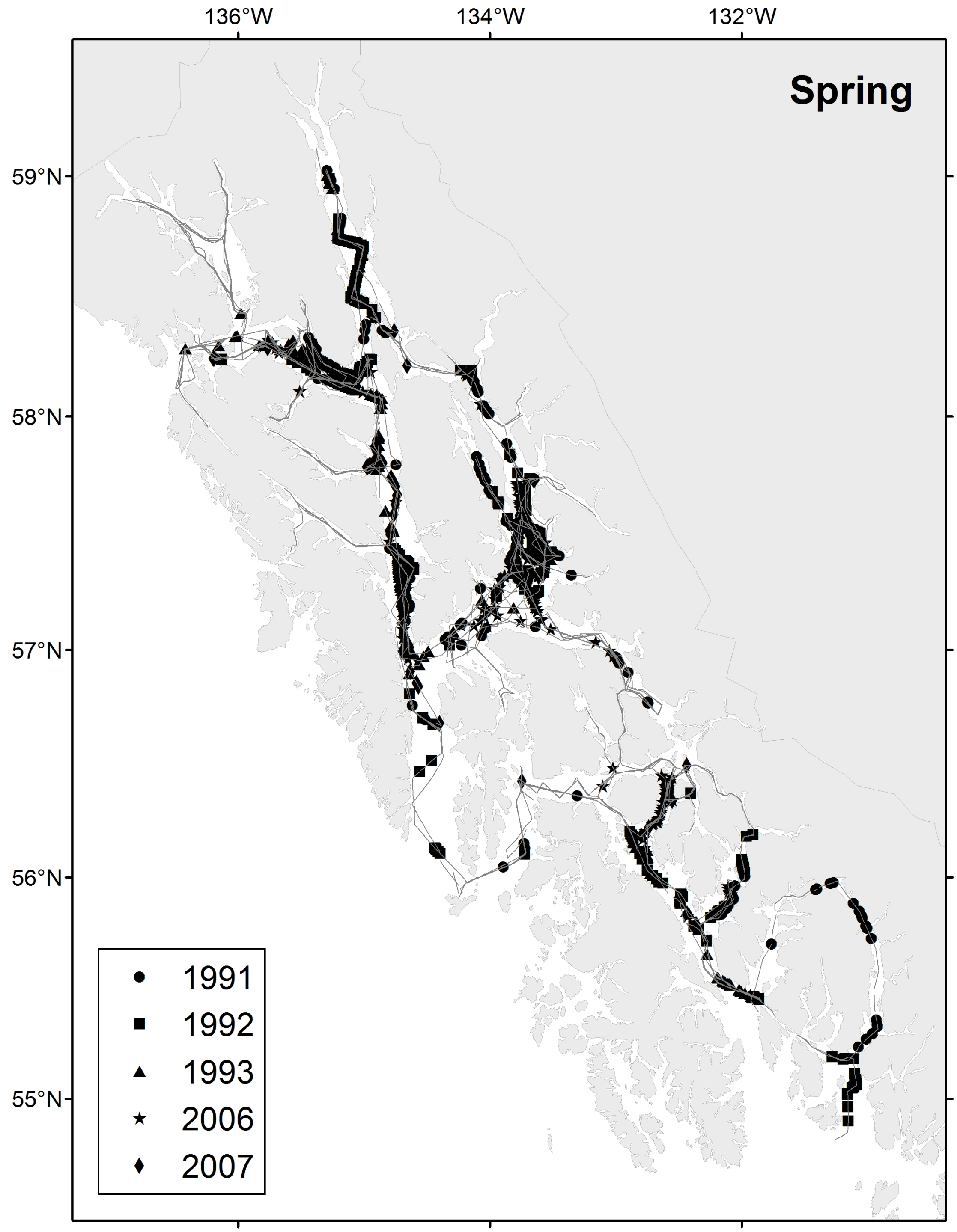

Figure 3. -- Tracklines and Dall's porpoise sightings, spring season.

