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Recent Trends in Abundance of Steller Sea Lions (*Eumetopias jubatus*) in British Columbia

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Canada

Foreword

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ABSTRACT

Recent trends in the abundance of Steller sea lions (*Eumetopias jubatus*) in British Columbia were assessed based on a series of 13 province-wide aerial surveys conducted during the summer breeding season (27-June to 09-July) between 1971 and 2013. Numbers of non-pups (juveniles and adults) 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, with most of the increase occurring since the mid-1980s. A review of historic counts for rookeries indicated that control programs and commercial harvests in B.C. from 1912 to 1967 eradicated one breeding site and reduced numbers on the remaining rookeries to about 25-30% of the peak levels observed in the early 1900s. During the most recent province-wide survey in 2013, 6,317 pups and 22,135 non-pups (10,969 on rookeries and 11,166 on haulouts) were counted. Applying correction factors to account for pups missed during surveys or obscured in oblique 35mm photographs, total pup production in B.C. was estimated to be about 7,300 pups. Based on life tables with adjustments for higher survival and reproductive rates in an increasing population, it was estimated that pup production on B.C. rookeries in 2013 would indicate a total population of about 32,900 (range 31,200 to 33,900) animals. Based on the distribution of non-pups observed during the 2013 survey, an estimated 35,600 (range 33,800 to 36,700) sea lions currently inhabit the coastal waters of B.C. during the summer breeding season. A second abundance estimate was made using survey correction factors based on satellite telemetry data, which indicated that about 67% of non-pups would be hauled out during summer surveys. Adjusting for the 33% of animals that were at sea and missed during summer surveys, it was estimated that 39,200 (95% confidence interval 33,600 to 44,800) animals inhabit coastal waters of B.C. during the breeding season. An average of 17,679 animals were counted during winter surveys conducted in B.C. during 2009 and 2010. Satellite telemetry indicated that only about 37% of animals (53% of yearlings and 33% of older animals) would be hauled out during daylight hours in winter. Adjusting for animals at sea during winter surveys, an estimated 48,500 (95% CI 38,100 to 58,900) Steller sea lions winter in coastal waters of B.C. The higher winter count suggests there is net immigration of sea lions into B.C. during the non-breeding season. Steller sea lions in California and Oregon are displaced northward by migrating California sea lions after the breeding season, and some animals dispersing from the large rookery on Forrester Island just north of the BC-Alaska border probably winter in B.C.

Les tendances récentes de l'abondance de l'otarie de Steller (*Eumetopias jubatus*) en Colombie-Britannique

RÉSUMÉ

Les tendances récentes de l'abondance de l'otarie de Steller (*Eumetopias jubatus*) en Colombie-Britannique ont été évaluées à partir d'une série de 13 relevés aériens menés à l'échelle de la province pendant la saison de reproduction (du 27 juin au 9 juillet) entre 1971 et 2013. Le nombre de juvéniles et d'adultes s'est accru à un taux moyen de 3,8 % par année, tandis que la production de petits a augmenté à un taux de 4,8 % par année pendant la période d'étude, ce qui représente une multiplication par quatre de l'abondance depuis que l'espèce a été protégée en 1970. La plus grande partie de cette augmentation et intervenue depuis le milieu des années 1980. Un examen des dénombrements historiques effectués aux roqueries révèle que les programmes d'abattage et la chasse commerciale menés en C.-B. de 1912 à 1967 ont entraîné la disparition d'un site de reproduction et ont réduit le nombre d'individus observés aux roqueries restantes à environ 25 à 30 % des niveaux maximaux observés au début des années 1900. Au cours du dernier relevé mené à l'échelle de la province, en 2013, nous avons dénombré 6 317 petits et 22 135 juvéniles et adultes (10 969 individus aux roqueries et 11 166 individus aux échoueries). L'application des facteurs de correction pour tenir compte des petits qui n'ont pas été dénombrés pendant les relevés ou masqués sur les photographies obliques de 35 mm a donné une estimation de la production totale de petits en C.-B. d'environ 7 300 petits. À partir des tables de survie avec ajustement en fonction de taux de survie et de reproduction plus élevés dans une population croissante, il a été estimé que la production de petits dans les roqueries de la C.-B. en 2103 dénote une population totale d'environ 32 900 (fourchette de 31 200 à 33 900) animaux. Compte tenu de la répartition des juvéniles et des adultes observée pendant le relevé de 2013, on estime que 35 600 (fourchette de 33 800 à 36 700) lions de mer vivent actuellement dans les eaux côtières de la C.-B. pendant la saison de reproduction estivale. Selon une deuxième estimation de l'abondance, élaborée à l'aide des facteurs de correction des relevés fondés sur les données de suivi télémétrique par satellite, environ 67 % des juvéniles et des adultes se trouveraient dans les échoueries pendant les relevés estivaux. Avec l'ajustement pour tenir compte des 33 % d'animaux qui étaient dans l'eau et non dénombrés pendant les relevés estivaux, cette méthode permet d'estimer à 39 200 individus (intervalle de confiance de 95 % de 33 600 à 44 800) vivant dans les eaux côtières de la C.-B. pendant la saison de reproduction. En moyenne, 17 679 animaux ont été recensés pendant les relevés hivernaux effectués en C.-B. entre 2009 et 2010. Le suivi télémétrique par satellite a indiqué que seulement 37 % environ des animaux (53 % des yearlings et 33 % d'animaux plus âgés) seraient présents aux échoueries pendant le jour en hiver. Avec l'ajustement pour tenir compte des animaux qui étaient dans l'eau pendant les relevés hivernaux, on estime à 48 500 individus (intervalle de confiance de 95 % de 38 100 à 58 900) vivant dans les eaux côtières de la C.-B. pendant l'hiver. Le nombre plus élevé en hiver laisse penser qu'il existe une immigration nette de lions de mer en C.-B. pendant la saison autre que la saison de reproduction. Les otaries de Steller de la Californie et de l'Oregon sont repoussées vers le nord par les lions de mer qui migrent de la Californie après la saison de reproduction et certains animaux dispersés de la grande roquerie située sur l'île Forrester, juste au nord de la frontière entre la C.-B. et l'Alaska, passent probablement l'hiver en C.-B.

1 INTRODUCTION

Steller sea lions (*Eumetopias jubatus*) range along the North Pacific Rim from northern Japan to the Kuril Islands, Sea of Okhotsk and Kamchatka Peninsula, west through the Bering Sea and Gulf of Alaska, and south along the continental shelf as far as central California (Kenyon and Rice 1961; Loughlin et al. 1984, 1992; Burkanov and Loughlin 2005). Two distinct populations are recognized based on genetic differences (Bickham et al. 1996, 1998a, 1998b; Ream 2002; Baker et al. 2005) and phylogeographic patterns (Loughlin 1997). The western stock breeds on the Kuril and Commander Islands, Kamchatka Peninsula, and Sea of Okhotsk in Russia, and on the Aleutian and Pribilof Islands and Gulf of Alaska as far west as Cape Suckling (144°W) in Alaska (Burkanov and Loughlin 2005). The eastern stock breeds in Southeast Alaska, British Columbia, Oregon and north-central California (Pitcher et al. 2007). The western stock, having declined by about 80% since the 1970s (Merrick et al. 1987; Loughlin et al. 1992; Trites and Larkin 1996; Loughlin 1998; NMFS 2008), is currently listed in the U.S. as *Endangered* under the Endangered Species Act, and has been the focus of much research in recent years (NMFS 2008). In contrast, the eastern stock appears to be increasing over most of its range (Calkins et al. 1999; Brown et al. 2002; Pitcher et al. 2007; Olesiuk 2008; NMFS 2013). In the U.S., the eastern stock had previously been listed as *Threatened* due to concerns that the declines – which were first observed in the eastern Aleutian Islands and spread to the Gulf of Alaska (Braham et al. 1980) – may continue spreading eastward and because there was some uncertainty at the time regarding the genetic division of stocks. However, the decreases never spread to the eastern stock and the genetic segregation of the two populations was reaffirmed. As a result, the U.S. recently delisted the eastern stock. In Canada, COSEWIC originally concluded Steller sea lions were *Not at Risk* (Bigg 1987, 1988), but more recent assessments in 2003 and 2013 recommended the species be designated as *Special Concern* under the Species at Risk Act (COSEWIC 2003, 2013). The re-designation was based on the limited number of breeding sites in Canadian waters, and because the species is sensitive to human disturbance while on land and vulnerable to catastrophic events such as major oil spills due to its highly concentrated breeding aggregations.

Aerial surveys have been regularly conducted during the summer breeding season to monitor Steller sea lion populations in British Columbia since the early 1970s. Bigg (1984, 1985) compiled and examined historic records of kills and counts, and analyzed trends from aerial survey data up to 1982. He concluded that the control programs and commercial harvests had reduced populations to approximately one-quarter to one-third of the peak historic levels that occurred in the early 1900s, but that abundance had remained stable since being protected in 1970. He estimated that counts on rookeries between 1971 and 1982 averaged about 3,800 (including pups), with an additional 1,900 animals on year-round haulouts. This compares with 11,000-14,000 animals on rookeries when the first studies in B.C. were initiated in 1913 (Newcombe and Newcombe 1914; Newcombe et al. 1918; Bigg 1985). Olesiuk et al. (1993) analyzed survey data for Haida Gwaii (Queen Charlotte Islands) up to 1992, and reported that both pup production and total abundance was slowly increasing at rates of 2.4% and 2.1% respectively. Olesiuk (2008) extended those analyses to the entire B.C. coast based on survey data up to 2006 and concluded that both pup production and total abundance was increasing at a rate of 3.2% per annum and that in both cases the rate of increase appeared to have accelerated since the 1980s. Pitcher et al. (2007) compiled information for the entire eastern stock up to 2002 and concluded that Steller sea lions were increasing at similar rates of 2.5% per annum in Oregon and 3.2% per annum in SE Alaska.

As recommended in DFO’s Steller sea lion management plan (Fisheries and Oceans Canada 2010), province-wide Steller sea lion surveys were conducted in 2008, 2010 and 2013. Following Olesiuk (2008), the recent survey data are used to analyze trends in pup production and total number of animals at haulouts and on rookeries. Historic and recent information on sea lion abundance in neighbouring waters, particularly the large rookery at Forrester Island in SE Alaska, are also reviewed to assess broader regional trends. The size of the breeding population that would be necessary to support observed pup production on B.C. rookeries is estimated based on life table statistics (Calkins and Pitcher 1982) adjusted for an expanding population (Pitcher et al. 2007; Pendelton et al. 2006). Satellite telemetry data are used to assess diurnal and seasonal haulout patterns, from which survey correction factors are derived to account for animals that are at sea and missed during surveys. Results of winter surveys conducted in B.C. during 2009 and 2010, and an autumn survey in 2012, are presented and the data used to assess abundance and movement patterns of Steller sea lions in B.C. outside the summer breeding season.

2 METHODS

2.1 SITE CLASSIFICATION

Following Bigg (1985), 3 distinct categories of Steller sea lion haulout sites were recognized:

1. rookeries;
2. year-round haulout sites; and
3. winter haulout sites (Figure 1).

All available information on the occurrence of sea lions at specific locations was used to categorize sites. This included not only data from the systematic aerial surveys presented in this report, but also opportunistic observations made by the author during seal surveys and other field studies, as well as anecdotal records and unpublished sightings provided by other researchers, lighthouse keepers, mariners, parks staff, fishing lodges, naturalists, and the general public.

Rookeries are situated the farthest from landmasses, and generally are the most exposed to ocean swells. The vast majority (>98%) of births and most breeding activity occurs at rookeries. Pitcher et al. (2007) arbitrarily defined rookeries as locations where 50 or more births had occurred in their assessment of the eastern Steller sea lion stock, and the same definition has been adopted for this assessment. Some non-breeding animals occupy rookeries throughout the year, but there is a distinct seasonal peak in utilization during the June-August breeding season (Bigg 1985). Social structure is well developed in the areas where pupping and mating occurs (Edie 1977), but there are typically aggregations of non-breeding animals and scattered adult males (bulls) on the periphery of breeding areas or on adjacent islands. In many cases, there may be multiple breeding sites located on the same or neighbouring islands separated by up to several tens of kilometers, 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 haulouts. These sites tend to be situated along the outer coast and exposed to ocean swells, but unlike rookeries are often close to land masses. Animals are present in all months, with no marked seasonal variation in abundance (Bigg 1985). The predictable presence of animals throughout the year, particularly during the June-July breeding season, is characteristic of year-round haulouts. A few births may occur at year-round haulouts, but they are assumed to account for only a small proportion (<2%) of total pup production.

Steller sea lions also use many additional sites intermittently on a seasonal basis. These can be located in exposed locations, as well as in sheltered inlets and channels and sometimes even up rivers. Sites in exposed locations are generally not directly exposed to ocean swells, but rather are sheltered to some extent by the surrounding topography, such as in a bay or on a leeward side of an island. The main period of occupancy is during winter months, but a few animals can also be present sporadically during May-August. Occupancy can be continuous or intermittent during winter months. The absence of animals, the presence of only a few animals, or the intermittent use during June-July characterizes these sites, referred to as winter haulouts. The location and timing of use of winter haulouts often appears to be related to the seasonal availability of prey resources, such as migrations or spawning aggregations of local fish stocks.

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. These tend to occur more in inshore waters during the winter, particularly used by California sea lions (*Zalophus californianus*), and were thus not often observed during summer breeding season surveys. However, we occasionally observed animals swimming or rafting adjacent to haulout sites, especially low-lying sites when there was a large oceanic swell. Counts of swimming or rafting animals observed during the surveys were added to adjacent haulout sites or tabulated as miscellaneous.

2.2 SURVEY PROCEDURES

Aerial surveys were conducted by 1-3 observers from a *DeHavilland* Beaver or *Cessna* 180 floatplane flown at an altitude of 150-200 meters and airspeed of 125 $km{\cdot}hr^{-1}$. In order to ensure consistency of the time-series, the author participated in all surveys since 1982, and all surveys up to 1987 were conducted by the late Dr. Michael Bigg. The 1982 and 1987 surveys were flown together. During the aerial censuses, all rookeries were surveyed and we attempted to check all known year-round haulouts, and as many winter haulouts 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, but coverage of the coastline was by no means complete[1].

Visual counts were made of swimming animals and small groups (<5-10) of animals on land. Larger groups were generally photographed with a hand-held 35mm single lens reflex camera equipped with a motor drive and 135-210 mm zoom telephoto lens. Prior to 2006, we used *Kodachrome* 200 ISO slide film which provided greater resolution and warmer contrast, which was especially important for discerning pups on dark substrates. When there was insufficient light to maintain a shutter speed of 1/500th second or less, *Extrachrome* (or in later years *Provia-F*) 400 ISO slide film was used, which, when necessary, was exposed and subsequently push-processed at 800 ISO. Light-meter readings were taken from the ocean surface away from land to prevent anomalous readings caused by the reflection off breaking surf. We tended to slightly over-expose film at rookeries to enhance the visibility of the black pups, especially on darker substrates. Non-pups were generally easy to photograph, but for pups we made a special effort to insure 35mm slides were taken from acute angles and with sufficient magnification for counting pups (see Olesiuk et al. 2008).

The 35mm slides were counted by projecting the image onto white paper using a Prado Leitz projector, which provided superior optics. We began by viewing all passes and selecting the highest quality images. Groups of animals were usually counted from the same pass, so we could use both individual animals and physical landmarks to delineate boundaries between overlapping slides. Generally, counts were made from the center of overlapping frames where possible, where optical distortion was minimal. Non-pups were generally very easy to discern and the counts can be considered as representing essentially the exact number present, although more subjectivity was required in identifying pups. Pups were distinguished on the basis of their darker colour, smaller size and proximity to nursing females. Each pup was

[1]Although shoreline coverage was incomplete during Steller sea lion surveys, the entire shoreline and all possible haulout locations were searched in detail during harbour seal surveys, which were also conducted during June-August and covered 98% of the B.C. coastline (Olesiuk 2010; unpublished data), and any new sea lion haulout sites would have been noted and checked on subsequent sea lion surveys.

marked on the paper with felt pen and the marks tallied once the count was complete. We adopted a “balance-of-probability” approach, 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 quickly going over the slide and marking those that were very clearly pups, and then carefully deliberating over each of those where there was some uncertainty.

In 2006, we began a transition from film to digital photography. Photographs at rookeries and haulout sites were subsequently taken with a 10.2 mega-pixel *Nikon D200* or 16.2 mega-pixel *Nikon* D4 single-lens reflex camera equipped with a *Nikon* AF-S 80-200mm f2.8 lens. Images were stored in RAW format, which offered 12 bits of depth for each of the 3 colour channels (compared with 8 bits for compressed JPEG and TIFF files). Digital images were managed (and if necessary adjusted) in *Aperture 3* on a *MacPro* computer with dual 24” *Dell UltraSharp* LCD monitors featuring high-colour range (i.e. 92% colour gamut compared with 72% on standard LCD monitors), or later on an *iMac* computer with high-resolution retina display. Images were counted in either PhotoShop CS2 using the Reindeer Graphics Image Processing Tool Kit or in PhotoShop CS5 using the built in Count Tool. Following the methodology developed by Withrow (National Marine Mammal Laboratory, Seattle, WA, pers. comm.) and adapted by Olesiuk (2010) for harbour seal surveys, separate layers with unique colours were created for pup counts, non-pup counts, and demarcation lines. To ensure consistency of the photographic time series, especially for pup counts, in 2006 all rookeries were photographed with both film and digital cameras within a few minutes of each. Comparison of the counts from the digital images and photographic slides indicated the two methods provided counts that were statistically indistinguishable from one another (Olesiuk et al. 2008).

To facilitate comparison with previous surveys, the breeding season censuses were conducted under standardized conditions when maximum numbers of animals were expected to be hauled out. The two most important factors were date and time-of-day. Date was especially important for counts of breeding animals and pups on rookeries which, as will be shown, provide the best index and estimates of the total abundance. Throughout their range, Steller sea lions pup from mid-May to early July (Bigg 1985, Pitcher et al. 2001). On average, less than 10% of births have occurred prior to the end of May, and about 95% have occurred by the end of June (Bigg 1985). Moreover, pups are poor swimmers at birth and therefore confined to rookeries for about the first month of life (Sandegren 1970). Censuses were therefore conducted in late June or early July (range June 27th to July 9th), by which time most pups had been born, but before they had begun to disperse from rookeries. Based on the pupping data given in Edie (1977), it was estimated that pupping would have been 98-100% complete at the time of the surveys. Since females give birth within a few days of their arrival on rookeries (Edie 1977), their peak numbers would 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 were hauled out (Withrow 1982).

During 2009-2010, we also conducted a series of winter surveys on the BC coast to document seasonal changes in abundance and distribution. Vancouver Island including the Scott Islands was surveyed on 8-9 February 2009, Haida Gwaii (Queen Charlotte Islands) was surveyed on 20-23 January 2009, northern Vancouver Island was surveyed and the Scott Islands resurveyed on 10 December 2009, and the north-central mainland coast was surveyed and west coast of Vancouver Island resurveyed on 22-24 January 2010. The surveys provided at least one count for all known sea lion sites in B.C., and counts were averaged when replicates were available.

In 2012, a province-wide autumn survey was conducted to document dispersal patterns of breeding females from rookeries, as indicated by the distribution of pups. The survey was conducted 19-25 October, at which time pups were still dependent upon and travelling with their mothers, but had not yet moulted so they could still be distinguished from older age-classes.

The 2013 survey was conducted as part of a coordinated multi-agency survey over the entire range of the eastern stock that was a component of the post-delisting monitoring plan developed by NMFS (2013). NMFS surveyed many of the B.C. sites, including all rookeries except Cape St. James, prior to initiating their surveys in Alaska. The NMFS survey was flown in a NOAA twin Otter aircraft equipped with three high-resolution digital cameras, and two replicate counts were made from the vertical 35mm images by two experienced biologists (Fritz et al. 2013; Fritz, National Marine Mammal Laboratory, Seattle, WA, personal communication). Unfortunately, the NMFS surveys were conducted on 20-22 June, outside the normal window for B.C. surveys, and 8-10 days prior to the DFO survey. It was thus possible that pups were born between the two surveys. This precluded a detailed comparison of the two surveys, but the NMFS counts are presented for completeness.

2.3 TREND ANALYSIS

Since it was not always possible to census all sites due to weather or logistical constraints, some minor adjustments were made to account for animals that may have been present on sites that were not surveyed. The number of animals missed was estimated by linear interpolation between the preceding and proceeding survey counts for the site on a logarithmic scale, or where necessary extrapolating from the first or last survey count for that site. The underlying assumption is that the rate of change was constant over time. This differed from the correction method used by Bigg (1985), who applied the mean count for the site over all years it had been surveyed (1971-1982). The interpolations are considered to be more appropriate because the population was increasing during the latter part of the study period, whereas Bigg (1985) assumed the population was stable. In any event, the corrections had little effect on the overall results because, except for the 1973 survey, surveys tended to be nearly complete (mean=99.0%; range 95.1-100%). The 1973 survey was attempted during a period of persistent fog, and 9 sites projected to account for 31% of the total non-pup count were missed. Nevertheless, counts were adjusted for the missed sites and the 1973 survey data included; the adjusted counts were very similar to preceding survey in 1971 and thus had little influence on the overall trends.

Temporal trends in abundance were assessed by regressing logarithmically transformed counts on time:

$$[1]\ \ln N_t = \ln N_o + rt$$

such that:

$$[2]\ N_t = N_o e^{rt}$$

where N_o and N_t denote the numbers of animals estimated to have been present in 1971 and 2013 respectively (i.e. the beginning and end of the survey time-series), and r the exponential or intrinsic rate of increase over the survey period (Caughley and Birch 1971). The mean finite annual rate of increase, expressed as a percentage, was subsequently calculated as $100 \cdot (1-e^r)$.

Models that allowed for changes in population growth rates were also evaluated. A second-order polynomial was fitted to logarithmically transformed counts:

$$[3]\ \ln N_t = a + b \cdot t + c \cdot t^2$$

This model, generally referred to as a Dynamic Response Assessment, is normally used to test for slowing of growth rates as a result of density dependence (Boveng et al. 1988), but it can also be used to assess whether growth rates are accelerating. The slope of the curve, given by the first derivative, represents the population growth rate at a given point in time, *r(t)*:

$$[4]\ r(t) = b + 2ct$$

Piecewise linear regressions that allowed for an abrupt change in the growth rate were also fitted to the logarithmically transformed counts on time:

$$[5]\ \ln N_t = \ln N_o + r_1 t + r_2 (t-x) Y_t$$

where x represents the year the rate changed, r_1 and r_2 the intrinsic rates of increases before and after the change, and Y_t a dummy variable assigned a value of 0 for all years before and a value of 1 for all years after the abrupt rate change. Whether or not the rate changed and the year in which it changed was determined iteratively by fitting all possible regressions and comparing their relative fit. The goodness-of-fit of regression models was evaluated based on its R-square values after adjusting for the loss of a degree of freedom with each parameter incorporated into the model (SAS Institute 1998).

Due to the potential for trans-boundary movements and redistribution of animals among breeding sites, trends for the combined breeding population on rookeries in B.C. and SE Alaska were also examined. Since the surveys in each jurisdiction were conducted by different agencies, they were not always coordinated to occur in the same years. Abundance for each rookery between surveys was interpolated from the preceding and proceeding survey counts on a logarithmic scale, which assumes the rate of change was constant between surveys. For each year that surveys were conducted in one or both regions, the total combined abundance based on the survey counts and, if necessary, the interpolated estimates for sites not surveyed, was estimated. In fitting trends, incomplete survey coverage was accounted for by weighting the abundance estimates by the proportion of the total number of animals actually counted (as opposed to interpolation).

2.4 ABUNDANCE ESTIMATION

Survey counts underestimate actual abundance as there are always some animals dispersed at sea and hence missed. As is the case for many other pinnipeds (Berkson and DeMaster 1985), total abundance of Steller sea lions has been extrapolated from pup production by applying multipliers based on the ratio of pups to non-pups in the population as indicated by life tables (Calkins and Pitcher 1982; Trites and Larkin 1996; Olesiuk 2008). To estimate pup production, a correction of 1.05 was applied to the counts to account for pups that were present on rookeries during the survey, but hidden in the oblique 35-mm images (see Olesiuk et al. 2008). Following Trites and Larkin (1996) and Pitcher et al. (2007), an arbitrary correction of 1.10 to account for fetuses that may have been aborted just prior to the breeding season (pup multipliers calculated from life tables are based on late-term pregnancy rates), pups that may have died and/or been washed off the rookery prior to surveys, and pups that may have been born following the survey or had already dispersed to sites that were not surveyed, was applied.

Published life tables for Steller sea lions are based on specimens collected in the Gulf of Alaska during 1975-78 (Calkins and Pitcher 1982; York 1994; Holmes and York 2003; Holmes et al. 2007), which was believed to represent a period of relative stability just prior to the sharp declines that occurred in that region during the 1980s (Loughlin et al. 1992; Trites and Larkin 1996; NMFS 2008). For the B.C. assessment, I adapted the life tables for the eastern stock, which has been increasing for the past several decades (see Results), by incorporating the higher survival rates estimated from resightings of pups (i.e. known-aged animals) branded on Forrester Island (Pendleton et al. 2006) and the higher late-term pregnancy rates reported prior to the population decline in western Alaska (Pitcher et al. 1998). Sensitivity analyses were conducted with matrix projection models (Leslie 1945) to determine how the pup multiplier changed as a function of the population growth rate. The simulations were conducted by adjusting each of 4 key vital rates (juvenile survival, adult survival, age at first birth, and fecundity rate) independently. However, vital rates likely change in unison (e.g. Eberhardt 1985), so the actual multiplier would be within the range indicated by the simulations.

