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An assessment of abundance and growth of the sea otter population (*Enhydra lutris*) in British Columbia

Évaluation de l'abondance et de la croissance de la population de loutres de mer (*Enhydra lutris*) en Colombie-Britannique

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ABSTRACT

Sea otters were re-introduced to British Columbia from Alaska between 1969 and 1972. The first population count was made in 1977. Since 1988, field surveys have been undertaken using small boat or helicopter, to determine sea otter population abundance and trends in British Columbia. Our goal in this study was to assess the survey procedure in use and to obtain current population counts. The results of this study suggest the present method of estimating sea otter abundance in British Columbia can provide a relatively precise (*CV* = 7-12%) index of abundance in *Good* to *Excellent* survey conditions. Surveys from helicopter and boat, made under similar sea conditions, provide comparable counts. A total of 3,180 sea otters were counted in a complete survey in 2001, 2,673 along Vancouver Island and 507 on the central mainland coast. Watson *et al.* (1997) estimated population growth to have been 18.6% $year^{-1}$ on Vancouver Island between 1977 and 1995. The population growth rate on Vancouver Island has declined to 15.6% $year^{-1}$, 1977 – 2004, and this appears to have taken place since 1995. Sea otters are a density dependent species and populations are limited largely by food. Rapid initial growth followed by a decline in growth rate as portions of the population range reach equilibrium with resources seems to be typical of re-introduced sea otter populations. On the central mainland coast, the sea otter population range is small in relation to the availability of habitat and resources, and thus rapid growth might be expected. Survey results indicate growth has been positive on the central mainland coast from 1990 to 2004, but the fit of the simple log-linear regression is relatively poor and the resulting growth rate estimate of 12.4% $year^{-1}$, seems low. Further survey effort will be needed to better ascertain the population growth rate on the central mainland coast.

RÉSUMÉ

Des loutres de mer de l'Alaska ont été réintroduites en Colombie-Britannique entre 1969 et 1972. Le premier dénombrement a été réalisé en 1977. Depuis 1988, des relevés ont été entrepris à partir d'embarcations ou d'hélicoptères, afin de déterminer l'abondance et les tendances de la population de loutres de mer en Colombie-Britannique. Le but de notre étude était d'évaluer la méthode de relevé en usage et de dénombrer la population actuelle. Les résultats semblent indiquer que la méthode courante d'estimation de l'abondance de la loutre de mer en Colombie-Britannique peut donner un indice d'abondance relativement précis (c.v. = 7-12 %) dans des conditions de relevés qui sont de *bonnes* à *excellentes*. Les relevés effectués par hélicoptère et par bateaux, dans des conditions semblables de l'état de la mer, ont fourni des résultats comparables. Un total de 3 180 loutres de mer ont été dénombrées dans le cadre d'un relevé complet en 2001, soit 2 673 le long de l'île de Vancouver et 507 sur la côte centrale de la C.-B. Selon Watson et coll. (1997), la croissance de la population aurait été de 18,6 % par année sur la côte de l'île de Vancouver entre 1977 et 1995. Par ailleurs, le taux de croissance de la population de l'île de Vancouver a baissé à 15,6 % par année entre 1877 et 2004, diminution qui semble avoir eu lieu à partir 1995. La loutre de mer est une espèce dont la croissance est liée à la densité et les populations sont limitées en grande partie par la nourriture. Une croissance initiale rapide, suivie par une baisse du taux de croissance alors que certaines parties de la population atteignent le point d'équilibre avec les ressources, semble caractéristique des populations de loutres de mer réintroduites. Sur la côte centrale de la province, l'étendue de la population de loutres de mer est restreinte par rapport à la disponibilité de l'habitat et des ressources; on peut donc s'attendre à une croissance rapide. Les résultats de relevés révèlent que la croissance a été positive sur la côte centrale de la C.-B. entre 1990 et 2004, mais la concordance avec une régression linéaire logarithmique simple n'est pas très bonne et l'estimation du taux de croissance qui en résulte, soit 12,4 % par année, semble faible. Il faudra d'autres relevés pour confirmer le taux de croissance de la population sur la côte centrale de la C.-B.

Introduction

Historically sea otters (*Enhydra lutris*) ranged along the Pacific rim from Baja California to Northern Japan, but were heavily hunted during the maritime fur trade of the 18th and 19th centuries. By the early 20th Century, sea otters were extirpated from much of their range, including British Columbia (Cowan and Guiguet 1960; Kenyon 1969). Between 1969 and 1970, 89 sea otters from Alaska were released into Checleset Bay, west coast Vancouver Island, in an effort to re-establish the species on the British Columbia coast (Bigg and MacAskie 1978). Similar translocations were made in Washington, Oregon and southeastern Alaska (Jameson *et al.* 1982).

