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Abundance and Distribution of Steller Sea Lions *(Eumetopias jubatus)* in British Columbia: Updates from 2016-17 Aerial Surveys

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Foreword

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

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ABSTRACT

An aerial survey was conducted during the 2017 breeding season to assess trends in abundance and distribution of Steller Sea Lions (*Eumetopias jubatus*) in British Columbia (BC). This survey was part of a range-wide assessment of the Eastern population of Steller Sea Lions conducted to fulfill requirements under the Canadian *Species at Risk Act* and the United States (US) *Endangered Species Act*. Additional surveys were conducted in fall 2016 and winter 2017 to examine seasonal changes in abundance and distribution. A total of 31,753 (6,640 pup and 25,113 non-pup) Steller Sea Lions were counted during the breeding season survey. Models fit to the counts indicate a possible slowing in the annual rate of pup production since 2013, but not in the rate of growth in the non-pup component of the population. An estimate of the total population size was obtained by applying a correction factor of 1.48 to non-pup counts to account for animals that were at sea and missed during surveys. The adjusted 2017 breeding season population estimate was 43,200 (95% CI of 38,700 to 48,200) suggesting no significant change from the previous assessment. However, there continues to be an increase in the number of rookeries and year-round haulout sites being used by Steller Sea Lions in BC waters. There was evidence of five new major year-round haulout sites and two year-round haulouts were re-classified as rookery sites since 2013. Surveys conducted outside of the breeding season indicated a continuing trend of increased numbers of animals overwintering in BC waters from 2010–17.

A total of ~31,400 animals were counted in October 2016, as compared to ~28,700 in fall 2012, while a total of ~22,400 animals were counted during surveys conducted in February 2017, as compared to the average of ~17,700 animals counted from multiple surveys flown during the winters of 2009-10. After applying a correction factor of 2.43 to account for animals that were at sea and missed during winter surveys, there were an estimated 52,700 (95% CI 41,000 to 67,800) Steller Sea Lions overwintering in the coastal waters of BC in 2017. Larger numbers of Steller Sea Lions estimated from winter surveys compared to breeding season surveys appear to be due to a net influx of animals from rookeries outside of BC.

The Potential Biological Removal (PBR) for Steller Sea Lions during the summer breeding season is 2,474 for Canadian waters.

1. INTRODUCTION

The Eastern population of Steller Sea Lions *(Eumetopias jubatus)* inhabits coastal and continental shelf regions of the North Pacific Ocean from central California north through British Columbia (BC) and southeast Alaska. Pupping occurs in southeast Alaska, BC, Washington, Oregon and north-central California. The Eastern population has been stable or increasing over much of its range with evidence of ongoing expansion of breeding and year-round haulout sites in both the United States (US) (Muto et al. 2016) and Canada (Olesiuk 2018). It was delisted from Threatened status under the US *Endangered Species Act* in 2013 (NMFS 2013). In Canada, the species continues to be listed as Special Concern under the *Species at Risk Act* (COSEWIC 2013) based on its sensitivity to human disturbance while on land, and vulnerability to catastrophic events (such as major oil spills) due to its highly concentrated breeding aggregations.

Prior to the protection of marine mammals in Canada under the *Fisheries Act* in 1970, Steller Sea Lions (SSL) in BC waters were subject to population control measures and commercial harvests, including eradication of some rookeries in the mid-1950s. Despite the limitations and potential biases in the historic data, it is clear that abundance of SSL declined during the first part of the 20th century (Olesiuk 2018). The first SSL counts were conducted in 1913 and estimated a breeding population of approximately 14,000 animals (Newcombe and Newcombe 1914; Newcombe et al. 1918). Historic reconstructions estimated that control programs and commercial harvests killed over 54,000 SSL in BC between 1910 and 1970, reducing the population to approximately one-quarter of the 1913 estimate (Bigg 1984, 1985).

Since protection of the species in the early 1970s, DFO has conducted a series of 14 aerial breeding season surveys to monitor the SSL population (a comprehensive review of assessment methodology and trends is provided in Olesiuk 2018). Surveys are timed to coincide with the end of the pupping season, when the greatest proportion of animals are hauled out. These surveys provide an estimate of pup production, as well as counts of juveniles and adults (non-pups) from which an estimate of the total population size is obtained. The numbers of SSL on BC rookeries appeared to have been relatively stable during the 1970s and early 1980s, with most of the increase in population occurring since the mid-1980s (Olesiuk 2018). Numbers of non-pups increased at an average rate of 3.8% per annum and pup production at a rate of 4.8% per annum over the study period, resulting in more than a 4-fold increase in abundance since the species was protected in 1970. Recolonization and occupancy of new rookeries, as well as expansion of year-round and winter haul-outs has also occurred.

The objective of this study is to update information on the abundance and distribution of SSL in BC waters to fulfill recommendations for monitoring of population status identified in the Management Plan for the Steller Sea Lion developed in accordance with the *Species at Risk Act* (DFO 2010) in Canada. It will also be used to support requirements for ongoing range wide monitoring identified in the post-delisting monitoring plan for the Eastern Distinct Population Segment of SSL developed in accordance with US endangered species legislation (NMFS 2013). We also report results for coast-wide surveys conducted in BC during fall 2016 and winter 2017 to update assessment of seasonal changes in abundance and distribution. Total breeding season and winter abundance for the population are estimated by applying correction factors derived from satellite telemetry data to account for animals that are at sea and missed during surveys (Olesiuk 2018). Potential Biological Removal (PBR) was calculated for the summer breeding season.

2. METHODS

2.1. SITE CLASSIFICATION

Following Bigg (1985) and Olesiuk (2018), three distinct categories of SSL haulout sites were recognized: rookeries (R), year-round haulout sites (Y), and winter haulout sites (W). Classification considers observations made during standardized sea lion surveys as well as those from Harbour Seal surveys and observations from other experts/observers. Cases where there is not enough evidence to confirm longer term changes in use of a given haulout site (versus a unique observation of a small number of animals) have been flagged for confirmation in subsequent surveys rather than being formally re-designated in this assessment.

Pitcher et al. (2007) subjectively define sea lion rookeries as locations where 50 or more births had occurred. As with previous DFO assessments, the same definition has been adopted here and the (re-) designation of sites as rookeries is based on this birth number threshold. This criterion is standard for other components of the Eastern population as it is also applied by the National Oceanic and Atmospheric Administration (NOAA) for the US portion of the range. The vast majority (>98%) of births and most breeding activity occurs at rookeries (Olesiuk 2018). While some non-breeding animals occupy rookeries throughout the year, there is a distinct seasonal peak in utilization during the June–August breeding season (Bigg 1985). In many cases, there may be multiple breeding sites located on the same or neighbouring islands separated by up to several tens of kilometres, and these are collectively referred to as a rookery complex.

Some non-breeding haulout sites appear to be used continuously throughout the year and are referred to as year-round haulout sites. Animals are present in all months, with no marked seasonal variation in abundance (Bigg 1985). While a few births may occur at year-round haulouts, they account for only a small proportion (<2%) of total pup production (Olesiuk 2018).

SSL also use many additional sites, referred to here as “winter” haulout sites, on a seasonal basis. Occupancy can be continuous or intermittent during winter (non-breeding season) months. The absence of animals, the presence of only a few animals, or the intermittent use during the breeding season further characterizes these sites (Olesiuk 2018).

Bigg (1985) recognized a fourth type of site referred to as winter rafting areas, where animals rest in groups in the water adjacent to land; this type of site is common during the fall and winter surveys. Counts of swimming or rafting animals observed during the surveys were added to adjacent haulout sites or tabulated as “miscellaneous”.

2.2. SURVEY PROCEDURES

Core survey methods remained consistent with those described in previous reports (Olesiuk 2008 and 2018). To facilitate comparison with previous surveys, breeding season censuses were conducted under standardized conditions when maximum numbers of animals were expected to be hauled out. Briefly, the two most important factors are date and time-of-day, with date being especially important for counts of breeding animals and pups on rookeries. Throughout their range, SSL give birth to pups from mid-May to early July (Bigg 1985; Pitcher et al. 2001); pups are poor swimmers at birth and are therefore confined to rookeries for about the first month of life (Sandegren 1970). As in 2013, the 2017 breeding season survey (June 28–July 3) was conducted as part of a coordinated multi-agency survey over the entire range of the Eastern stock, as a component of the post-delisting monitoring plan developed by the National Marine Fisheries Service (NMFS) (2013). SSL breeding season censuses are conducted in late June or early July (range June 27th to July 9th), by which time most pups have been born, but before they begin to disperse from rookeries. Based on the pupping data presented in Edie

(1977), it was estimated that pupping would have been 98–100% complete at the time of the survey. Since females give birth within a few days of their arrival on rookeries, their peak numbers are expected to coincide with that of pups. Non-pups typically leave on foraging trips in the evening and return in the morning, so we attempted to make counts between 10:00 and 18:00 local time when peak numbers are expected to be hauled out (Withrow 1982). We did not survey when there was more than a trace of precipitation or high winds (>25 kts).

Additional BC coast-wide surveys were conducted in fall (28–31 October 2016) and winter (27 January–1 February 2017). While these surveys targeted SSL, California Sea Lions at known sea lion haulout sites were also photographed and counted. Province-wide fall surveys allow for documentation of dispersal patterns of breeding females from rookeries, as indicated by the distribution of pups (Olesiuk 2018), and are timed such that pups are still dependent upon their mothers, but have not yet moulted (i.e., can still be distinguished from older age-classes). In the 2017 winter survey, all known haulout sites were covered, however, some sites were not visited in 2009 and 2010 and not all sites were flown in a single survey. The winter counts for 2009-10 are therefore presented as averages as per Olesiuk (2018) (Tables 3 and 4). As in summer, the fall and winter surveys were flown without regard to tide height, temperature or wind direction; surveys were not flown when there were high winds (>25 kts) or heavy precipitation (Olesiuk 2018).

During 2016-17 aerial surveys were conducted by 1–3 observers from a *Cessna* 180 floatplane flown at an altitude of ~200–250 metres and airspeed of ~145 km/hr. Sites were circled and photographed from directly overhead (vertically) through an open window. Known haulout sites were uploaded to GPS and iNavX chart software; detailed track lines (1s interval) recorded using a BadElf GPS. All known rookeries and year-round haulouts were surveyed during the 2016-17 surveys, and as many winter haulouts (including newly reported observations) as logistical constraints and weather conditions permitted. Between known haulout sites, the shoreline was opportunistically scanned, and potential hauling areas were opportunistically checked for new sites. Although shoreline coverage was incomplete during SSL surveys, the entire shoreline and all possible haulout locations were searched during Harbour Seal surveys, which are also conducted during June–August and cover ~98% of the coastline (Olesiuk 2010). New observed sea lion haulout sites are noted and checked on subsequent sea lion surveys.

Animals were photographed with a hand-held 20.8 Megapixel Nikon D5 digital SLR camera equipped with a 70–200 mm (VRII f2.8) lens. Overviews of sites were taken with a second handheld digital SLR camera equipped with a 12–24 mm (VRII f2.8) lens. Special effort was made to ensure photos were taken from directly overhead at sufficient magnification for counting pups.

Photographs were geotagged to survey tracklines and counted in Adobe Photoshop using the built in “Count” tool with custom action scripts to count and tally animals, on 5K monitors. SSL pups, non-pups, animals in the water and California Sea Lions were counted and recorded separately. Overview photos were used where possible to piece together the sites, ensuring that all groups were counted, and individual animals were not missed. The “Brush” tool in Photoshop was used to mark areas of overlap between photos and ensure that animals were not counted twice. Counts were tallied using the “Measurement” tool in Photoshop. Non-pups are generally easy to distinguish and the counts are considered to represent the exact number present; there is more subjectivity in identifying pups which are distinguished on the basis of their darker colour, smaller size, and proximity to nursing females (Olesiuk 2018). All breeding season counts were done by one reader. Counted rookery images were then verified by a second, more experienced reader to add missed animals and confirm pup and species identifications (missed animals were counted and added to the totals). Fall and winter counts were completed by one experienced reader.