Abundance estimates based on pup production are useful for large-scale assessments, but of limited use for estimating abundance on smaller geographic scales or abundance outside the breeding season, as non-breeding animals may disperse considerable distances from their natal rookeries (Raum-Suryan et al. 2002). Therefore, a second survey correction factor was derived based on the estimated proportion of animals hauled out during surveys. Haulout patterns were determined from satellite tags deployed on 25 Steller sea lions of various sexes and ages in 2004-2006 (Tables 1&2). The 25 instruments were deployed in winter and the tagged animals monitored through spring (23 tags) and into summer (11 tags). The instruments were glued to the pelage and thus shed when animals moulted. Juveniles are the first to moult in early July, followed by adult females at the end of July, and bulls in early September (Daniel 2003). The head-mounted satellite tags transmitted daily timelines indicating the proportion of each hour registered as dry (rounded into bins of 0 to 2.5%, 2.5 to <5%, 5 to <10%, 10 to <20%, …, 80 to <90%, 90 to <95%, 95 to <97.5%, and 97.5 to 100%). It was assumed animals were at sea (but occasionally registering dry when they surfaced) for hours in which less than 10% of the readings were dry, and hauled out for the proportion of the hour registered as being dry for hours in which 10% or more of the readings were dry.

The interpretation of the satellite daily timelines was evaluated using time-depth recorders recovered from a subset (18 of 25) of the satellite-tagged animals. The TDRs provided finer-scale (10 second intervals) data on haulout behaviour, but usually for only a portion of the satellite tag deployment period (mean of 43.8 days for TDRs versus 118.7 days for PTTs). A regression of the proportion of each day spent hauled out as indicated by the satellite timelines, $Pr(HO)_{STL}$, versus the proportion of each day spent hauled out as indicated by the time-depth recorders, $Pr(HO)_{TDR}$, indicated the satellite data provided a good index of the time spent hauled out (R^2=0.994; $F_{1,652}$=104,312; P<0.0001) (see Figure 14), but that a small adjustment was required to correct for bias:

$$[6] \qquad Pr(HO)_{STL} = 0.997 \bullet Pr(HO)_{TDR} - 0.01454$$

The inverse of the regression was used to obtain unbiased estimates of $Pr(HO)_{jk}$, the proportion of time the *k*th animal was hauled out during the *j*th hour.

The satellite tags provided a continuous record of haulout patterns over all conditions, whereas surveys were generally flown during favorable conditions; flying was avoided during inclement weather, which often affected the timing of surveys during winter months. To assess whether this may have biased survey correction factors, the influence of various environmental factors including precipitation, wind speed and direction, air temperature, air pressure and tide height on haulout patterns was examined. Since this bias was most likely during winter surveys, the analyses were restricted to satellite telemetry data obtained between the first deployments in early January and the end of March. Because some animals travelled widely during this period, the analyses were further restricted to animals that remained within (or returned to) an area within 100 kilometers of the capture site at Norris Rocks. This limited the analyses to 19 animals (yearlings excluded) with records representing a total of 771.3 animal-days (mean = 40.6 days per animal).

Data on local precipitation and daily minimum and maximum temperatures were obtained from the nearest weather station at Qualicum Airport, situated about 25 kilometers from the capture site. Records of hourly wind speed and direction, temperature, and air pressure were obtained from the nearest lighthouse on Sisters Island, situated about 15 kilometers from the capture site. Tide heights were predicted for Hornby Island reference station, situated about 3 kilometers from the capture site, using Tide & Currents Pro 3.0e software.

The proportion of animals hauled during a survey was estimated as:

$$[7] \qquad p = \sum_{i=1}^{n} \left[\overline{Pr(HO)}_j \cdot C_{ij} \right] \Big/ \sum_{i=1}^{n} C_{ij}$$

where C_{ij} represents the count for the *i*th of *n* sites made in the *j*th hour, and $\overline{Pr(HO)}_j$ the mean proportion of tagged animals hauled out during the *j*th hour. The satellite timelines indicated that the proportion of time animals spent hauled out varied significantly with season ($F_{2,48}$=14.75; P<0.0001), and among sex- and age-classes ($F_{3,48}$=7.35; P=0.0004), with a significant interaction between season and sex- and age-class ($F_{5,43}$=4.54; P=0.0021). The seasonal effect was due to animals spending more time hauled out during summer, but when summer was excluded there was no difference in the proportion of time hauled out during winter and spring ($F_{1,40}$=1.59; P=0.2149). Yearlings stood out as spending more time hauled out, but when yearlings were excluded there were no differences among juveniles, adult females and adult males ($F_{2,39}$=1.22; P=0.3056) or any seasonal interaction ($F_{4,39}$=0.50; P=0.7385). Survey correction factors were thus 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 the adapted life tables (see above). Survey correction factors could not be derived for autumn surveys because tags had been moulted by the end of summer.

Abundance estimates calculated in this manner are subject to two sources of variability:

1. variability in the proportion of tagged animals hauled out during surveys; and
2. variability in survey counts as animals move among sites and potentially in and out of the survey area.

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, as we were interested in 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 using the delta method as per Mood et al (1974) cited in Huber (1995):

$$[8] \quad \mathrm{Var(CF)} = \mathrm{Var}\ (1/p) \approx \mathrm{Var}\ (p)\ /\ p^4$$

Since sites were generally only counted once during a survey, true replicates were lacking to calculate the variability of site counts. Instead, site counts from the 2008, 2010 and 2013 breeding season surveys were used to estimate the variability of counts by site, Var(SC_{it}). Since the population was increasing over this period, the counts were adjusted to 2013 levels based on the observed rate of increase over the period (See Figure 9). The weighted overall variance was calculated over all sites using the procedure developed for harbour seal site counts (Ann York, pers. comm. cited in Withrow et al. 1995).

Assuming that the variances of the correction factor (derived from the satellite timelines) and site counts (based on aerial surveys) were independent of each other, the overall variance of the abundance estimate, Var(N_{it}), was estimated as:

$$[9] \quad \mathrm{Var}(N_{it}) = 1/p_{it}^2.\mathrm{Var}(SC_{it}) + SC_{it}^2.\mathrm{Var}(1/p_{it}) - \mathrm{Var}(1/p_{it}).\mathrm{Var}(SC_{it})$$

where the parameters are as previously defined (Goodman 1960).

3 RESULTS

3.1 DISTRIBUTION

Until recently, Steller sea lions in British Columbia utilized 3 rookeries:

1. the chain of islands extending off the northwestern tip of Vancouver Island known as the Scott Islands;
2. at Cape St. James off the southern end of the Queen Charlotte; and
3. on North Danger Rocks off the northern mainland coast (Figure 1).

On the Scott Islands, rookeries are situated on several sites distributed around Triangle Island (Figure 2a), on the rocks just to the east of Sartine Island (Figure 2c), and on a small island just north of Beresford Island known as Maggot Island (Figure 2b). At Cape St. James, rookeries are situated at two sites in the Keourard Islands (Figure 2i). The North Danger Rocks rookery is comprised of a cluster of rocks, with pups born on the islands lying to the northeast and southwest (Figure 2f). Non-breeding animals, mainly bachelor males and barren females, are typically distributed near the periphery of the rookeries and on adjacent islands. Although small numbers of pups have occasionally been observed at nonbreeding haulout sites, it is unclear whether they had been born there or had moved there from nearby rookeries.

Historically, a fourth breeding site had been situated on Virgin and Pearl Rocks in the Sea Otter Group off the central mainland coast (Figure 2d), but the rookery was eradicated by intensive control kills during 1923-1939. Although a few pups were occasionally observed during surveys in the 1980s and 1990s (Table 4), the site was utilized mainly by non-breeding animals and classified as a year-round haulout site (Table 3). However, increasing number of pups began to be observed during brand resight and scat collecting trips in the late 1990s and early 2000s[2]. During the 2006 aerial survey a total of 51 pups were counted on Virgin Rocks and 4 pups on Pearl Rocks. Pup production has continued to increase with 100 pups counted in 2008, 155 in 2010, and 268 in 2013. The Sea Otter Group has thus been re-established as a rookery.

In 2002, Steller sea lions were observed at a new site on Garcin Rocks off the southeast end of Gwaii Haanas in Haida Gwaii (Queen Charlotte Islands). Two pups were observed during the 2002 survey, but pup numbers rapidly increased from 12 in 2006, to 104 in 2008, 217 in 2010 and 315 in 2013. A similar pattern occurred on the Gosling Islands, which had been classified as a year-round haulout since the site was first noted in 1956. A few pups were occasionally observed in earlier surveys, but numbers rapidly increased from 14 in 2006, to 26 in 2010 and 122 in 2013. The pup counts surpass the threshold of 50 pups for the sites to be considered new rookeries (Pitcher et al. 2007). A third site, Bonilla Island, which has been utilized as a year-round haulout since the first surveys in 1913, also appears to be emerging as a new rookery, with pup counts increasing from 4 in 2006, to 17 in 2008, 19 in 2010 and 55 in 2013. The new rookeries on Garcin Rocks, Gosling Island and possibly Bonilla Island are noteworthy, as they represent the first new breeding sites to be established in B.C. since the first sea lion assessments were conducted in 1913. Steller sea lions in B.C. are thus now breeding at all known historic rookeries and at two or three new rookeries.

Rookeries accounted for essentially all (98-99%) of the pup production in B.C., although in recent surveys increasing numbers of pups have been observed on non-breeding haulout sites (Table 4). However, none of the non-breeding haulouts have accounted for more than a dozen pups, except for Warrior Rocks where 22 pups were counted in 2008, 11 pups in 2010 and 28 pups in 2013. However, unlike rookeries, including the new rookeries, where pups tend to be

[2] Olesiuk, P.F., unpublished data.

clustered in particular areas and the spacing of animals is indicative of breeding activity, the pups observed on Warrior Rocks tend to be more scattered in the dense herd, and the author suspects they may have been born elsewhere and moved to the site.

Although the distribution of pup production has remained fairly stable among the traditional rookeries, some minor shifts have occurred, especially in recent years (Figure 3). The Scott Islands accounted for 55-65% (mean 61%) of total pup production during the 1970s, 1980s and early 1990s, but that figure has risen to 66-74% (mean 71%) since 2002. In contrast, Cape St. James accounted for 27-36% (mean 32%) of pup production up to the mid 1990s, but that figure has declined to 15-22% (mean 19%) since 2002. North Danger Rocks accounted for 5-10% (mean 7%) of total pup production throughout the study period. In 2013, the rookery re-established on the Sea Otter Group and the new rookeries formed on Garcin Rocks, Gosling Island and possibly Bonilla Island accounted for 12% of pup production, and pups at haulout sites accounted for almost 1% of total pup production (Figure 3).

The location of rookeries at Cape St. James and on North Danger Rocks has not changed much during the study period, although it now appears that pupping is more widely distributed at the latter site and the smaller rookery on the southern Keourard Islands has shifted slightly to the east. On the Scott Islands, however, there has been a dramatic shift in distribution, breeding activity moving from Maggot and Sartine Islands onto Triangle Island. The proportion of pups born on Triangle Island increased from about 24-35% (mean 29%) of the Scott Islands total in the 1970s to 24-46% (mean 35%) in the 1980s, to 57-85% (mean 75%) in the 1990s, and to 91-96% (mean 94%) since 2002 (Figure 4). Triangle Island now represents the largest breeding aggregation for the species over its entire range. There has also been a pronounced re-distribution of rookery areas on Triangle Island (Figure 2a). During the 1970s and 1980s, the major rookeries were situated on the rocks lying off the north and northeast tip of the island (Sites E & F). During the 1980s, animals began pupping in increasing numbers on the rocky ledges off the southeast tip of the island (Site C), and by the early 1990s extended onto the pebble beaches and flat rock ledges that run along the southeast coast (Site G). In the three most recent surveys, the latter two sites accounted for 84-91% of total pup production on Triangle Island.

Bigg (1985) noted that utilization patterns of haulout sites sometimes changed over time, and a number of additional revisions have been made to his designations (Table 3). Based on examination of sighting records from 1892-1982, and the systematic aerial surveys conducted up to 1982, Bigg (1985) recognized a total of 15 year-round haulouts. However, he noted that one (Isnor Rocks) had been abandoned since the mid-1960s, and two others (Solander Island and Langara Rocks) had only been used as winter haul-out sites since the mid-1960s, resulting in 12 year-round sites being used during the 1970s. All 12 of those year-round haulouts are still currently in use, although Virgin Rocks has re-established its status as a rookery and Gosling and possibly Bonilla Islands have been reclassified as new rookeries. Bigg (1985) considered Carmanah Rocks to be a winter haulout, but it has been reclassified as a year-round haulout site due to animals being observed there on every survey since 1977, and according to local lighthouse keepers the site is almost always occupied during summer months (J. Etzkorn, Carmanah Lighthouse, B.C., pers. comm.). It is suspected that animals may have been missed during some of the earlier surveys, since the rocks are relatively low and animals are often forced off and raft nearby when there is a large oceanic swell. The three year-round sites that Bigg (1985) considered to have been abandoned or only used during winter since the mid-1960s (Solander Island, Langara Island and Isnor Rocks), have all been utilized on a regular basis during June-July in recent years, have therefore been reclassified as year-round haulouts. Two other sites Bigg (1985) considered to be winter haulouts – Ashby Point in Queen Charlotte Strait and Mara Rocks in Barkley Sound – have also been used on a fairly regular basis during June-July, and have been reclassified as year-round haulouts. Another winter site at Chernley Island off the northern mainland coast has been occupied by large numbers of animals in the last few years, and animals (mainly bulls) regularly occur during the breeding season at what was formerly regarded as a winter haulout at Rose Spit off the Queen Charlotte Islands[3].

In addition to the aforementioned changes in haulout use, four entirely new year-round haulouts have been established: animals were first seen at Anthony Island in the Queen Charlotte Islands in 1987, at Warrior Rocks off the northern mainland coast in 1992, and both sites have been occupied by significant numbers of animals in subsequent surveys. Animals were also first seen at Garcin Rocks in the Queen Charlotte Islands during the 2002 survey and were also present during the 2006 survey, and the site attained rookery status in 2008. No animals were present when a detailed reconnaissance was conducted during harbour seal surveys in 1992 (Olesiuk et al. 1993), but the site has apparently been used on a fairly regular basis since the late 1990s (Ray Breneman, Canada Parks Service, Queen Charlotte City, B.C., pers. comm.), and may have been overlooked during the 1998 sea lion survey. Animals were first observed on Perez Rocks off the west coast of Vancouver Island in 2004, and large numbers were present in subsequent surveys. The number of year-round haulouts in B.C. has thus approximately doubled in recent decades from about 12 sites in the 1970s and 1980s to 23-34 sites since 2000.

During the breeding season surveys, an average of 59% (range 50-66%) of the total province-wide count (including pups) occurred on rookeries. Despite the population increases in recent years (see Recent Trends), this proportion has remained remarkably constant over the study period (CV=7.6%) (Figure 5). The number of animals utilizing winter haulouts during the summer breeding season seems to have increased slightly in recent years, from negligible levels in the 1970s, 1980s and 1990s to as high as 3% of total non-pup count in the most recent survey. The latter increase would have been much greater had sites classified as winter haulouts early in the study not been reclassified as year-round haulouts later in the study period as animals began using them on a regular basis during the summer breeding season (Table 3).

Counts for the winter surveys conducted in 2009-2010 are given in Table 5. Compared with the breeding season surveys conducted in roughly the same time-frame (2008-2013), there was a dramatic seasonal shift in distribution (Figure 6). The number of animals on rookeries declined from 59-61% of the total count in summer to 10% in winter. Numbers on year-round haulouts remained fairly stable, accounting for 36-41% of the total summer counts compared with 51% of the winter counts. Numbers on winter sites increased sharply, from 0-3% in summer to 40% in winter. As a result, animals were far less aggregated during winter (Figure 7). A total of 74 sites were occupied by >10 sea lions in winter compared with only 37-45 sites in the summer surveys (Figure 7). Moreover, the 3 largest sites (2 rookeries and a major year-round haulout site) accounted for almost half (39-45%) of the total count during summer surveys, and the 20 largest sites for 85-89% of the total count. In contrast, the 3 largest sites accounted for only 15% of the total winter count, and the 20 largest sites for only 61% of the total winter count.

Counts for the autumn survey in 2012 are given in Table 6. Distribution during autumn was intermediate to that observed during summer and winter surveys (Figure 6). A total of 16% of animals (27% of pups) were on rookeries in autumn, compared with 59% of animals (99% of pups) in summer and 10% of animals (pups had moulted and were no longer distinguishable from other age-classes) in winter, indicating that dispersal was underway. Females with pups often appeared to move from the large traditional rookeries to smaller new rookeries. For example, the proportion of the total pup count at Cape St. James declined from 16% in summer to less than 1% in autumn, whereas the proportion at nearby Garcin Rocks increased from 4% in summer to 5% in autumn. Similarly, the proportion of the total pup count on the Scott Islands declined from 69% in summer to 7% in autumn, whereas the proportion counted at the nearby

[3]Olesiuk, P.F., unpublished data.

Sea Otter Group increased from 3% in summer to 5% in autumn, and at the nearby Gosling Rocks from 1% in summer to 8% in autumn. A total of 27% of animals (14% of pups) occupied winter haulouts in autumn, compared with 2% of animals in summer and 40% in winter. The degree of aggregation observed during autumn surveys was intermediate to that observed during summer and winter (Figure 7), with the largest aggregations occurring at haulouts along the outer exposed coast that were closest to rookeries (Figure 6). However, a few animals, including some pups, began to appear at winter haulouts in protected areas like the Strait of Georgia, indicating they had travelled at least several hundred kilometers from the closest rookery.

The pup counts made by NMFS from vertical images were very similar to the DFO counts made from oblique images (Table 7). The strong correlation implies that pups could be reliably distinguished in both sets of aerial photographs, and that there was little movement of pups in the 8-10 days between surveys (Figure 8). The DFO oblique counts were on average 3.3% greater the NMFS vertical images, which a paired *t*-test indicated was statistically significant (t_{11}=2.35, P=0.0384). The intercepts of the regressions were not significantly different from zero for either the untransformed or log-transformed counts ($F_{1,10}$=1.6; P=0.2262 and $F_{1,10}$=2.8; P=0.1230 respectively), and were forced through the origin. The resulting slope indicated no significant difference between the untransformed counts ($F_{1,11}$=8810.4; P<0.0001), but the regression was highly influenced by counts for the two largest pupping areas on Triangle Island. The slope was significantly less than one for the log-transformed counts ($F_{1,11}$=1947.4; P<0.0001), indicating that the DFO counts from oblique images tended to be slightly higher than the NMFS counts from vertical images. This is contrary to previous comparisons between counts made from vertical and oblique images taken within a few hours of each other, which indicated that 4.3% of pups were missed in oblique photographs (Olesiuk et al. 2008). The slightly higher counts for the oblique images in 2013 suggests that some additional pups were born in the 8-10 day gap between the two surveys, but there is too much uncertainty in the exact chronology of pupping to adjust for this relatively small bias. Counts of non-pups on rookeries were also similar for the DFO and NMFS surveys (Table 7) and the differences statistically insignificant (t_{11}=0.90, P=0.4352). As one would expect, the non-pup counts exhibited greater variability (Figure 8) because their numbers fluctuate depending on the proportion that are ashore during surveys and due to movements of non-breeding animals between sites.

3.2 RECENT TRENDS

Steller sea lion counts increased dramatically during the study period. Total non-pup counts increased at a mean rate of 3.8% per annum (SE=0.30% r^2=0.9352; $F_{(1,11)}$=158.8; P<0.0001) (Figure 9a). Non-pup numbers increased at an average rate of 3.2% on rookeries (SE=0.28% r^2=0.9233; $F_{(1,11)}$=132.3; P<0.0001), and 4.4% at haulout sites (SE=0.45% r^2=0.8933; $F_{(1,11)}$=92.1; P<0.0001), but the rates were not significantly different. In all cases, the second-order term of the polynomial regression was positive and highly significant (0.0001<P<0.0137), indicating the growth rate accelerated during the study period. Piecewise regressions provided the best statistical fit (r^2=0.9916; $F_{(2,10)}$=591.4; P<0.0001), indicating that non-pup numbers were stable during 1971-1983 ($F_{(2,10)}$=0.1; P=0.9907), but subsequently increased at a rate of about 4.9% (SE=0.60% $F_{(2,10)}$=67.2; P<0.0001). Overall, the number of non-pups counted more than quadrupled from an average of 4,860 (SE=254) during the 1971-1982 surveys to 22,135 in the 2013 survey.

Pup production on B.C. rookeries also increased. During 1971-2013, pup counts increased at a mean rate of 4.8% per annum (SE=0.55%; r^2=0.8694; $F_{(1,11)}$=73.3; P<0.0001) (Figure 9b), which was similar and not significantly different from the average rate of increase of non-pups. Similar to the pattern found for non-pups, the second-order term of the polynomial regression was positive and highly significant (P<0.0002), indicating that the rate of increase accelerated during the study period. A piecewise regression model provided the best fit (r^2=0.9809; $F_{(2,10)}$=256.1; P<0.0001), indicating that pup numbers increased at a rate of 1.7% (SE=0.45%; P=0.0032) during 1971-1994, but the rate subsequently increased to 7.0% (SE=0.89% P<0.0001). Due primarily to the high rate of increase in recent years, pup production in B.C. increased more than 6-fold since the 1970s.

Abundance of Steller sea lions also increased on neighbouring rookeries in SE Alaska since the first aerial surveys were conducted in 1961 (Bigg 1984, 1985; Pitcher et al. 2007; Olesiuk 2008; Fritz et al. 2015a, 2015b) (Figure 10). Weighted regressions indicate that the combined total counts and pup counts for B.C. and SE Alaska both increased significantly (r^2=0.8767; $F_{(1,27)}$=191.9 P<0.0001 and r^2=0.9531; $F_{(1,27)}$=549.0 P<0.0001 respectively). In both cases, second-order polynomial regressions provided a better fit (r^2=0.9536; $F_{(2,26)}$=266.9; P<0.0001 and r^2=0.9755; $F_{(2,26)}$=518.3; P<0.0001 respectively), indicating the rate of increase had accelerated over the study period. Overall, the rate of increase of total numbers (pups and non-pups) on rookeries steadily increased from 1.3% per annum during the 1960s when some kills were being made, to 1.8% during the 1970s, to 2.3% during the 1980s, to 2.8% during the 1990s, and to 4.3% since 2000. Similarly, pup production increased at a rate of 0.4% per annum during the 1960s, 1.3% during the 1970s, 2.2% during the 1980s, 3.1% during the 1990s, and 5.5% since 2000. The number of breeding sites increased from 4 when aerial surveys were initiated in 1961 (3 when the first assessments were conducted in the early 1900s) to 5 rookeries by 1990, 7 by 2000, and 12 rookeries at present. However, the 4 original rookeries are still predominant, accounting for 68% of pup production in 2013, whereas the 8 new and re-established rookeries accounted for 32% of pup production in 2013.

3.3 HISTORIC TRENDS

The earliest assessments of Steller sea lions in British Columbia focused on rookeries, and the few counts available for non-breeding sites are too sporadic and incomplete to assess trends in total abundance. Pups were not always distinguished from non-pups, and in most cases only the total number of animals on rookeries was reported. However, survey data for 1971-2013 indicated there was a strong linear relationship between number of animals on rookeries and total province-wide counts, indicating that the rookery counts serve as a good index of total abundance (Figure 5). The early censuses were made by boat or from vantage points on land, and often on sub-optimal dates or following disturbances, so the original data and field notes need to be carefully examined when interpreting the historic information. Bigg (1985) presented what is probably the most thorough and objective interpretation possible for the historic data, which has been revised only slightly.

Despite the limitations and potential biases in the historic data, it seems clear that abundance of Steller sea lions declined during the first part of the 20th century (Figure 11). The first systematic assessments of sea lions in B.C. were conducted in 1913 and 1916, indicating there were about 9,300 and 9,800 animals (pups and non-pups) on rookeries, respectively (Newcombe and Newcombe 1914; Newcombe et al. 1918; Bigg 1985). Making allowance for disturbances prior to the counts and the sub-optimal timing of surveys, Bigg (1985) suggested that the total abundance was more likely on the order of 14,000 animals during both years. Numbers on rookeries were reduced to about 9,500 by the mid-1950s, mainly due to the eradication of the Sea Otter Group rookeries on Virgin, Pearl and possibly Watch Rocks. During 1923-1939, most of each year's cohort was killed as fishery officers visited these rookeries annually toward the end of the pupping season, shooting as many non-pups as possible with machine guns as they approached by boat, and then landed and killed pups which were generally too young to escape into the water. (Figure 12), and numbers of animals breeding on Virgin and Pearl Rocks declined exponentially due to the lack of recruitment. By the late 1930s, total numbers had been reduced to a few hundred animals and pupping had been eradicated. The site continued to be utilized regularly by several hundred animals between the 1940s and 1990s, but only a few sporadic births occurred. However, increasing numbers of pups have been observed at the site in recent years, and based on pup counts since the 2006 survey it has been re-classified as a rookery.

While not as intensive, control programs were also conducted at the Scott Islands in 1913-1916 and again in late-1930s (Figure 12), and those kills appear to have reduced numbers to perhaps half their original levels. The Scott Islands, Cape St. James and North Danger Rocks rookeries were all subject to intense commercial harvesting and control kills during the 1960s, which seemed to have had a widespread impact on overall abundance. Bigg (1985) estimated that total abundance and pup production on Cape St. James declined by about 70% during the 1960s. During the same period, abundance and pup production on North Danger Rocks was also estimated to have declined by about 70%, and on the Scott Islands the decline was about 40%. Thus, by the time the species was protected in 1970, total abundance on rookeries had been reduced to roughly 25-33% of the peak known levels observed in the early 1900s, which was prior to any large-scale control or commercial kills.