Sea otters seldom range beyond 1-2 km of shore unless shallow areas extend further offshore (Riedman and Estes 1990). They feed on benthic invertebrates and most foraging occurs in depths of 30m or less, although they are capable of foraging to depths of 100m (Estes 1980; Riedman and Estes 1990; Bodkin *et al.* 2004). Sea otters are non-migratory and individuals occupy overlapping home ranges (Jameson 1989). Otters are gregarious and spend a considerable part of each day resting on the water in groups called rafts that form habitually in the same locations, often associated with specific reefs or kelp beds (Ribic 1982; Jameson 1989; Ralls and Siniff 1990). Rafts, which can include more than 100 animals, are segregated aggregations, such that males and females form separate rafts in spatially separate areas (Riedman and Estes 1990). Males have larger home ranges than females, primarily because of movements of breeding-age males that leave male areas and establish exclusive breeding territories in female areas. Breeding peaks in autumn, after which, territorial males rejoin male rafts (Garshelis and Garshelis 1984; Jameson 1989). The front, or periphery of the expanding population range, tends to be occupied by male rafts and population range expansion occurs by mass movement of a raft of males into new previously unoccupied habitat (Garshelis *et al.* 1984; Jameson 1989). Within a few years, female rafts move into these areas once the male raft has moved on (Loughlin 1980; Garshelis *et al.* 1984; Wendell *et al.* 1986).

Seventy sea otters were counted in the first sea otter population survey in British Columbia in 1977 (Bigg and MacAskie 1978). Until 1987, sea otters were found in only two locations along the west coast of Vancouver Island, Checleset Bay and at Bajo Reef off Nootka Island. Early surveys (1977 to 1987) of these two areas were made mainly by fixed-wing aircraft with some boat counts (Bigg and MacAskie 1978; Morris *et al.*1981; MacAskie 1987; Watson *et al.* 1997). By 1995, the population had increased to 1,522 otters and ranged along Vancouver Island from Estevan Point to the entrance of Quatsino Sound and in 1989 females with pups were also reported on the central mainland coast (BC Parks 1995) (Fig. 1). The survey approach used presently was developed in 1988 and between 1988 and 2000, surveys were made primarily from small boat with some surveys also made from helicopter (Watson 1993; Watson *et al.* 1997). Continued range expansion and population growth has made it increasingly difficult to survey the whole range by boat, given the limited number of suitable survey days per season. More of the range can be surveyed per unit time by air than by boat and in recent years (since 2001), more surveys have been made by helicopter than in the past.

In most regions, sea otter populations are counted from more than one platform-type e.g. fixed-wing aircraft, helicopter, small boat or shore. Counts obtained from different platforms often yield different results and these need to be dealt with in a consistent manner among surveys if future trends in population growth are to be assessed (Geibel and Miller 1984; Estes and Jameson 1988; Burns 1994; Evans *et al.* 1997; Doroff *et al.*

2003). In this study we assess the British Columbia sea otter survey procedure first by comparing boat counts and helicopter counts made between 2001 and 2004 and then by assessing the precision of replicate counts. Following this we present the most recent population count and assess population growth using survey data collected in this study and data from Watson *et al.* (1997) and Watson (unpubl. data).

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Methods

Survey Methods

In British Columbia, during spring and summer, sea otters occupy areas with extensive rock reefs, kelp beds and associated shallow depths along rugged exposed sections of the west coast of Vancouver Island and the central mainland coast. Surveys were made of this type of habitat in areas known to be occupied by sea otters and all otters encountered were counted. Some individuals undoubtedly travel into deeper water, are further offshore, or are further inshore up inlets and may have been missed. The resulting population count thus provides an index of abundance which is close to, but less than, the true abundance. Essentially the same approach is used to document the population trends of the California and Washington State sea otter populations (Estes and Jameson 1988; Jameson and Jeffries 2003).

For population assessment, the sea otter range was divided into segments. Segments were geographic areas that could typically be surveyed in a day by boat given the logistics of access and travel to the area. Over time new segments were added as the sea otter range expanded. Evidence of sea otter range expansion, based on the presence of rafts of sea otters in previously unoccupied areas, was gathered from periodic reconnaissance surveys and from sightings reported by other researchers, coastal residents and fishermen. The sea otter range on the west coast of Vancouver Island was divided into two segments from 1977 to 1988. The population range expanded along Vancouver Island and there were seven segments by 1995 with one additional segment on the central mainland coast after 1989. By 2001, there were 12 survey segments on Vancouver Island and two survey segments on the central mainland coast (Fig. 2).

Surveys were conducted from April through September. From our survey experience since 1988 we have not observed discernible changes in distribution or behaviour through this period that would affect survey results. Sea conditions, however, are important. Survey conditions were defined primarily by sea conditions. *Excellent* to *Good* survey conditions existed when sea state ranged from flat calm (Beaufort 0) to swells up to 1m and wind speeds less than 10 knots (18km/hr) (Beaufort 3). *Fair* conditions were defined generally as seas 1 to 1.5m or when wind speeds ranged from 10 to 15 knots (28km/hr) (Beaufort 4). Poor conditions were generally defined as seas greater than 1.5m or wind speeds greater than 15 knots (28km/hr). High overcast created ideal lighting conditions due to reduced sun glare. Surveys were not conducted in rain or fog.