A “balance-of-probability” approach was adopted, rather than counting only objects that could positively be identified as pups (which would lead to an underestimate) or all objects that could possibly have been pups (which would lead to an overestimate). This was achieved by going over the photograph and marking those that were very clearly pups, and then carefully deliberating over each instance where there was some uncertainty.

For the purpose of examining trends in different areas of BC (as per Olesiuk 2018) counts were summarized by regions as shown in Figure 1. The six regions were the West Coast Vancouver Island (WCVI), Scott Islands (SI), Strait of Georgia (SOG), Central Mainland Coast (CMC), North Mainland Coast (NMC) and Haida Gwaii (HG).

2.3. TREND ANALYSIS OF COUNTS

We used regression and multi-model inference techniques based on information theory (Burnham and Anderson 2002) to characterize the pattern of sea lion counts over time (1971–2017) and derive current growth rates. Growth is calculated as the difference of the natural logarithms of the predicted values from the model fit between the end and beginning of the last inter-survey interval (2013–2017) divided by the length of the period (4 yrs) expressed as a percentage. Survey counts of pups, non-pups and total counts were each fit with an exponential and a second order polynomial model using GLM, as well as a logistic model using DLM (Dynamic Linear Model; drc package Ritz et al. 2015). The exponential model allows for unconstrained growth (i.e., per capita growth rate is constant making the population grow faster as it gets larger). The polynomial model allows for changes in population growth rates (for example, slowing of growth rates as a result of density dependence or accelerating growth rates) while in the logistic model, the rate of population increase may be limited or constrained (i.e., per capita growth rate decreases as population size approaches a maximum imposed by limited resources). For model selection we used Akaike’s information criterion (AIC) corrected for small sample sizes (AICc), AICc differences (Δi), and Akaike weights (w_i) (Burnham and Anderson 2002). The models were ranked according to AICc; Δi and Akaike weights (wi were calculated for each model (Burnham and Anderson 2002). The model with the minimum Δi value is deemed the “best” model in the set of candidates. Akaike weights (w_i) are an estimate of the probability that the model is the best among the entire set of candidate models.

2.4. ABUNDANCE ESTIMATION

The counts from the aerial surveys cannot be used to represent a total population abundance estimate as they do not account for animals at sea during surveys (and therefore not counted). An estimate of abundance was therefore calculated by applying survey correction factors to non-pup counts. Separate survey correction factors were applied to the breeding season and winter non-pup counts. These were based on haulout patterns from satellite tagged animals in 2004–2006 (see Olesiuk 2018 for detailed description of correction factors and associated coefficient of variation (CV)).

Briefly, haulout patterns were determined from satellite tags deployed on 25 SSL of various sexes and ages in 2004–2006 (Olesiuk 2018). The 25 instruments were deployed in winter and animals monitored through spring (23 tags) and into summer (11 tags). The instruments were shed when animals moulted. Juveniles are the first to moult in early July, followed by adult females at the end of July, and adult males in early September (Daniel 2003). Eighteen out of the 25 animals with satellite tags also had time-depth recorders (TDRs) but usually for only a portion of the satellite tag deployment period. The estimates of daily proportion hauled out derived from the satellite timelines and the TDRs was highly correlated ($r^2 = 0.99$).

The satellite timelines indicated that the proportion of time animals spent hauled out varied significantly with season, and among sex- and age-classes, with a significant interaction between season and sex- and age-class. Animals spent more time hauled out during summer, but there was no difference in the proportion of time hauled out during winter and spring. Yearlings spent more time hauled out, but there were no differences among juveniles, adult females and adult males. Survey correction factors were calculated separately for the breeding and non-breeding seasons. For winter surveys, correction factors were calculated separately for yearlings and all other sex- and age-classes and subsequently weighted according to the proportion of yearlings (0.188) in the population during winter based on adapted life tables (Olesiuk 2018). Survey correction factors could not be derived for fall surveys because tags had been moulted by the end of summer therefore no calculation of estimated abundance is provided for the fall 2016 survey.

The variance of the proportion of animals hauled out, Var(p), was estimated based on the variability of the hourly averages (separately by season) among the tagged animals (i.e., the variance was calculated by averaging over animals as opposed to averaging over days: the proportion of animals in the population that would be hauled out within a given hour as opposed to the proportion of time an individual animal would be hauled out). The variance of the CF, Var(CF), was calculated (Mood et al. (1974) cited in Huber (1995):

(1) $Var(CF) = Var\ (1/p) \approx Var\ (p)\ /\ p4$

An estimated 67.4% of non-pups are hauled out during the standardized breeding season survey window; therefore a survey correction factor of 1.48 was applied to the 2017 survey counts (not including swimmers). A CV of 5.6% of the mean was used to calculate the standard error, based on the variance in the proportion of satellite-tagged animals hauled out during the survey window in the breeding season (Olesiuk 2018).

An estimated 62% of yearlings and 36% of older animals were hauled out in winter during the 10:00–18:00 survey window, therefore an overall weighted survey correction factor of 2.43 was applied to the 2017 winter counts (again not including swimmers) (Olesiuk 2018). A CV of 12% for the proportion of animals hauled out during the survey window in winter was used to calculate the standard error.

2.5. POTENTIAL BIOLOGICAL REMOVAL (PBR)

Guidelines have been developed to evaluate whether a stock lends itself to a Data Rich or a Data Poor framework within the context of applying the Precautionary Approach (DFO 2018). Given a series of 14 surveys, the BC portion of the Eastern Steller Sea Lion stock is considered data rich.

The Potential Biological Removal (PBR), was therefore calculated as:

(2) $PBR = 0.5 * R_{max} * f * N_{min}$

where R_{max} is the maximum rate of population increase and was set to the default of 12% for pinnipeds (Wade and Angliss 1997; NMFS 2016), f is a recovery factor and was set to 1 (DFO 2018) and N_{min} is the estimated population size using the 20-percentile of the log-normal distribution of the most recent population estimate (Wade 1998).

3. RESULTS

3.1. SURVEY COVERAGE

All previously documented sea lion haulouts were surveyed in 2016-17, with the exception of Northwest Bay log-booms (a documented California Sea Lion haulout) in fall 2016. Survey coverage was expanded by adding new sites observed:

1. at the time of the 2016-17 sea lion surveys;
2. during 2014-16 harbour seal surveys, or
3. by experienced observers outside of standardized DFO pinniped surveys.

Locations of SSL breeding rookeries, year-round haulout sites, and major winter haulout sites observed in BC during 2016-17 surveys are shown in Figure 2.

3.2. COUNTS AND RECENT TRENDS

A total of 31,753 SSL were counted during the breeding season in 2017; 6,640 pups and 25,113 non-pups (12,120 on rookeries and 11,770 on other haulouts with an additional 467 in the water) (Tables 1 and 2, Figure 3b). This compares to 28,452 SSL counted in 2013; 6,317 pups and 22,135 non-pups (10,969 on rookeries and 11,166 on other haulouts). A total of 48% of non-pups and 99% of pups were counted on rookeries in 2017 (Table 2).

Two new rookeries were observed in 2017, with >50 pups counted at Warrior Rocks off Bonilla Island (North Mainland Coast) and at Joyce Rocks off Moresby Island (Haida Gwaii). One new year-round haulout site (not previously documented as winter haulout sites) and 4 known winter haulouts were potentially re-designated as year-round haulout sites. (Tables 1 and 2, Figure 2).

Ongoing shifts in pup production among rookeries and among regions was observed, with rookeries on the North and Central Mainland Coast showing continued increases in abundance for both pups and non-pups, while the largest rookery complex at the Scott Islands showed a relative decline (Table 2, Figure 4). The number of pups born on the Scott Islands decreased to 3,997 (61% of the total), as compared to 4,300 (68%) in 2013 and 3,936 (72%) in 2010, while the number of pups born on Central Mainland Coast rookeries increased from 390 (6%) in 2013 to 770 (11%) in 2017. Pup production at rookeries in the other regions remained stable.

Based on multi-model inference, the polynomial model applied to the survey counts provided the best fit for non-pups (and the total population) in 2017, while the logistic model provided the best fit for pups (Figure 5, Table 4). Growth rates calculated for the 2013–2017 interval were estimated to be 2.8% per year for pups and 4.3% per year for non-pups, with an overall growth rate of 4.5% for the population.

A total of approximately 31,400 animals were counted in October 2016, as compared to ~28,700 in fall 2012. A total of approximately 22,400 animals were counted during surveys conducted in February 2017, compared to the average of ~17,700 animals counted from multiple surveys flown during the winters of 2009-10. (Table 3, Figure 3; Olesiuk 2018). There is continued evidence of dramatic seasonal shifts in distribution of SSL throughout BC (Figure 3), as animals aggregate at rookeries for breeding after dispersal throughout the fall and winter for foraging (Olesiuk 2018).

3.3. ABSOLUTE ABUNDANCE

The total abundance of SSL during the 2017 breeding season was estimated at 43,200 (95% CI of 38,700 to 48,200), as compared to 39,200 (95% CI of 33,600 to 44,800) in 2013. The standard error for the summer abundance estimate was 2,447 in 2017.

It is estimated that a total of 52,700 (95% CI 41,000 to 67,800) SSL wintered in coastal waters of BC in 2017 as compared to 48,500 (95% CI 38,100 to 58,900) in 2009-10. The standard error for the 2017 winter abundance estimate was 6,798.

3.4. POTENTIAL BIOLOGICAL REMOVAL (PBR)

Based on an N_{min} of 43,215, using a recovery factor of 1.0 and the default R_{max} of 12%, the PBR for the BC population of SSL during the summer breeding season is 2,474.

3.5. CALIFORNIA SEA LION COUNTS

California Sea Lions (CSL) were opportunistically counted in fall and winter surveys. A total of approximately 11,400 CSL were counted (on land or swimming at or near haulout sites) during sea lion surveys flown in fall 2016, and ~5,300 were counted in winter 2017 survey photos (Figure 6). This compares to approximately 10,000 animals counted in the fall of 2012 and 3,000 in the fall of 2008. Approximately 1,950 CSL were counted in winter 2009-10 (Olesiuk, unpublished data).

4. DISCUSSION

4.1. BREEDING SEASON ABUNDANCE

A portion of the Eastern stock of SSL has historically bred on rookeries located in BC. DFO has conducted 14 breeding season aerial surveys since the early 1970s to monitor the population in BC. Abundance of SSL has grown dramatically since the stock was protected in 1970, with significant increases in pup production, and in numbers of non-pups on rookeries and on haulout sites since the first DFO survey in 1971 (Olesiuk 2018). Here we document a continued increase in counts of animals and expansion of sites used in BC waters. However, after adjusting for animals in the water and incorporating the subsequent uncertainty in haulout behaviour, SSL breeding season abundance remains equivalent to the previous assessment in 2013 at ~43,000.

In previous SSL assessments, an arbitrary correction factor of 1.10 was applied to pup counts to account for pups that may have been born and died or swept off rookeries prior to surveys, or pups born after the survey (Olesiuk 2018). For the purposes of this assessment, pups that died prior to the survey are not considered part of the population. There is little information on the actual number of pups missed, and the number could vary from year to year and between sites. Since most pups are born on traditional rookeries during June and are confined to land for the first month of life, standardized surveys of rookeries at the end of June or early July are expected to provide a nearly complete account of annual pup production. This correction factor was consequently not applied here. The correction previously used for pups hidden in oblique photos (Olesiuk et al. 2008, Olesiuk 2018) was also not used as counts were made from vertical photos.