With the recent increases in abundance on B.C. rookeries, Steller sea lions appear to have fully recovered from the predator control kills and commercial harvests. The total count on B.C. rookeries in the 2013 survey (6,259 pups and 10,969 non-pups) represents about 1.3-1.6X the peak historic levels present prior to major kills (Figure 11). In addition to the increases observed in B.C., Steller sea lion populations have also expanded in neighbouring waters in SE Alaska. The species was not known to breed in SE Alaska during the early 1900s (Bigg 1985; Calkins et al. 1999; Pitcher et al. 2007), but established a rookery on Forrester Island just north of the Canadian border while the large-scale kills were underway in B.C. Historic information on Forrester Island is sparse, but one count made in the summer of 1929 indicated fewer than 100 animals were present (Rowley 1929), and another count in August of 1945 indicated only about 350 animals were present (Imler and Sarber 1947). No large-scale kills were conducted in SE Alaska, and the Forrester Island rookery expanded rapidly while control programs reduced numbers in B.C. A total of 800 pups and 1200 non-pups were counted when the first aerial survey was flown in 1961, and by the 1970s Forrester Island had become the largest Steller sea lion rookery for the species, and by the 1980s almost twice as many pups were born on Forrester Island than in all of B.C. (Table 4). Given its size and close proximity to the Canadian border (<50 kilometers), it is difficult to assess overall trends without considering the influence of Forrester Island.

The combined abundance of Steller sea lions on B.C. rookeries and Forrester Island appears to have surpassed peak historic levels by a significant margin (Figure 11). In addition to the growth of Forrester Island, several new rookeries have been established in SE Alaska during the last 3 decades: Hazy Island in the early 1980s, White Sisters Island in the early 1990s Graves Rocks in 2000, and Baili Rocks in 2002 (Calkins et al. 1999; Pitcher et al. 2007). Overall, breeding populations on rookeries in B.C. and SE Alaska have exhibited exponential growth since the early 1960s (Figure 10). During the 1960s and 1970s, the increases occurred almost entirely at Forrester Island (numbers were in fact reduced in B.C. during the 1960s as kills continued). However, growth at Forrester Island began to slow in the 1980s, but increased at B.C. rookeries and the new rookeries established in SE Alaska. Since the early 1990s, B.C. rookeries have accounted for 62% of the overall increase in pup production in this region, Forrester Island for 3% of the increase, and the new rookeries in SE Alaska for 34% of the overall increase in pup production. Total pup production quintupled over the last 5 decades, and total abundance on rookeries in B.C. and SE Alaska appears to have surpassed the peak historic levels observed in the early 1900s by a factor of at least 2.5 times. Nevertheless, there is no evidence the growth rates are slowing; polynomial regressions indicate the rate of increase in pup production has accelerated from an average of 0.5% in the 1960s to 1.3% during the 1970s, 2.2% during the 1980s, 3.1% during the 1990s, and 5.5% since 2000. In the 2013 survey, total numbers were 19.4% greater and pup numbers 17.1% greater than the previous complete survey in 2010 (Tables 3 & 4; Fritz et al. 2015a, 2015b). The lower rate of increase during the early part of the time-series may be attributed to the predator-control kills and commercial harvests still occurring in B.C. during the 1960s, but the rate of increase has continued to accelerate over the 4 decades since any large kills.

3.4 ABSOLUTE ABUNDANCE

Total abundance (including animals missed during surveys) can be extrapolated from pup production by applying multipliers based on the estimated ratio of pups to non-pups in the population. After adjusting for pups missed because they were not present during surveys or obscured in oblique 35mm photos, total pup production in B.C. in 2013 was estimated to be about 7,300 pups. As noted previously, published life tables represent a stable population in the Gulf of Alaska, and thus are not directly applicable to the increasing populations in B.C. and SE Alaska. Simulations indicate the multiplier (ratio of non-pups to pups) would increase if the population growth was due to improved juvenile survival, and decrease if the population growth was attributable to increased fecundity or earlier maturation. Pendelton et al. (2006) recently published a survivorship schedule for Steller sea lions in the eastern population based on resightings of animals branded during 1994-2003. Substituting their schedule into the Calkins and Pitcher (1982) life tables gives a rate of increase of 3.0%, which is similar to the observed population growth rate of 3.8% over the period the branding study was conducted. However, the observed rate of population growth has subsequently accelerated to 4.3% since 2000, so I examined the potential range of vital life history parameters required to correspond with the observed rate of population growth. The simulations indicate the multiplier would be 4.51 if just survival rates improved (increase of 1.5%), or potentially range from 4.28 to 4.65 if other life history parameters were also allowed to vary (Figure 13). Thus, it is estimated that a population of 32,900 (range 31,200 to 33,900) would be required to support the pup production observed on B.C. rookeries in 2013.

Given the close proximity of the large rookery on Forrester Island to the border and the potential for trans-boundary movements, it was more meaningful to consider the combined abundance in B.C. and SE Alaska. Based on the most recent survey in 2013, total combined pup production was estimated to be about 14,700 pups (7,300 pups in B.C. and 7,400 pups in SE Alaska). Applying the calculations outlined above, this represents a total population size of 66,300 (range 62,900 to 68,400). During the most recent survey in 2013, 53.7% of non-pups in the region occurred in B.C. (22,135 in B.C. and 19,101 in SE Alaska). Given this distribution, it was estimated that 35,600 (range 33,800 to 36,700) animals were present in Canadian waters. This estimate is slightly higher than the population required to support the pup production on B.C. rookeries, suggesting there is a surplus of non-breeding animals associated with Alaskan rookeries, which would be expected given the close proximity of Forrester Island.

A second estimate of abundance in B.C. in 2013 can be obtained by adjusting survey counts for the proportion of non-pups that were dispersed at sea and missed during surveys. Based on diurnal haulout patterns during the summer breeding season indicated by the satellite telemetry data (Figures 14 & 15), it was estimated that 67.4% of non-pups were hauled out (and presumably counted) during the 2013 breeding season survey, which represents a survey correction factor of 1.48. This was very similar to the correction factor of 1.49 (67.2% of non-pups hauled out) calculated for the previous breeding season survey in 2010 using the same methods[4]. Both corrections are similar to the unweighted average of 67% (range 63% to 71%) of non-pups hauled out over the 10:00 to 18:00 survey window, indicating that the exact timing

[4]Olesiuk, P.F. 2010. Abundance of Steller sea lions (*Eumetopias jubatus*) in British Columbia. Working Paper 10A, Meeting of the National Marine Mammal Peer Review Group, 22-26 November, 2010, Mont-Joli, Quebec. Unpublished Report.

of the counts within the survey window had little effect on the correction factor. Based on the variance of the proportion of satellite-tagged animals hauled out each hour (weighted by the number of animals counted each hour), the CV of the proportion of animals hauled out during the survey was estimated to be 5.6% of the mean. The CV of the de-trended site counts for the 2008-2013 summer surveys was 3.2%, slightly less than the CV of 4.2% for the unadjusted counts. As per equation [9], the overall standard error of the 2013 survey count was estimated to be 2,860. About 28% of the uncertainty associated with the estimate was due to the variability of the replicate counts, and the remaining 72% to the variability in the proportion of animals hauled out during the survey. A total of 21,490 non-pups were counted on land (and another 645 or 2.9% in the water) in the 2013 survey. Applying the correction factor to the number of non-pups counted on land, and adding the estimated pup production, total abundance of Steller sea lions in B.C. during the 2013 breeding season was estimated to be 39,200 (95% confidence interval of 33,600 to 44,800). This estimate is slightly greater than, but not significantly different from, the estimate based on pup production and the relative distribution of non-pups between BC and SE Alaska (35,600 with range 33,800 to 36,700).

During winter, it was estimated that 53% of yearlings and 33% of older animals were hauled out (and presumed counted) during the 2009-2010 surveys (Figure 15), giving an overall weighted survey correction factor of 2.82. If only the 10:00 to 18:00 period was used, 62% of yearlings and 36% of older animals would have been hauled out, giving a correction factor of 2.43. However, the correction for the actual surveys was larger because some of the counts at major sites had been made early in the morning when relatively few animals were ashore (the winter surveys were conducted before the satellite telemetry data had been analyzed and revealed that diurnal haulout patterns in winter differed from the summer pattern). The CV of the proportion of yearlings and older animals hauled out during the 2009-2010 surveys was 6.5% and 2.1% respectively. The CV for replicate site counts made outside the breeding season was 8.3%, which was more than twice as variable as the replicate site counts for the summer breeding season surveys. As per equation [9], the overall SE of the 2009-2010 winter survey count was estimated to be 5,300. About 36% of the uncertainty associated with the estimate was due to the variability of the replicate counts, and the remaining 64% to the variability in the proportion of animals hauled out during the survey. The sum of mean counts was 17,188 animals on land (and another 491 or 2.8% in the water). Accounting for animals that were dispersed at sea and missed during surveys, total winter abundance of Steller sea lions in B.C. during 2009-2010 was estimated to be 48,500 (95% confidence interval of 38,100 to 58,900). In comparison, based on the 2010 summer survey abundance was estimated to be 32,500 (95% confidence interval of 28,200 to 36,800)[2]. The winter estimate was 49% greater than the corresponding summer estimate and significantly different (P<0.05), implying there was an influx of about 16,000 (range 1,300 to 30,700) animals during winter months.

Satellite telemetry data for January-March indicated that haulout behavior was significantly affected by environmental conditions ($F_{7,18,208}$=138.4; P<0.0001), but these effects were too small to account for the higher winter abundance estimate. Daily precipitation had a significant effect ($F_{1,18,208}$=141.5; P<0.0001), with animals spending less time hauled out on days with more than a trace of precipitation (Figure 16). Hourly wind speed also had a significant effect ($F_{1,18,208}$=113.1; P<0.0001), with animals less likely to haul out when hourly winds were above about 30-40 km per hour, and spending little time ashore when winds exceeded 70-80 km per hour (Figure 17, top panel). However, such strong winds rarely occurred (Figure 17, bottom panel), so wind speed had relatively little influence on the overall proportion of time tagged animals spent on land. Hourly tide height also has significant effect ($F_{1,18,208}$=515.4; P<0.0001), with animals spending more time ashore during low tides and less time ashore during high tides (Figure 18a). However, tides in the study area are mixed semi-diurnal, and during winter months the extreme low and high tides generally occur at night, with more moderate tides during the day, so the apparent tide effect may have been an artifact of a diurnal tendency for animals to spend more time hauled out during night. The tide effect was still evident but much reduced when examined just for daylight hours (Figure 18b), so it had little effect on survey counts. Hourly air temperature also had a significant effect ($F_{1,18,208}$=53.8; P<0.0001), with animals spending less time hauled out when air temperatures were very low, and more time hauled out when air temperatures were very high (Figure 19). The temperature effect seemed to be more than just a diurnal effect, as animals tended to spend a lower proportion of time hauled out on days when daily minimum temperatures were low, and a higher proportion of time hauled out on days when daily maximum temperatures were high (Figure 20). While the temperature effect appeared to be real, it had little effect on the overall time spent hauled out as very warm and very cool conditions rarely occurred (Figure 19, bottom panel). Wind direction had a significant effect ($F_{1,18,208}$=18.5; P<0.0001), with animals spending the least time ashore when winds were from the southeast (Figure 21), which prevail in winter and are generally indicative of wet, stormy weather. Animals were also less inclined to haul out during northwest winds, which are generally indicated of cold, outflow winds. Air pressure was the only environmental variable included in the model that did not significantly affect haulout behaviour ($F_{1,18,208}$=1.4; P=0.2396).

The winter surveys were conducted during daylight hours (08:00 to 18:00) without regard to tide height, temperature or wind direction, although we avoided flying during stormy conditions or when there were high winds or heavy precipitation. To determine the extent to which the winter correction factors may have been biased by avoiding adverse weather, the correction factor was re-calculated excluding days in which there was more than a trace of precipitation and any periods in which the winds exceeded 30 km.hr-1, which reduced the dataset to about half (49.4%) the number of records. Total time animals spent ashore increased from 35.8% (29.9% during daylight hours) under all conditions to 39.4% (33.5% during daylight hours) under ideal condition (Figure 22). When winter abundance (yearlings excluded) was recalculated based on the proportion of animals hauled out under ideal conditions, rather than all conditions, the estimate increased by about 6%. Too few yearlings were tagged to assess how their haulout patterns may have been affected by environmental conditions, but the influence was probably smaller as yearlings spent more time ashore during winter than older animals. Thus, the winter abundance estimates were likely slightly inflated due to flying surveys in favourable conditions, but the bias probably accounted for a small fraction of the nearly 50% difference between the summer and winter abundance estimates.

Abundance could not be estimated for the autumn survey due to the lack of satellite telemetry data for deriving correction factors for the proportion of animals hauled out and counted during the survey.

4 DISCUSSION

Abundance of Steller sea lions in B.C. have grown dramatically in recent years. Surveys indicate there have been significant increases in pup production, and in numbers of non-pups on rookeries and on haulout sites. In contrast, Bigg (1985) analyzed survey data up to 1982 and concluded that populations were stable and had not exhibited any significant recovery since being protected in 1970. The discrepancy can be explained by the fact that essentially all of the increase in non-pup numbers has occurred since the early 1980s, and most of the increase in pup production has occurred since the mid-1990s. Bigg’s (1985) shorter time series may also have provided less power for detecting population trends, but even in retrospect there appears to be little evidence of appreciable growth in B.C. prior to 1982.

The summer breeding season surveys were all conducted within a fairly narrow window (27-June to 09-July), so it is unlikely the long-term trends have been confounded by seasonal attendance patterns at haulouts or rookeries. Although recent data on the timing of pupping in B.C. are not available, the timing of pupping appears to have remained fairly stable over time and similar among sites (Bigg 1985; Pitcher et al. 2001). However, the similarity of pup counts in the NMFS survey during 20-22 June, 2013, and the DFO survey during 30 June to 02 July, 2013, indicate nearly all pups had been born by late June. Moreover, the lack of pups at non-breeding haulouts indicates dispersal from rookeries was negligible. Most of the survey counts were within the prescribed window of 10:00 to 18:00 when peak numbers would be expected to be on land (Withrow 1982), and the satellite tag data indicates that the proportion of animals hauled out during summer is relatively stable within that window. Surveys were conducted without regard to tide, which has been reported to have a significant effect at some sites (Kastelein and Weltz 1990), but not at others (Withrow 1982). Most of the year-round haulouts occupied during summer are comprised of relatively large islets with substrate available at all tides, and swell height may have been a more important factor. Calkins et al. (1999) applied co-variate analysis to account for date, tide and time effects, but none of the resulting trends estimates differed significantly as a result of the adjustments. Furthermore, I am somewhat skeptical of the predictive value of their co-variates as they often fitted multivariate quadratic equations to as few as 6 observations, and their time-series spanned only 7 years. Satellite telemetry data indicated that haulout patterns during winter were affected by environmental factors, but the effects were too small to have had an appreciable effect on the proportion of animals hauled out during winter surveys. The issue of co-variate effects warrants further examination with more extensive datasets, but their effects are likely inconsequential relative to the exponential population growth observed in recent decades.

Steller sea lion abundance has also increased in neighbouring waters. The species was not known to breed in SE Alaska prior to the rookery at Forrester Island being established, probably sometime near the middle of the 20th century (Bigg 1985). Forrester Island was initially a minor site with about 50-100 animals during the 1920s with no mention of pupping (Rowley 1929), and about 350 animals were present by the mid-1940s (Imler and Sarber 1947). However, numbers increased rapidly during the 1950s, 1960s and 1970s, and by the 1980s had become the largest breeding site for Steller sea lions (recently surpassed by higher pup counts on Triangle Island in the 2010 and 2013 surveys). Growth at Forrester Island had slowed by the early 1980s, but several new rookeries were established in SE Alaska during the 1980s and 1990s (Calkins et al. 1999; Pitcher et al. 2007). Calkins et al. (1999) estimated pup production increased at a rate of 5.9% during 1979-97, but slowed to 1.7% during 1989-97. The slowing of growth in SE Alaska coincided with the sharp increases in pup production in B.C. beginning in the early to mid-1980s. Growth in B.C. initially occurred at the 3 traditional rookeries used continuously since the early 1900s, but in the past decade sea lions have recolonized the rookery in the Sea Otter Group that had been eradicated by predator control programs in the 1920s and 1930s, and have established new rookeries on Garcin Rocks, Gosling Rocks, and possibly Bonilla Island. Overall, breeding populations and pup production in B.C. and SE Alaska, which are difficult to separate due to the transboundary movements, have sustained exponential growth since the early 1960s. Steller sea lions do not breed in Washington, but numbers of non-breeding animals have increased in recent years (Pitcher et al. 2007). Non-pup and pup counts in Oregon increased at an average rate of 2.5% and 2.3% respectively during 1977-2002, over which period abundance more than doubled (Brown and Reimer 1992; Pitcher et al. 2007), and recent surveys indicate the growth in Washington and Oregon has been sustained and perhaps accelerated (Brown et al. 2002; ODF&W and WDF&W 2010[5]; NMFS 2013).

[5]ODFW and WDFW (Oregon Department of Fish and Wildlife. Washington Department of Fish and Wildlife). 2010. Petition to delist the eastern distinct population segment of the Steller sea lion from the Endangered Species Act. Submitted August 30, 2010, to US Dept. of Commerce.

The recent increases almost certainly represent, at least in part, the recovery of populations that had been depleted by kills during 1913-1967 in control programs and commercial harvests. By the time the species was protected in 1970, abundance in B.C. was estimated to have been reduced to 25-33% of known peak levels that existed at the turn of the century, which was prior to any large scale kills (Bigg 1985). Since 1970, however, abundance in B.C. has more than quadrupled, and the local breeding populations are currently estimated to be at 25-40% larger than the peak historic counts. Steller sea lion populations in California, Oregon and Washington were also reduced by over-hunting and predator control (Rowley 1929; Bonnot and Ripley 1948; Pearson and Verts 1970; Scheffer 1950; Kenyon and Scheffer 1959). However, while kills were underway in the southern portion of the range, only one small kill (187 animals at Forrester Island in 1960) was known to have been made in SE Alaska (Bigg 1984), which probably explains why sea lions flourished on Forrester Island. With the colonization of new rookeries in SE Alaska, and the recent growth at B.C. rookeries, it now appears the species has fully recovered. Indeed, breeding populations appear to have surpassed the peak historic levels observed in the early 1900s by a factor of 2.5 - 2.8 times. The species now breeds on 10 rookeries in B.C. and SE Alaska, compared with 4 rookeries in the early 1900s. Assuming carrying capacity has not changed, one might expect density-dependent mechanisms to become more prevalent, and populations to stabilize (or exhibit long-term fluctuations). It is also possible that Steller sea lion populations in B.C. and SE Alaska had already been depleted by subsistence harvesting when the first surveys were conducted in the early 1900s (Newcombe et al. 1918; Wailes and Newcombe 1929; ADF&G 1973; Bigg 1985). However, First Nation populations and their reliance on sea lion products both declined during the 1800s (Duff 1977). The first Steller sea lion studies in B.C. were prompted by mounting complaints over the impact of sea lions on salmon fisheries, but it is unclear to what extent these complaints stemmed from the growth of sea lion populations or the expansion and industrialization of salmon fisheries.

The 10:00 to 18:00 survey window advocated by Withrow (1982) was based on diurnal haulout patterns observed at a rookery in the Gulf of Alaska during the summer, which indicated that animals tended to depart on foraging trips in the late afternoon or evening and arrive back on the rookery in the morning, such that peak numbers were ashore during mid-day. Similar diurnal patterns have been noted at other sites by researchers making observations during summer months (Gentry 1970; Sandegren 1970; Edie 1977; Merrick 1987; Withrow 1982; Gisiner 1985; Higgins et al. 1988; Smith 1988). Based on the number of non-pups observed in surveys relative to the number expected from pup counts and life tables, Loughlin et al. (1992) suggested that 75% of non-pups were counted during summer surveys in the Gulf of Alaska. The satellite telemetry data examined in this study confirmed the diurnal haulout patterns for summer months, and indicated that 67% of non-pups were hauled out and presumably counted during summer surveys in B.C.

Satellite telemetry data indicated that a much lower proportion of animals were hauled out during daylight hours in winter, regardless of when counts are made, but especially early in the morning. There is relatively little information on the haulout patterns of Steller sea lions during winter. The only observational study during winter was by Porter (1997), who saw no evidence of diurnal haulout patterns, and reported that animals continued to arrive and depart with no predictable pattern or diurnal cycle. Only small numbers of satellite tags have been deployed on Steller sea lions in winter, but both Merrick (1995) and Swain (1996) reported that animals spent more time at sea during winter than in the summer. The apparent seasonal change in haulout behaviour has important implications for interpreting survey data, as it implies that more animals are missed and larger correction factors need to be applied to counts made outside the breeding season to determine actual abundance.

The number of Steller sea lions wintering in coastal waters of B.C. appears to be substantially greater than the number breeding in local waters. There is greater uncertainty in the abundance estimate for winter because of the larger correction factors required to adjust for animals at sea and missed during surveys, as well as because animals were more widely dispersed in winter and site counts tended to be more variable. Nevertheless, the abundance estimate from winter surveys was almost 50% greater than the abundance estimate from summer surveys, and the difference was statistically significant.

Unfortunately, abundance could not be estimated during autumn due to the lack of survey correction factors. However, the number of animals counted in October 2012 (28,677) was 29% higher than the number of non-pups counted 8 months later in June-July 2013 (22,135). The summer estimate was expected to have declined slightly due to mortality, which based on the adjusted life tables would have been approximately 13% between the autumn and summer surveys. More importantly, however, a larger proportion of animals were probably at sea and missed during the October survey as pups had begun to make foraging trips (Raum-Suryan et al. 2004) and non-pups spend less time on land outside the breeding season (Merrick 1995; Figure 15). However, it should be noted that our satellite tags were not deployed until January-February, and Merrick's (1995) tags were deployed in November-March. If we assume, for illustrative purposes, that haulout patterns in October were intermediate to those observed in summer and winter, abundance in October would have been on the order of 60,000 animals, about 60% greater than estimated the following summer. While these calculations are crude, they tend to support premise of a seasonal increase in abundance in B.C. during the non-breeding season.

The seasonal increase in abundance implies there is an influx of animals from rookeries outside B.C. during the non-breeding season. Steller sea lions are highly mobile, and animals range widely during the non-breeding season. For example, the satellite-tagged animals referred to in this study were captured while wintering off southeastern Vancouver Island, but had become widely distributed between California and Prince William Sound, Alaska, (i.e. the entire range of the eastern stock) by summer[6]. Based on the size and location of rookeries and known migration patterns, a net immigration of animals into B.C. during the non-breeding season would be expected. Mate (1973, 1975) noted that Steller sea lions on the Oregon coast were displaced northwards in autumn by a northward migration of California sea lions following their breeding season, and the declines of sea lions off Oregon coincided with increases off southern Vancouver Island (Bigg 1985). Scordino (2006) reported that by October and through the winter, male Steller sea lions were rarely sighted in Oregon, and numbers of females, pups and juveniles were greatly reduced as they moved north beyond the Oregon border. Many of the pups branded on Oregon rookeries were resighted off southern Vancouver Island (Scordino 2006), although resight effort was too limited to quantify the numbers wintering in B.C. Judging from the northern extent of migrating California sea lions, most of the Steller sea lions displaced northwards probably winter off Washington and Vancouver Island, and a few in northern B.C. and SE Alaska (Bigg 1985; Maniscalco et al. 2004). Winter surveys in December indicate that only a few hundred animals remain on Forrester Island during winter (Bigg 1984; Daniel 2003; Fritz et al. 2015b). The site is situated less than 50 km north of the B.C. border and there are only two relatively minor haulout sites between Forrester Island and the Canadian border[7], so most of the animals dispersing southward would enter B.C. Based on pup counts from the most recent range-wide survey of the eastern stock (Pitcher et al. 2007; Fritz et al. 2015a; this report), the rookeries in California and Oregon support about 18% of breeding animals and Forrester

[6] Olesiuk, P.F., S. Jeffries, M. Lance, A.W. Trites, P. Gearin, K. Miller-Saunders, D. Lambourn, and S. Riemer. 2011. Prey requirements and salmon consumption by Steller Sea Lion (*Eumetopias jubatus*) in British Columbia and Washington State. Pacific Salmon Commission Report, Submitted 01-Feb-2011. vi + 96 p. Unpublished Report.

[7] In the most recent winter survey of the area on 03-Dec-1994 a total of 248 animals were counted on Point Marsh and 334 animals on West Rock, and numbers of animals breeding on Forrester Island has remained relatively stable since the counts were made in the 1990s (Fritz et al. 2015b; Fritz et al. 2015c).

Island about 20% of breeding animals. If many of the animals breeding off California and Oregon are displaced northward into B.C. and almost half of the animals breeding on Forrester Island disperse southwards into B.C. waters, it could easily account for a 50% increase in B.C. during the non-breeding season. In support, the autumn survey indicated large aggregations of pups at haulouts off southeastern Vancouver Island, the central coast, and just south of the Canada-Alaska border, presumably representing dispersal of breeding animals from rookeries in California and Oregon, the Scott Islands, and Forrester Island respectively. If this interpretation is accurate, it suggests that about a third of the eastern stock occurs and breeds in B.C. during summer, and half the eastern stock occurs and forages in B.C. during winter, highlighting the importance of Canadian waters for Steller sea lions.