Boat surveys generally started at daybreak, whereas helicopter surveys typically commenced later in the morning due to flight time to the survey start point. Surveying generally continued until the survey was completed, or survey conditions deteriorated. Whereas only one segment could typically be surveyed in a day by boat, by helicopter several segments could often be completed in one day. Occasionally, if conditions deteriorated during a boat survey, and it was not possible to complete the segment in one day, the segment was counted in subsections and the resulting counts summed to yield a total count. Partial counts were only used if the subsections had been counted within a few days of each other to minimize the possibility of localized movements of sea otters.

Within each survey segment, coastal areas of less than 40m depths, areas near islets, rock reefs and kelp beds were surveyed. From 2000 onward, survey routes were recorded by interfacing a GPS device with navigation software (Nobeltec Visual Navigation Suite, Nobeltec Corporation). Prior to this, survey routes were recorded by hand on hydrographic charts. Once routes were established, subsequent surveys included coverage of these previously identified habitat areas.

During surveys, the location and number of single and rafted otters was recorded. Female rafts were distinguished from male rafts by the presence of pups. Rafts of sea otters were counted using 7X50 binoculars and 14X40 stabilized binoculars. Experienced observers have been used on all surveys and since 1988 all surveys have been consistently led by either one of two experienced individuals.

Boat surveys were conducted by three or four observers from a 5.5-m welded aluminum boat or a 4-m inflatable boat traveling at speeds of less than 10 knots (18.5 km/hour). One of the observers drove the boat and navigated. The remaining observers searched for and counted sea otters on either side of the boat. Speed was altered as required, and the boat was stopped to search complex areas with binoculars and to obtain counts of rafts. Rafts were counted by all observers. Each person assessed the raft size independently, then compared counts and recounted the raft to obtain the best overall repeatable count. This value was often among the higher of the initial estimates, because counts were made as the boat and otters rose and fell in the ground swell and high counts were obtained when an observer achieved an unobstructed view of the sea otter raft.

Aerial surveys were conducted from a Eurocopter A-Star helicopter. The helicopter flew at an elevation of approximately 90 metres and a speed of approximately 70 km/hr, although speed and height were altered as necessary to allow observers to search areas, verify sightings and photograph large rafts. Three observers participated in helicopter surveys. One observer sat forward, to the left of the pilot. The second and third observers sat in the rear seats on either side of the helicopter. Observers searched for and counted all sea otters sighted from their side of the helicopter. To assess how well observers could visually estimate the number of otters in rafts, rafts of more than 20 individuals were simultaneously counted and photographed by the observers on the left side of the helicopter. To photograph a raft, the helicopter ascended to 180 metres and slowly descended as it approached to avoid disturbing the animals. The helicopter then circled the raft area while a count and a series of images were taken. The pilot approached the raft area with the sun behind the photographer. Photographs were taken by the observer in the co-pilot's seat using a SLR 35-mm camera with a 300mm lens, colour transparency film (Fuji Provia ISO 400) shot at 1/1000 or 1/2000 of a second, or a digital camera programmed for large fine format jpegs with a 300mm lens and comparable ISO and shutter settings. To count otters from photographs, the images were projected onto a screen. Composites of several images were used for rafts that were captured across more than one image.

Analytical Methods

A paired samples *t*-test was used to test the hypothesis that counts obtained by boat did not differ from those obtained by helicopter. Counts were paired according to year and segment. Only pairs in which survey conditions during both surveys had been *Good* or *Excellent* were used. Five boat counts and five helicopter counts, made between 2001 and 2004, met this criterion.

To assess precision, surveys of the same segment made in the same year and made during comparable survey conditions were considered. Three samples of three replicate counts from 2001 and 2005 met these criteria. One replicate set was obtained by boat on consecutive days, the second set was obtained by helicopter with in several days of each other, and the third set of replicates was obtained over a period of months, during which two counts were made by boat and the third was made by helicopter.

To determine if rafts of otters could be reliably counted visually from the air, a paired samples *t*-test was used to test the hypothesis that visual estimates of raft size made on helicopter surveys did not differ from those obtained from photographs. Data were tested for normality and transformed as required.

Population Abundance and Trends

A total population count for a year was calculated by summing survey segment counts. Where more than one survey of a segment was available, the survey made under the best conditions, which generally yielded the higher count, was selected. This approach was consistent with the methodology used in Watson *et al.* (1997).

The percentage of each annual total count obtained during *Excellent*, *Good*, *Fair* or *Poor* conditions was calculated. The percentage of each total obtained during *Good* or *Excellent,* conditions was used as a comparative measure of inter-annual survey conditions. This calculation was made for each annual total used in trend analysis between 1988 and 2004, and was calculated separately for Vancouver Island and the central mainland coast.