Non-pup counts are corrected for the unknown proportion of juvenile and adult animals foraging at sea during surveys (and therefore not included in counts from survey photos). The survey correction factors currently used were derived from satellite telemetry data collected from 25 SSL (of various sexes and ages) captured near Hornby Island in the Strait of Georgia between 2004-06. There is uncertainty around the correction factor and associated variance applied to survey counts to provide estimates of abundance. It is uncertain whether haul-out behaviour has remained consistent, and the current survey correction factors are applicable, in light of potential changes in population demographics, predator abundance, dynamic ocean conditions and prey availability.

4.2. TRENDS IN BREEDING SEASON COUNTS AND RATES OF INCREASE

Models fit to the counts indicate a potential slowing in the annual rate of increase in pup production since 2013, but not in the rate of increase for the non-pup component of the population. The logistic fit to the pup counts actually suggests an inflection in production in the mid-2000s. Growth rates calculated for the previous survey interval (2010–2013) were 5.6% for pups and 4.6% for non-pups (DFO 2021). These growth rates are based on a polynomial regression with similar trends to those obtained using a piecewise log-linear regression used in previous assessments (Olesiuk 2018). Here, growth rates calculated for the 2013–2017 interval were estimated to be 2.8% per year for pups and 4.3% per year for non-pups.

The reduction in the annual rate of increase in pup production is a preliminary observation and caution is warranted; further surveys are required to confirm a trend. Notably however, surveys in SE Alaska indicated a 6% decrease in pup production at rookeries in SE Alaska between 2015 and 2017 (Sweeney et al. 2017). It is possible that the observation here is simply due to a chance event (i.e., pups swept off rookeries prior to surveys), a shift in the timing of pupping, or the emergence of pressures of density dependence as per the inference of the logistic model fit. Alternatively, the modest decrease in pups observed in 2017 may be due to environmental variability affecting vital rates that directly influence population trends (Philips et al. 2011; Jemison et al*.* 2018; Maniscalco et al*.* 2015). Despite changing climate and ocean conditions, the last evaluation of pupping phenology for the Eastern stock was undertaken on data collected between 1968–98 (Pitcher et al*.* 2001) and should be the focus of future work.

In the case of density dependence or environmental factors, the mechanisms are unclear and are not possible to evaluate with simple count data obtained from aerial surveys every four years. It should be noted however that the marine heat wave in the North Pacific of 2014-15 was the most extreme ever recorded with compounding negative effects across the ecosystem and dramatic alterations to community composition and species abundances (Chandler et al. 2017, 2018). This included changes at the base of the food web such as exceptional blooms of phytoplankton including harmful algae, unusually high abundances of gelatinous zooplankton, and range extension northwards of plankton and fish species more commonly found further south. Associated effects included multiple fisheries collapses, large seabird die-offs and elevated strandings of California Sea Lions (CSL) in southern California. Although the large mass of relatively warm water observed in the Northeast Pacific Ocean in 2014 and 2015 (the "Blob"), characterized by surface and subsurface temperatures well above normal dissipated in 2016 (except for a brief interval in mid-summer), this dissipation was only partial and many indices of biological and oceanographic conditions continued to deviate from long term norms into 2017 (Chandler et al. 2017, 2018).

4.3. DISTRIBUTION

We observed a continued increase in the number of rookeries and year-round haulout sites being used by SSL in BC waters in 2016-17) (Tables 1 and 2, Figure 2). Two new rookeries were observed in 2017 (Warrior Rocks and Joyce Rocks); as with other recently established rookeries, these sites were previously classified as year-round haulouts. Including the 2017 additions, SSL are currently breeding at all known historic rookeries and at five "new" since 2008 rookeries in BC (this study; Olesiuk 2018), increasing the relative contribution of central and north mainland coast rookeries to total pup production (Figure 4). Accordingly, the relative contribution of the Scott Islands (which remains by far the largest rookery complex in terms of total pup production) declined from 72% in 2010 to 61% in 2017. Further shifts in distribution and use of haulout sites were noted, with observation a new year-round haulout site (not previously documented as winter haulout sites) and four known winter haulouts re-designated as year-round haulout sites. This included two new major year-round haulout sites in the Strait of Georgia, where summer haulout use has not been previously documented during standardized surveys. While there have been changes in patterns of haulout use including redistribution of animals among haulout sites and expansion to new sites, it is possible that previously unidentified haulouts have been missed during surveys.

4.4. RANGE-WIDE AND HISTORICAL CONTEXT FOR BC BREEDING POPULATION

Trends in SSL abundance, population growth rate, and distribution in BC (including the expansion of haulout and rookery sites) are generally consistent with those in other parts of their range. A northward shift in the overall breeding distribution has occurred in recent decades, with a contraction of the range in southern California and new rookeries established in southeast Alaska, and most recently, Washington (>100 pups counted in 2015) (Pitcher et al. 2007; Sweeney et al. 2017; Muto et al. 2020). As described in the 2019 US stock assessment (Muto et al. 2020), the Eastern stock of SSL was estimated to have been increasing in all US regions from 1990 to 2017, with the most significant growth observed in SE Alaska. As of 2017, the counts for the US portion of the stock had increased to 43,201 individuals (32,510 non-pups and 10,691 pups), with increases being driven by growth in pup counts in all regions. When considering BC counts reported here, the US portion represents ~60% of the total breeding season stock. The Canadian portion would therefore represent ~40% of the total stock with 44% of non-pup counts and 38% of total pup counts.

This population is expected to continue increasing until reaching carrying capacity with available prey resources (Wiles 2015). Ongoing seasonal surveys are required to track continuing changes in distribution and abundance and emerging patterns throughout the range. Coordinated range-wide surveys should continue, possibly increasing frequency of breeding season surveys to be consistent with the US National Marine Fisheries Service, and an updated range-wide assessment is required.

There is uncertainty associated with reconstruction of historic populations of SSL in BC due to limited data and changing survey methods (e.g., counts conducted from boats or high points on land) prior to establishment of standardized aerial surveys in the early 1970s. While useful in considering overall trends and impacts of predator control programs on Steller Sea Lion populations, reconstructions only extending to the early 1900s (e.g., Olesiuk 2018) may not represent long-term historical abundance of SSL. Population levels prior to that are essentially unknown, and caution should be exercised in comparing estimates of present-day populations with those in the early 1900s to gauge conservation targets.

Although populations have grown in recent years, SSL still face a number of potential threats. During the breeding season, animals aggregate in large numbers on rookeries (~60% of pup production in Canada occurs on the Scott Islands), at which time animals are vulnerable to disturbances or potential environmental calamities. The Eastern population of SSL may be adversely impacted by a number of additional known or potential human-related factors, including human disturbance, reduced prey abundance due to competition with fisheries, toxic algal blooms, and entanglement in fishing gear, among others (Wiles 2015).

4.5. BREEDING POPULATION PBR

PBR is the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. PBR can provide scientific advice on limits on human-caused mortality of marine mammals (Wade 1998). The PBR for the BC portion of the Eastern population of SSL during the summer breeding season is 2,474. A recovery factor of 1.0 was used for this population due to its overall abundance, ongoing expansion of breeding and year-round haulout sites and the available time series data. There is currently limited data regarding anthropogenic sources and rates of Steller Sea Lion mortality in BC (i.e., harvest, bycatch and incidental predator control) let alone natural sources for that matter. This could make it difficult for managers to effectively apply PBR and subsequently for science to interpret population trends.

4.6. NON-BREEDING SEASON ABUNDANCE, TRENDS AND DISTRIBUTION

Total counts of SSL in fall 2016 increased approximately 9% from previous values in the fall of 2012. Similarly, 2017 winter counts were approximately 21% higher than in 2009-10. However, once uncertainty in the correction factor is considered for winter values, this difference does not necessarily represent a significant increase in abundance overall from the breeding population.

There is greater uncertainty in the abundance estimate for winter because animals are more widely dispersed across sites, and larger correction factors are required to adjust for animals at sea and missed during surveys. Nevertheless, the abundance estimate from the winter survey is ~20% higher than summer abundance, although again, confidence intervals overlap. This apparent increase is thought to be due to an influx of animals from US waters (Wiles 2017; Wright et al. 2017; Olesiuk, 2018). Satellite telemetry data from tagged animals and sightings of animals branded at US rookeries in BC waters throughout the year confirm that animals born at US rookeries do in fact overwinter and/or breed in Canada (Jemison et al. 2018; DFO unpublished data). However, numbers of animals from SE Alaska, Washington, Oregon and California contributing to breeding season and overwintering populations in BC waters are unknown.

SSL are highly mobile, and animals range widely during the non-breeding season with distribution highly influenced by prey availability (Womble et al. 2009; Sigler et al. 2009, 2017). For example, the increased numbers in the Strait of Georgia during winter 2017 versus 2008-09 could have been driven by the historic high spawning biomass of Strait of Georgia herring documented in recent years (Boldt et al. 2019).

SSL are one of two sea lion species found in BC waters. The second species is the California Sea Lion *(Zalophus californianus; CSL),* a species that breeds predominantly in California and whose population has also been increasing since the early 1970s (Caretta et al. 2020). The species, which shares many haulout sites with SSL (primarily in southern BC), and whose diet in the winter appears to consist largely of herring and salmon, represent a potentially significant source of competition for space and prey resources. There is evidence of a continued northward shift of CSL in BC as well as a large increase in numbers of males overwintering in the Strait of Georgia and on the west coast of Vancouver Island (Figure 6). They have established large haulouts at Seabird Rocks, Folger Rock, and Perez Rocks as numbers continue to grow, and recent observations suggest they are arriving earlier and staying longer.

Given the recent recovery and continued growth of populations, it is expected that natural regulatory mechanisms will likely begin to play a greater role in BC waters. Predator-prey interactions in the food web are not well understood and continued efforts should be made to explore seasonal patterns of abundance, distribution and diet of SSL throughout their range. Increasing numbers of California Sea Lions have been observed overwintering in BC in recent years; abundance, distribution, and diet of CSL should be considered in assessing potential resource competition with SSL. Changes in the ocean environment (including warmer temperatures resulting in reduced prey availability) have been considered as a possible factor favoring CSL over SSL in some parts of the range and influencing trends in distribution and abundance for both species.

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6. REFERENCES CITED

Bigg, M.A. 1984. Sighting and kill data of Steller Sea Lions (*Eumetopias jubatus*) and California sea lions *(Zalophus californianus)* from British Columbia during 1892-1982, with some records from Washington and southeastern Alaska. Can. Tech. Rep. Fish. Aqu. Sci. 460: 191 p.

Bigg, M.A. 1985. Status of the Steller Sea Lion (*Eumetopias jubatus*) and California sea lion (*Zalophus californianus*) in British Columbia. Can. Spec. Publ. Fish. Aquat. Sci. 77: 20 p.

Boldt, J.L., Leonard, J., and Chandler, P.C. (Eds.). 2019. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2018. Can. Tech. Rep. Fish. Aquat. Sci. 3314: vii + 248 p.

Burnham, K.P. and Anderson, D.R. 2002. Model selection and multimodel inference: a practical information-theoretic approach (2nd Ed). Springer Science and Business Media. 488 p.

Carretta, J.V., Forney, K.A., Oleson, E.M., Weller, D.W., Lang, A.R., Baker, J., Muto, M.M., Hanson, B., Orr, A.J., Huber, H., Lowry, M.S., Barlow, J., Moore, J.E., Lynch, D., Carswell, L., and Brownell Jr., R.L. 2020. U.S. Pacific Marine Mammal Stock Assessments: 2019. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-629.