The recent increases in the eastern stock contrasts sharply with the western stock, where Steller sea lions have declined by about 80% since the 1970s, and are now considered to be *endangered* (Merrick et al. 1987; Loughlin et al. 1992; Trites and Larkin 1996; Loughlin 1998, NMFS 2008). In the 1960s and 1970s the eastern stock accounted for about 10-12% of worldwide Steller sea lion abundance (Loughlin et al. 1984), compared with 55-60% since the turn of the century (Burkanov and Loughlin 2005; Pitcher et al. 2007; Fritz et al. 2015a; this report). The reasons for the decline in the Gulf of Alaska and Bering Sea are poorly understood, although a leading hypothesis is nutritional stress as a result of a change in oceanographic conditions that affected the prey availability or quality (Alverson 1992; Alaska Sea Grant 1993; DeMaster and Atkinson 2002; Trites and Donnelly 2003; Trites et al. 2007). At this juncture, the reasons for the continued and accelerating growth of the eastern stock, which appears to have fully recovered from control programs and commercial harvests and surpassed peak historic levels, is also unclear. While the ecological processes are poorly understood, Steller sea lions are likely limited by bottom-up forcing and could serve as an indicator of the state of marine food chains. Aleut traditional knowledge, archaeological data and ethnographic records indicate Steller sea lions have repeatedly declined and recovered in the Gulf of Alaska and Aleutian Islands, and the fluctuations have been associated with changes in fish stocks, consistent with the ocean regime hypothesis (Maschner et al. 2014). With the expansion of local Steller sea lion populations, more research is required on their prey requirements and diet to develop a better understanding of their dependence upon, interactions with, and impacts on, other fishery resources.

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7 TABLES

***Table 1**. Summary of instrument deployments on 25 Steller sea lions and 2 California sea lions during 2004-2006. All animals were captured and released in January-February at Norris Rocks off Hornby Island in the central Strait of Georgia. Duration of TDR and PTT records are given in days.*

Animal ID	Date	Sex	Weight (kg)	Length (cm)	Category	TDR (days)	PTT (days)	ARGOS locns
GG200	05-Feb-2004	M	173	204	Juvenile	-	-	-
YY2004	05-Feb-2004	M	-	284	Adult	-	-	-
OO200	06-Feb-2004	M	250	-	Adult	72	-	-
BB2004	06-Feb-2004	M	87	-	Yearling	2	-	-
RR2004	05-Mar-2004	M	-	-	Adult[1]	15	-	-
PP2004	04-Mar-2004	M	-	-	Adult[1]	-	-	-
YY2005	26-Jan-2005	F	278	227	Adult	44	11.2	67
OO200	28-Jan-2005	M	163	207	Juvenile	42	72.1	366
PP2005	28-Jan-2005	F	115	171	Yearling	51	71.3	392
GG200	28-Jan-2005	M	233	222	Adult	2	48.4	298
BB2005	26-Jan-2005	M	101	162	Yearling[2]	62	14.1	80
RR2005	28-Jan-2005	M	221	214	Juvenile	20	89.4	464
YB2005	09-Feb-2005	M	213	219	Juvenile	23	96.5	850
OY2005	10-Feb-2005	F	222	217	Adult	39 / 127	128.0	1238
YR2005	09-Feb-2005	M	269	242	Adult	17	196.1	1205
PR2005	09-Feb-2005	M	166	207	Juvenile	44	124.5	833
YG2005	09-Feb-2005	M	241	231	Adult	43 / 112	185.1	1154
OG200	10-Feb-2005	M	195	208	Juvenile	38	115.0	882
OO200	11-Jan-2006	M	479	278	Adult	-	112.4	956
PP2006	11-Jan-2006	F	200	203	Adult	23	159.1	1123
GG200	23-Jan-2006	M	385	247	Adult	45	58.1	409
RR2006	11-Jan-2006	M	216	209	Juvenile	95	107.7	926
OY2006	25-Jan-2006	F	140	188	Juvenile	14	168.4	1384
YG2006	25-Jan-2006	M	298	242	Adult	12	221.4	1615
YY2006	24-Jan-2006	F	187	211	Adult	-	233.9	1406
OR200	25-Jan-2006	F	155	197	Juvenile	17	140.3	1120
YP2006	08-Feb-2006	F	332	233	Adult	-	139.2	1226

[1]California sea lion

[2]Juvenile-sized, but classified as yearling as it was observed nursing on several occasions after release.

Table 2. *Summary of sex- and age-distribution of instrumented Steller sea lions compared to the estimated sex- and age-composition of the study population as indicated by life tables.*

Age-Group	Number Tagged	Percent of Tagged Sample	Percent of Population
Yearlings	3[1]	12%	20%
Juveniles	9	36%	36%
Adults Females	5	20%	33%
Adult Males	8	32%	11%
Total	25	100%	100%

[1]Includes one over-size yearling classified as a yearling as it was observed nursing on several occasions after release.

Table 3. *Number of non-pup Steller sea lions counted during province-wide breeding season surveys during 1971-2013. Sites were classified as rookeries (R), year-round haulouts (Y), or winter haulouts (W), although in some cases usage patterns appeared to change over the course of the study period. Parentheses indicate sites were not surveyed and counts extrapolated or interpolated (see text for details).*

West Coast Vancouver Island

Site Name	Latitude	Longitude	Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
CARMANAH POINT	48º 36.9'N	124º 45.7'W	W/Y	0	(0)	181	170	146	103	150	255	237	247	162	514	1209
PACHENA POINT	48º 43.4'N	125º 06.3'W	W/Y	0	0	0	0	0	0	0	1	0	44	53	166	157
WOUWER ISLAND	48º 51.8'N	125º 21.5'W	W/Y	0	0	0	0	0	0	0	0	31	4	48	89	104
MARA ROCK	48º 52.5'N	125º 28.7'W	W/Y	0	(0)	0	3	0	0	41	87	296	264	376	514	332
STARLIGHT REEF	48º 52.9'N	125º 29.1'W	W/Y	0	0	0	0	0	0	0	0	0	0	0	25	155
LONG BEACH ROCKS	49º 02.3'N	125º 43.1'W	Y	394	265	10	262	231	344	298	535	714	388	295	367	447
PLOVER REEF	49° 10.9'N	126° 5.1'W	W/Y	0	0	0	0	0	0	0	0	0	0	10	0	154
RAPHAEL POINT	49º 18.5'N	126º 13.7'W	W	0	0	0	0	0	0	58	0	0	0	0	0	0
PEREZ ROCKS	49º 24.2'N	126º 35.0'W	Y	-	-	-	-	-	-	-	-	-	353	466	321	320
FERRER POINT	49º 44.6'N	126º 58.7'W	W	0	0	0	0	0	0	0	0	0	16	2	0	2
BARRIER ISLANDS	50º 00.7'N	127º 31.6'W	Y	(145)	(145)	105	153	149	274	290	843	585	542	1051	1284	1049
O'LEARY ISLETS	50º 06.1'N	127º 38.8'W	Y/W	331	(266)	200	85	60	81	14	74	2	141	0	0	0
SOLANDER ISLAND	50º 06.7'N	127º 56.4'W	W/Y	0	3	1	0	0	51	419	179	187	876	320	632	285
CAPE SCOTT	50º 47.1'N	128º 25.2'W	W	0	(0)	1	0	1	42	68	0	0	0	0	0	0
Region Subtotal	- -	- -	-	**870**	**679**	**498**	**673**	**587**	**895**	**1338**	**1974**	**2052**	**2875**	**2783**	**3912**	**4214**

Scott Islands

Site Name	Latitude	Longitude	Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
MAGGOT ISLAND	50º 48.1'N	128º 46.8'W	R	418	416	627	442	550	511	371	245	456	590	362	286	322
BERESFORD ISLAND	50º 47.5'N	128º 46.2'W	Y	71	69	24	100	124	164	119	5	147	13	397	153	222
SARTINE ISLAND	50º 49.2'N	128º 54.2'W	R	628	616	879	806	600	575	343	262	268	379	264	231	239
TRIANGLE ISLAND	50º 52.3'N	129º 04.6'W	R	550	375	570	376	1057	1603	1626	2540	2995	3576	3645	4651	5249
Region Subtotal	- -	- -	-	**1667**	**1476**	**2100**	**1724**	**2331**	**2853**	**2459**	**3052**	**3866**	**4558**	**4668**	**5321**	**6032**

Queen Charlotte Strait

Site Name	Latitude	Longitude	Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
ASHBY POINT	50º 56.5'N	127º 55.2'W	W/Y	(3)	(3)	4	1	210	3	226	225	519	786	541	479	632
BRIGHT ISLAND	50º 56.5'N	127º 39.4'W	W/Y	0	(0)	0	0	0	(0)	(0)	(0)	47	0	0	461	806
MILLER GROUP	50º 54.6'N	127º 26.5'W	W/Y	0	0	0	0	0	0	0	0	1	2	151	140	208
EDEN ISLAND	50° 44.8'N	126° 43.3'W	W/Y	-	-	-	-	0	0	0	0	(0)	(0)	(0)	32	45
Region Subtotal	- -	- -	-	**3**	**3**	**4**	**1**	**210**	**3**	**226**	**225**	**567**	**788**	**692**	**1112**	**1691**
Total Southern BC	- -	- -	-	**2540**	**2158**	**2602**	**2398**	**3128**	**3751**	**4023**	**5251**	**6485**	**8221**	**8143**	**10345**	**11937**

Central Mainland Coast

Site Name	Latitude	Longitude	Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
VIRGIN ROCKS	51º 16.8'N	128º 12.2'W	Y/R	317	205	62	190	229	157	131	168	419	516	595	533	1350
PEARL ROCKS	51º 21.8'N	128º 00.1'W	Y	100	81	276	23	128	126	98	199	467	449	247	263	414

Site Name	Latitude	Longitude	Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
WATCH ROCK	51º 22.8'N	128º 6.4'W	Y		0	0	0	0	0	0	0	(0)	0	0	20	0
BLENHEIM ISLAND	51° 48.5'N	128° 15.2'W	W/Y	-	-	0	0	0	0	0	0	(0)	(0)	0	3	42
AIRACOBRA ROCK	51° 45.5'N	128° 13.2'W	Y	-	-	-	-	-	-	-	-	-	-	-	30	14
GOSLING ROCKS	51º 52.1'N	128º 27.6'W	Y/R	106	(93)	37	179	135	72	192	133	160	257	308	439	384
MCINNES ISL	52º 15.8'N	128º 43.3'W	Y	196	(80)	45	0	0	109	241	163	25	(81)	263	139	262
STEELE ROCK	52º 27.8'N	129º 22.3'W	Y	(88)	(88)	85	150	7	35	137	227	101	92	194	173	228
ISNOR ROCK	52° 44.2'N	129° 31.8'W	Y	0	(0)	1	0	1	0	0	0	72	29	0	109	229
Region Subtotal	- -	- -	-	**807**	**547**	**506**	**542**	**500**	**499**	**799**	**890**	**1244**	**1424**	**1607**	**1709**	**2923**

North Mainland Coast

Site Name	Latitude	Longitude	Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
ASHDOWN ISL	53º 03.0'N	129º 12.7'W	W	(0)	(0)	0	(13)	(13)	25	(13)	0	(0)	(0)	(0)	17	525
GOODACRE POINT	52° 56.6'N	129° 33.2'W	?	-	-	-	-	-	-	-	-	-	-	-	19	-
MCDONALD	52° 58.8'N	129° 41.7'W	?	-	-	-	-	-	-	-	-	-	-	-	43	5
JOSEPH ISL	53° 8.7'N	130° 2.5'W	W/Y	0	(0)	(0)	0	0	(0)	(0)	0	2	3	0	128	345
N DANGER RKS	53º 15.3'N	130º 20.5'W	R	148	347	230	288	339	301	309	583	592	1003	652	527	783
BONILLA ISL	53º 28.0'N	130º 36.8'W	Y/R	29	158	333	219	19	265	272	303	215	375	282	508	392
WARRIOR ROCKS	54º 03.9'N	130º 51.1'W	Y	-	-	-	-	-	416	2	282	588	692	1114	1106	1221
CHEARNLEY ISL	54° 26.5'N	130° 59.2'W	W/Y	(0)	(0)	0	0	(0)	1	3	0	19	498	244	508	137
Region Subtotal	- -	- -	-	**177**	**505**	**563**	**520**	**371**	**1008**	**599**	**1168**	**1416**	**2571**	**2292**	**2856**	**3408**

Haida Gwaii (Queen Charlotte Islands)

Site Name	Latitude	Longitude	Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
ROSE SPIT	54° 12.7'N	131° 36.8'W	W/Y	1	(0)	(0)	(0)	(0)	(0)	(0)	0	(0)	30	132	57	50
SKEDANS	52° 57.2'N	131° 33.2'W	W	0	(0)	0	45	0	0	0	0	0	0	0	0	0
REEF ISL	52º 52.3'N	131º 29.1'W	Y	207	105	88	36	482	489	538	216	370	253	294	316	289
TATSUNG ROCK	52° 32.6'N	131° 21.4'W	W/Y	0	10	0	0	0	0	0	(0)	(0)	(0)	24	(43)	77
JOYCE ROCKS	52° 20.2'N	131° 7.9'W	?	-	-	-	-	-	-	-	-	-	-	53	(83)	165
GARCIN ROCKS	52° 12.8'N	130° 57.6'W	Y/R	-	-	-	-	-	-	-	-	329	261	305	565	594
CAPE ST. JAMES	51º 54.7'N	130º 58.9'W	R	631	549	782	698	1021	867	797	763	982	1094	811	1077	1020
ANTHONY ISL	52º 06.2'N	131º 14.4'W	Y	-	-	-	-	44	279	617	359	313	513	473	186	521
S NANGWAI ISLANDS	52º 24.5'N	131º 36.3'W	W	-	-	-	-	-	-	-	-	-	-	15	0	0
S TASU HD	52º 42.2'N	132º 04.5'W	Y	76	(375)	278	117	263	80	196	285	151	47	98	251	273
N CHADS POINT	52º 49.1'N	132º 14.4'W	W?	(0)	(0)	1	0	1	0	2	2	0	24	0	0	0
MORESBY ITS	52º 58.4'N	132º 21.6'W	W	(0)	(0)	(0)	(0)	0	3	115	65	2	1	0	0	0
MARBLE	53° 12.3'N	132° 39.1'W	W	0	(0)	0	0	0	0	0	0	0	1	0	0	67
CONE HD	53º 22.6'N	132º 43.3'W	W/Y	(0)	(0)	(0)	(0)	0	70	21	1	131	27	85	97	220
JOSEPH ROCKS	53º 48.8'N	133º 08.0'W	Y	408	(391)	399	366	309	327	397	601	696	770	(511)	339	249
LANGARA ISL	54º 15.6'N	133º 00.9'W	W/Y	6	(3)	0	3	3	(2)	0	217	3	484	(218)	98	337
Region Subtotal	- -	- -	-	**1329**	**1433**	**1548**	**1265**	**2123**	**2117**	**2683**	**2509**	**2977**	**3505**	**3019**	**3112**	**3862**
Total Northern BC	- -	- -	-	**2313**	**2485**	**2617**	**2327**	**2994**	**3624**	**4081**	**4567**	**5637**	**7500**	**6918**	**7677**	**10193**
Miscellaneous	- -	- -	-	0	0	0	1	0	3	0	0	0	0	0	7	5

Site Name	Latitude		Longitude		Site Type	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	01 July to 09 July 2008	26 June to 03 July 2010	29 June to 02 July 2013
Total Counted	**-**	**-**	-	-	**-**	**4853**	**4643**	**5219**	**4726**	**6122**	**7378**	**8104**	**9818**	**12122**	**15721**	**15061**	**18029**	**22135**
Survey Coverage	-	-	-	-	-	95.1%	68.9%	100%	99.7%	99.8%	100%	99.8%	100%	100%	99.5%	95.2%	99.3%	100%

Table 4. *Number of Steller sea lion pups counted during province-wide breeding season surveys during 1971-2013. Greyed counts in square brackets show number of pups counted prior to the site attaining rookery status.*

Site Name	28 June to 30 June 1971	29 June to 03 July 1973	27June to 30 June 1977	28 June to 01 July 1982	29 June to 03 July 1987	28 June to 03 July 1992	28 June to 01 July 1994	29 June to 04 July 1998	02 July to 06 July 2002	01 July to 03 July 2006	03 July to 07 July 2008	27 June to 02 July 2010	29 June to 02 July 2013
MAGGOT ISL	174	188	147	171	180	107	76	72	77	62	36	56	54
SARTINE ISL	163	273	309	409	176	253	62	148	146	178	101	104	140
TRIANGLE ISL	181	189	140	185	305	476	630	1221	2199	2674	2550	3776	4106
VIRGIN & PEARL RKS	[0]	[0]	[0]	[1]	[2]	[0]	[0]	[0]	[0]	55	100	155	268
GOSLING RKS	[0]	[(0)]	[0]	[1]	[0]	[0]	[0]	[0]	[2]	[0]	[14]	[26]	122
N DANGER RKS	86	93	64	74	54	148	85	144	219	403	216	272	374
BONILLA ISLAND	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[4]	[17]	[19]	55
CAPE ST. JAMES	337	272	303	404	367	484	333	488	635	723	900	846	825
GARCIN ROCKS	-	-	-	-	-	-	-	-	[2]	[12]	104	217	315
Haulout Sites	0	0	0	0	0	0	0	0	1	7	29	14	58
B.C. Total	**941**	**1015**	**963**	**1245**	**1084**	**1468**	**1186**	**2073**	**3281**	**4118**	**4067**	**5485**	**6317**
FORRESTER ISLAND	-	2371	-	2120	2073	-	2073	2364	2398	-	-	-	3215

Table 5. *Number of Steller sea lions counted during winter surveys in 2009-2010. Sites were classified as rookeries (R), year-round haulouts (Y), or winter haulouts (W).*

Strait of Georgia

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Race Rocks	48° 17.88'N	123° 31.89'W	W	-	63	9	-	-	2	36.0
Boiling Point Reef	48° 47.27'N	123° 2.51'W	W	-	0	31	-	-	2	15.5
Belle Chain	48° 50.02'N	123° 12.08'W	W	-	32	131	-	-	2	81.5
Active Pass	48° 51.50'N	123° 18.70'W	W	-	2	0	-	-	2	1.0
E Valdez Island	49° 4.60'N	123° 38.40'W	W	-	-	53	-	-	1	53.0
Entrance Island	49° 12.54'N	123° 48.57'W	W	-	-	11	-	-	1	11.0
S Winchelsea Island	49° 17.50'N	124° 4.75'W	W	-	-	14	-	-	1	14.0
Norris Rocks	49° 29.03'N	124° 38.89'W	W	-	-	423	-	-	1	423.0
Flora Islet	49° 31.02'N	124° 34.60'W	W	-	-	97	-	-	1	97.0
Scotch Fir Point	49° 44.59'N	124° 16.59'W	W	-	-	15	-	-	1	15.0
Vivian Island	49° 50.42'N	124° 42.05'W	W	-	-	193	-	-	1	193.0
Mittlenatch Island	49° 57.05'N	124° 59.85'W	W	-	-	6	-	-	1	6.0
Centre Islet	50° 7.48'N	125° 5.55'W	W	-	-	6	-	-	1	6.0

West Coast Vancouver Island

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Carmanah Point	48° 36.92'N	124° 45.68'W	Y	-	-	74	-	-	1	74.0
Pachena Point	48° 43.78'N	125° 6.85'W	Y	-	-	763	-	-	1	763.0
Wouwer Island	48° 51.77'N	125° 21.60'W	Y	-	-	223	360	-	2	291.5
Mara Rock	48° 52.50'N	125° 28.73'W	Y	-	-	213	112	-	2	162.5
S Wya Point	48° 56.70'N	125° 35.43'W	W	-	-	116	57	-	2	86.5
Long Beach Rocks	49° 2.33'N	125° 43.13'W	Y	-	-	322	356	-	2	339.0
Berryman Point	49° 9.36'N	125° 40.79'W	W	-	-	0	614	-	2	307.0
Plover Reef	49° 10.88'N	126° 5.09'W	Y	-	-	206	518	-	2	362.0
N Raphael Point	49° 22.29'N	126° 19.35'W	W	-	-	389	529	-	2	459.0
Perez Rocks	49° 24.80'N	126° 36.60'W	Y	-	-	11	31	-	2	21.0
Escalante Point	49° 32.84'N	126° 34.42'W	W	-	-	218	509	-	2	363.5
Ferrer Point	49° 44.60'N	126° 58.76'W	W	-	-	-	369	-	1	369.0
Barrier Islands	50° 0.74'N	127° 31.57'W	Y	-	-	156	30	-	2	93.0
O'Leary Islets	50° 6.14'N	127° 38.77'W	W	-	-	293	405	-	2	349.0
Solander Island	50° 6.68'N	127° 56.39'W	Y	-	-	146	537	-	2	341.5

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Rowley Reefs	50° 23.83’N	127° 57.96’W	W	-	-	28	284	21	3	111.0
Cape Scott	50° 47.10’N	128° 25.19’W	W	-	-	40	65	22	3	-

Scott Islands

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Beresford Island	50° 47.52’N	128° 46.18’W	Y	-	-	0	241	138	3	126.3
Maggot Island	50° 48.11’N	128° 46.76’W	R	-	-	0	0	6	3	2.0
Sartine Island	50° 49.19’N	128° 54.18’W	R	-	-	72	0	0	3	24.0
Triangle Island	50° 52.28’N	129° 4.64’W	R	-	-	453	844	672	3	656.3

Johnstone & Queen Charlotte Straits

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Nimpkish River	50° 34.05’N	126° 58.43’W	W	-	-	0	-	22	2	11.0
Plumper Islands	50° 35.55’N	126° 47.53’W	W	-	-	0	-	33	2	16.5
Stubbs Island	50° 36.22’N	126° 49.03’W	W	-	-	0	-	3	2	1.5
W Eden Island	50° 44.78’N	126° 43.32’W	Y	-	-	89	-	132	2	110.5
SE Gordon Islands	50° 48.22’N	127° 27.58’W	W	-	-	66	-	175	2	120.5
Echo Islands	50° 53.00’N	127° 27.11’W	W	-	-	0	-	12	2	6.0
Miller Group	50° 54.58’N	127° 26.61’W	Y	-	-	130	-	295	2	212.5
Buckle Group	50° 56.47’N	127° 39.44’W	Y	-	-	0	-	0	2	0.0
Ashby Point	50° 56.53’N	127° 55.24’W	Y	-	-	113	487	859	3	486.3

Central Mainland Coast

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Virgin Rocks	51° 16.81’N	128° 12.24’W	R	-	-	-	215	-	1	215.0
Pearl Rocks	51° 21.79’N	128° 0.11’W	Y	-	-	-	0	-	1	0.0
Dugout Rocks	51° 22.64’N	127° 47.17’W	W	-	-	-	786	-	1	786.0
Blenheim Island	51° 48.47’N	128° 15.21’W	Y	-	-	-	145	-	1	145.0
Gosling Rocks	51° 52.14’N	128° 27.59’W	Y	-	-	-	1072	-	1	1072.0
McInnes Island	52° 15.75’N	128° 43.25’W	Y	-	-	-	606	-	1	606.0

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Steele Rock	52° 27.83'N	129° 22.25'W	Y	-	-	-	273	-	1	273.0
Lindsay Rocks	52° 34.15'N	129° 15.30'W	W	-	-	-	5	-	1	5.0
Isnor Rock	52° 44.15'N	129° 31.81'W	Y	-	-	-	119	-	1	119.0

Northern Mainland Coast

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Ashdown Island	53° 2.95'N	129° 12.80'W	W	-	-	-	530	-	1	530.0
North Danger Rocks	53° 15.34'N	130° 20.50'W	R	-	-	-	267	-	1	267.0
Bonilla Island	53° 27.97'N	130° 36.77'W	Y	-	-	-	716	-	1	716.0
S Cape George	53° 50.38'N	130° 40.24'W	W	-	-	-	193	-	1	193.0
Joachim Rock	53° 51.16'N	130° 43.02'W	W	-	-	-	22	-	1	22.0
Warrior Rocks	54° 3.88'N	130° 51.12'W	Y	-	-	-	287	-	1	287.0
Roland Rocks	54° 10.30'N	130° 50.65'W	W	-	-	-	274	-	1	274.0
S Chearnley Island	54° 24.26'N	130° 55.38'W	W	-	-	-	187	-	1	187.0
Chearnley Island	54° 26.48'N	130° 59.19'W	Y	-	-	-	768	-	1	768.0
Zayas Island	54° 35.71'N	131° 5.35'W	W	-	-	-	95	-	1	95.0

Haida Gwaii (Queen Charlotte Islands)

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
Rose Spit	54° 12.74'N	131° 36.79'W	Y	0	-	-	-	-	1	0.0
Near Maude Island	53° 12.23'N	132° 4.47'W	Raft	70	-	-	-	-	1	70.0
Cumshewa Island & Rocks	53° 0.67'N	131° 34.97'W	W	111	-	-	-	-	1	111.0
Skedans Island	52° 57.23'N	131° 33.16'W	W	297	-	-	-	-	1	297.0
Reef Island	52° 52.30'N	131° 29.06'W	Y	549	-	-	-	-	1	549.0
Helmet Island	52° 48.93'N	131° 39.83'W	W	365	-	-	-	-	1	365.0
Tatsung Rock	52° 32.62'N	131° 21.35'W	Y	391	-	-	-	-	1	391.0
Scudder Point	52° 27.00'N	131° 14.02'W	W	2	-	-	-	-	1	2.0
Joyce Rocks	52° 20.22'N	131° 7.90'W	Y	181	-	-	-	-	1	181.0
Garcin Rocks	52° 12.79'N	130° 57.64'W	R	264	-	-	-	-	1	264.0
Cape St James	51° 54.67'N	130° 58.91'W	R	256	-	-	-	-	1	256.0
Anthony Island	52° 4.87'N	131° 13.78'W	Y	18	-	-	-	-	1	18.0