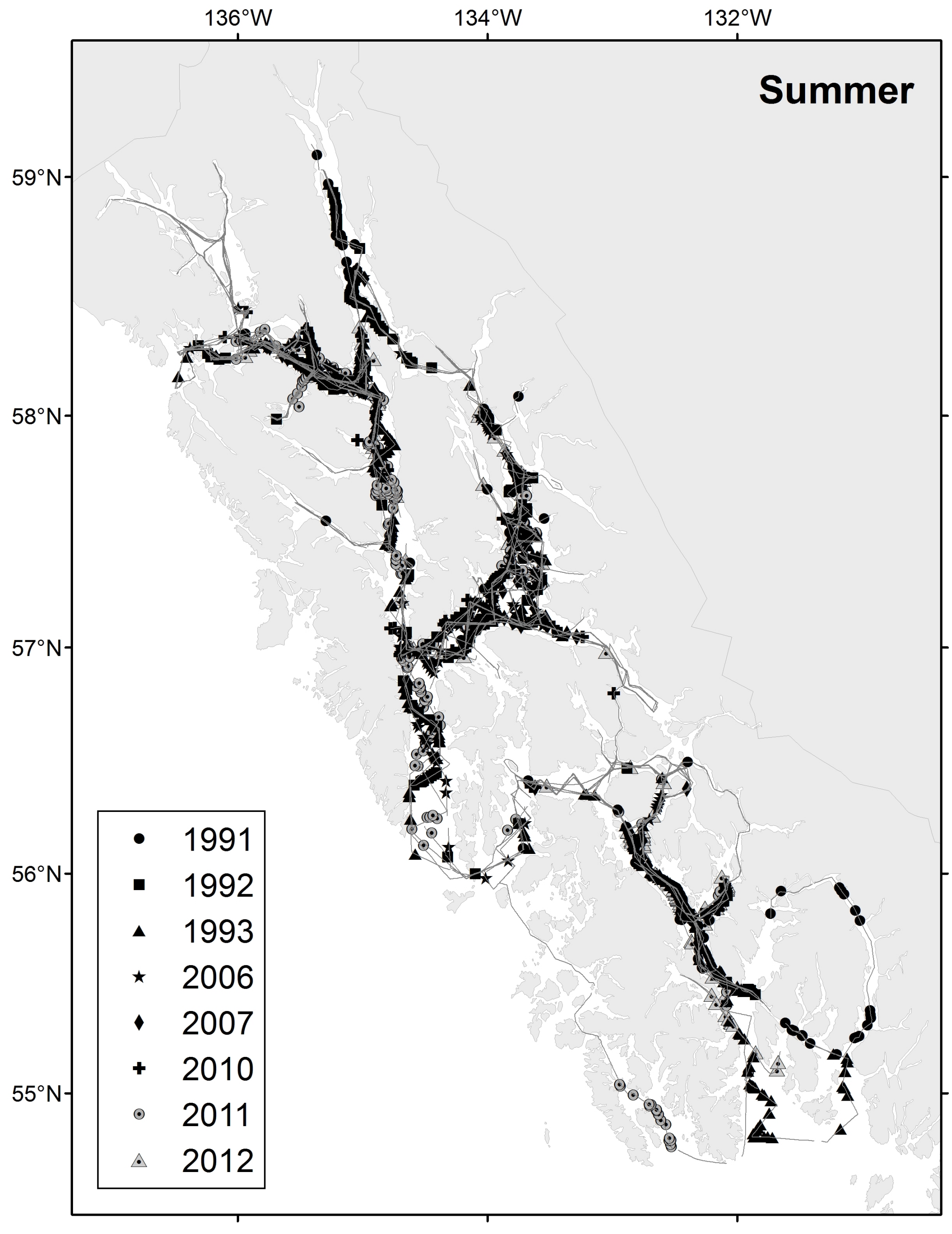

Figure 4. -- Tracklines and Dall's porpoise sightings, summer season.