Chandler, P.C., King, S.A., and Boldt, J. (Eds.) 2017. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2016. Can. Tech. Rep. Fish. Aquat. Sci. 3225: 243 + vi p.

Chandler, P.C., King, S.A., and Boldt, J. (Eds.) 2018. State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2017. Can. Tech. Rep. Fish. Aquat. Sci. 3266: viii + 245 p.

COSEWIC. 2013. COSEWIC assessment and status report on the Steller Sea Lion *Eumetopias jubatus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. xi + 54 pp.

Daniel, R.G. 2003. The timing of moulting in wild and captive Steller sea lions (*Eumetopias jubatus*). M.Sc. Thesis, University of British Columbia, Vancouver, British Columbia, Canada. 64 pp.

DFO. 2011. Management Plan for the Steller Sea Lion (*Eumetopias jubatus*) in Canada [Final]. *Species at Risk Act* Management Plan Series. Fisheries and Oceans Canada, Ottawa. vi + 69 pp.

DFO. 2018. Harvest advice for eastern and western Hudson Bay Beluga (*Delphinapterus leucas*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/008. (Erratum: September 2020)

DFO. 2021. Trends in Abundance and Distribution of Steller Sea Lions (*Eumetopias Jubatus*) in Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/035.

Edie, A.G. 1977. Distribution and movements of Steller Sea Lion cows (*Eumetopias jubatus*) on a pupping colony. M.Sc. Thesis, University of British Columbia, Vancouver, British Columbia. 81 pp.

Huber, H.R. 1995. The abundance of harbor seals (*Phoca vitulina richardsi*) in Washington, 1991-1993. M.Sc. Thesis, University of Washington, Seattle, WA. 37 pp.

Jemison, L.A., Pendleton, G.W., Hastings, K.K., Maniscalco, J.M. and Fritz, L.W. 2018. Spatial distribution, movements, and geographic range of Steller Sea Lions (*Eumetopias jubatus*) in Alaska. PLoS ONE 13(12)**:** e0208093.

Maniscalco. J.M., Springer, A.M., Adkison, M.D. and Parker, P. 2015. Population trend and elasticities of vital rates for Steller Sea Lions (*Eumetopias jubatu*s) in the Eastern Gulf of Alaska: A New Life-History Table Analysis. PLoS ONE, 10(10)**:** e0140982.

Muto, M.M., Helker, V.T., Angliss, R.P., Allen, B. A., Boveng, P.L., Breiwick, J.M., Cameron, M. F., Clapham, P.J., Dahle, S.P., Dahlheim, M.E., Fadely, B.S., Ferguson, M.C., Fritz, L.W., Hobbs, R.C., Ivashchenko, Y.V., Kennedy, A.S., London, J.M., Mizroch, S.A., Ream, R.R., Richmond, E.L., Shelden, K.E.W., Towell, R.G., Wade, P.R., Waite, J M. and Zerbini, A.N. 2016. Alaska marine mammal stock assessments, 2015. U.S. Dep. Commer., NOAA Tech. Memo. NMFSAFSC-323, 300 p.

Muto, M.M., Helker, V.T., Delean, B.J., Angliss, R.P., Boveng, P.L., Breiwick, J.M., Brost, B.M., Cameron, M.F., Clapham, P.J., Dahle, S.P., Dahlheim, M.E., Fadely, B.S., Ferguson, M.C., Fritz, L.W., Hobbs, R.C., Ivashchenko, Y.V., Kennedy, A.S., London, J.M., Mizroch, S.A., Ream, R.R., Richmond, E.L., Shelden, K.E.W., Sweeney, K.L., Towell, R.G., Wade, P.R., Waite, J.M. and Zerbini, A.N. 2020. Alaska marine mammal stock assessments, 2019. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-404. 395 p.

National Marine Fisheries Service (NMFS). 2013. Status review of the eastern Distinct Population Segment of Steller Sea Lion (*Eumetopias jubatus*). NMFS, Juneau, AK. 144 p. + App.

National Marine Fisheries Service (NMFS). 2016. Guidelines for preparing stock assessment reports pursuant to the 1994 amendments to the *Marine Mammal Protection Act*. 23 p.

Newcombe, C.F., Greenwood, W.H. and Fraser, C.M. 1918. Part 1. Preliminary report of the Commission on the sea lion question, 1915. Part 2. Report and conclusion of the sea lion investigation, 1916. Contributions to Canadian Biology p. 1–19.

Newcombe, C.F. and Newcombe, W.A. 1914. Sea lions on the coast of British Columbia. Annual Report of the British Columbia Commission for Fisheries for 1913. p. 131–145.

Olesiuk, P.F. 2008. Abundance of Steller Sea Lions (*Eumetopias jubatus*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/063. iv + 29 p.

Olesiuk, P.F. 2010. An assessment of population trends and abundance of harbour seals (*Phoca vitulina*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/105. vi + 157 p.

Olesiuk, P.F. 2018. Recent trends in Abundance of Steller Sea Lions (*Eumetopias jubatus*) in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/006. v + 67 p.

Olesiuk, P.F., Calkins, D.G., Pitcher, K.W., Perryman, W.L., Stinchcomb, C. and Lynn, M. 2008. An evaluation of Steller Sea Lion (*Eumetopias jubatus*) pup counts from 35mm oblique photographs. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/064. v + 42 p.

Phillips, C.D., T.S. Gelatt, J.C. Patton and Bickham, J.W. 2011. Phylogeography of Steller Sea Lions: relationships among climate change, effective population size, and genetic diversity. J. Mammal. 92(5): 1091-1104.

Pitcher, K.W., Burkanov, V.M., Calkins, D.G., Le Bouef, B.J., Mamaev, E.G., Merrick, R.L. and Pendleton, G.W. 2001. Spatial and temporal variation in the timing of births of Steller Sea Lions. J. Mammal. 82: 1047–1053.

Pitcher, K.W., Olesiuk, P.F., Brown, R.F. Lowry, M.S., Jeffries, S.J., Sease, J.L., Perryman, W.L., Stinchcomb, C.E. and Lowry, L.F. 2007. Abundance and distribution of the eastern North Pacific Steller Sea Lion (*Eumetopias jubatus*) population. Fish. Bull. 107: 102–115.

Ritz, C., Baty, F., Streibig, J.C. and Gerhard, D. 2015. Dose-Response Analysis Using R. PLoS ONE 10(12): e0146021.

Sandegren, F.W. 1970. Breeding and maternal behaviour of the Steller Sea Lion *(Eumetopias jubatus*) in Alaska. M.Sc. Thesis, University of Alaska, Fairbanks, Alaska.

Sigler, M.F., Tollit., D.J., Vollenweider, J.J., Thedinga, J.F., Csepp, D.J., Womble, J.N., Wong, M.A., Rehberg, M.J., and Trites, A.W. 2009. Steller sea lion foraging response to seasonal changes in prey availability. Mar. Ecol. Progr. Ser. 388: 243–261.

Sigler, M.F., Gende, S.M. and Csepp, D.J. 2017. Association of foraging Steller Sea Lions with persistent prey hot spots in southeast Alaska. Mar. Ecol. Progr. Ser. 571: 233–243.

Sweeney, K.L., Fritz, L., Towell, R. and Gelatt, T. 2017. Results of Steller Sea Lion surveys in Alaska, June-July 2017. Memorandum to The Record. November 29, 2017.

Wade, P. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Mar. Mamm. Sci. 14: 1–37.

Wade, P.R. and Angliss, R.P. 1997. Guidelines for assessing marine mammal stocks: Report of the GAMMS workshop April 3-5, 1996, Seattle, Washington. NOAA Technical Memorandum NMFS-OPR-12. Available from Office of Protected Resources, MFS, Silver Spring, MD. 93 p.

Wiles, G.J. 2015. Washington state periodic status review for the Steller Sea Lion. Washington Department of Fish and Wildlife, Olympia, WA. 38 pp.

Withrow, D.E. 1982. Using aerial surveys, ground truth methodology, and haulout behavior to census Steller Sea Lions, *Eumetopias jubatus*. M.Sc. Thesis, University of Washington, Seattle, WA. 102 pp.

Womble, J.N., Sigler, M.F. and Wilson, M.F. 2009. Linking seasonal distribution patterns with prey availability in a central-place forager, the Steller Sea Lion. J. Biogeogr. 36(3): 439–451.

Wright, B.E., Brown, R.F., DeLong, R.L., Gearin, P.J., Riemer, S.D., Laake, J.L. and Scordino, J.J. 2017. Survival rates of Steller Sea Lions from Oregon and California. J. Mammal. 98(3): 885–894.

7. TABLES

Table 1. Number of non-pup Steller Sea Lions counted during province-wide breeding season surveys during 1971–2017 with pooled regional and BC totals. WCVI=West Coast Vancouver Island; SI=Scott Islands; SOG=Strait of Georgia; CMC=Central Mainland Coast; NMC=North Mainland Coast and HG=Haida Gwaii. Sites were classified as rookeries (R), year-round haul-outs (Y), or winter haul-outs (W) with usage patterns having changed at some sites over the study period. Sites at which designation changed since the last survey are highlighted in grey and marked with an asterisk; those with an question mark indicate sites with limited observations requiring further data to confirm reclassification. Parentheses indicate sites were not surveyed and counts extrapolated or interpolated (see Olesiuk 2018 for further details, including survey dates to 2013). Dashes indicate sites not surveyed. Counts include swimmers associated with known haulout sites (Note: swimmers are removed for abundance estimation). For details of site locations please refer to [Government of Canada Open Data on Steller Sea Lion counts and haulout locations across the British Columbia coast](#).

Region	Site/Complex Name	Site Type	1971	1973	1977	1982	1987	1992	1994	1998	2002	2006	2008	2010	2013	2017
WCVI	Carmanah Point	W/Y	0	(0)	181	170	146	103	150	255	237	247	162	514	1209	1363
WCVI	Pachena Point	W/Y	0	0	0	0	0	0	0	1	0	44	53	166	157	112
WCVI	Folger Island	W/Y?*	-	-	-	-	-	-	-	-	-	0	0	0	0	9
WCVI	Wouwer Island	W/Y	0	0	0	0	0	0	0	0	31	4	48	89	104	54
WCVI	Mara Rock & Starlight Reef	W/Y	0	(0)	0	3	0	0	41	87	296	264	376	539	487	197
WCVI	Long Beach Rocks	Y	394	265	10	262	231	344	298	535	714	388	295	367	447	385
WCVI	Plover Reef & Cleland Island	W/Y	0	0	0	0	0	0	0	0	0	0	10	0	154	294
WCVI	Raphael Point	W	0	0	0	0	0	0	58	0	0	0	0	0	0	0
WCVI	Perez Rocks	Y	-	-	-	-	-	-	-	-	-	353	466	321	320	715
WCVI	Ferrer Point	W	0	0	0	0	0	0	0	0	0	16	2	0	2	1
WCVI	Barrier Islands	Y	(145)	(145)	105	153	149	274	290	843	585	542	1051	1284	1049	1361
WCVI	O'Leary Islets	Y/W	331	(266)	200	85	60	81	14	74	2	141	0	0	0	0
WCVI	Solander Island	W/Y	0	3	1	0	0	51	419	179	187	876	320	632	285	1464
WCVI	Cape Scott	W	0	(0)	1	0	1	42	68	0	0	0	0	0	0	0
	WCVI Subtotal	**-**	**870**	**679**	**498**	**673**	**587**	**895**	**1338**	**1974**	**2052**	**2875**	**2783**	**3912**	**4214**	**5955**
SI	Beresford Island (incl. Maggot Island)[1]	R	489	485	651	542	674	675	490	250	603	603	759	439	544	428
SI	Sartine Island	R	628	616	879	806	600	575	343	262	268	379	264	231	239	333
SI	Triangle Island	R	550	375	570	376	1057	1603	1626	2540	2995	3576	3645	4651	5249	5023
	SI Subtotal	**-**	**1667**	**1476**	**2100**	**1724**	**2331**	**2853**	**2459**	**3052**	**3866**	**4558**	**4668**	**5321**	**6032**	**5784**