Site Name	Latitude	Longitude	Site Type	20-22 Jan 2009	02 Feb 2009	08-09 Feb 2009	22-24 Jan 2010	10 Dec 2009	# Reps	Mean Count
S McLean Fraser Point	52° 12.91'N	131° 25.73'W	W	139	-	-	-	-	1	139.0
Gowgaia	52° 24.45'N	131° 36.91'W	W	47	-	-	-	-	1	47.0
S Tasu Head	52° 42.17'N	132° 4.50'W	Y	58	-	-	-	-	1	58.0
Kootenay Inlet	52° 51.43'N	132° 15.56'W	W	13	-	-	-	-	1	13.0
Moresby Islets	52° 58.20'N	132° 21.02'W	W	85	-	-	-	-	1	85.0
Marble Island	53° 12.28'N	132° 39.11'W	W	69	-	-	-	-	1	69.0
Kindakun	53° 19.96'N	132° 45.49'W	W	102	-	-	-	-	1	102.0
Hippa Island	53° 33.13'N	133° 0.57'W	W	363	-	-	-	-	1	363.0
Joseph Rocks	53° 48.83'N	133° 8.00'W	Y	305	-	-	-	-	1	305.0
Sadler Point	54° 6.01'N	133° 6.94'W	W	72	-	-	-	-	1	72.0
Langara Island	54° 15.63'N	133° 0.88'W	Y	101	-	-	-	-	1	101.0
TOTAL										**17678.3**

Table 6. *Number of Steller sea lions counted during an autumn survey 19-25 October, 2012. Sites were classified as rookeries (R), year-round haulouts (Y), or winter haulouts (W).*

Strait of Georgia

Site Name	Latitude		Longitude		Site Type	Survey Date	Count		
							NPs	Pups	Total
Race Rocks	48°	17.88' N	123°	31.89' W	W	25-Oct-2012	37	2	39
Cowichan Bay	48°	45.10' N	123°	37.29' W	W	25-Oct-2012	9	0	9
Boiling Point Reef	48°	47.27' N	123°	2.51' W	W	25-Oct-2012	5	0	5
Belle Chain	48°	50.02' N	123°	12.08' W	W	25-Oct-2012	246	4	250
Active Pass	48°	51.50' N	123°	18.70' W	W	25-Oct-2012	0	0	0
NE Valdez Isl	49°	6.23' N	123°	39.81' W	W	25-Oct-2012	99	1	100
Harmac Logbooms	49°	8.37' N	123°	51.05' W	W	25-Oct-2012	0	0	0
Entrance Island	49°	12.54' N	123°	48.57' W	W	25-Oct-2012	0	0	0
S Winchelsea Island	49°	17.50' N	124°	4.75' W	W	25-Oct-2012	0	0	0
Northwest Bay	49°	17.96' N	124°	12.30' W	W	25-Oct-2012	11	0	11
White Islets	49°	25.08' N	123°	42.75' W	W	25-Oct-2012	16	0	16
Norris Rocks	49°	29.03' N	124°	38.89' W	W	25-Oct-2012	618	31	649
SE Jedediah Island	49°	29.87' N	124°	10.35' W	W	25-Oct-2012	29	0	29
Flora Islet	49°	31.02' N	124°	34.60' W	W	25-Oct-2012	74	1	75
N Union Point	49°	36.00' N	124°	53.36' W	W	25-Oct-2012	9	1	10
Scotch Fir Point	49°	44.59' N	124°	16.59' W	W	21-Oct-2012	0	0	0
McRae Islet	49°	44.65' N	124°	17.55' W	W	21-Oct-2012	181	11	192
Vivian Island	49°	50.42' N	124°	42.05' W	W	21-Oct-2012	3	0	3
Mittlenatch Island	49°	57.05' N	124°	59.85' W	W	21-Oct-2012	103	2	105
Menzies Bay	50°	7.43' N	125°	22.48' W	W	25-Oct-2012	3	0	3
Centre Islet	50°	7.48' N	125°	5.55' W	W	21-Oct-2012	3	0	3

Johnstone & Queen Charlotte Straits

Site Name	Latitude		Longitude		Site Type	Survey Date	Count		
							NPs	Pups	Total
North Bluff	50°	8.47' N	125°	21.05' W	W	25-Oct-2012	7	0	7
Granite Point	50°	16.63' N	125°	23.00' W	W	25-Oct-2012	4	0	4
Stuart Island	50°	23.14' N	125°	9.17' W	W	21-Oct-2012	17	0	17
Jimmy Judd Island	50°	23.70' N	125°	9.43' W	W	21-Oct-2012	80	0	80
Helmcken Island	50°	24.49' N	125°	53.23' W	W	21-Oct-2012	8	0	8
Plumper Islands	50°	35.55' N	126°	47.53' W	W	21-Oct-2012	74	2	76
W Eden Island	50°	44.78' N	126°	43.32' W	Y	21-Oct-2012	99	4	103
SE Gordon Islands	50°	48.22' N	127°	27.58' W	W	19-Oct-2012	6	0	6
Echo Islands	50°	53.00' N	127°	27.11' W	W	19-Oct-2012	14	2	16
Miller Group	50°	54.58' N	127°	26.61' W	Y	19-Oct-2012	410	131	541
Buckle Group	50°	56.47' N	127°	39.44' W	Y	19-Oct-2012	295	15	310
Ashby Point	50°	56.53' N	127°	55.24' W	Y	19-Oct-2012	1898	1007	2905
Pine Island	50°	58.60'N	127°	43.42' W	W	19-Oct-2012	163	8	171

West Coast Vancouver Island

Site Name	Latitude		Longitude		Site Type	Survey Date	Count		
							NPs	Pups	Total
Sombrio Point	48°	28.98' N	124°	17.11' W	W	25-Oct-2012	84	0	84
Carmanah Point	48°	36.92' N	124°	45.68' W	Y	25-Oct-2012	785	27	812
Pachena Point	48°	43.78' N	125°	6.85' W	Y	25-Oct-2012	1446	112	1558
Folger Island	48°	49.72' N	125°	14.65' W	W	25-Oct-2012	551	34	585
Wouwer Island	48°	51.77' N	125°	21.60' W	Y	25-Oct-2012	217	69	286
Mara Rock	48°	52.50' N	125°	28.73' W	Y	25-Oct-2012	23	4	27
George Fraser Islands	48°	54.75' N	125°	30.86' W	W	25-Oct-2012	0	0	0

Site Name	Latitude		Longitude		Site Type	Survey Date	Count		
							NPs	Pups	Total
S Wya Point	48°	56.70’ N	125°	35.43’ W	W	25-Oct-2012	0	0	0
Long Beach Rocks	49°	2.33’ N	125°	43.13’ W	Y	25-Oct-2012	7	0	7
Berryman Point	49°	9.36’ N	125°	40.79’ W	W	25-Oct-2012	0	0	0
Plover Reef	49°	10.88’ N	126°	5.09’ W	Y	25-Oct-2012	341	126	467
N Raphael Point	49°	22.29’ N	126°	19.35’ W	W	19-Oct-2012	0	0	0
Perez Rocks	49°	24.80’ N	126°	36.60’ W	Y	19-Oct-2012	1928	441	2369
Escalante Point	49°	32.84’ N	126°	34.42’ W	W	19-Oct-2012	0	0	0
Ferrer Point	49°	44.60’ N	126°	58.76’ W	W	19-Oct-2012	207	14	221
Barrier Islands	50°	0.74’ N	127°	31.57’ W	Y	19-Oct-2012	568	239	807
O'Leary Islets	50°	6.14’ N	127°	38.77’ W	W	19-Oct-2012	885	339	1224
Solander Island	50°	6.68’ N	127°	56.39’ W	Y	19-Oct-2012	321	33	354
Rowley Reefs	50°	23.83’ N	127°	57.96’ W	W	19-Oct-2012	5	0	5
Cape Scott	50°	47.10’ N	128°	25.19’ W	W	19-Oct-2012	32	0	32

Scott Islands

Site Name	Latitude		Longitude		Site Type	Survey Date	Count		
							NPs	Pups	Total
Beresford Island	50°	47.52’ N	128°	46.18’ W	Y	19-Oct-2012	90	55	145
Maggot Island	50°	48.11’ N	128°	46.76’ W	R	19-Oct-2012	80	30	110
Sartine Island	50°	49.19’ N	128°	54.18’ W	R	19-Oct-2012	31	2	33
Triangle Island	50°	52.28’ N	129°	4.64’ W	R	19-Oct-2012	548	414	962

Central Mainland Coast

Site Name	Latitude		Longitude		Site Type	Survey Date	Count		
							NPs	Pups	Total
Virgin Rocks	51°	16.81’ N	128°	12.24’ W	R	19-Oct-2012	413	280	693
Pearl Rocks	51°	21.79’ N	128°	0.11’ W	Y	19-Oct-2012	330	153	483
Dugout Rocks	51°	22.64’ N	127°	47.17’ W	W	19-Oct-2012	481	73	554
Watch Rock	51°	22.94’ N	128°	6.05’ W	W	19-Oct-2012	7	2	9
Airacobra Rock	51°	45.54’ N	128°	13.19’ W	Y	19-Oct-2012	4	0	4
Blenheim Island	51°	48.47’ N	128°	15.21’ W	Y	19-Oct-2012	256	41	297
Gosling Rocks	51°	52.14’ N	128°	27.59’ W	R	19-Oct-2012	1198	486	1684
McInnes Island	52°	15.75’ N	128°	43.25’ W	Y	20-Oct-2012	356	76	432
Steele Rock	52°	27.83’ N	129°	22.25’ W	Y	20-Oct-2012	174	17	191
Isnor Rock	52°	44.15’ N	129°	31.81’ W	Y	20-Oct-2012	90	22	112

Northern Mainland Coast

Site Name	Latitude		Longitude		Site Type	Survey Date	Count		
							NPs	Pups	Total
McDonald Island	52°	58.75’ N	129°	41.73’ W	W	20-Oct-2012	27	4	31
Ashdown Island	53°	2.95’ N	129°	12.80’ W	W	20-Oct-2012	356	23	379
Joseph Island	53°	8.67’ N	130°	2.55’ W	W	20-Oct-2012	0	0	0
North Danger Rocks	53°	15.34’ N	130°	20.50’ W	R	21-Oct-2012	132	65	197
Bonilla Island	53°	27.97’ N	130°	36.77’ W	Y	21-Oct-2012	178	66	244
Bonilla #2	53°	32.90’ N	130°	38.90’ W	W	21-Oct-2012	318	20	338
S Cape George	53°	50.38’ N	130°	40.24’ W	W	21-Oct-2012	182	2	184
Joachim Rock	53°	51.16’ N	130°	43.02’ W	W	21-Oct-2012	0	0	0
Warrior Rocks	54°	3.88’ N	130°	51.12’ W	Y	21-Oct-2012	445	109	554
Roland Rocks	54°	10.30’ N	130°	50.65’ W	W	21-Oct-2012	511	79	590
S Chearnley Island	54°	24.26’ N	130°	55.38’ W	W	20-Oct-2012	274	3	277
Chearnley Island	54°	26.48’ N	130°	59.19’ W	Y	20-Oct-2012	747	234	981
Zayas Island	54°	35.71’ N	131°	5.35’ W	W	20-Oct-2012	67	7	74

Haida Gwaii (Queen Charlotte Islands)

Site Name	**Latitude**		**Longitude**		**Site Type**	**Survey Date**	**Count**		
							NPs	**Pups**	**Total**
Rose Spit	54°	12.74' N	131°	36.79' W	Y	20-Oct-2012	543	118	661
Cumshewa Island &	53°	0.67' N	131°	34.97' W	W	20-Oct-2012	36	2	38
Skedans Island	52°	57.23' N	131°	33.16' W	W	20-Oct-2012	347	23	370
Reef Island	52°	52.30' N	131°	29.06' W	Y	20-Oct-2012	429	92	521
Helmet Island	52°	48.93' N	131°	39.83' W	W	20-Oct-2012	131	6	137
Tatsung Rock	52°	32.62' N	131°	21.35' W	Y	20-Oct-2012	116	4	120
Scudder Point	52°	27.00' N	131°	14.02' W	W	20-Oct-2012	0	0	0
Joyce Rocks	52°	20.22' N	131°	7.90' W	Y	20-Oct-2012	213	98	311
Garcin Rocks	52°	12.79' N	130°	57.64' W	R	20-Oct-2012	433	316	749
Cape St James	51°	54.67' N	130°	58.91' W	R	20-Oct-2012	79	25	104
Anthony Island	52°	4.87' N	131°	13.78' W	Y	20-Oct-2012	118	17	135
S McLean Fraser	52°	12.91' N	131°	25.73' W	W	20-Oct-2012	9	1	10
Gowgaia	52°	24.45' N	131°	36.91' W	W	20-Oct-2012	0	0	0
Lindsay Rocks	52°	34.15' N	129°	15.30' W	W	20-Oct-2012	31	0	31
S Tasu Head	52°	42.17' N	132°	4.50' W	Y	20-Oct-2012	2	0	2
Kootenay Inlet	52°	51.43' N	132°	15.56' W	W	20-Oct-2012	0	0	0
Moresby Islets	52°	58.20' N	132°	21.02' W	W	20-Oct-2012	23	0	23
Kindakun	53°	19.96' N	132°	45.49' W	W	20-Oct-2012	237	45	282
Cone Head	53°	22.57' N	132°	43.27' W	Y	20-Oct-2012	0	0	0
Hippa Island	53°	33.13' N	133°	0.57' W	W	20-Oct-2012	194	49	243
Joseph Rocks	53°	48.83' N	133°	8.00' W	Y	20-Oct-2012	277	153	430
Sadler Point	54°	6.01' N	133°	6.94' W	W	20-Oct-2012	129	6	135
Langara Island	54°	15.63' N	133°	0.88' W	Y	20-Oct-2012	130	74	204
NW Cape Naden	54°	7.64' N	132°	35.95' W	W	20-Oct-2012	26	6	32
TOTAL							22791	5958	28677

Table 7. *Comparison of counts on B.C. rookeries made by DFO from oblique images and by NMFS from vertical images in 2013. Cape St. James is excluded as it was not surveyed by NMFS.*

Site	**DFO Oblique Images**			**NMFS Vertical Images**		
	Survey Date	**Pups**	**NPs**	**Survey Date**	**Pups**	**NPs**
Beresford & Maggot Islands	30-Jun-2013	54	533	20-Jun-2013	53	1188
Sartine Island	30-Jun-2013	140	239	20-Jun-2013	118	336
Triangle Island - Site B	30-Jun-2013	143	214	20-Jun-2013	149	240
Triangle Island - Sites C & D	30-Jun-2013	1060	1203	20-Jun-2013	1064	1306
Triangle Island - Site E	30-Jun-2013	347	683	20-Jun-2013	276	616
Triangle Island - Site F	30-Jun-2013	148	225	20-Jun-2013	132	251
Triangle Island - Site G	30-Jun-2013	2408	2924	20-Jun-2013	2386	2936
Virgin Island	30-Jun-2013	265	1350	21-Jun-2013	261	1074
Gosling Rocks	30-Jun-2013	122	384	21-Jun-2013	113	451
North Danger Rocks	30-Jun-2013	374	783	22-Jun-2013	374	674
Bonilla Island	01-Jul-2013	55	392	22-Jun-2013	49	370
Garcin Rocks	02-Jul-2013	315	594	22-Jun-2013	286	696
TOTAL		5431	9524	-	5261	10138

8 FIGURES

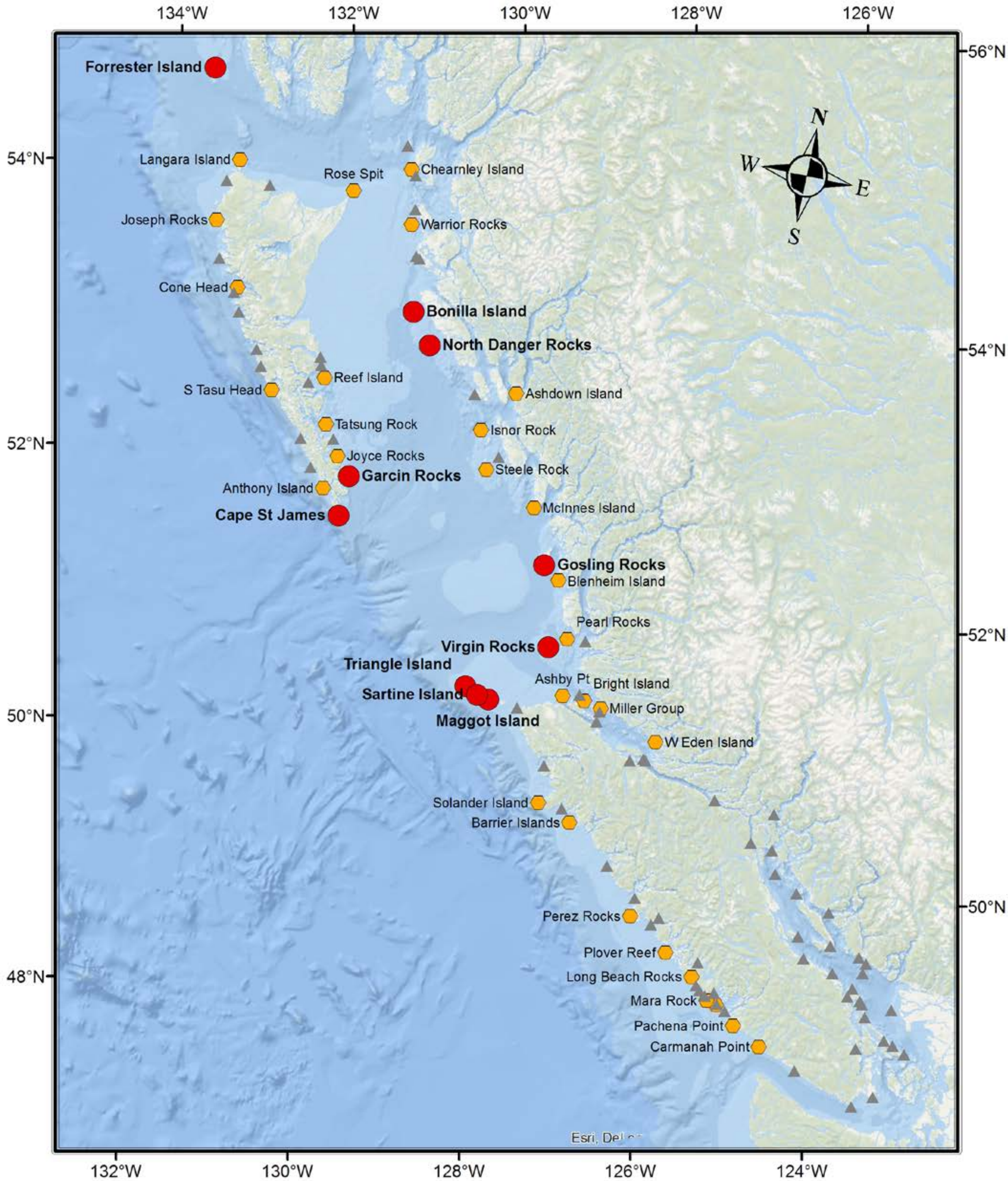


Figure 1. *Map showing location of Steller sea lion breeding rookeries (●), year-round haulout sites (●), and major winter haulout sites (▲) in British Columbia and at Forrester Island, Alaska.*

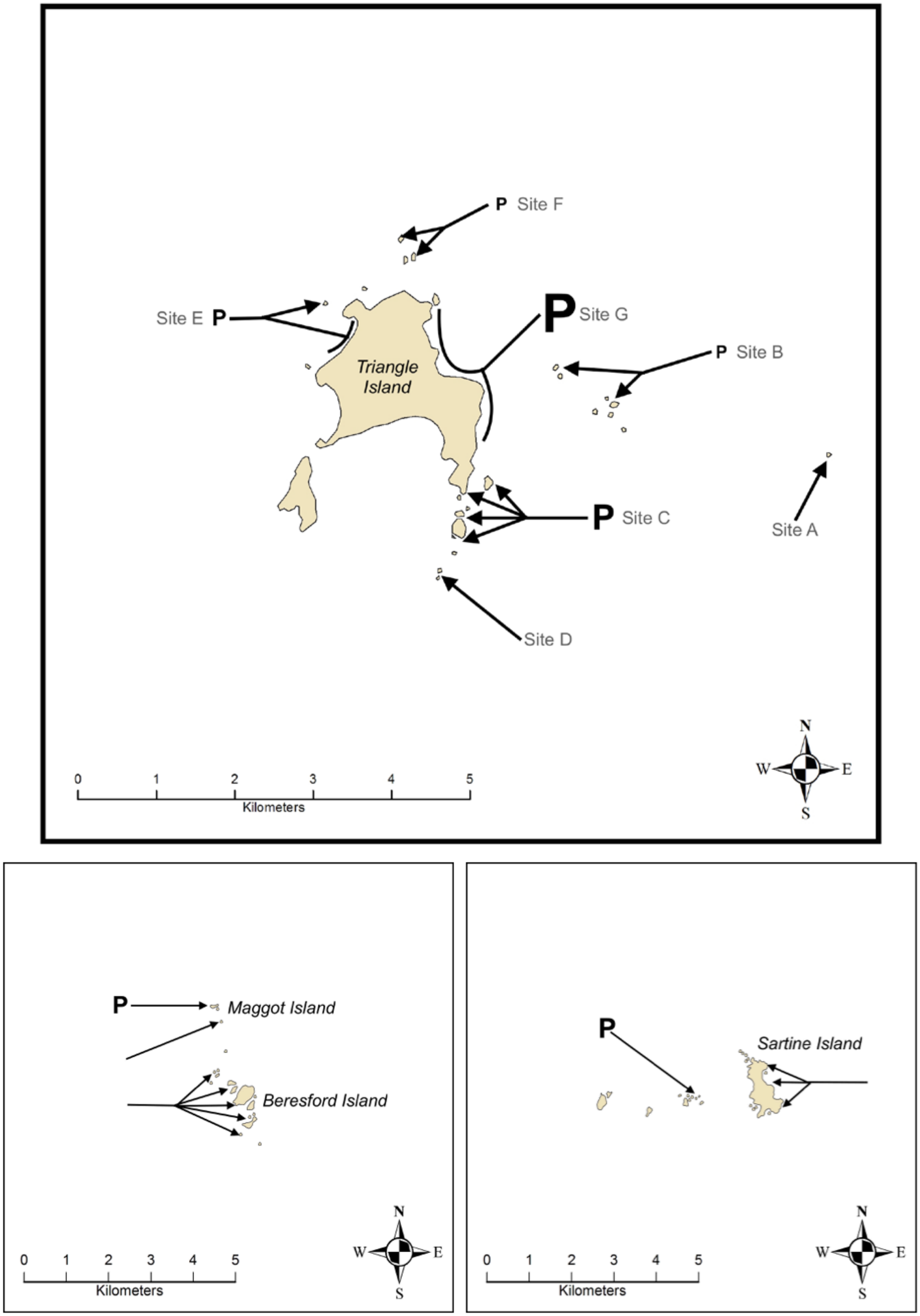


Figure 2. *Detailed maps showing distribution of sea lions on rookeries. Arrows show the location of animal aggregations and P's denote the location and relative size of pupping areas.*

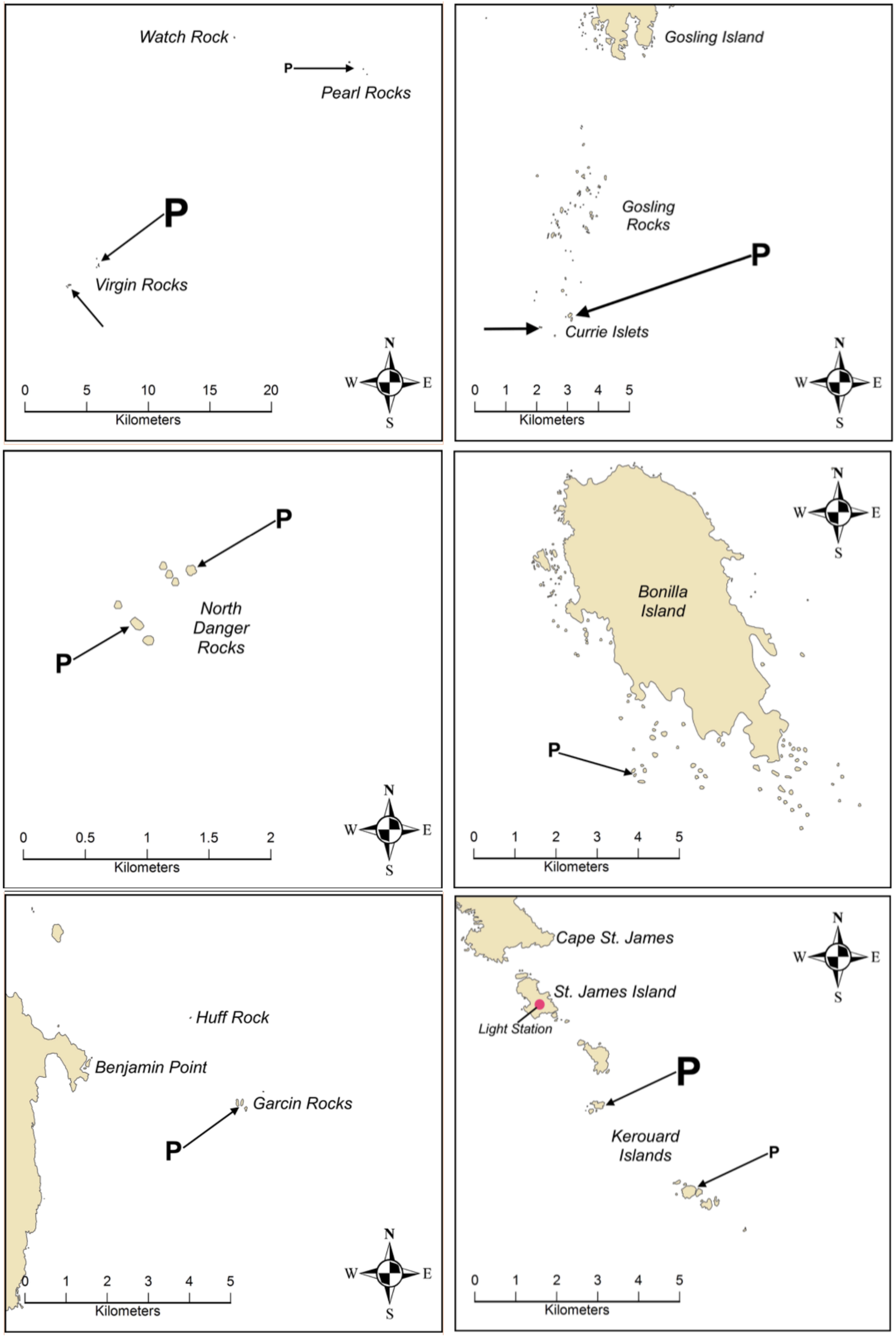


Figure 2 Continued. *Detailed maps showing distribution of sea lions on rookeries. Arrows show the location of animal aggregations and P's denote the location and relative size of pupping areas.*