It was not always possible, due to weather or for other logistical reasons, to survey all the segments occupied by sea otters in one year. To address this problem an estimate was made of the number of animals in missed segments by interpolation using the exponential equation that best fit a maximum of four counts preceding and/or succeeding the missing count. Interpolation was restricted to survey years in which the missing segment had not been missed for more than two consecutive years and where at least 70% of the resulting population estimate for the year was based on actual counts. Only 2 of 7 years with interpolated values, had less than 90% of their total estimate based on actual counts and only 7 of 18 annual totals included interpolated values. Each annual population estimate was then weighted in regression analyses according to the square root of the proportion of the total population actually counted that year. In this way the annual estimates that included interpolated values were given less weight in regression than complete population counts.

Population growth was estimated for the whole population as well as separately for Vancouver Island and the central mainland coast. Watson *et al.* (1997) estimated population growth rate using only Vancouver Island survey data because they felt the central coast surveys were poor. Sea otter counts made between 1996 and 2000 were excluded from the Vancouver Island and the whole population analysis because extensive gaps existed in survey coverage for Vancouver Island. Surveys of the central mainland coast made in 1996 and 1998, however, were included in the central mainland coast trend analysis.

Annual rates of change in abundance between 1977 and 2004 were estimated by linear regression of ln (counts) versus time to obtain the best fit to the log transformed exponential growth equation:

$$\ln N_t = \ln N_0 + rt$$

Where N_0 represents the initial population size and r the intrinsic rate of growth.
Finite rates of growth α were derived from the slope r (intrinsic rate) of the regression equations by:

$$\alpha = e^r - 1$$

Changes in population growth between 1977 and 2004 were evaluated by fitting piece-wise linear regressions to the logarithmically transformed counts on time:

$$\ln N_t = \ln N_0 + r_1 t + r_2 (t-x) Y_t$$

Where x represents the year in which growth rate changed, r_1 represents the intrinsic rate of growth before the change, and r_2 represents the amount by which the rate is adjusted after the change. Y_t is a variable assigned 0 for years before the change in growth and 1 for years after. All possible regressions were fitted and those in which both coefficients were significant were evaluated by the resulting r^2 values.

Results

Current Range

In 2001, the sea otter population ranged along Vancouver Island from Hesquiat Harbour northward to Cape Scott, and eastward to Hope Island in Queen Charlotte Strait. In 2004 a raft of sea otters was observed off Vargas Island, approximately 40 linear kilometres south of Hesquiat Harbour and indicated range expansion (Fig. 1). On the central mainland coast, sea otters range from the southern end of the Goose Group, northward through Queens Sound to Cape Mark at the edge of Milbanke Sound. Reconnaissance surveys in 2001 and 2004 north of Milbanke Sound and south of the Goose Group, did not locate rafts of otters beyond this range.

Survey Procedure Assessment

Sixty-three segment surveys were made, 2001 - 2005. Of these 27 were made from helicopter and 36 from small boat. These surveys, along with earlier counts from Watson *et al.* (1997) and Watson (unpubl. data), were used in analyses of the survey procedure and population trends. Surveys (2001 to 2005) were made between April and September, although most surveys (78%) were made in June, July and August (Fig. 3).

Five boat counts were compared to five helicopter counts all made during *Good* or *Excellent* conditions to test the hypothesis that the counting platform did not affect sea otter estimates. The aerial estimates were not significantly different from the estimates obtained by boat ($t_{(0.05,\ 4)}$ = -0.32) (Table 1, Fig. 4). Estimates obtained from either platform were also found to be repeatable. The mean of three replicate boat counts from the Nuchatlitz Inlet segment was 693.00 (*CV* = 9%), of three replicate helicopter counts from the McMullin Group to Cape Mark segment was 260.33 (*CV* = 7%) and of two boat counts and one helicopter count from the Checleset Bay segment was 582.00 (*CV* = 12%) (Table 2). Visual estimates of the number of sea otters in 42 rafts counted during helicopter surveys did not differ significantly from the counts obtained from the photographs ($t_{(0.05,41)}$ = 0.76) (Fig. 5).

Abundance

All 14 segments were surveyed in 2001 and a total of 3,180 otters were counted, 2,673 along the Vancouver Island coast and 507 on the central mainland coast. In 2002, 2003 and 2004,13,13 and 11 segments were surveyed respectively. Including interpolated values for missed segments, population estimates in these years were 2,369, 2,809 and 3,185 (Table 3). The percent of each annual count on Vancouver Island made during *Good* or *Excellent* conditions ranged from 57% to 88% in 2001 to 2004 and on the central coast ranged from 53% to 100%, these are compared with conditions during surveys prior to 2001 (Fig. 6).