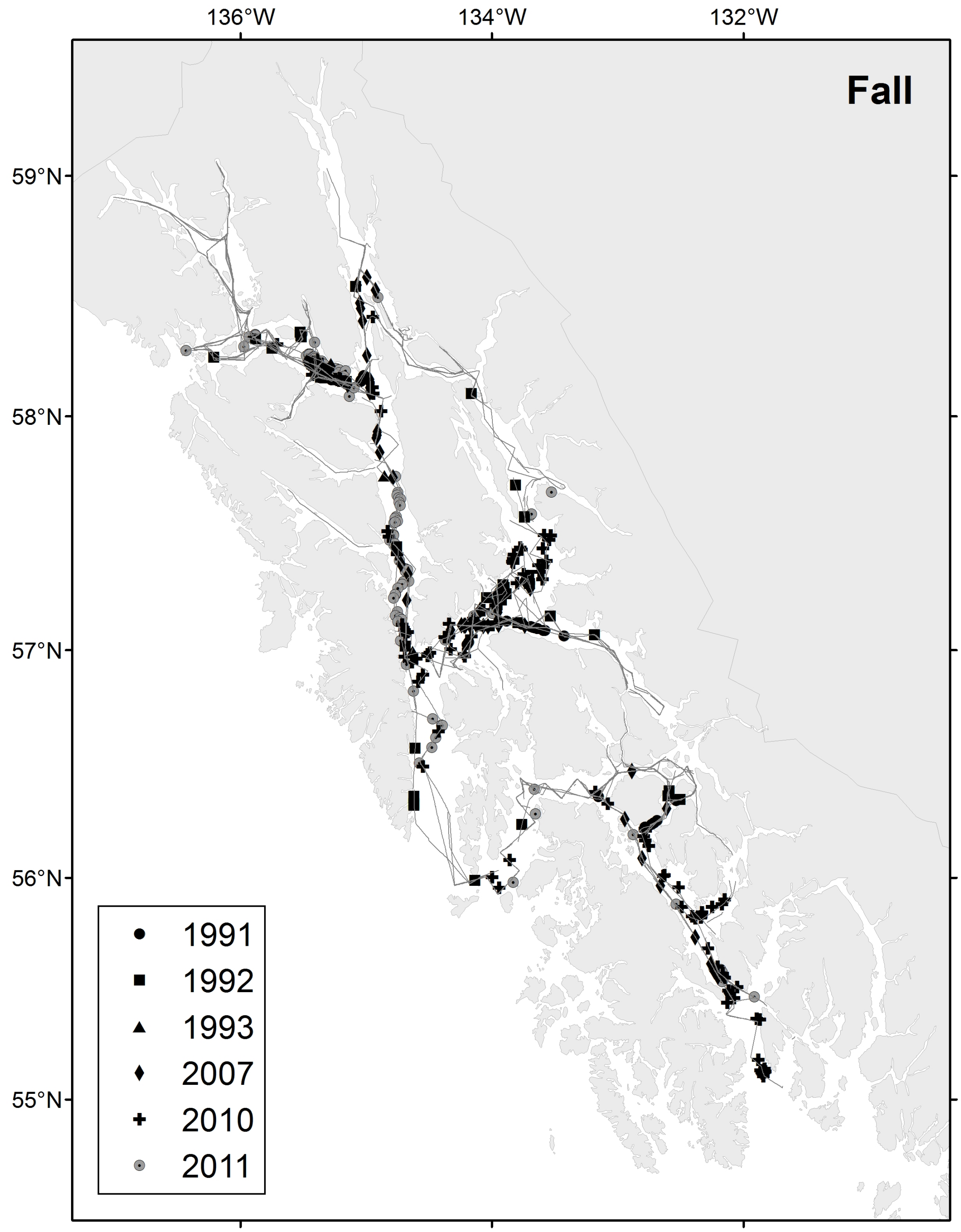

Figure 5. -- Tracklines and Dall’s porpoise sightings, fall season.