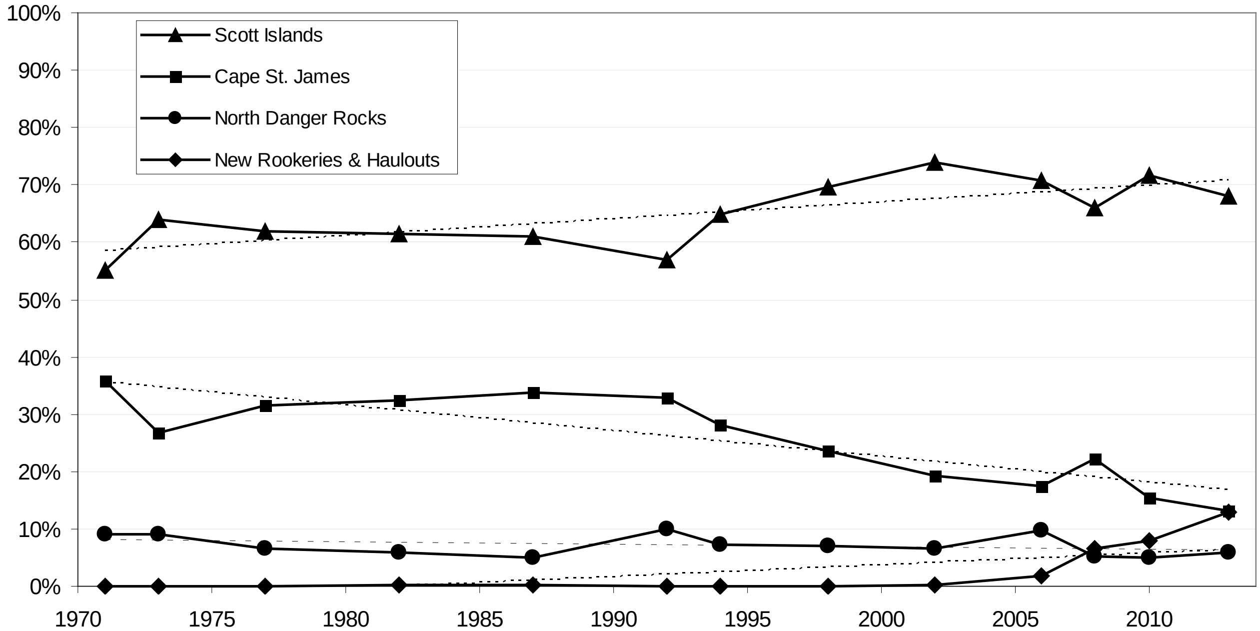
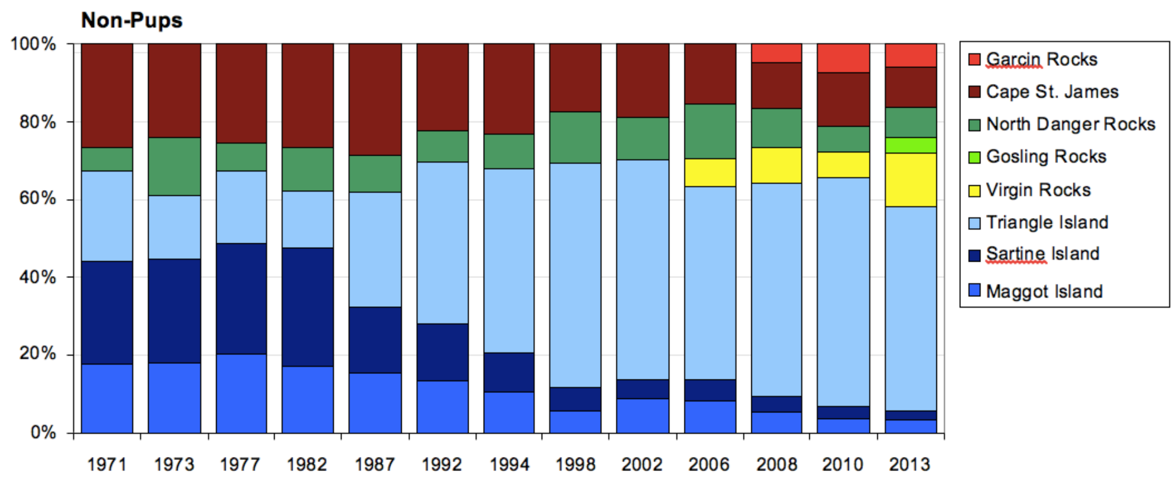


Figure 3*. Temporal changes in relative distribution of pup production among major breeding areas in B.C. during 1971-2013. Dashed lines denote regressions showing long-term average rates of change over time. Regressions indicate a significant decreasing trend for Cape St. James ($F_{(1,11)}$=28.7; P=0.0002), a significant increasing trend for the Scott Islands ($F_{(1,11)}$=13.3; P=0.0039), a significant increasing trend on new rookeries and haulout sites ($F_{(1,11)}$=10.9; P=0.0071), but no significant trend for North Danger Rocks ($F_{(1,11)}$=1.6; P=0.2294).*



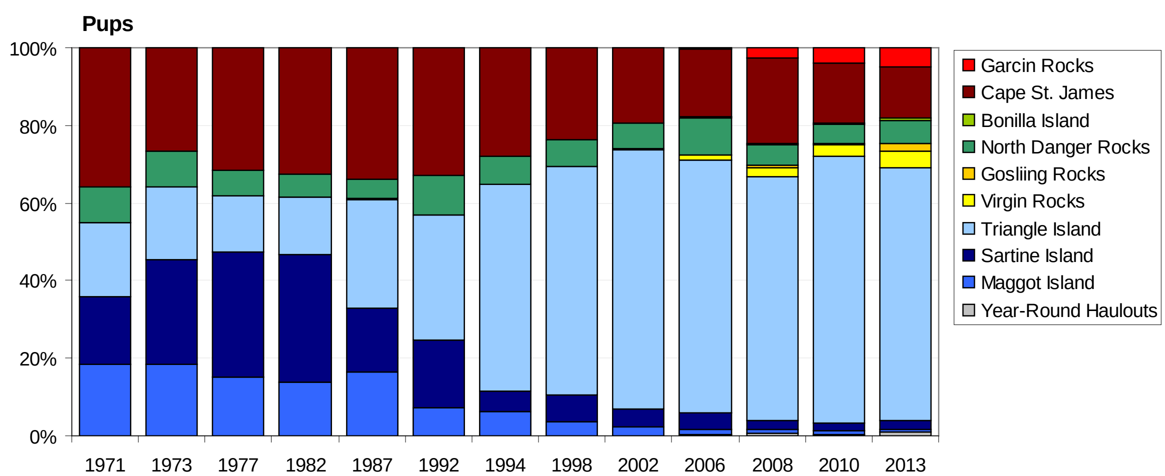


Figure 4. *Changes in relative distribution of non-pups (top panel) and pups (bottom panel) among B.C. rookeries observed during province-wide aerial surveys in 1971-2013. Rookeries in Haida Gwaii are shown in various shades of red, rookeries on North Danger Rocks in green, rookeries on the Sea Otter Group in yellow, and rookeries on the Scott Islands in various shades of blue.*

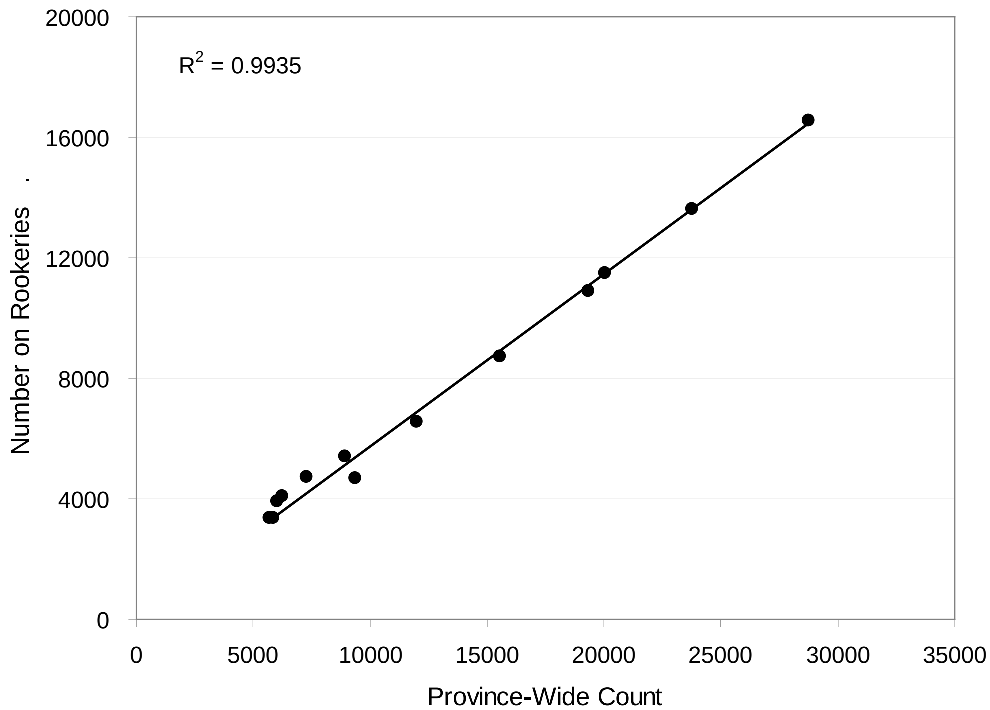


***Figure 5**. Proportion of the total province-wide count (including pups) that occurred on rookeries during 1971-2013. Solid line represents a least squares regression. The slope was significantly greater than one ($F_{(1,11)}$=1879.9; P<0.0001), but the intercept was not significantly different than zero ($F_{(1,11)}$=1.3; P=0.2755), so the regression was forced through the origin. The resulting slope indicated that 57% (SE=0.65%) of all animals occurred on rookeries.*

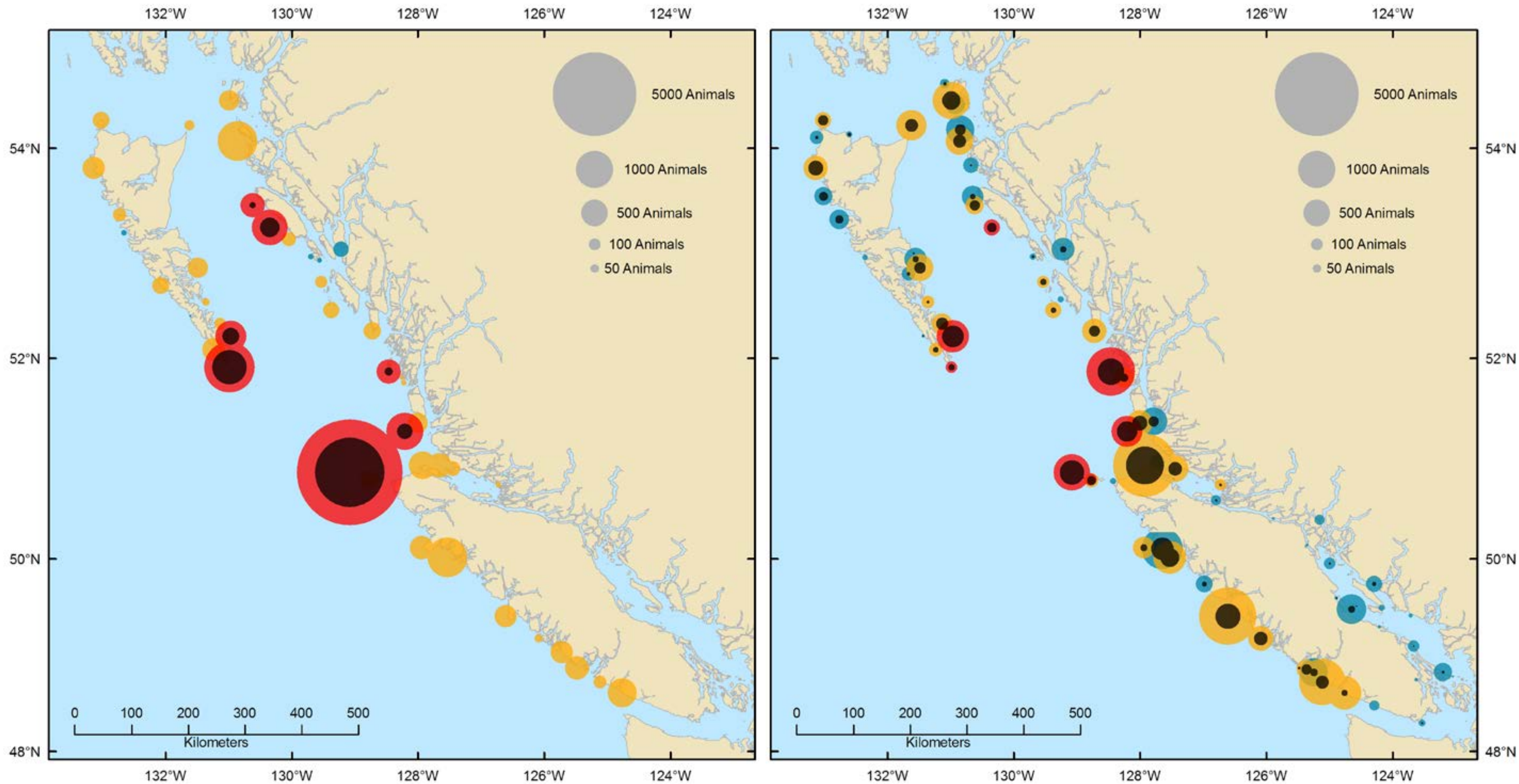


Figure 6. *Maps showing seasonal changes in distribution of Steller sea lion counts during summer surveys in 2008-2013 (top left), an autumn survey in 2012 (top right), and winter surveys in 2009-2010 (next page). Symbol sizes are proportional to the total number of animals (pups and non-pups) counted at each site. Black inner circles indicate the number of pups at each site in summer and autumn surveys (pups had moulted and could no longer be distinguished from older animals in winter surveys). Red symbols denote rookeries, orange symbols year-round haulouts, and blue symbols winter haulouts.*

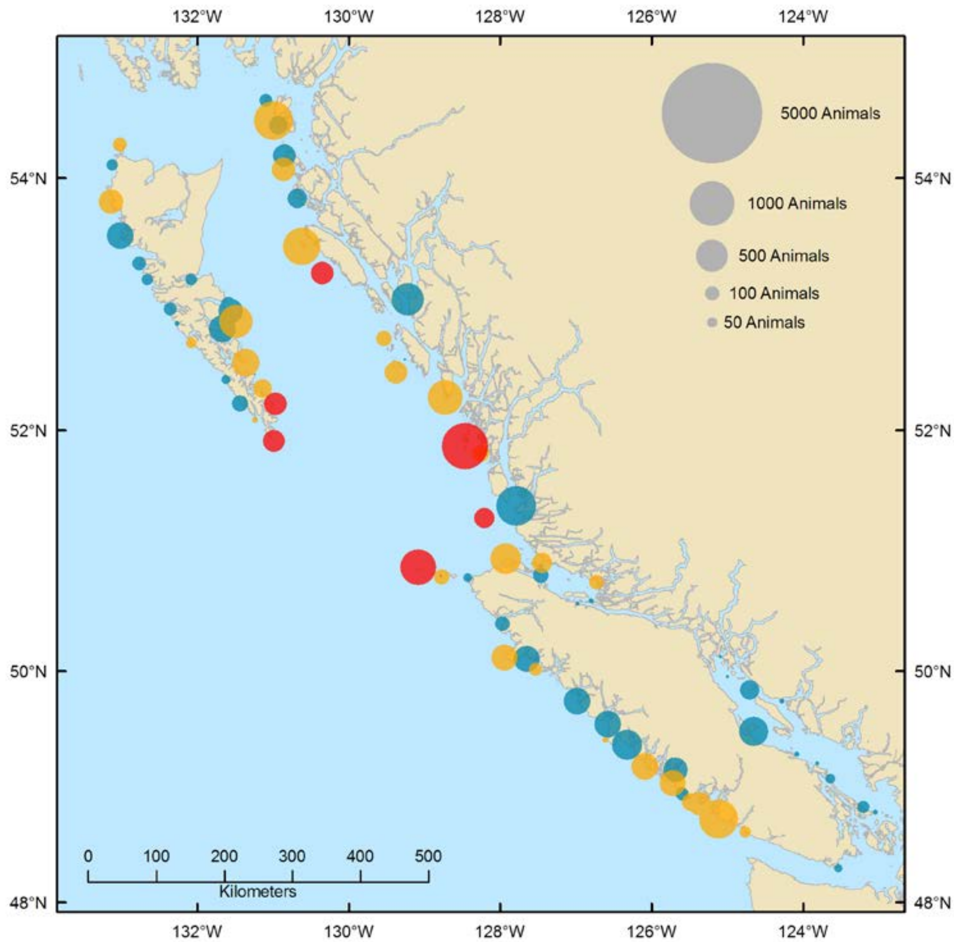


Figure 6. Continued. *Maps showing seasonal changes in distribution of Steller sea lion counts during summer surveys in 2008-2013 (previous page, left), an autumn survey in 2012 (previous page, right), and winter surveys in 2009-2010 (above). Symbol sizes are proportional to the total number of animals (pups and non-pups) counted at each site. Black inner circles indicate the number of pups at each site in summer and autumn surveys (pups had moulted and could no longer be distinguished from older animals in winter surveys). Red symbols denote rookeries, orange symbols year-round haulouts, and blue symbols winter haulouts.*

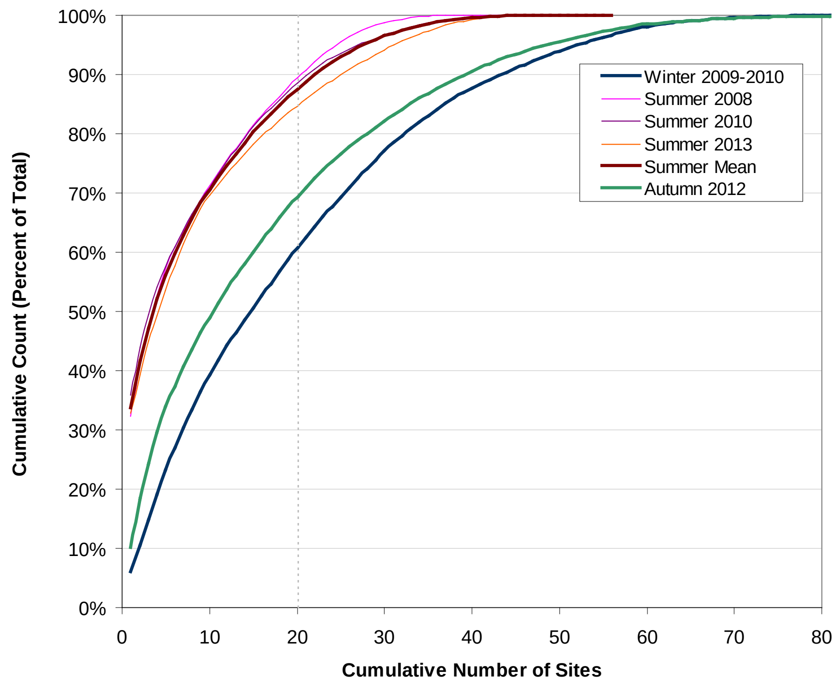


Figure 7. *Plot showing the degree of aggregation of Steller sea lion counts during summer surveys in 2008-2013 (red line), the autumn survey in 2012, and winter surveys in 2009-2010. Sites were sorted by size from largest to smallest, and the cumulative count plotted as a function of number of sites. For example, the vertical dotted line indicates the 20 largest sites accounted for 85-90% of the total number of animals counted during summer surveys, but for only about 70% of the total count in the autumn survey and 60% of the total count during winter surveys.*

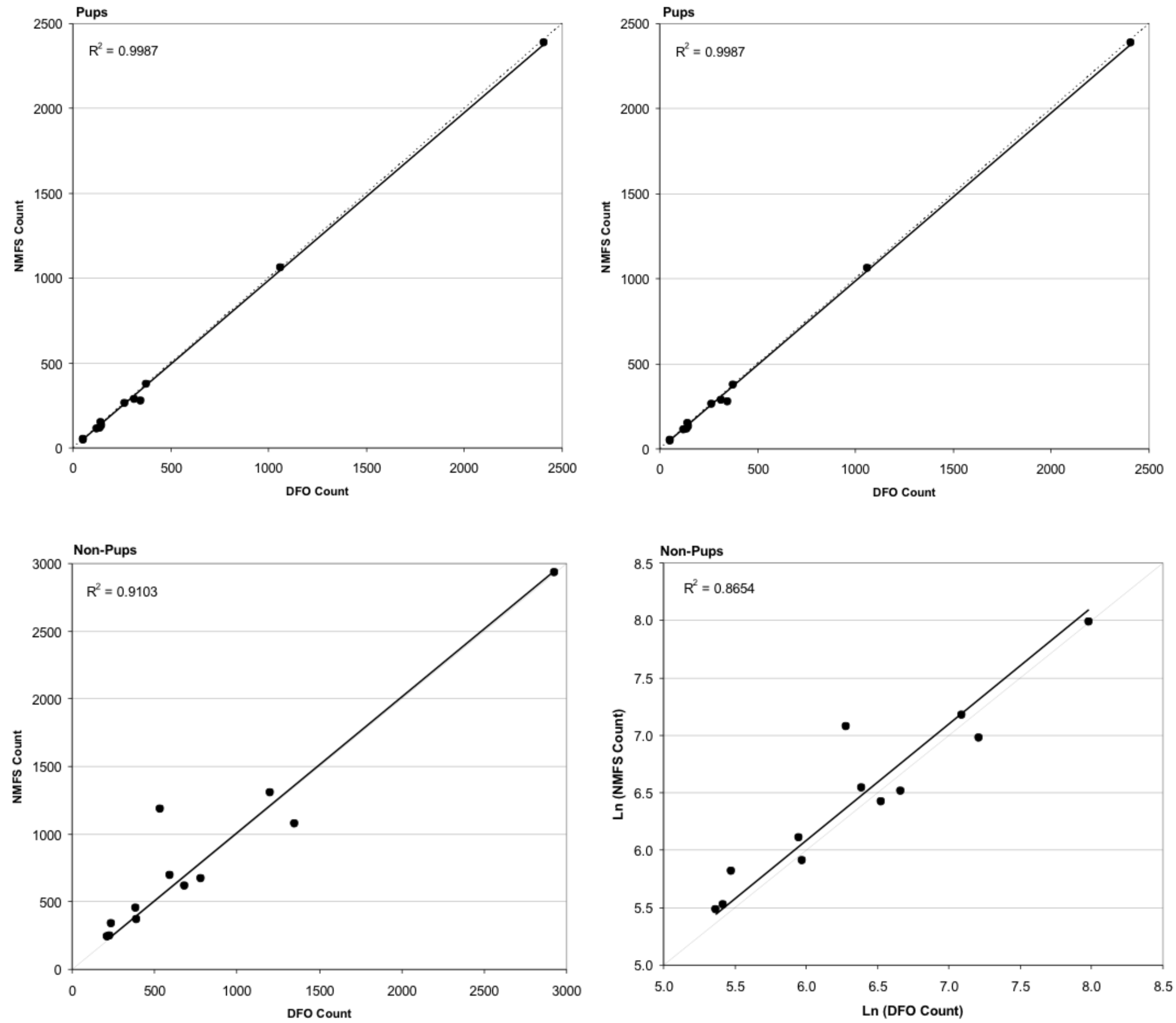
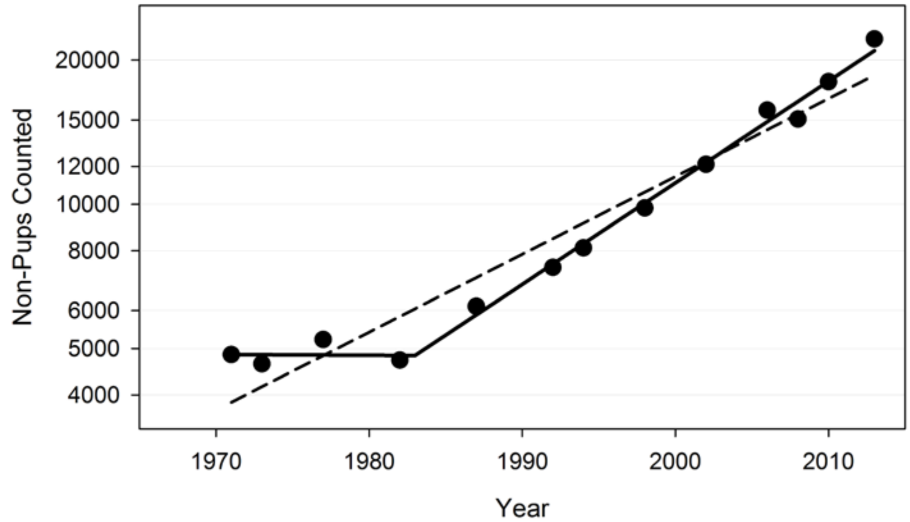