Region	Site/Complex Name	Site Type	1971	1973	1977	1982	1987	1992	1994	1998	2002	2006	2008	2010	2013	2017
SOG	Major Island	W/Y?*	-	-	-	-	-	-	-	-	-	-	-	-	-	12
SOG	Vivian Island	W/Y*	-	-	-	-	-	-	-	-	-	-	-	-	-	414
SOG	Mittlenatch Island	W/Y?*	-	-	-	-	-	-	-	-	-	-	-	-	-	11
SOG	McRae Islets	W/Y*	-	-	-	-	-	-	-	-	-	-	-	-	-	37
	SOG Subtotal	**-**	**-**	**-**		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**474**
JQCS	Ashby Point	W/Y	(3)	(3)	4	1	210	3	226	225	519	786	541	479	632	822
JQCS	Buckle Group	W/Y	0	(0)	0	0	0	(0)	(0)	(0)	47	0	0	461	806	112
JQCS	Millar Group	W/Y	0	0	0	0	0	0	0	0	1	2	151	140	208	250
JQCS	Screen Island (West Eden Island)[1]	W/Y	-	-	-	-	0	0	0	0	(0)	(0)	(0)	32	45	135
	JQCS Subtotal	**-**	**3**	**3**	**4**	**1**	**210**	**3**	**226**	**225**	**567**	**788**	**692**	**1112**	**1691**	**1319**
	SOUTHERN BC	**-**	**2540**	**2158**	**2602**	**2398**	**3128**	**3751**	**4023**	**5251**	**6485**	**8221**	**8143**	**10345**	**11937**	**13532**
CMC	Virgin Rocks	Y/R	317	205	62	190	229	157	131	168	419	516	595	533	1350	1222
CMC	Pearl Rocks	Y	100	81	276	23	128	126	98	199	467	449	247	283	414	443
CMC	Airacobra Rock & Blenheim Island	W/Y	-	-	0	0	0	0	0	0	(0)	(0)	0	33	56	8
CMC	Gosling Rocks	Y/R	106	(93)	37	179	135	72	192	133	160	257	308	439	384	1082
CMC	McInnes Island	Y	196	(80)	45	0	0	109	241	163	25	(81)	263	139	262	168
	CMC Subtotal	**-**	**719**	**459**	**420**	**392**	**492**	**464**	**662**	**663**	**1071**	**1303**	**1413**	**1427**	**2466**	**2923**
NMC	Steele Rock	Y	(88)	(88)	85	150	7	35	137	227	101	92	194	173	228	266
NMC	Isnor Rock & McKenney Island	Y	0	(0)	1	0	1	0	0	0	72	29	0	109	229	250
NMC	Ashdown Island	W/Y*	(0)	(0)	0	(13)	(13)	25	(13)	0	(0)	(0)	(0)	17	525	355
NMC	MacDonald Island & Goodacre Point	?	-	-	-	-	-	-	-	-	-	-	-	62	5	0
NMC	Joseph Island	W/Y	0	(0)	(0)	0	0	(0)	(0)	0	2	3	0	128	345	950
NMC	North Danger Rocks	R	148	347	230	288	339	301	309	583	592	1003	652	527	783	664
NMC	Bonilla Island & Northwest Rocks[2]	Y/R	29	158	333	219	19	265	272	303	215	375	282	508	392	756
NMC	Warrior Rocks	Y/R*	-	-	-	-	-	416	2	282	588	692	1114	1106	1221	1135
NMC	Roland Rocks	W/Y?*	-	-	-	-	-	-	-	-	-	0	0	0	0	66

Region	Site/Complex Name	Site Type	1971	1973	1977	1982	1987	1992	1994	1998	2002	2006	2008	2010	2013	2017
NMC	Chearnley Islet	W/Y	(0)	(0)	0	0	(0)	1	3	0	19	498	244	508	137	445
	NMC Subtotal	**-**	**265**	**593**	**649**	**670**	**379**	**1043**	**736**	**1395**	**1589**	**2692**	**2486**	**3138**	**3865**	**4887**
HG	Rose Spit	W/Y	1	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)	30	132	57	50	15
HG	Skedans Islands	W	0	(0)	0	45	0	0	0	0	0	0	0	0	0	0
HG	Reef Island	Y	207	105	88	36	482	489	538	216	370	253	294	316	289	279
HG	Tatsung Rock	W/Y	0	10	0	0	0	0	0	(0)	(0)	(0)	24	(43)	77	53
HG	Joyce Rocks	Y/R*	-	-	-	-	-	-	-	-	-	-	53	(83)	165	270
HG	Garcin Rocks	Y/R	-	-	-	-	-	-	-	-	329	261	305	565	594	613
HG	Cape Saint James	R	631	549	782	698	1021	867	797	763	982	1094	811	1077	1020	807
HG	Anthony Island	Y	-	-	-	-	44	279	617	359	313	513	473	186	521	227
HG	McLean Fraser Point	W/Y?*	-	-	-	-	-	-	-	-	-	-	-	0	0	102
HG	S Nangwai Islands	W	-	-	-	-	-	-	-	-	-	-	15	0	0	0
HG	South Tasu Head	Y	76	(375)	278	117	263	80	196	285	151	47	98	251	273	254
HG	North Chads Point	?	(0)	(0)	1	0	1	0	2	2	0	24	0	0	0	0
HG	Moresby Islets	W	(0)	(0)	(0)	(0)	0	3	115	65	2	1	0	0	0	0
HG	Marble Island	W/Y?*	0	(0)	0	0	0	0	0	0	0	1	0	0	67	78
HG	Cone Head	W/Y	(0)	(0)	(0)	(0)	0	70	21	1	131	27	85	97	220	86
HG	Tian Islets	Y*	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	273
HG	Joseph Rocks	Y	408	(391)	399	366	309	327	397	601	696	770	(511)	339	249	187
HG	Langara Island & Rocks	W/Y	6	(3)	0	3	3	(2)	0	217	3	484	(218)	98	337	527
	HG Subtotal	**-**	**1329**	**1433**	**1548**	**1265**	**2123**	**2117**	**2683**	**2509**	**2977**	**3505**	**3019**	**3112**	**3862**	**3771**
	NORTHERN BC	**-**	**2313**	**2485**	**2617**	**2327**	**2994**	**3624**	**4081**	**4567**	**5637**	**7500**	**6918**	**7677**	**10193**	**11581**
	Miscellaneous	-	0	0	0	1	0	3	0	0	0	0	0	7	5	0
	TOTAL COUNT BC	**-**	**4853**	**4643**	**5219**	**4726**	**6122**	**7378**	**8104**	**9818**	**12122**	**15721**	**15061**	**18029**	**22135**	**25113**

[1] Site name used in Olesiuk 2018

[2] Referred to as Bonilla #2 in Olesiuk 2018

Table 2. Number of Steller Sea Lion pups counted during province-wide breeding season surveys during 1971–2017. Greyed counts in square brackets show number of pups counted prior to the site attaining rookery status (n>50 pups).

Site Name	Region	1971	1973	1977	1982	1987	1992	1994	1998	2002	2006	2008	2010	2013	2017
Beresford Island (Maggot Island)[1]	SI	174	188	147	171	180	107	76	72	77	62	36	56	54	48
Sartine Island	SI	163	273	309	409	176	253	62	148	146	178	101	104	140	215
Triangle Island	SI	181	189	140	185	305	476	630	1221	2199	2674	2550	3776	4106	3734
Virgin & Pearl Rocks[2]	CMC	[0]	[0]	[0]	[1]	[2]	[0]	[0]	[0]	[0]	55	100	155	268	490
Gosling Rocks	CMC	[0]	[(0)]	[0]	[1]	[0]	[0]	[0]	[0]	[2]	[0]	[14]	[26]	122	280
North Danger Rocks	NMC	86	93	64	74	54	148	85	144	219	403	216	272	374	294
Bonilla Island	NMC	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[4]	[17]	[19]	55	188
Warrior Rocks	NMC	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[2]	[22]	[11]	[28]	93
Cape Saint James	HG	337	272	303	404	367	484	333	488	635	723	900	846	825	633
Garcin Rocks	HG	-	-	-	-	-	-	-	-	[2]	[12]	104	217	315	477
Joyce Rocks	HG	-	-	-	-	-	-	-	-	-	-	-	-	[5]	122
Other Haulouts	-	0	0	0	0	0	0	0	0	1	7	29	14	25	66[3]
Total Count BC	**-**	**941**	**1015**	**963**	**1245**	**1084**	**1468**	**1186**	**2073**	**3281**	**4118**	**4067**	**5485**	**6317**	**6640**

[1] Site name used in Olesiuk 2018

[2] 39 pups from Pearl Rocks were added to the counts at nearby Virgin Rocks as per Olesiuk 2018

[3] Pups were counted at Perez Rocks (27), Long Beach Rocks (13), Barrier Reefs (9), Mara Rocks (9), McInnes Island (2), and Tian Rocks (4)

Table 3. Number of Steller Sea Lions counted during fall and winter surveys in 2016-17 with pooled regional and BC totals. Sites were classified as rookeries (R), year-round haulouts (Y), or winter haulouts (W). Sites at which designation changed since the last survey are highlighted in grey and marked with an asterisk; those with an question mark indicate sites with limited observations requiring further data to confirm reclassification. Counts include swimmers associated with known haulout sites (Note: swimmers are removed for abundance estimation). Pups could not be reliably differentiated in winter survey photos and are included in the total count.

Region	Site Name	Site Type	26–30 Oct 2016			31 Jan–7 Feb 2017
			NPs	Pups	Total	Total
SOG	Race Rocks	W	407	29	**436**	**27**
SOG	Discovery Islands	W*	0	0	**0**	**6**
SOG	Cowichan Bay	W	37	0	**37**	**0**
SOG	Tumbo & Boiling Point Reefs	W	1	0	**1**	**0**
SOG	Belle Chain	W	312	5	**317**	**109**
SOG	Active Pass & Helen Point	W	0	0	**0**	**31**
SOG	Canoe Islets	W	8	0	**8**	**620**
SOG	Northeast Valdez Island	W	160	7	**167**	**398**
SOG	Harmac Logbooms	W	0	0	**0**	**5**
SOG	Entrance Island	W	0	0	**0**	**37**
SOG	Winchelsea & Ada Island	W	0	0	**0**	**125**
SOG	Northwest Bay Logbooms	W	ns	ns	ns	**17**
SOG	White Islets	W	77	0	**77**	**36**
SOG	Norris & Heron Rocks	W	470	53	**523**	**869**
SOG	Flora Islet	W	226	10	**236**	**316**
SOG	Southeast Jedediah Island	W	9	0	**9**	**13**
SOG	McRae Islets & Scotch Fir Point	W/Y*	207	7	**214**	**645**
SOG	North Union Point Logbooms	W	9	0	**9**	**0**
SOG	Mouat & Texada Islands	W*	0	0	**0**	**183**
SOG	Favada Point	W	17	0	**17**	**55**
SOG	Vivian Island	W/Y*	367	22	**389**	**28**
SOG	Mittlenatch Island	W/Y?*	86	12	**98**	**24**
SOG	Major Islet	W/Y?*	94	0	**94**	**18**
SOG	Centre Islet	W	1	0	**1**	**2**
JQCS	North Bluff	W	0	0	**0**	**15**
JQCS	Jimmy Judd Reef & Stuart Island	W	29	0	**29**	**59**
JQCS	Helmken Island	W	16	0	**16**	**0**
JQCS	Plumper & Stubbs Islands	W	213	2	**215**	**14**
JQCS	Northeast Hanson Island	W	122	0	**122**	**78**
JQCS	Screen Island (West Eden Island)[1]	Y	85	11	**96**	**233**
JQCS	Southeast Gordon Islands	W	23	0	**23**	**104**
JQCS	Echo Islands	W	9	27	**36**	**0**
JQCS	Millar Group	Y	546	160	**706**	**219**
JQCS	Buckle Group	Y	798	132	**930**	**31**
JQCS	Ashby Point	Y	1093	483	**1576**	**97**