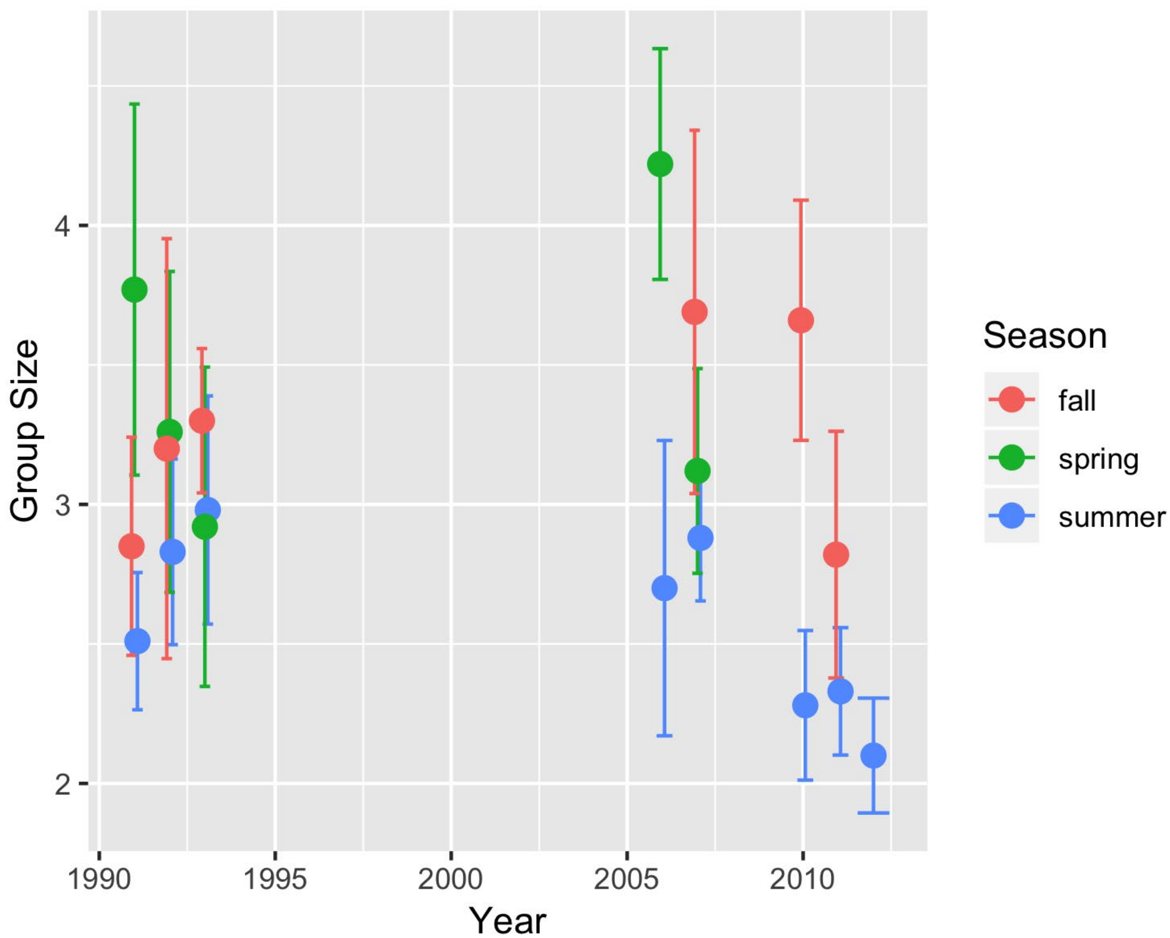

Figure 6. -- Average Dall's porpoise group size (with 95% confidence intervals), by year and season.