Population Trends

The finite rate of population growth in British Columbia, 1977 – 2004, based on a log-linear regression was 16.4% year^{-1} (*SE* = 0.289 r^2 = 0.954; $F_{(1,16)}$ = 328.32 P<0.0001). A piece-wise regression in which the rate changes after 1994 provided a better fit (*SE* = 0.206, r^2 = 0.978; $F_{(2,15)}$ = 333.62 P<0.0001). The finite growth rate, 1977 - 1994, estimated from the piece-wise regression, was 20.2% year^{-1} and 9.5% year^{-1}, 1994 - 2004 (Fig. 7). Using only Vancouver Island surveys, the growth rate, 1977 - 2004, estimated from a log-linear regression, was 15.6% year^{-1} (*SE* = 0.288 r^2 = 0.950; $F_{(1,\ 16)}$ = 302.99 P<0.0001). A piece-wise regression in which the rate changes after 1995 provided a better fit (*SE* = 0.211 r^2 = 0.975; $F_{(2,15)}$ = 289.41 P<0.0001), with growth of 19.1% year^{-1}, 1977 - 1995 and 8.0% year^{-1}, 1995 - 2004 (Fig. 8). The central mainland coast growth rate estimated from a log-linear regression was, 12.4% year^{-1}, 1990 - 2004 (*SE* = 0.391 r^2 = 0.737 $F_{(1,8)}$ = 22.43 P = 0.001) (Fig. 9).

Discussion

The range of precision of replicate counts in this study (CV = 7 -12%) likely represents the highest that is possible with this survey procedure under *Good* to *Excellent* survey conditions. This precision was very similar to a *CV* of 13% calculated from seven replicate aerial counts made in California using a similar survey method (Estes 1990; USFW 2003). Since sea otters occupy home ranges and have preferred rafting and foraging areas within these ranges (Ribic 1982; Garshelis and Garshelis 1984; Jameson 1989), their distribution is relatively predictable. Without this predictability, the coefficients of variation of replicate counts would have been considerably higher.

Surveys from different platform-types are expected to produce disparate results given differences in speed, elevation and field of view, however, in this study we were able to use the same approach to search for and count otters regardless of platform-type. This may account for the similar counts obtained from boat and helicopter. We could not have used the same approach from the air as we did from boat, had it not been possible to alter speed and hover. Helicopters were, in fact, chosen over fixed-wing aircraft, for sea otter surveys in British Columbia, because of their superior maneuverability and the ease with which speed can be altered. These factors are important because of the geographic complexity of coastal areas occupied by sea otters in British Columbia. The ability to slow down and hover in a helicopter is important and has been noted by others. DeGange *et al.* (1995) found that on average one-third more sea otters were counted after one minute of hovering than on the initial pass.

Helicopters, however, are noisy, and the potential to disturb rafts of sea otters (which could result in a low count) is greater than by boat. Three-blade rotor helicopters, such as the A-Star used in this study, produce less rotor noise than many other types of helicopters, particularly two-blade rotor helicopters (Craig Huston, West Coast Helicopters, Box 17, 2901 Spit Rd., Campbell River B.C. V9W 4Z9, pers. comm. 2005). Rotor noise was a consideration in our choice of the A-Star helicopter. To further minimize the risk of disturbance, pilot experience and prior knowledge of the distribution of sea otters in the area to be surveyed was important to avoid disturbing nearby rafts while a focal raft was being counted.

Population Trends

The total count of 3,180 sea otters obtained in 2001 and the 2004 estimate of 3,185 otters contrast sharply with expected numbers based on Watson *et al.'s* (1997) estimated population growth rate of 18.6% year^{-1}. At this growth rate the population should have numbered ~ 4,000 otters in 2001 and about ~6,600 by 2004. This suggests that there has been a change in the growth rate of at least part of the population. Simple log-linear regressions explain 95% of the variation with a growth rate of 16.4% year^{-1} for the whole population or 15.6% year^{-1}, for just Vancouver Island counts. However piece-wise regressions fit better and explain 97% to 98% of the variation. By piece-wise regression, growth appears to have been rapid up to 1994 or 1995 at 20.2% year^{-1} for the whole population or 19.1% year^{-1} on Vancouver Island, but then dropped after 1994 or 1995 to 9.5% and 8.0% year^{-1} respectively.

It is notable that the trends for the whole population are similar to the trends for Vancouver Island, except that all rates are slightly higher after 1989 and reflect the abrupt addition of central mainland coast otter counts. This suggests that the apparent decline in the growth rate is largely a result of the Vancouver Island counts. The central mainland coast and Vancouver Island otter groups appear to be disjunct as sightings between the two areas are rare. For this reason population growth in these two parts of the range will be considered separately in the following discussion.

There are several possible explanations that account for a decline in growth rate. These include: 1) a decline in growth has occurred on Vancouver Island, where the amount of unoccupied habitat for continued expansion has decreased; 2) there have been mortality events in the population; 3) otters are dispersing into unidentified habitat; and 4) poor survey conditions in recent years have resulted in lower counts.

It is not unreasonable to expect population growth to have declined on Vancouver Island. Sea otters are a density-dependent species whose populations are typically limited by food (Riedman and Estes 1990), although the current sea otter population trend in the Aleutian Islands presents an exception (Doroff *et al.* 2003). As the number of sea otters in an area increases and food becomes limiting, otter density in the area is maintained at equilibrium (*K*) through mortality and emigration (Estes 1990). Areas near the centre of the sea otter range on Vancouver Island have been at or near equilibrium density since the early to mid 1990s (Watson *et al.* 1997), and since then more of the range is likely to be at or near equilibrium density. In this scenario, the contribution of emigration to population growth may diminish as young sea otters in areas at equilibrium would have to travel greater and greater distances to reach rafts near the edge of the range and thus mortality would be a more likely outcome. However, on the central mainland coast, distances from the centre of the range to unoccupied habitat are still relatively small and most of the mainland coast is as yet unoccupied by sea otters. For these reasons, a density-dependent related decline in growth is unlikely in the central mainland coast area.