Region	Site Name	Site Type	26–30 Oct 2016			31 Jan–7 Feb 2017
			NPs	Pups	Total	Total
JQCS	Pine & Tree Islands	W	77	1	**78**	**0**
WCVI	Sombrio Point	W	173	6	**179**	**96**
WCVI	Carmanah Point	Y	310	0	**310**	**304**
WCVI	Nitinat River Mouth	W*	200	0	**200**	**0**
WCVI	Pachena Point	Y	1795	152	**1947**	**818**
WCVI	Seabird Rocks	W	321	30	**351**	**0**
WCVI	Folger Island	W/Y?*	67	1	**68**	**0**
WCVI	Wouwer & Batley Islands	Y	199	48	**247**	**614**
WCVI	Mara Rock & Starlight Reef	Y	31	3	**34**	**0**
WCVI	George Fraser	W	0	0	**0**	**27**
WCVI	Florencia Islet & South Wya Point	W	10	0	**10**	**654**
WCVI	Long Beach Rocks	Y	19	0	**19**	**352**
WCVI	Berryman Point	W	0	0	**0**	**0**
WCVI	Plover Reefs & Cleland Island	Y	399	57	**456**	**0**
WCVI	North Raphael Point	W	40	0	**40**	**650**
WCVI	Perez Rocks	Y	1731	447	**2178**	**181**
WCVI	Escalante Point	W	10	0	**10**	**388**
WCVI	Bajo Point and Reefs	W	0	0	**0**	**7**
WCVI	Ferrer Point	W	59	0	**59**	**282**
WCVI	Esperanza Inlet Reefs	W	14	0	**14**	**0**
WCVI	Rosa Island	W	64	0	**64**	**0**
WCVI	Barrier Islands	Y	826	135	**961**	**400**
WCVI	O'Leary Islets	W	569	178	**747**	**294**
WCVI	Solander Island	Y	209	5	**214**	**262**
WCVI	Rowley Reefs	W	7	0	**7**	**610**
WCVI	Cape Scott	W	263	0	**263**	**47**
SI	Beresford Island (Maggot Island)[1]	R	415	82	**497**	**150**
SI	Sartine Island	R	66	1	**67**	**195**
SI	Triangle Island	R	1513	1177	**2690**	**663**
CMC	Virgin Rocks	R	695	265	**960**	**398**
CMC	Pearl Rocks	Y	359	136	**495**	**0**
CMC	Dugout Rocks	W	332	133	**465**	**142**
CMC	Blenheim Island	Y	203	123	**326**	**51**
CMC	Gosling Rocks	R	2024	641	**2665**	**728**
CMC	McInnes Island	Y	363	151	**514**	**335**
NMC	Steele Rock	Y	198	68	**266**	**391**
NMC	Lindsay Rocks	W	0	0	**0**	**0**
NMC	Isnor Rock & McKenney Island	Y	284	85	**369**	**159**
NMC	Ashdown Island	W/Y*	431	85	**516**	**230**
NMC	MacDonald Island	W	34	2	**36**	**169**
NMC	Joseph Island	W	260	28	**288**	**251**

Region	Site Name	Site Type	26–30 Oct 2016			31 Jan–7 Feb 2017
			NPs	Pups	Total	Total
NMC	North Danger Rocks	R	129	81	**210**	**208**
NMC	Bonilla Island	Y/R	122	349	**471**	**392**
NMC	Northwest Rocks (Bonilla #2)[1]	W/Y*	21	143	**164**	**410**
NMC	Joachim & Cape George Rocks	W	191	0	**191**	**226**
NMC	Warrior Rocks	Y/R*	444	191	**635**	**468**
NMC	Roland Rocks	W	374	86	**460**	**613**
NMC	Connel Islands (S Chearnley)[1]	W	179	15	**194**	**398**
NMC	Chearnley Islet	Y	928	162	**1090**	**690**
NMC	Zayas Island	W	92	11	**103**	**0**
HG	Rose Spit	Y	0	0	**0**	**0**
HG	Cumshewa Island and Rocks	W	24	11	**35**	**0**
HG	Skedans Island	W	302	71	**373**	**262**
HG	Tuft & Tar Islets	W*	15	0	**15**	**22**
HG	All-Alone-Stone	W	0	0	**0**	**22**
HG	Reef Island	Y	241	72	**313**	**224**
HG	Helmet Island	W	340	50	**390**	**266**
HG	Tatsung Rock	Y	381	18	**399**	**622**
HG	Scudder Point	W	0	0	**0**	**0**
HG	Joyce Rocks	Y/R*	136	107	**243**	**354**
HG	Garcin Rocks	R	286	282	**568**	**200**
HG	Cape Saint James	R	242	98	**340**	**100**
HG	Anthony Island	Y	87	17	**104**	**0**
HG	South McLean Fraser Point	W	0	0	**0**	**151**
HG	South Nangwai Islands (Gowgaia)[1]	W	0	0	**0**	**18**
HG	South Tasu Head	Y	0	0	**0**	**118**
HG	Kootenay Inlet	W	0	0	**0**	**0**
HG	Moresby Islets	W	0	0	**0**	**90**
HG	Marble Island	W/Y?*	0	0	**0**	**121**
HG	Kindakun Point	W	0	0	**0**	**312**
HG	Cone Head	Y	0	0	**0**	**0**
HG	Hippa Island	W	84	19	**103**	**289**
HG	Tian Islets	Y*	135	42	**177**	**357**
HG	Joseph Rocks	Y	0	0	**0**	**14**
HG	Sadler Point	W	66	15	**81**	**0**
HG	Langara Island & Rocks	Y	325	134	**459**	**323**
HG	Northwest Cape Naden	W	130	11	**141**	**79**

[1] Site name used in Olesiuk 2018

Table 4. The number of parameters in the model (k), log-likelihood (loglike), Akaike's information criterion corrected for small sample sizes (AIC_c), AIC_c differences (∆i), and Akaike weights (w_i) for candidate models (exponential, polynomial and logistic) of Steller Sea Lion survey counts by year. Model sets are presented for three counts (pups, non-pups and total counts) in ascending order of the change in Akaike's information criterion (∆i), with the lowest value being the best fit to the data.

Steller counts	Model	k	loglike	AIC_c	∆ i	w_i
Pups	logistic	4	-96.83	211.17	0	0.82
	polynomial	3	-101.1	214.65	3.48	0.14
	exponential	2	-104.66	217.73	6.56	0.03
Non-pups	polynomial	3	-113.43	239.31	0	0.75
	logistic	4	-112.06	241.62	2.32	0.24
	exponential	2	-119.78	247.97	8.66	0.01
Total	polynomial	3	-113.43	239.31	0	0.75
	logistic	4	-112.06	241.62	2.32	0.24
	exponential	2	-119.78	247.97	8.66	0.01

8. FIGURES

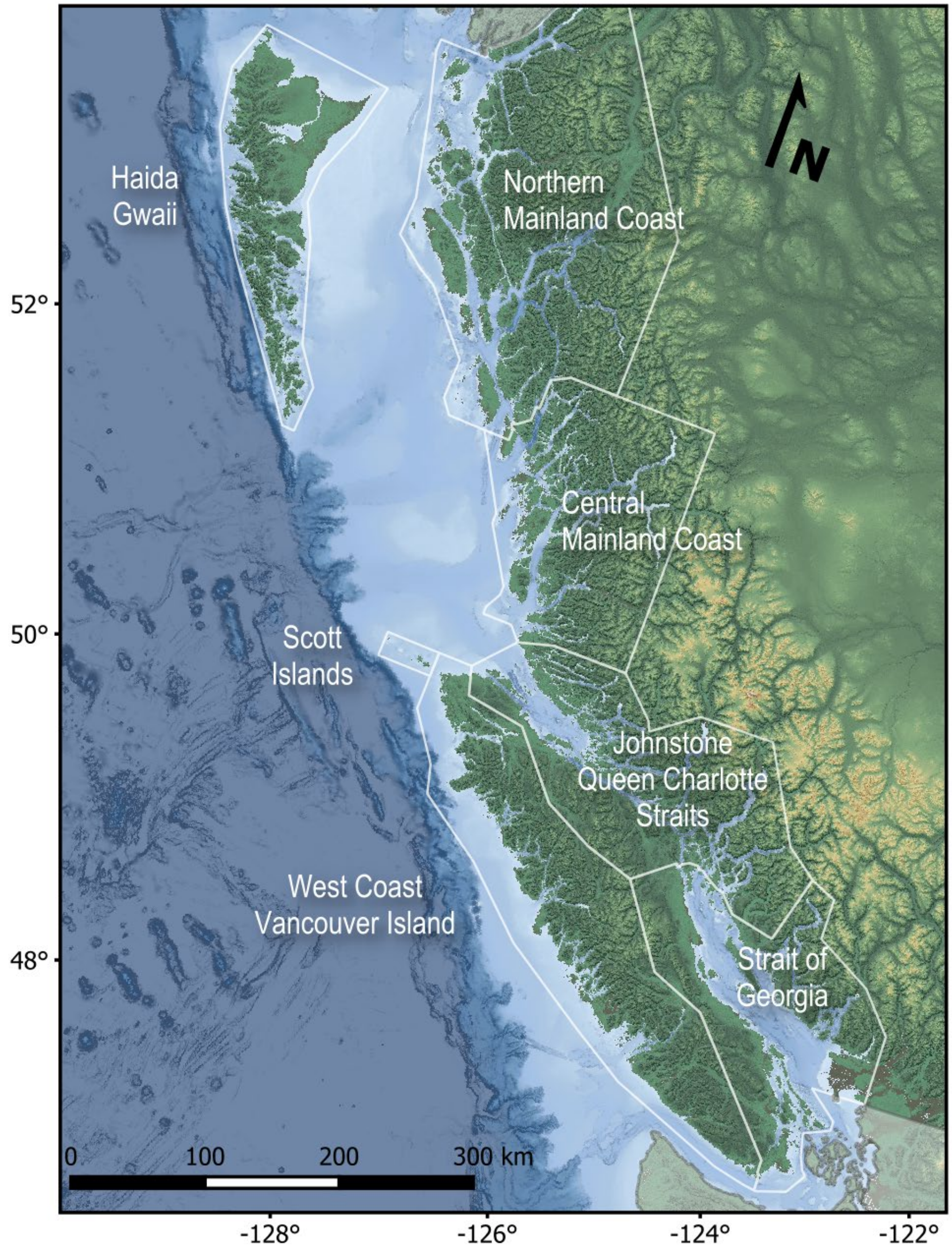

Figure 1. Map showing regional designations used for 2016-17 Steller Sea Lion surveys in British Columbia (BC).