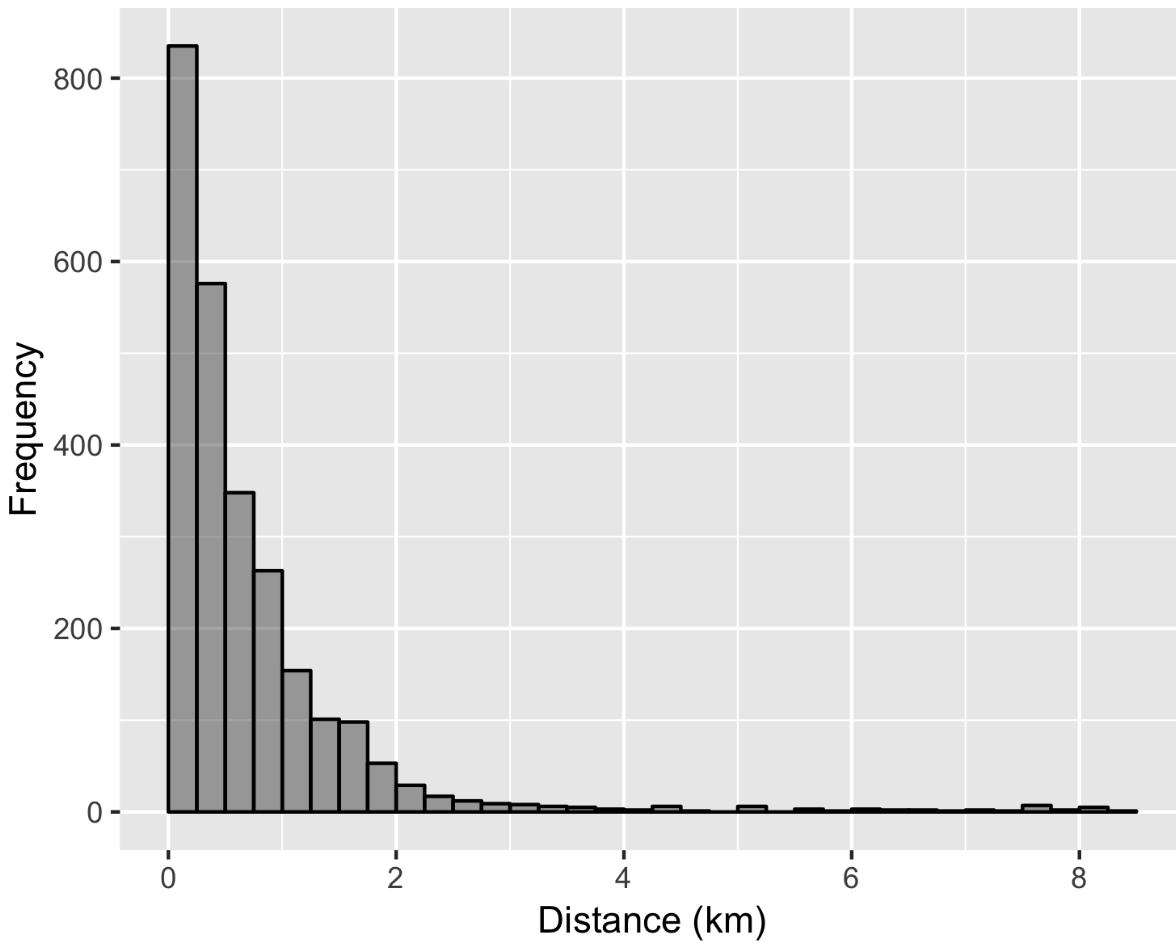

Figure 7. -- Distribution of perpendicular sighting distances for Dall's porpoise sightings.