Another possible explanation for a decline in growth rate is the occurrence of morality events in the population. If this were occurring we would expect to detect declines in some survey segments, but declines are not evident in the survey data for Vancouver Island. On the central mainland coast there has been less survey effort and there is more inter-annual variability in counts, therefore, we can not dismiss the possibility that this has occurred.

It is possible that sea otter population growth has not slowed but rather that expansion of the range has taken place and otters have been missed during surveys. Sea otter sightings are reported by other researchers, eco-tour operators and commercial fishermen. These opportunistic sightings, and our reconnaissance surveys beyond the current range, provide good coverage of the coast of Vancouver Island. Thus, it is unlikely that concentrations of sea otters have been missed. Sea otter range expansions occurs by rapid mass movement of male sea otters to a new area (Garshelis *et al.* 1984; Jameson 1989). Range expansion movements are evident among some of the counts in Table 3. The counts in the Catala Island and Nuchatlitz Inlet segments in 1992 and 1993, likely represent a mass movement of male otters from the Catala Island segment in 1992 to the Nuchatlitz Inlet segment in 1993. Furthermore, the large raft of males counted at Catala Island in 1992 had likely moved there from the Kyuquot Sound segment after 1990.

Undetected range expansion is a possibility on the central mainland coast. The area is more remote, has been less extensively surveyed and is more sparsely populated by people than Vancouver Island. On the other hand, descriptions of the sea otter distribution from commercial fishermen operating on the central coast are consistent with our observations during dedicated surveys.

Environmental factors such as glare, sea state and wind can introduce significant variation into survey results (Geibel and Miller 1984; Drummer *et al.* 1990; Bodkin and Udevitz 1999). Even in good conditions sea otters easily blend in with the kelp beds and rocky reefs with which they associate. Furthermore because of their small size, otters easily disappear behind swells. In British Columbia areas occupied by sea otters are remote, rugged and generally exposed to ocean swell which creates challenging survey conditions. It is possible that from 2001 to 2004 sea otter counts on Vancouver Island were low because survey conditions were on average poorer than during 1988 to 1995 and this may have contributed to the lower growth rate. Although survey conditions undoubtedly contribute to uncertainties in population estimates, it does not seem likely that poor conditions could account for all of the discrepancy between the projected value from a growth rate of 18.6% year^{-1} in 2004 of ~6,600 and the estimate from survey data in 2004 of 3,185.

Sea otters were re-introduced to southeastern Alaska and Washington State during the same period they were re-introduced to British Columbia (Jameson *et al.* 1982). Until the late 1980s, these populations are estimated to have grown at 17-20% year^{-1}, rates near r_{max} estimated for this species (Estes 1990). Such high rates of growth in the early years following re-introduction are thought to be fuelled by an abundance of prey that arose in the absence of sea otter predation following extirpation of historic populations (Estes and Duggins 1995; Bodkin *et al.* 1999). Growth in the Washington State sea otter population has slowed to 8.2% year^{-1} since 1989 and the population is now thought to be approaching equilibrium in high-quality rocky habitat (Jameson and Jeffries 2003). In southeastern Alaska, growth has also declined. From annual counts since 1994 growth was estimated at 12% year^{-1} for at least part of the population, but recent counts suggest the growth rate is lower (USFW 2002).

After a consideration of the possible explanations for a decline in growth rate, we conclude that the growth rate has slowed on Vancouver Island since the previous assessment, and that it has occurred mostly as a result of natural density dependent factors. Given the precision of counts (CV = 7 -12%) that can be obtained during *Good* to *Excellent* sea conditions, we should be able to detect a growth rate as low as 6% year^{-1} over an 11-year period (1994-2004) with 6 surveys in *Good* to *Excellent* conditions (see Gerrodette (1987)). However, whether or not growth declined as low as 8.0% year^{-1} after 1995, as suggested by piece-wise regression will require a longer time series of surveys because survey conditions were frequently less than *Good* or *Excellent* in recent years compared to earlier years.

It is seems unlikely that the population growth rate is lower on the central mainland coast than on Vancouver Island, unless mortality is higher, or inter-annual counts are more variable for reasons such as less survey effort, parts of the range have been missed, or because of surveys conditions. Survey effort has been lower, than on Vancouver Island and survey conditions were variable, prior to 2001, ranging from 0% of counts obtained in *Good* to *Excellent* conditions to 100%. The log-linear regression that results in a growth rate of 12.4% year $^{-1}$ (1990 – 2004) is a relatively poor fit (r^2 = .737) and may reflects some of these factors. Most of the central and northern mainland coast is currently unoccupied by otters and thus a high population growth rate, as estimated by Watson *et al.* (1997) for Vancouver Island (1977 – 1995) would be expected. At this time we can conclude that growth has been positive on the central mainland coast between 1990 and 2004 and that the population range has doubled since 1995 but that further surveys will be required to better ascertain the growth rate.