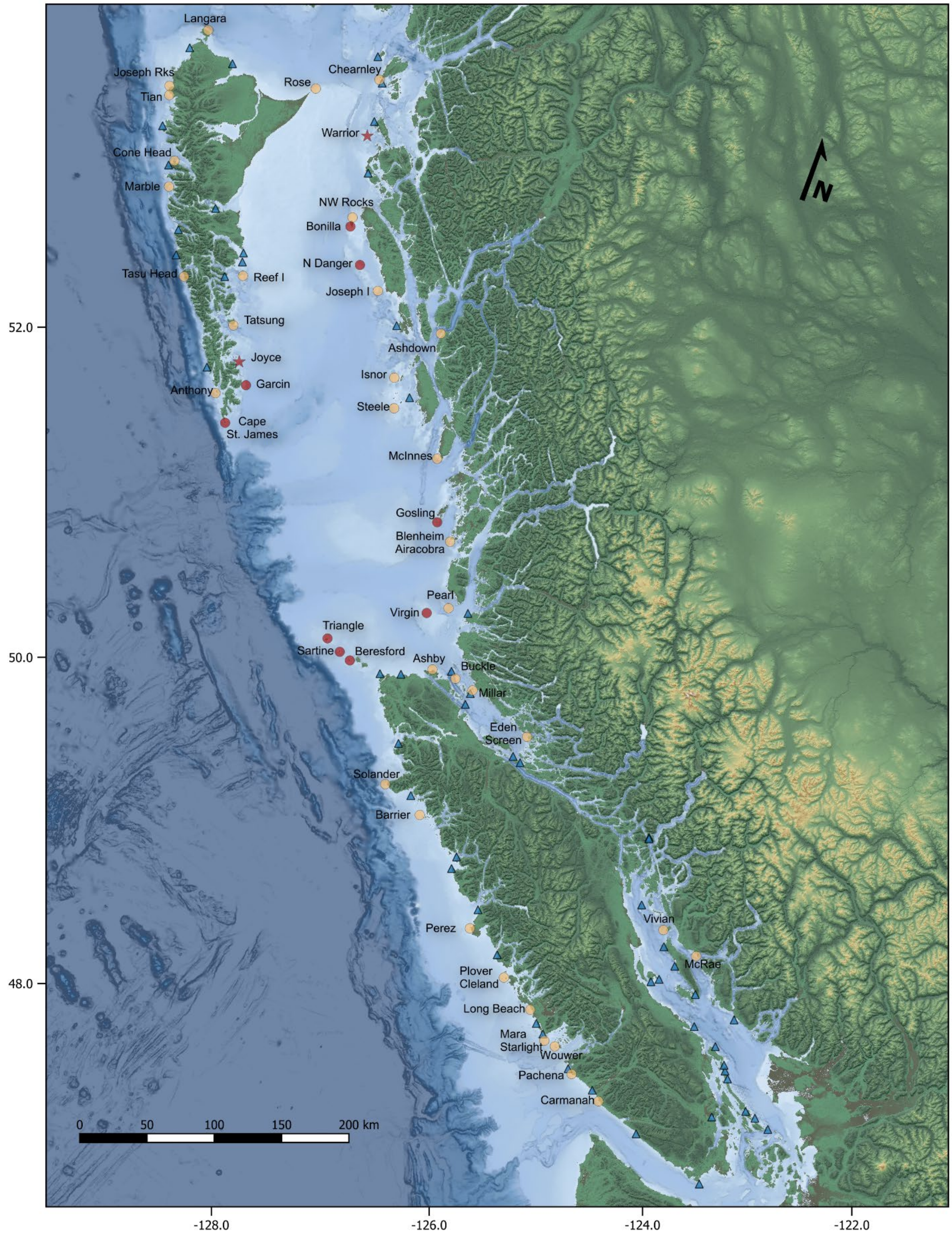

Figure 2. Map showing location of Steller Sea Lion breeding rookeries (red circle), new rookeries observed in 2017 (red star), year-round haulout sites (yellow circle), and major winter haulout sites (blue triangle) in British Columbia (BC).

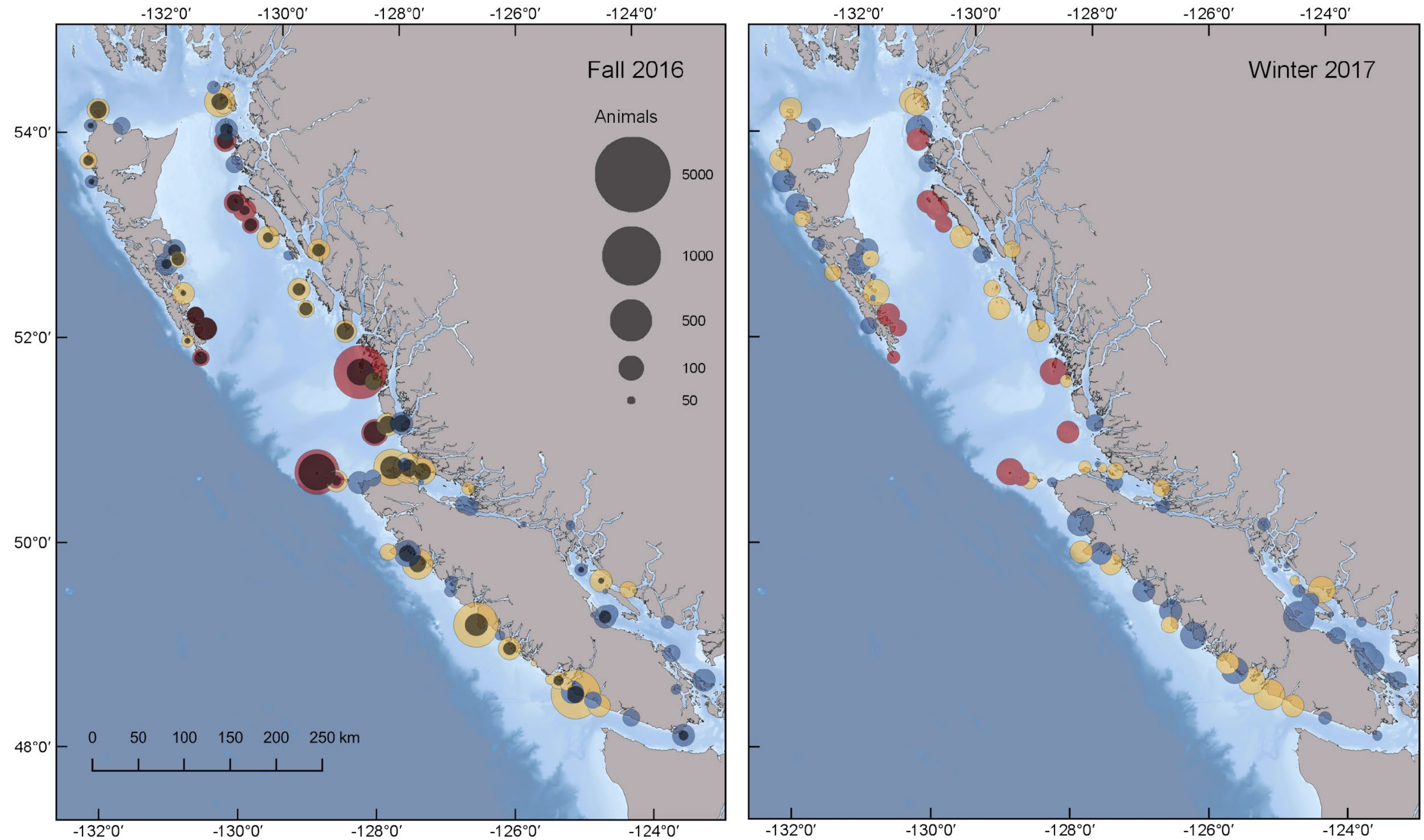

Figure 3a. Maps showing seasonal changes in distribution of Steller Sea Lion counts between surveys conducted fall 2016 (left) and winter 2017 (right). Symbol sizes are proportional to the total number of animals (pups and non-pups) counted at each site. Black inner circles indicate the number of pups at each site in the fall surveys (pups had moulted and could no longer be distinguished from older animals in winter surveys). Red symbols denote rookeries, orange symbols year-round haul-outs, and blue symbols winter haulouts.

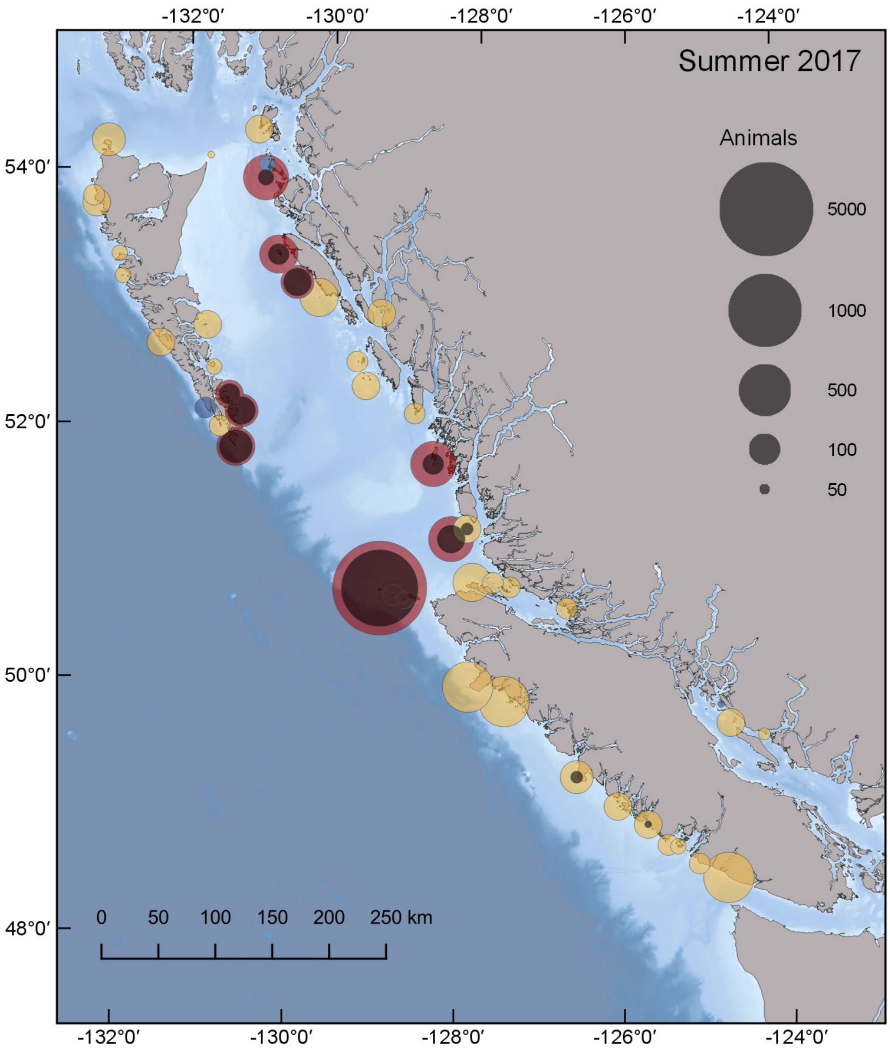

Figure 3b. Map showing distribution of Steller Sea Lions based on counts from the summer 2017 breeding season survey. Symbol sizes are proportional to the total number of animals (pups and non-pups) counted at each site. Black inner circles indicate the number of pups at each site.. Red symbols denote rookeries, orange symbols year-round haul-outs, and blue symbols winter haulouts.