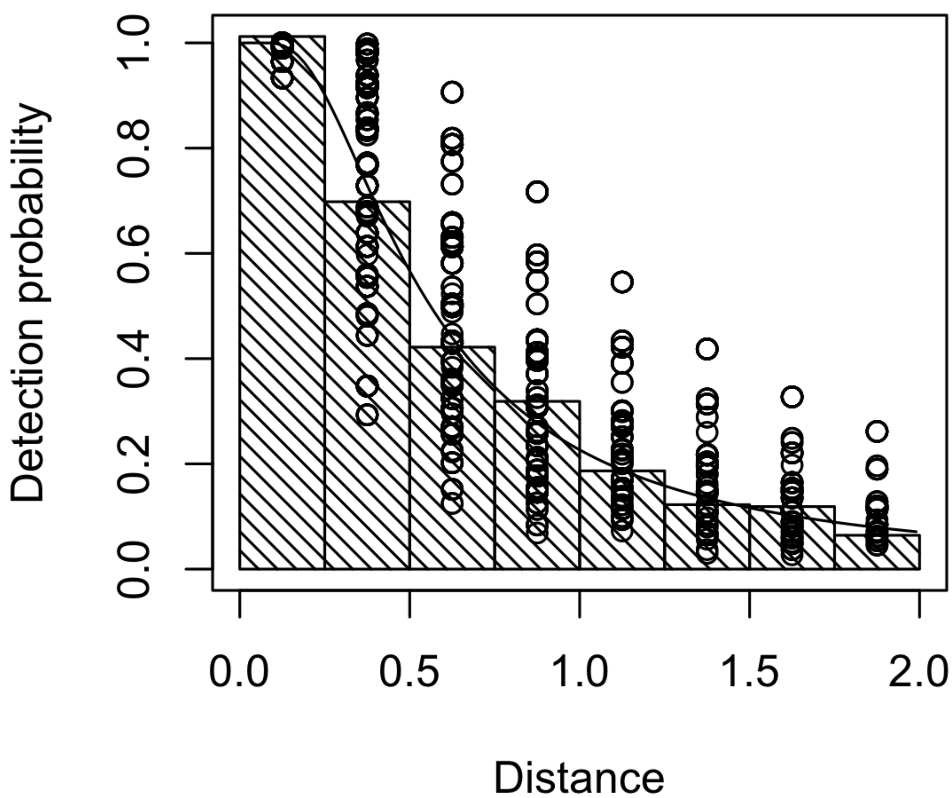

Figure 8. -- Histogram of perpendicular sighting distances (km, after truncation), and fitted detection function from best-fit model selected by AIC.