Figure 8. *Comparison of DFO counts from oblique images and NMFS counts from vertical images on B.C. rookeries (excluding Cape St. James) for pups (top panels) and non-pups (bottom panels). Left panels show untransformed counts, and right panels show log-transformed counts. Solid lines represent least squares regressions forced through the origin (see text for details). Dashed lines show 1:1 relationship.*



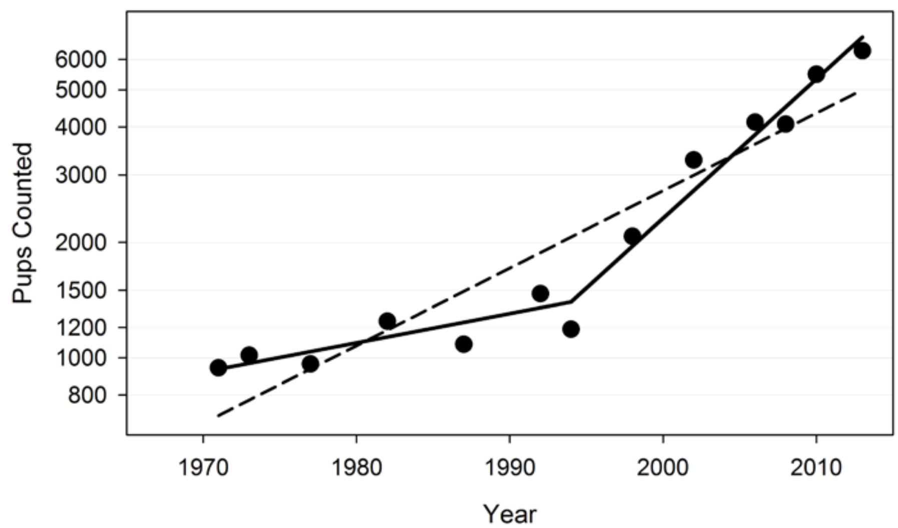


***Figure 9**. Recent trends in the number of non-pups (top panel) and pups (bottom panel) in B.C. based on province-wide aerial surveys conducted during 1971-2013. Dashed lines denote log-linear regressions and solid lines piecewise log-linear regressions that allowed for a change in the rate of increase (see text for details).*

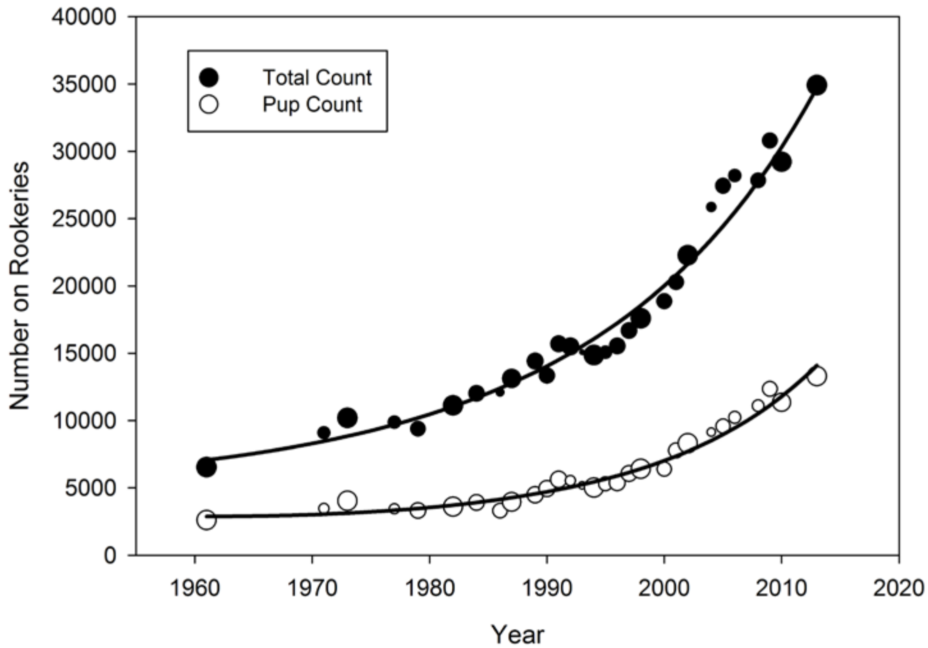


Figure 10. *Increase in number of pups (open circles) and total animals (closed circles) on rookeries in B.C. and SE Alaska during 1961-2013. Because surveys in the two areas were not always conducted in the same year, the combined total count was estimated by assuming the rate of change at each rookery was constant between surveys (i.e. the counts were linearly interpolated on a logarithmic scale). Pup counts made from oblique 35mm slides were adjusted by a factor of 1.05 for rookeries in B.C., and by a factor of 1.25 for Forrester Island to account for pups that are obscured when photographed from oblique angles (Olesiuk et al. 2008). The trend lines represent second-order polynomial regressions fitted to log-transformed counts. Symbol sizes indicate the relative weighting given to counts based on the proportion of the animals surveyed each year (i.e. weighting was discounted based on the proportion of the total count that had been interpolated). The legend indicates the symbol size when survey coverage was complete.*

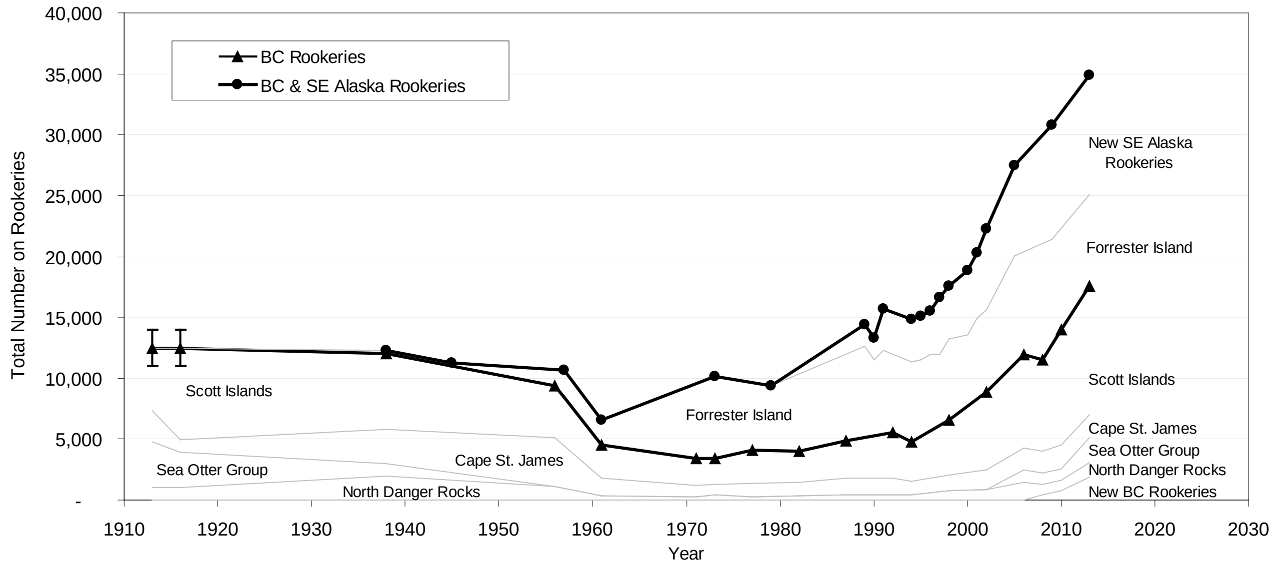


Figure 11. *Historic trends in total numbers of Steller sea lions (pups and non-pups) on breeding rookeries in B.C. (lower thick line with triangles) and combined numbers in B.C. and SE Alaska (upper thick line with circles). The thin grey lines shows the distribution among breeding sites. Pup counts made from oblique 35mm slides were adjusted by a factor of 1.05 for rookeries in B.C. and by a factor of 1.25 for Forrester Island to account for pups that are obscured when photographed from oblique angles (Olesiuk et al. 2008).*

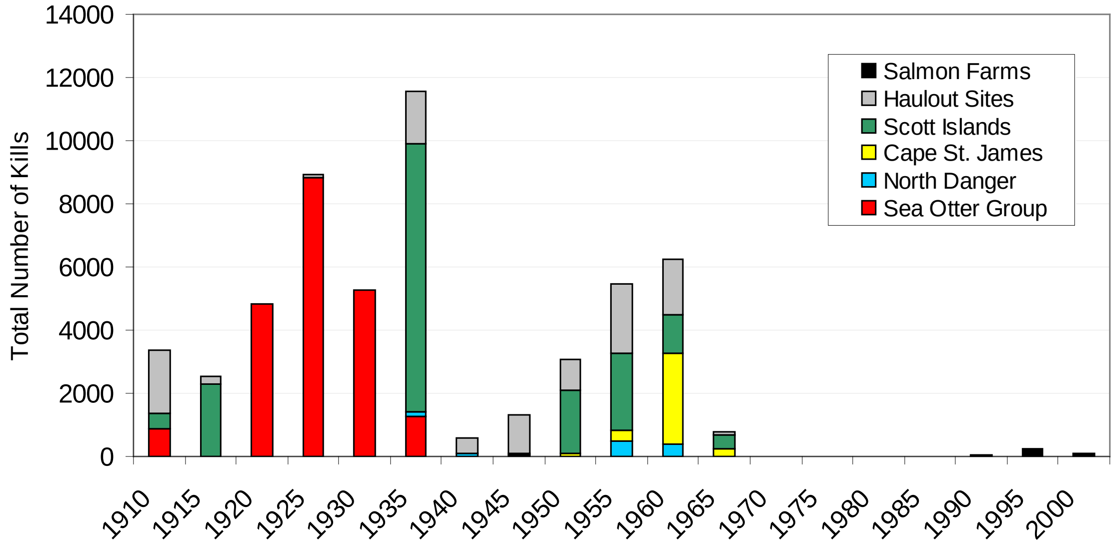


Figure 12. *Total numbers of Steller sea lions (pups and non-pups) killed in B.C. during control programs and commercial harvests in B.C. during 1912-2003. Bars represent the total numbers killed during each 5-year period, and colours denote the distribution of kills among major breeding areas and haulout sites. Based on data from Bigg (1984) and Jamieson and Olesiuk (2001).*

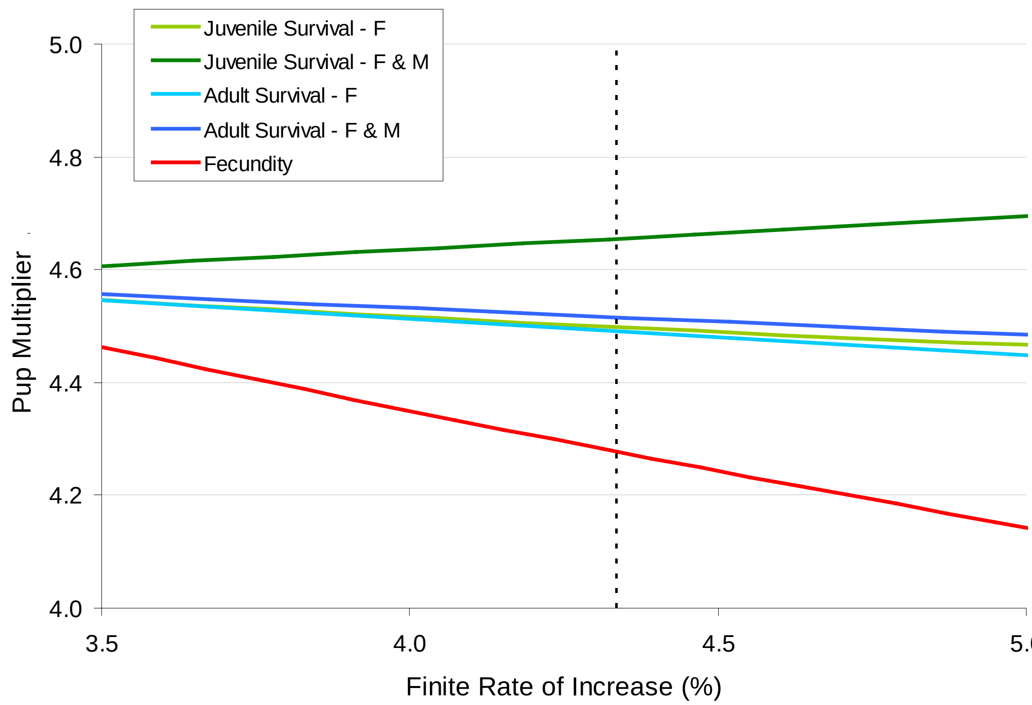


Figure 13. *Sensitivity of the pup multiplier (ratio of total population size to the number of pups born) as a function of the population growth rate corresponding to changes in 3 key vital parameters (juvenile survival, adult survival, and fecundity). The baseline model for a stable population increasing at 3.4% per annum was derived from the Calkins and Pitcher (1982) life table with the survivorship adjusted based on brand resightings of Forrester Island animals (Pendelton et al. 2006). The simulations indicate that the pup multiplier for a population increasing at the current rate of 4.3% per annum could range from 4.28 to 4.65 depending on which vital parameter is changed to induce population growth.*

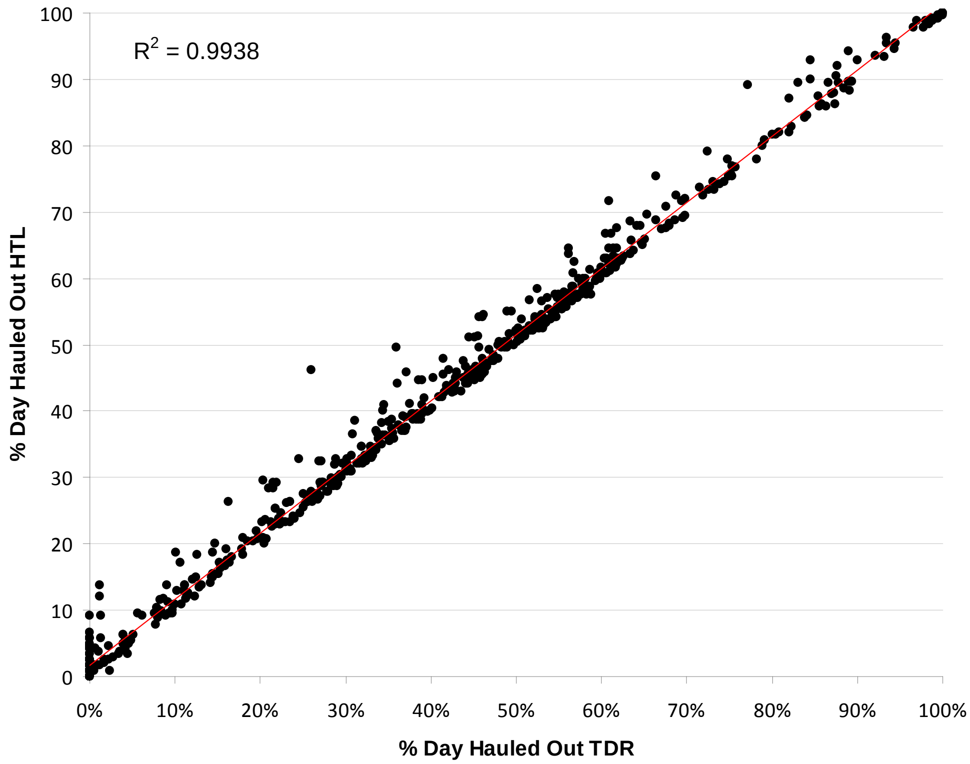


Figure 14. *Comparison of the proportion of each day spent hauled out as indicated by the fine-scale time-depth recorder data (TDR) and the hourly timelines transmitted by satellite (HTL).*

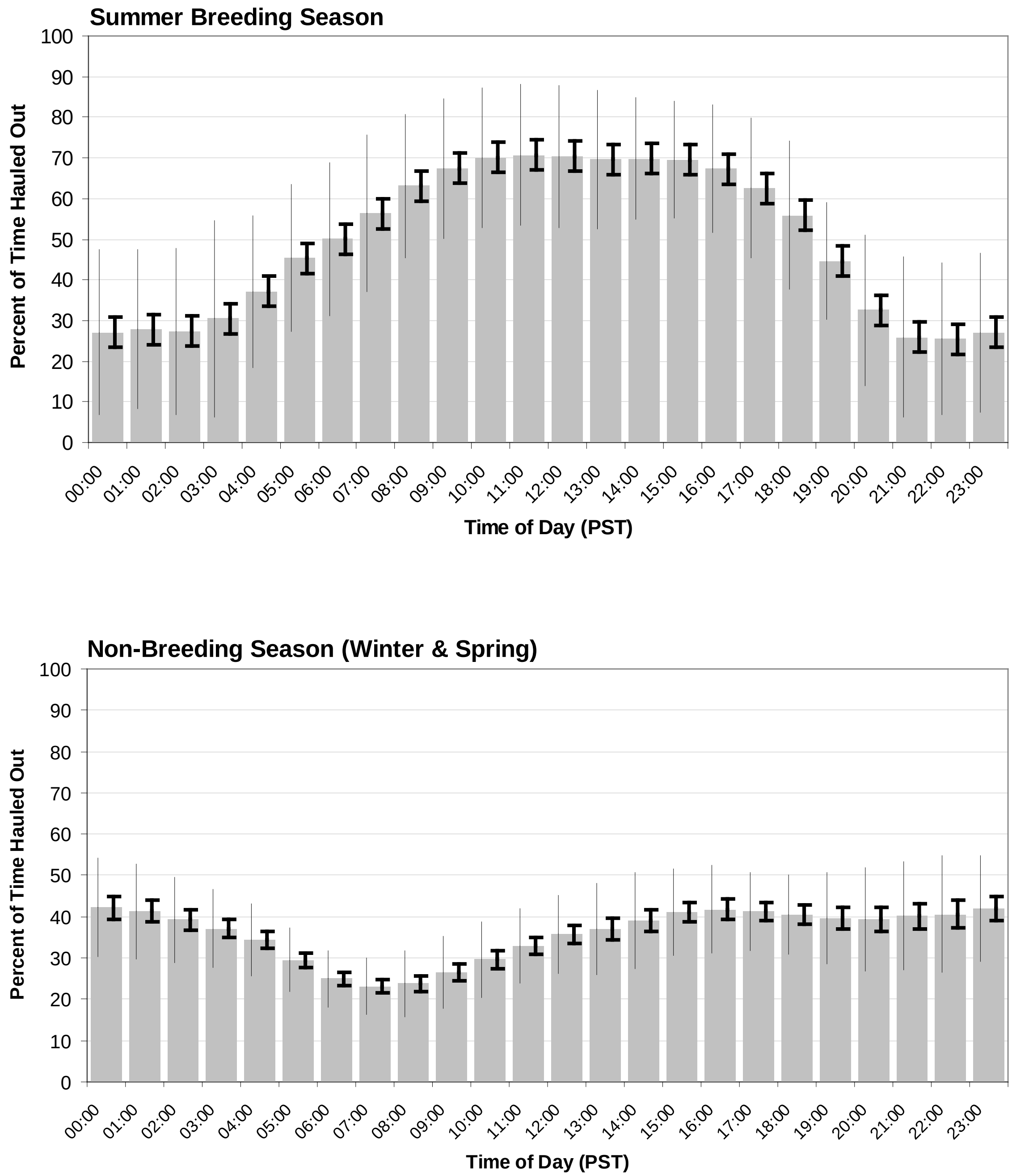


Figure 15. *Diurnal haulout patterns of satellite-tagged Steller sea lions during: a) the summer breeding season; and b) winter and spring. The thin vertical lines denote Standard Deviations for individual animals, and the bold vertical bars to the right the Standard Errors for animal averages (see text for details).*

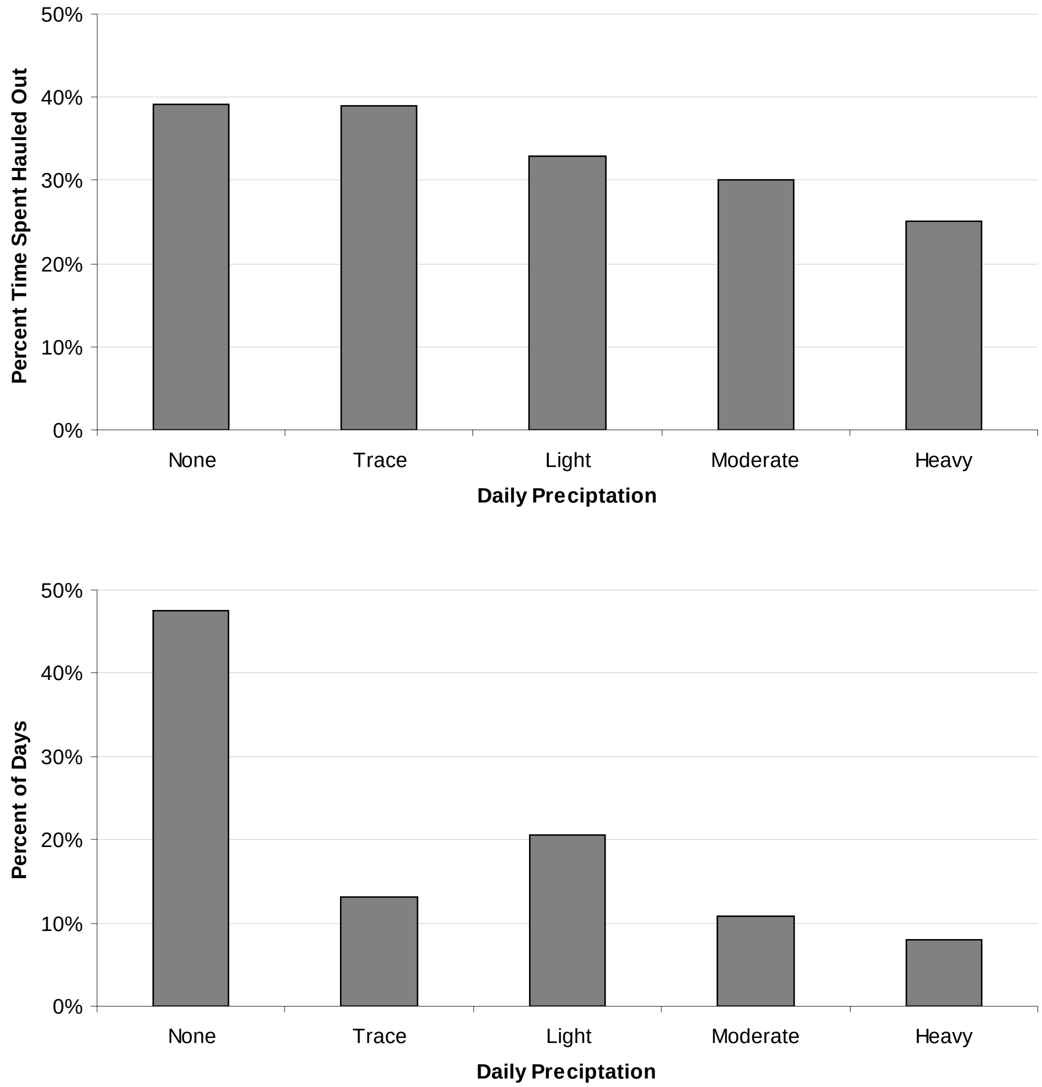
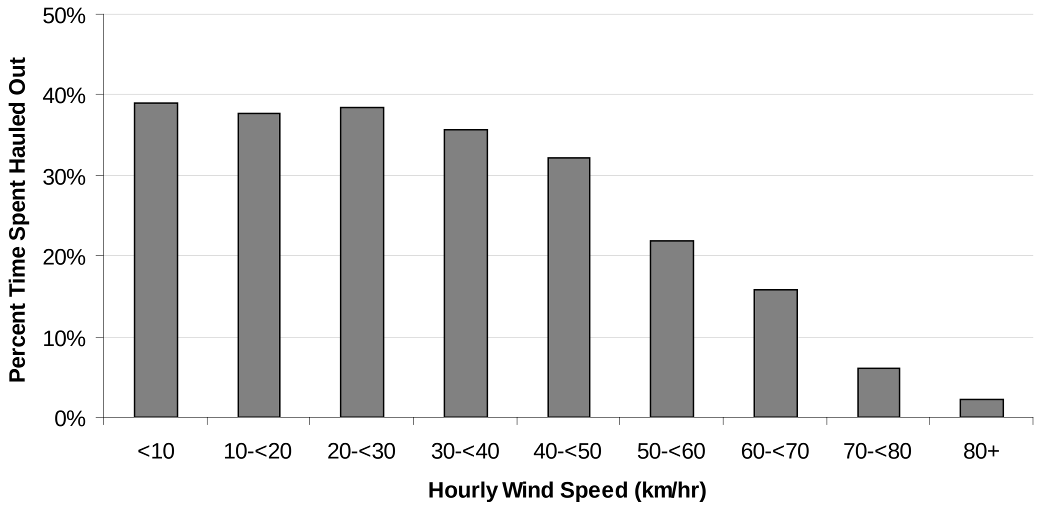


Figure 16. *Effect of daily precipitation levels on the proportion of time satellite-tagged Steller sea lions spent ashore during winter months (top panel). Bottom panel shows the relative proportion of days each precipitation level occurred. Levels were no rain (0 cm), trace (>0-1mm), light (>1-5cm), moderate (>5-10cm) and heavy (>10cm). Precipitation data are from Qualicum Airport, situated about 25 kilometers from the capture site.*