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Literature Cited

B.C. Parks 1995. Sea Otter Management Plan, for Hakai Recreation Area. [Unpublished reported prepared by J.C. Watson for] British Columbia Ministry of Water Land and Air Protection, Parks and Protected Areas Branch.

Bigg, M.A. and I.B. MacAskie. 1978. Sea otters re-established in British Columbia. J. Mammal. 59: 874-876.

Bodkin J.L., B.E. Ballachey, M.A. Cronin, and K.T. Schribner. 1999. Population demographics and genetic diversity of remnant and translocated populations of sea otters. Conservation Biology 13(6): 1378 – 1385.

Bodkin, J.L. and M.S. Udevitz. 1999. An aerial survey method to estimate sea otter abundance. *In* Marine Mammal Survey and Assessment Methods. Edited by G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson. Balkema, Rotterdam. pp13-25.

Bodkin, J.L., G.G. Esslinger, and D. Monson. 2004. Foraging depths of sea otters and implications to coastal marine communities. Mar. Mamm. Sci. 20 (2): 305-321.

Burn, D.M. 1994. Boat-based population surveys of sea otters in Prince William Sound. *In* Marine Mammals and the *Exxon Valdez*. Edited by T.R. Loughlin. Academic Press. pp 61- 80.

Cowan, I.M. and C.J. Guiguet. 1960. The Mammals of British Columbia. British Columbia Provincial Museum Handbook. No. 11. 413 pp.

DeGange, A.R., D.C. Douglas, D.H. Monson, and C.M. Robbins. 1995. Surveys of sea otters in the Gulf of Alaska in response to the *Exxon Valdez* oil spill, Exxon Valdez state/federal natural resource damage assessment final report. (Marine Mammal Study 6J), U.S. Fish and Wildlife Service, Anchorage, AK. 15 pp.

Doroff, A.M., J.A. Estes, M.T. Tinker, D.M. Burn, and T.J. Evans. 2003. Sea otter population declines in the Aleutian archipelago. J. Mammal. 84(1): 55-64.

Drummer, T.D., A.R. DeGange, L.L. Pank, and L.L. McDonald. 1990. Adjusting for group size influence in line transect sampling. J. Wildl. Manage. 54(3): 511-514.

Estes, J.A. 1980. *Enhydra lutris*. American Society of Mammalogists, Mammalian Species 133. 8pp.

Estes, J.A. 1990. Growth and equilibrium in sea otter populations. J. Anim. Ecol. 59:385-401.

Estes, J.A. and R.J. Jameson. 1988. A double-survey estimate for sighting probability of sea otters in California. J. Wildl. Manage. 52(1): 70-76.

Estes J.A. and D.O. Duggins. 1995. Sea otters and kelp forests in Alaska: generality and variation in a community ecological paradigm. Ecological Monographs. 65(1): 75-100.

Evans, T.J., D.M. Burn, and A.R. DeGange. 1997. Distribution and relative abundance of sea otters in the Aleutian Archipelago. Marine Mammals Management, Fish and Wildlife Service, Region 7, Alaska. Technical Report. MMM 97-5. 29p.

Garshelis D.L. and J.A. Garshelis 1984. Movements and management of sea otters in Alaska. J. Wildl. Manage. 48(3): 665-678.

Garshelis, D.L., A.M. Johnson, and J.A. Garshelis. 1984. Social organization of sea otters in Prince William Sound, Alaska. Can. J. Zool. 62:637-647.

Geibel, J.J. and D.J. Miller. 1984. Estimation of sea otter, *Enhydra lutris*, population, with confidence bounds, from air and ground counts. Calif. Fish. Game. 70(4): 225-233.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68(5): 1364-1372.

Jameson, R.J. 1989. Movements, home range, and territories of male sea otters off central California. Mar. Mamm. Sci. 5:159-172.

Jameson, R.J., K.W. Kenyon, A.M. Johnson, and H.M. Wright. 1982. History and status of translocated sea otter populations in North America. Wild. Soc. Bull. 10:100-107.

Jameson, R.J. and S. Jeffries. 2003. Results of the 2003 survey of the reintroduced sea otter population in Washington State. USGS Biological Resources Division, Corvallis, Oregon. 6pp.

Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. N. Am. Fauna 68:1-352.

Loughlin, T.R. 1980. Home range and territoriality of sea otters near Monterey, California. J. Wildl. Manage. 44:576-582.

MacAskie, I.B. 1987. Updated status of the sea otter (*Enhydra lutris*) in Canada. Can Field-Nat. 101:279-283.

Morris, R.D., D.V. Ellis, and B.P. Emerson. 1981. The British Columbia transplant of sea otters *Enhydra lutris*. Biol. Cons. 20:291-295.