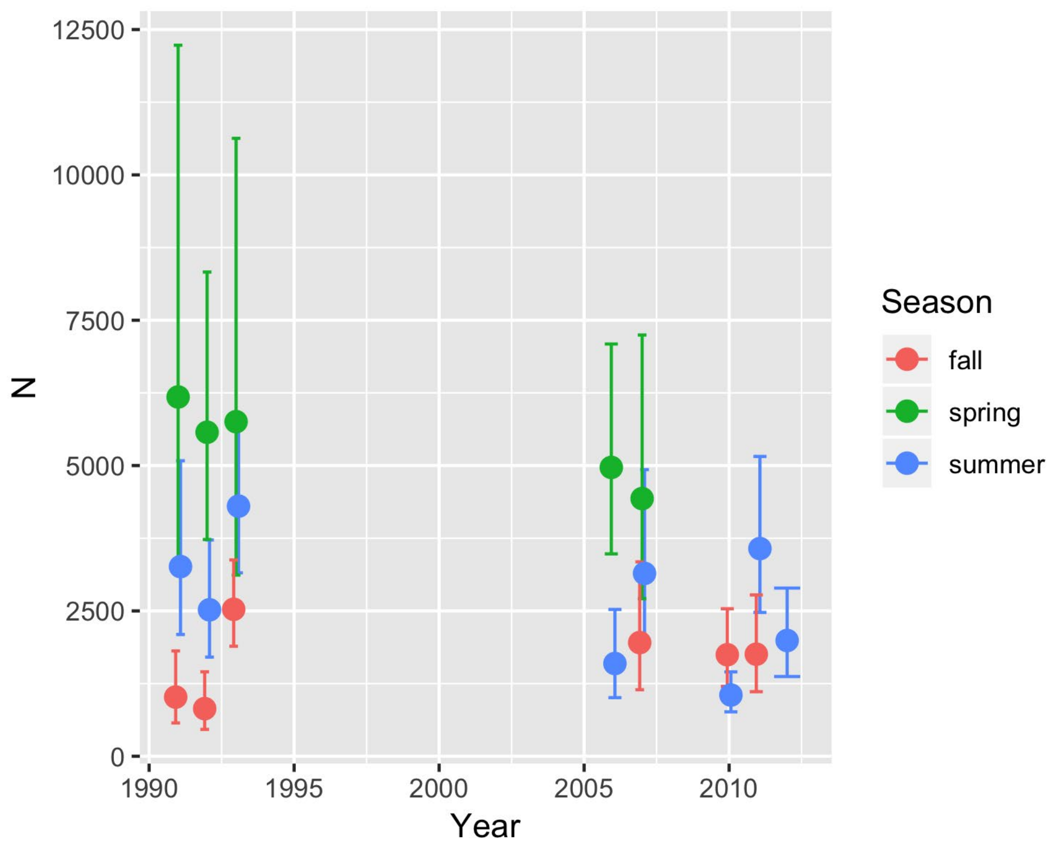

Figure 9. -- Point estimates (with 95% confidence intervals) of abundance of Dall's porpoise in Southeast Alaska, by year and season.

Appendix Table A. -- Southeast Alaska waterways. Depth categories are deep (D, > 200 m), moderate (M, 100-200 m), and shallow (S, < 100 m).

Region	Stratum Name	Area (km^2)	Depth
1	Cross Sound, Icy Strait, and Glacier Bay	2,302	D
2	Lynn Canal, Stephens Passage	1,985	D/S
3	Frederick Sound	2,951	D/M
4	Chatham Strait	4,267	D
5	Sumner Strait, Wrangell, and Zarembo Island	2,943	D/S
6	Clarence Strait to Ketchikan	3,218	D
		17,666	

Appendix Table B. -- Available Dall's porpoise line-transect density estimates (standardized to individuals/100 km^2) from the literature.

Area	Country	Habitat	A/V#	Period	Season	Density	Reference
Prince William Sound, Alaska	USA	Inshore	A	1977	F	45.9*	Hall 1979, 1981
S Strait of Georgia, B.C.	Canada	Inshore	V	2000/01	F	3.0	Keple 2002
S Strait of Georgia, B.C.	Canada	Inshore	V	2000/01	Sp	17.0	Keple 2002
St. Juan de Fuca/Gulf Islands	Canada	Inshore	A	1991	Su	15.3	Calambokidis et al. 1997
St. Juan de Fuca/Gulf Islands	Canada	Inshore	A	1996	Su	6.5	Calambokidis et al. 1997
St. Juan de Fuca/San Juan Islands	USA	Inshore	A	1991	Su	15.7	Calambokidis et al. 1997
St. Juan de Fuca/San Juan Islands	USA	Inshore	A	1996	Su	5.1	Calambokidis et al. 1997
Prince William Sound, Alaska	USA	Inshore	A	1977	Su	19.4*	Hall 1979, 1981
S Strait of Georgia, B.C.	Canada	Inshore	V	2000/01	Su	9.0	Keple 2002
BC mainland inlets	Canada	Inshore	V	2004/05	Su	0.6	Williams and Thomas 2007
Johnstone Strait/Discovery Pass	Canada	Inshore	V	2004/05	Su	11.9	Williams and Thomas 2007
Strait of Georgia	Canada	Inshore	V	2004/05	Su	5.5	Williams and Thomas 2007
Gulf of Alaska	USA	Inshore	V	2013	Su	21.8	Rone et al. 2017
Gulf of Alaska	USA	Inshore	V	2015	Su	8.8	Rone et al. 2017
S Strait of Georgia, B.C.	Canada	Inshore	V	2000/01	W	14.0	Keple 2002
Shelikof Strait	USA	Island/Strait	A	19821983	All	5.3	Leatherwood et al. 1983
Monterey Bay, CA	USA	Offshore	V	1997-2007	All	6.5	Burrows et al. 2012
SE Bering Sea "pelagic"	USA	Offshore	A	19821983	All	2.8	Leatherwood et al. 1983
SE Bering Sea shelf	USA	Offshore	A	19821983	All	0.2	Leatherwood et al. 1983
Japan, northern coastal	Japan	Offshore	V	1983-86	All	10.8	Miyashita and Kasuya 1988
Japan, northern offshore	Japan	Offshore	V	1983-86	All	4.5	Miyashita and Kasuya 1988
Japan, southern coastal	Japan	Offshore	V	1983-86	All	7.9	Miyashita and Kasuya 1988
Oregon/Washington	USA	Offshore	A	1989/90	Sp/Su/F	1.6	Green et al. 1992
Washington offshore	USA	Offshore	V	1995-2002	Su	4.0	Calambokidis et al. 2004
E Bering Sea shelf	USA	Offshore	V	1999, 2004	Su	12.3	Friday et al. 2012
Aleutian Islands	USA	Offshore	V	1987-91	Su	20.6	Hobbs and Lerczak 1993