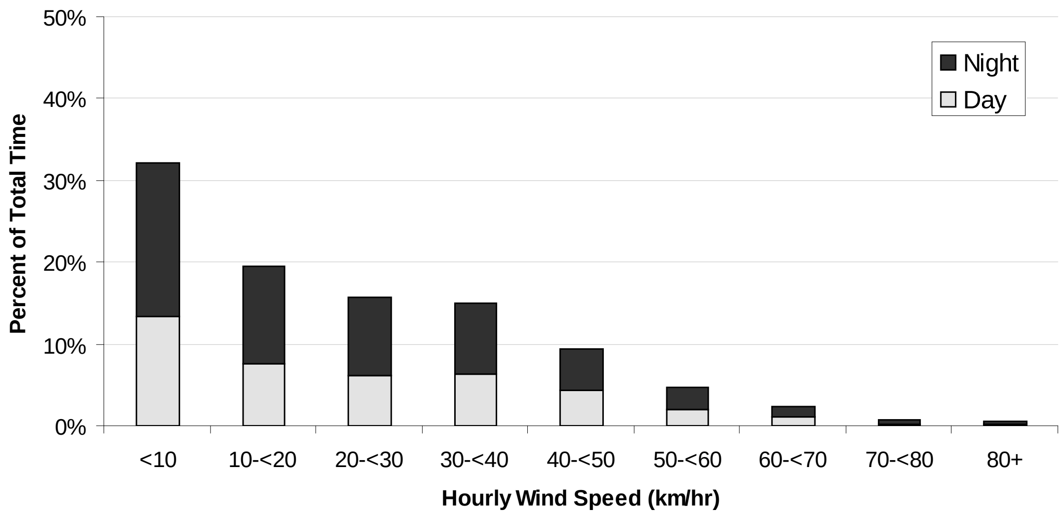


Figure 17. *Effect of hourly wind speed (km·hr^{-1}) on the proportion of time satellite-tagged Steller sea lions spent ashore during winter months (top panel). Bottom panel shows the relative proportion of hours each level of wind speed was recorded. Hourly wind speed data are from the Sisters Island lighthouse, situated about 15 kilometers from the capture site.*

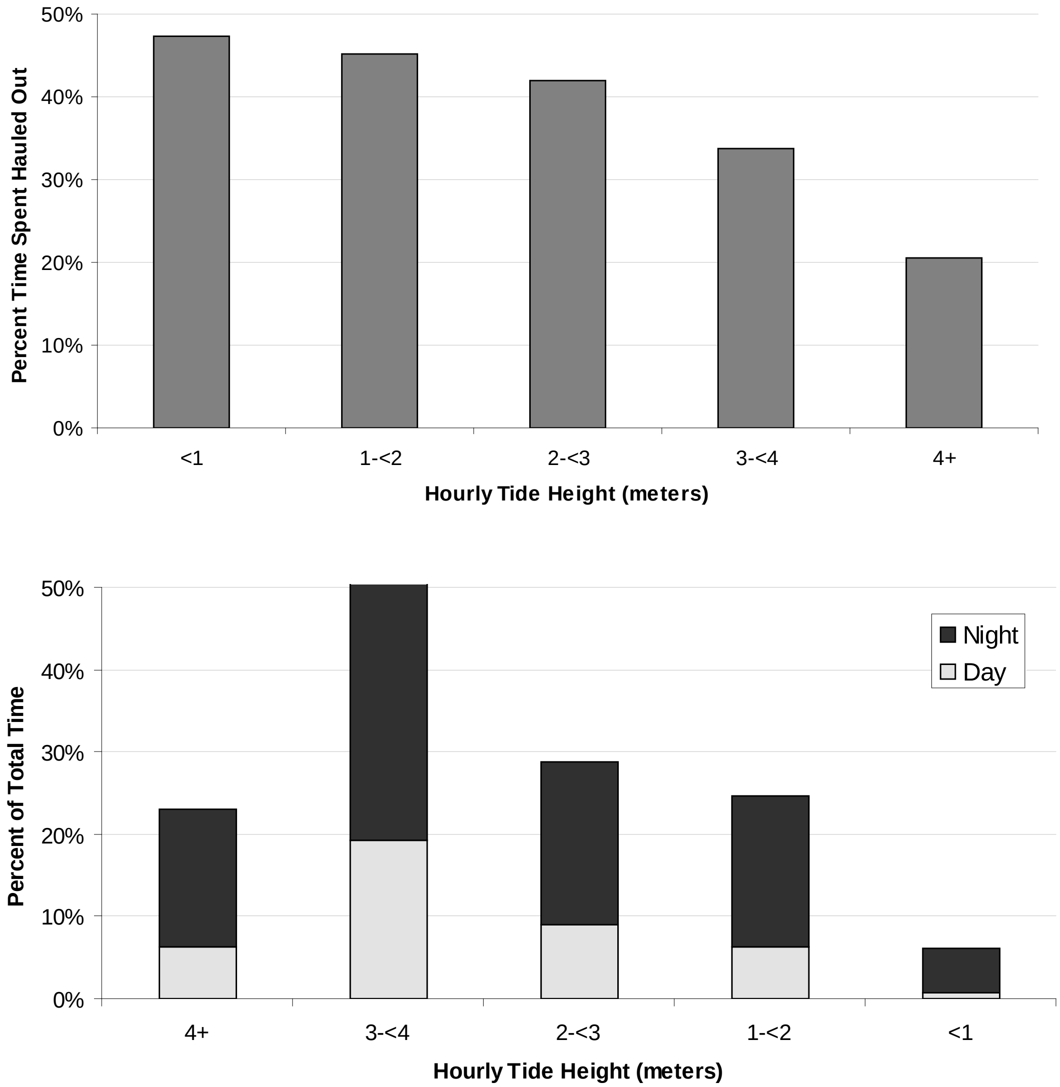


Figure 18a. *Effect of hourly tide height (meters) on the proportion of time satellite-tagged Steller sea lions spent ashore during winter months (top panel). Bottom panel shows the relative proportion of hours each level of tide height occurred during daylight and night-time. Tide heights were predicted for the Hornby Island Secondary Station (situated about 3 kilometers from the capture site) using Tides & Currents Pro 3.0e.*

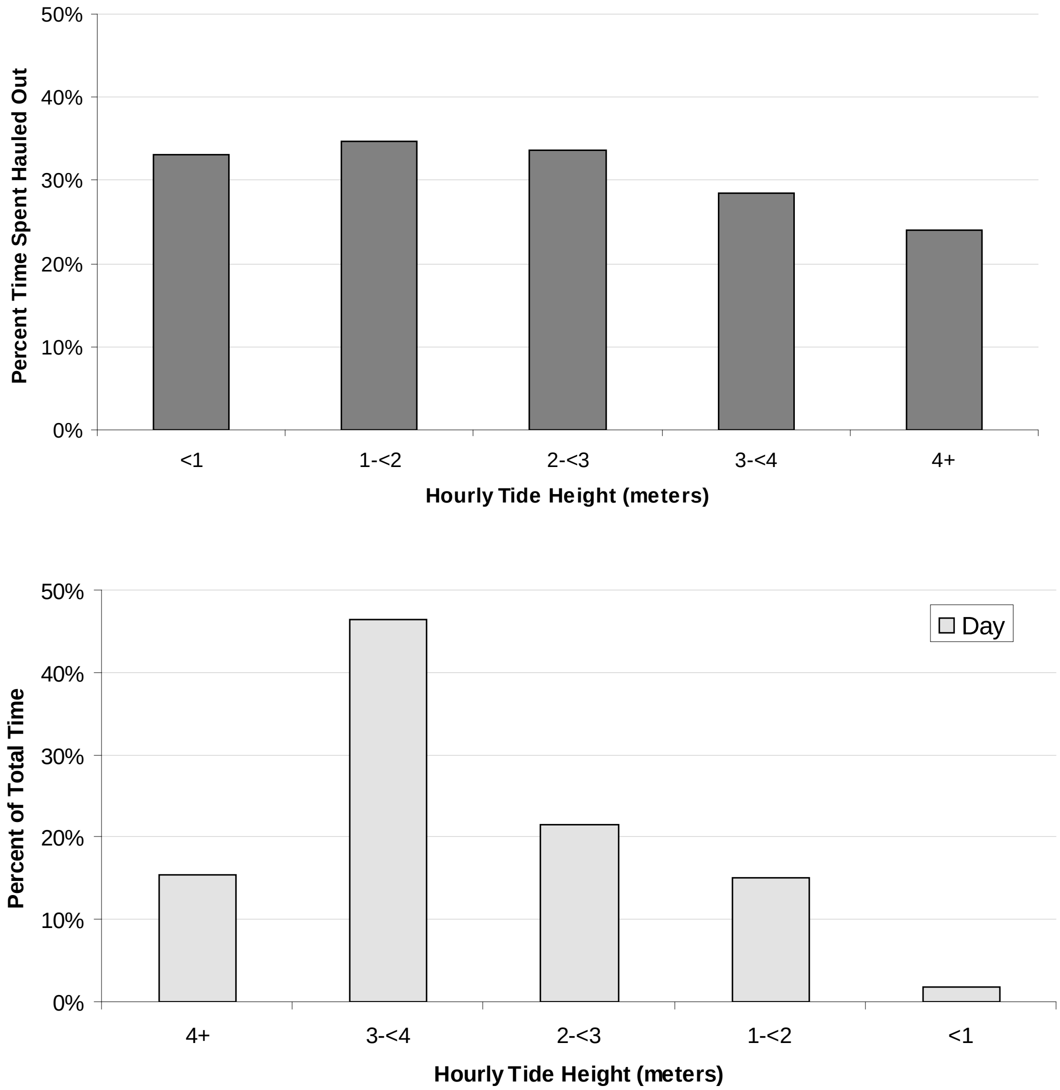


Figure 18b. *Effect of hourly tide height (meters) on the proportion of time satellite-tagged Steller sea lions spent ashore during daylight hours in winter months (top panel). Bottom panel shows the relative proportion of hours each level of tide height occurred during daylight hours. Tide heights were predicted for the Hornby Island station using Tides & Currents Pro 3.0e.*

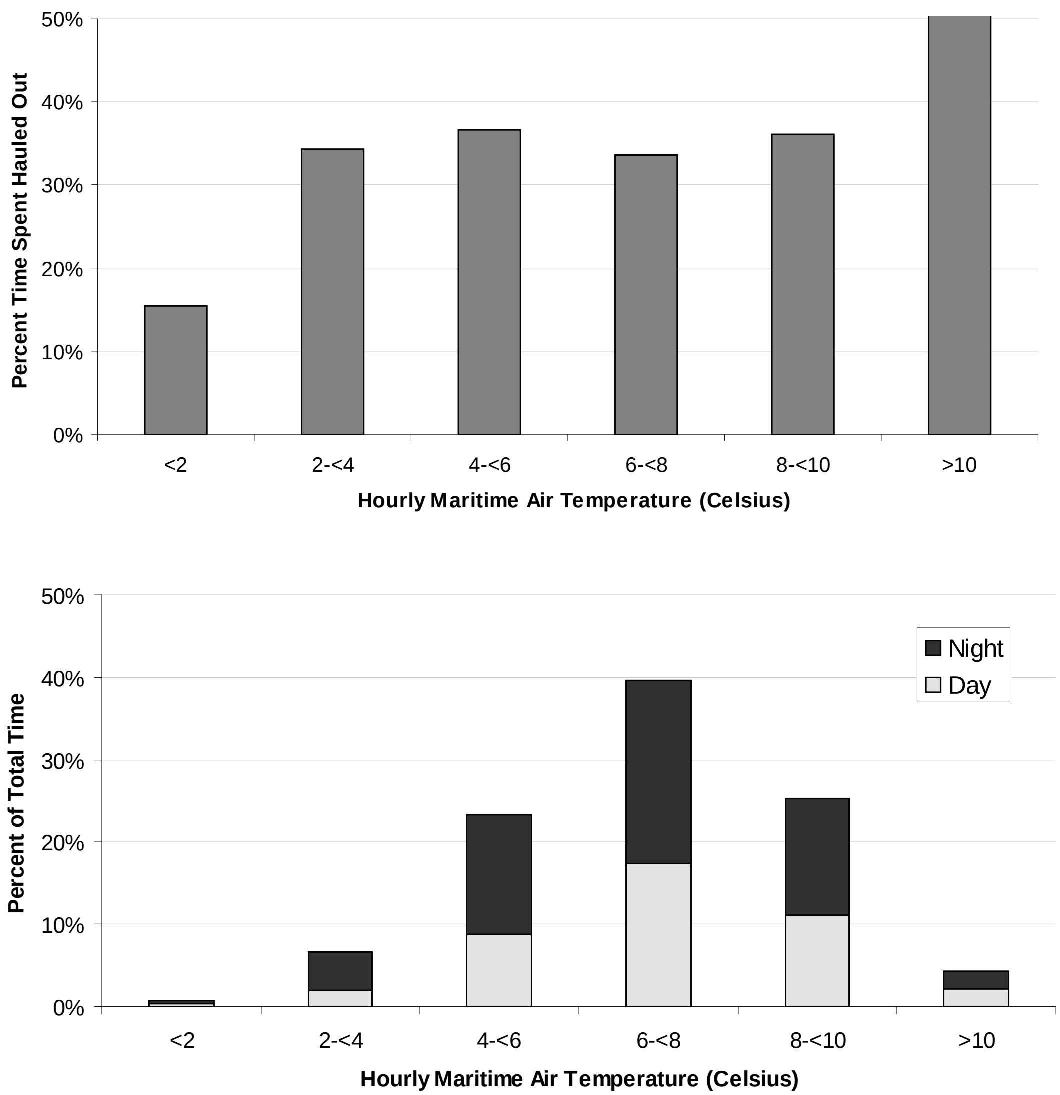


Figure 19. *Effect of hourly maritime air temperature (ºCelsius) on the proportion of time satellite-tagged Steller sea lions spent ashore during winter months (top panel). Bottom panel shows the relative proportion of hours each level of temperature was recorded. Hourly air temperature data are from the Sisters Island lighthouse, situated about 15 kilometers from the capture site.*

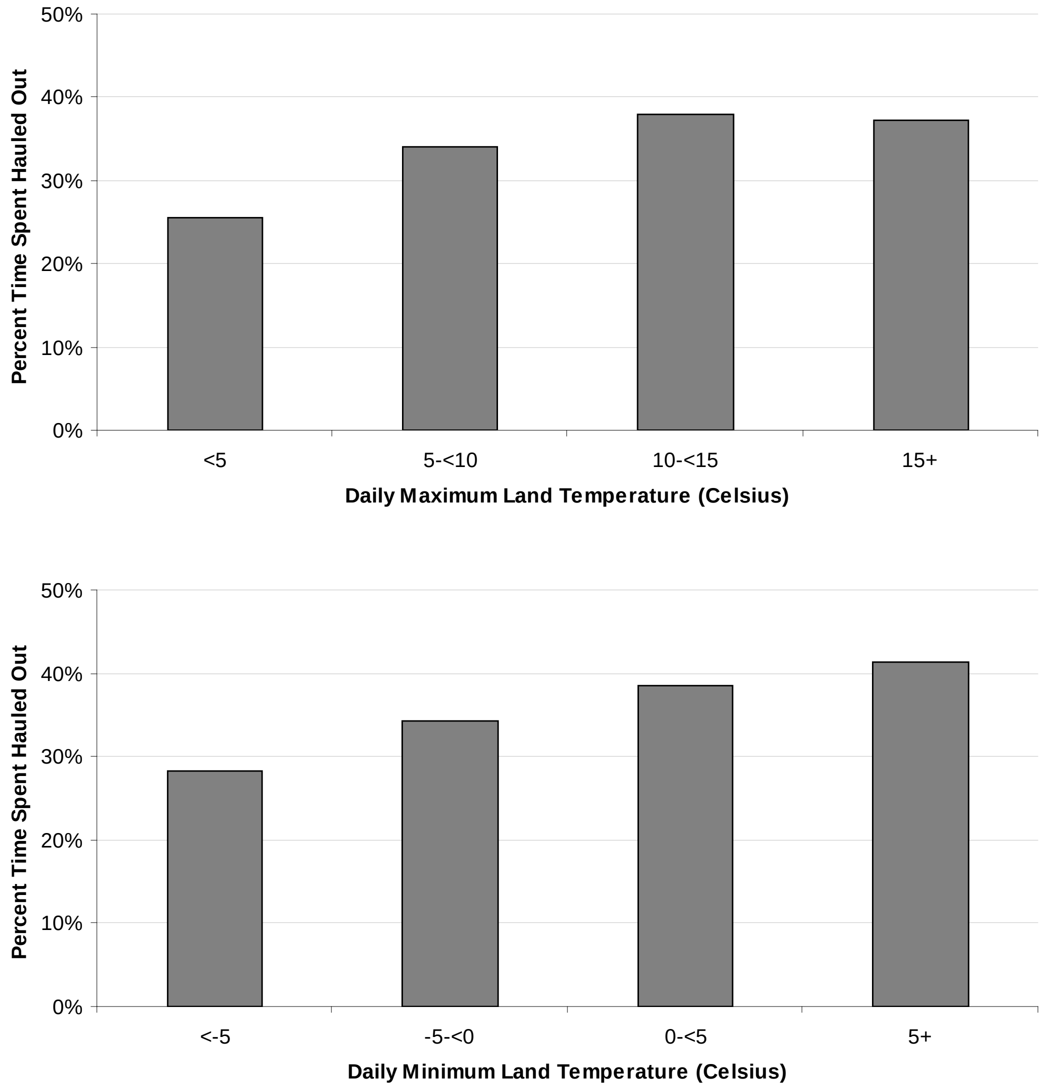


Figure 20. *Effect of daily maximum (top) and minimum (bottom) land temperatures (ºCelsius) on the proportion of time satellite-tagged Steller sea lions spent ashore during winter months (top panel). Daily temperature data are from Qualicum Airport, situated 25 kilometers from the capture site.*

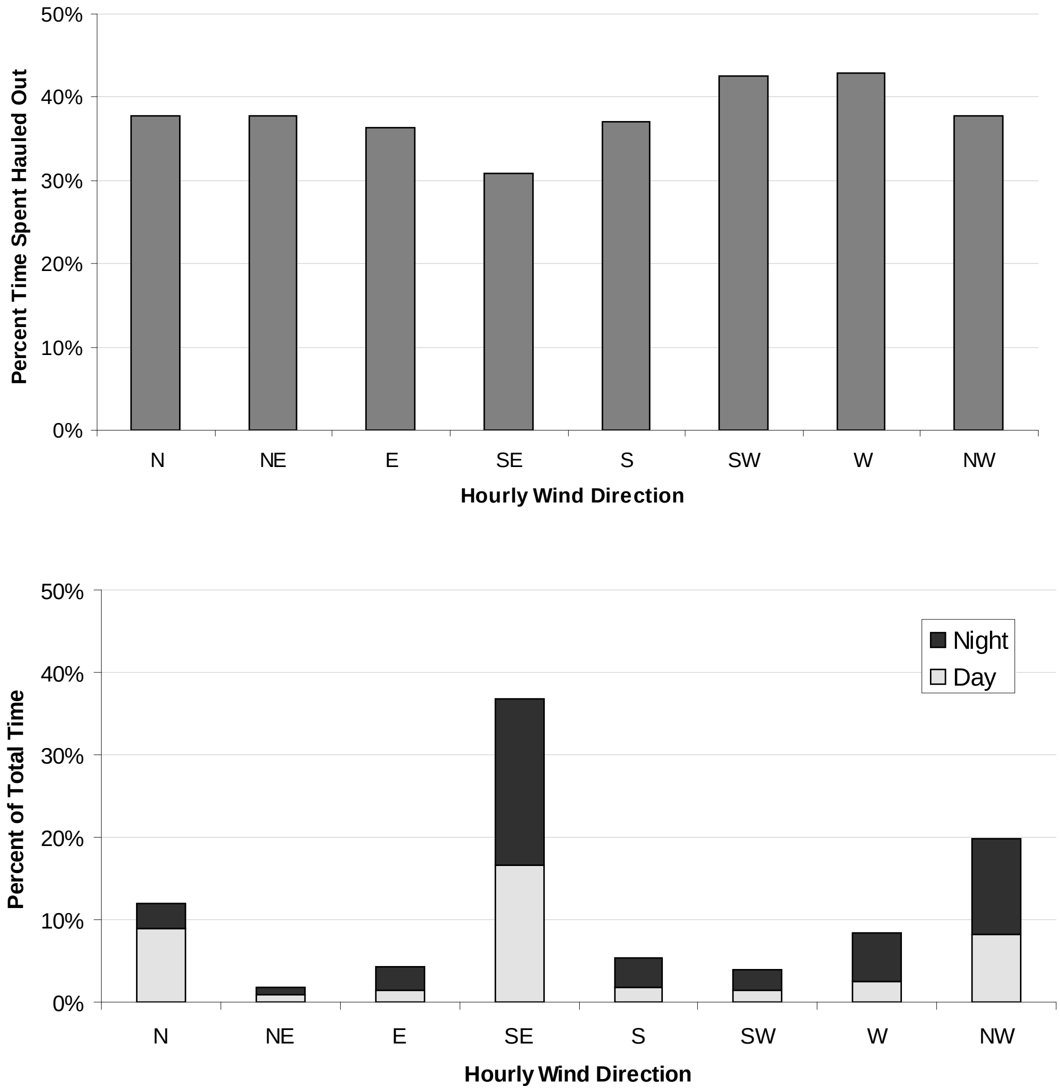
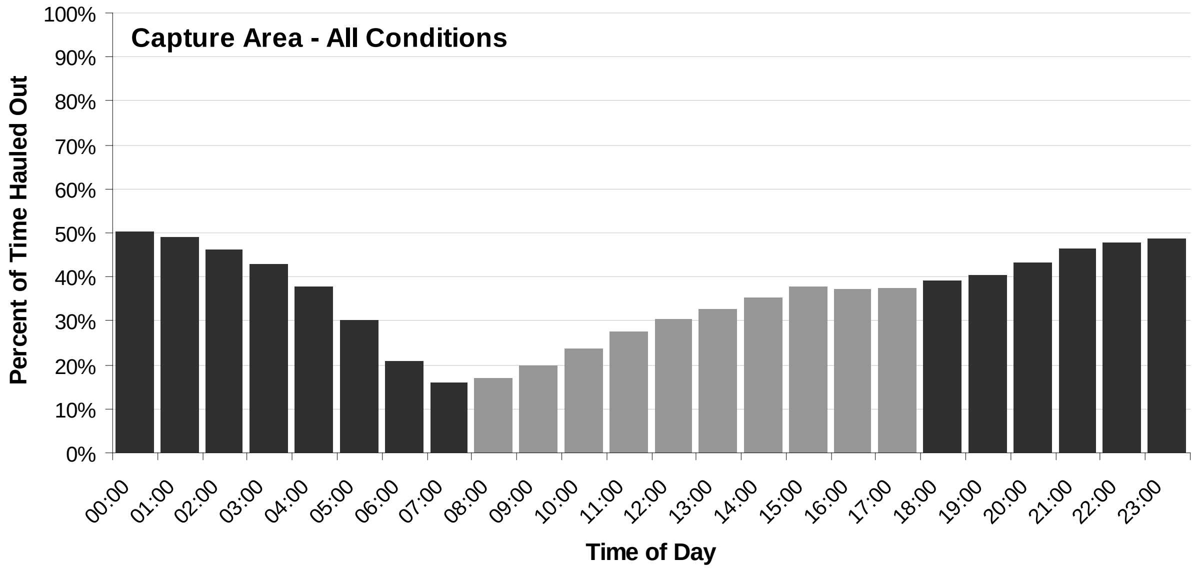


Figure 21. *Effect of hourly wind direction (compass bearing) on the proportion of time satellite-tagged Steller sea lions spent ashore during winter months (top panel). Bottom panel shows the relative proportion of hours each category of wind direction was recorded. Hourly wind direction data are from Sisters Island lighthouse, situated about 15 kilometers from the capture site.*



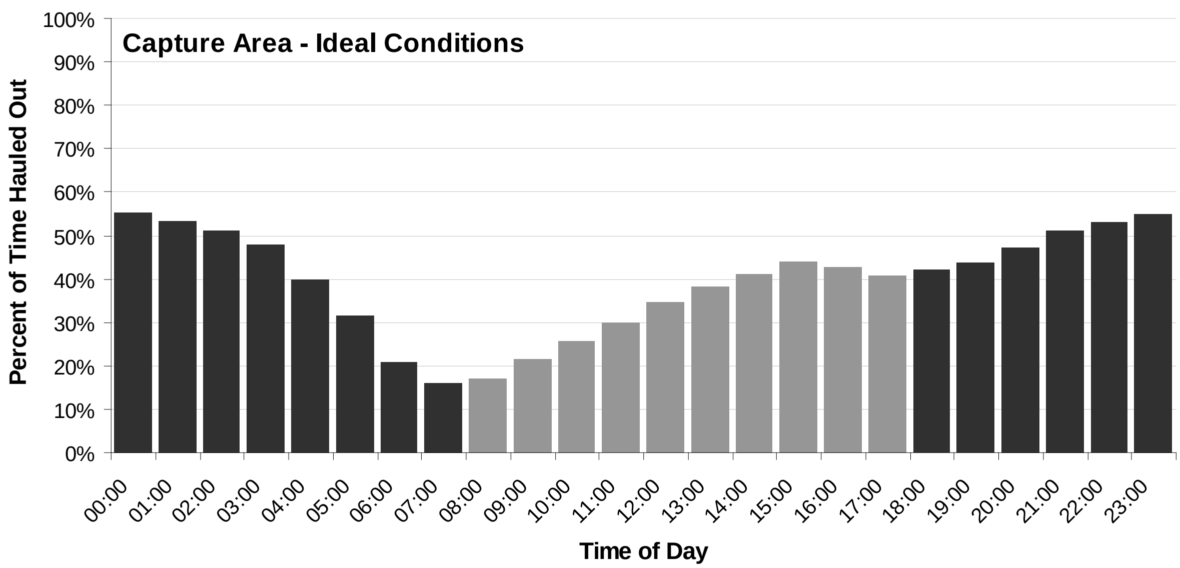


Figure 22. *Diurnal haulout patterns for satellite-tagged Steller sea lions in winter months during all conditions (top) and during ideal conditions (bottom). Ideal conditions excluded days with more than a trace of precipitation and hours with wind speed >10 km·hr*$^{-1}$ *(see text for details). Gray shaded bars depict the daylight survey window that extended from 08:00 to 18:00.*