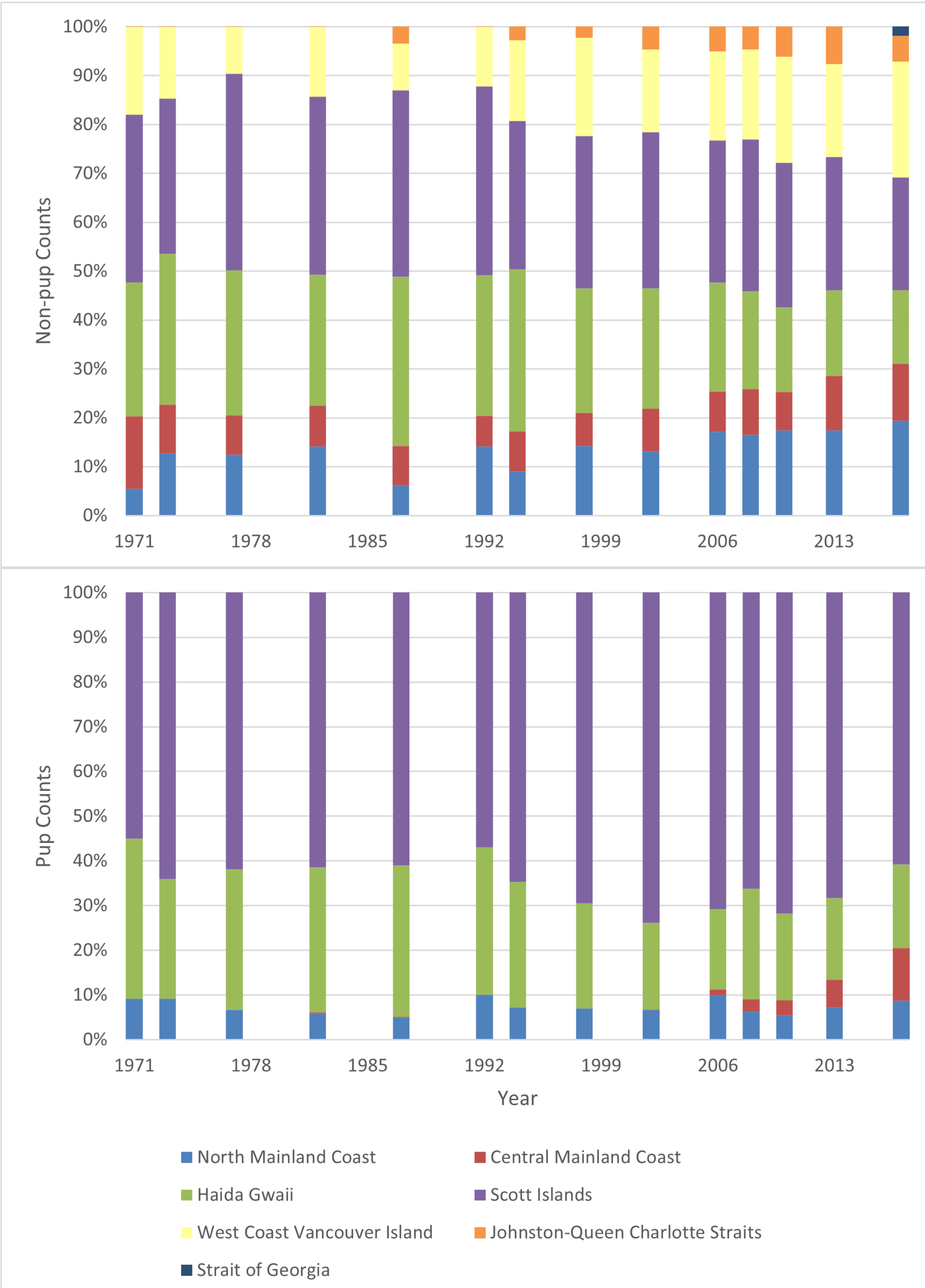

Figure 4. Proportion of counts of non-pups (top) and pups (bottom) on haulouts by region during province-wide aerial surveys 1971–2017.

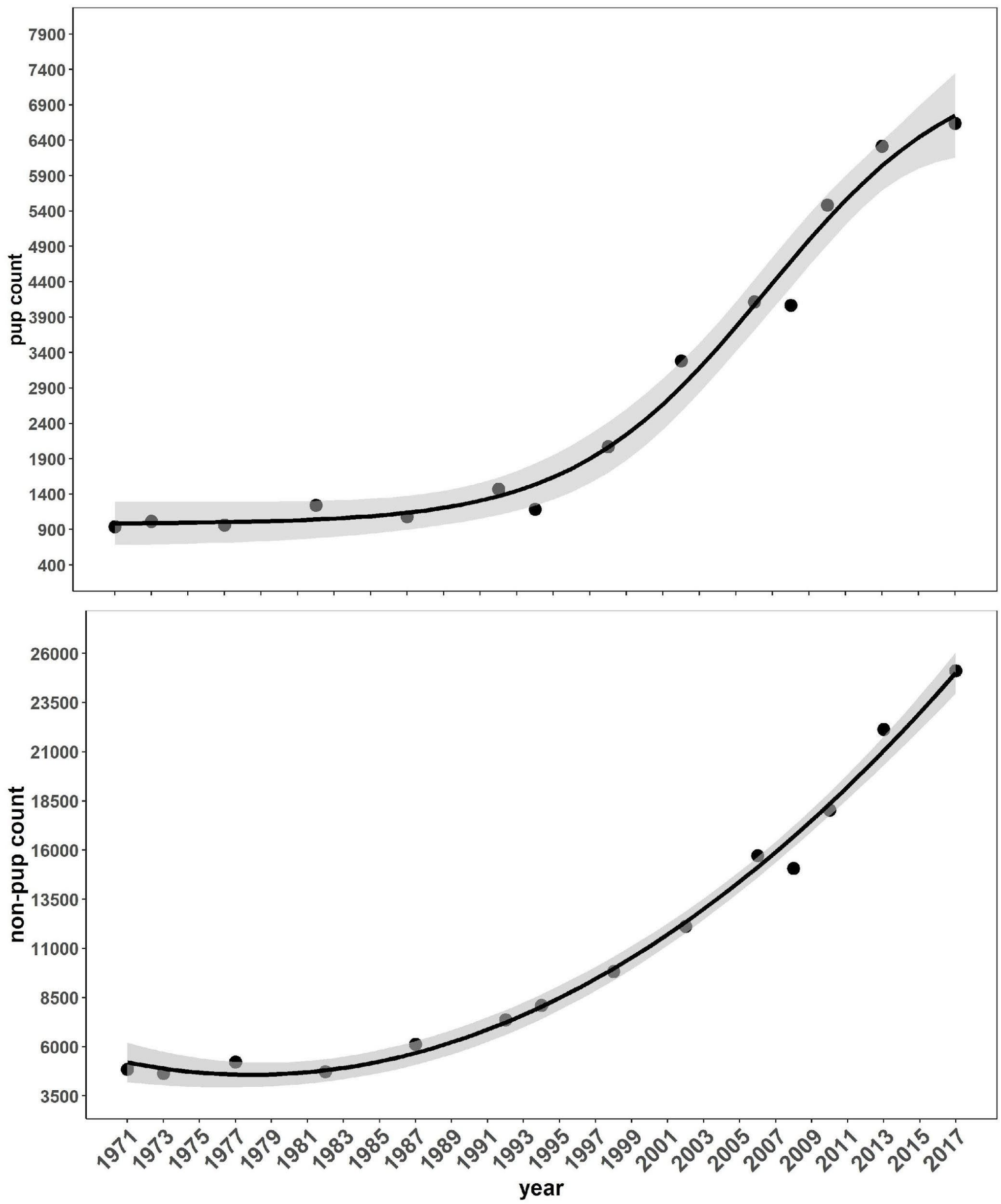

Figure 5. Recent trends in the number of pups (top panel) and non-pups (bottom panel) based on breeding season aerial surveys, 1971–2017. Black lines and shading denote the logistic model fit to pup counts (top panel) and the polynomial model fit for non-pup counts (bottom panel). Grey shading denotes 95% confidence intervals.

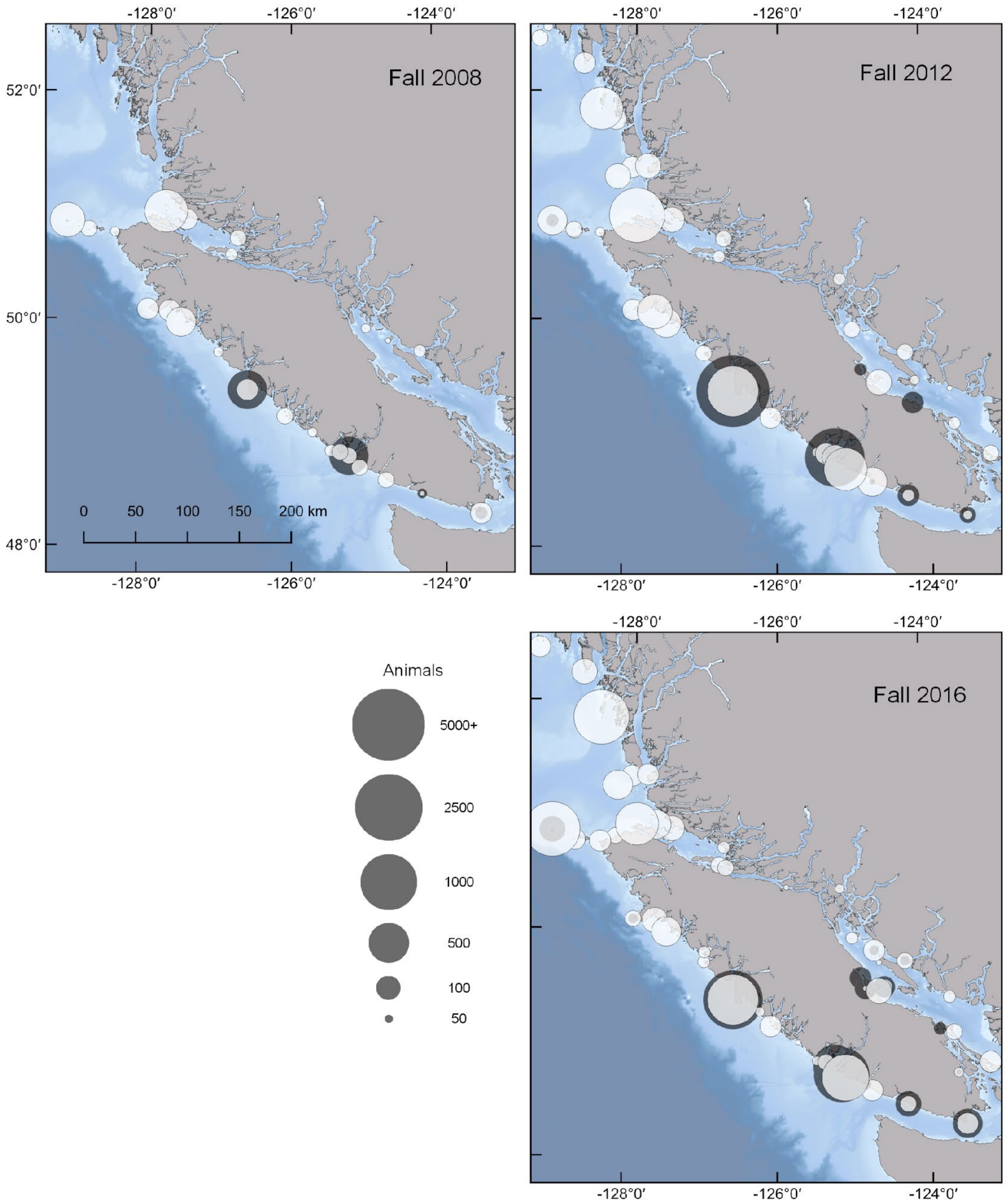

Figure 6. Changes in distribution of Steller Sea Lions (white circles) and California Sea Lions (dark grey circles) counted on haulouts in southern BC during fall surveys flown in 2008, 2012 and 2016. Symbol sizes are proportional to the total number of animals (pups and non-pups) counted at each site. (Note that the Central Mainland Coast was not surveyed in fall 2008).