Appendix Table B. – Cont.

Area	Country	Habitat	A/V#	Period	Season	Density	Reference
Gulf of Alaska	USA	Offshore	V	1987-91	Su	10.8	Hobbs and Lerczak 1993
N Bering Sea	USA	Offshore	V	1987-91	Su	1.1	Hobbs and Lerczak 1993
Offshore North Pacific	International	Offshore	V	1987-91	Su	10.9	Hobbs and Lerczak 1993
East of Kurile Islands	Russia	Offshore	V	1989/90	Su	37.1	Miyashita 1991
Okhotsk Sea	Japan/Russia	Offshore	V	1989/90	Su	18.3	Miyashita 1991
SE Bering Sea shelf	USA	Offshore	V	1999-2000	Su	6.2	Moore et al. 2002
Off Alaska Peninsula	USA	Offshore	A	1984	Su	39.3	Stewart et al. 1987
St. George Basin, Bering Sea	USA	Offshore	A	1984	Su	5.8	Stewart et al. 1987
Western North Pacific	International	Offshore	V	1979-84	Su	24.5	Turnock and Buckland 1995
Queen Charlotte Basin	Canada	Offshore	V	2004/05	Su	6.9	Williams and Thomas 2007
Bering Sea shelf	USA	Offshore	V	2002	Su	3.3	Friday et al. 2013
Bering Sea shelf	USA/Russia	Offshore	V	2008	Su	1.6	Friday et al. 2013
Bering Sea shelf	USA/Russia	Offshore	V	2010	Su	1.1	Friday et al. 2013
Gulf of Alaska	USA	Offshore	V	2013	Su	3.7	Rone et al. 2017
Gulf of Alaska	USA	Offshore	V	2015	Su	1.6	Rone et al. 2017
California/Oregon/Washington	USA	Offshore	V	2008	Su/F	2.3	Barlow 2010
Central California	USA	Offshore	V	1991-2005	Su/F	3.7	Barlow and Forney 2007
Northern California	USA	Offshore	V	1991-2005	Su/F	10.6	Barlow and Forney 2007
Oregon/Washington	USA	Offshore	V	1991-2005	Su/F	15.2	Barlow and Forney 2007
Southern California	USA	Offshore	V	1991-2005	Su/F	2.0	Barlow and Forney 2007
Central/northern California	USA	Offshore	V	2005	Su/F	7.6	Forney 2007
Oregon/Washington	USA	Offshore	V	2005	Su/F	7.2	Forney 2007
Southern California	USA	Offshore	V	2005	Su/F	0.9	Forney 2007
San Clemente Island	USA	Offshore Islan	A	1998/99	W	4.4	Carretta et al. 2000

* Based only a single day's effort, using a non-standard line-transect-like estimator. Therefore, reliability is suspect.

\# A = aerial survey, V = vessel survey.

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