Ralls, K. and D.B. Siniff 1990. Time budgets and activity patterns in California sea otters. J. Wildl. Manage. 54(2): 251-259.

Ribic, C.A. 1982. Autumn activity of sea otters in California. J. of Wildl. Manage. 63: 702-706.

Riedman, M.L., and J.A. Estes. 1990. The sea otter (*Enhydra lutris*): Behaviour, ecology and natural history. US Fish and Wildl. Serv. Biol. Rep. 90(14). 126 pp.

Watson, J.C. 1993. The effects of the sea otter (*Enhydra lutris*) foraging on shallow rocky communities off northwestern Vancouver Island, British Columbia. Ph.D. dissertation. Univ. of California, Santa Cruz. 169 pp.

Watson, J.C., G.M. Ellis, T.G. Smith, and J.K.B. Ford. 1997. Updated status of the sea otter, *Enhydra lutris*, Canada. Can. Field-Nat. 111(2): 277-286.

Wendell, F.E., R.A. Hardy, J.A. Ames, and R.T. Burge 1986. Temporal and spatial patterns in sea otter (*Enhydra lutris*) range expansion and in the loss of the clam fisheries. Cal. Fish. Game. 72:197-100.

United States Fish and Wildlife Service 2002. Stock Assessment Report: Sea otters (Enhydra lutris): Southeast Alaska stock 6pp. http://www.r7.fws.gov/mmm/sar/

United States Fish and Wildlife Service. 2003. Final Revised Recovery Plan for the Southern Sea Otter (*Enhydra lutris nereis*). Portland, Oregon. xi + 165pp.

Table 1. Counts from sea otter surveys made from boat and from helicopter in the same segment during *Good* to *Excellent* survey conditions.

Segment	Year	Boat (*count and date*)		Helicopter (*count and date*)	
Checleset Bay	2001	663	Aug. 29	557	July 27
Checleset Bay	2002	564	Aug. 4	667	Aug. 5
Estevan Peninsula	2003	74	Aug. 5	57	May 6
Kyuquot Sound	2001	216	Aug. 29	372	July 20
Nootka Island	2003	99	Aug. 5	41	May 6

Table 2. Results of replicate counts made in three survey segments.

Segment	Date/Platform	Count	Mean	SE	CV%
Nuchatlitz Inlet	24-Aug-05/boat	688			
	25-Aug-05/boat	759			
	26-Aug-05/boat	632	693.00	36.75	9
McMullin Group to Cape Mark	12-Jun-01/helicopter	279			
	12-Jun-01/helicopter	244			
	18-Jun-01/helicopter	258	260.33	10.17	7
Checleset Bay	23-May-01/boat	526			
	27-Jul-01/helicopter	557			
	29-Aug-01/boat	663	582.00	41.47	12

Table 3. Maximum segment counts for the British Columbia sea otter population used in abundance and trend analysis. Interpolated values are italicized and underlined. Superscripts indicate the survey platform used: fixed-wing aircraft- 1, helicopter- 2, small boat- 3.

Segment	1977	1978	1980	1982	1984	1987	1988	1989	1990	1991	1992	1993	1994	1995	2001	2002	2003	2004
Queen Charlotte Strait															74[3]	56[2]	34[3]	97[3]
Kains to Cape Scott															152[3]	0[2]	29[3]	*60*
Quatsino Sound														1[3]	52[3]	16[2]	39[3]	32[3]
Brooks Bay								12[3]	8[3]	28[3]	116[2]	245[3]	96[3]	235[3]	489[3]	166[2]	409[3]	496[3]
Checleset Bay	55[1]	51[1]	60[1]	97[1]	196[3]	234[1]	201[3]	329[3]	288[3]	230[3]	257[3]	272[3]	413[3]	530[3]	663[3]	667[2]	683[3]	740[3]
Mission Group											4[2]				83[3]	*72*	80[3]	111[3]
Kyuquot Sound								25[2]	173[3]	50[3]	74[3]	91[3]	397[3]	240[3]	372[2]	417[3]	293[3]	296[3]
Catala Island										0[3]	182[3]	4[3]	5[3]	11[3]	80[2]	89[3]	101[2]	104[3]
Nuchatlitz Inlet									5[2]	23[3]	19[3]	139[3]	149[3]	149[3]	344[2]	260[2]	391[3]	457[3]
Nootka Island	15[1]	16[1]	14[1]	19[1]	149[1]	136[1]	153[3]	216[2]	138[2]	*155*	*149*	159[3]	128[3]	237[3]	85[2]	92[2]	99[3]	*107*
Estevan Peninsula														20[3]	50[2]	65[2]	74[3]	*84*
Clayoquot Sound															229[3]	234[2]	183[2]	181[3]
Subtotal Vanc. I.	70	67	74	116	345	370	354	582	612	486	801	910	1188	1423	2673	2134	2415	2765
Goose Island Group									56[3]	104[3]	168[3]	135[3]	*112*	*104*	129[3]	33[2]	*32*	31[2]
McMullin Group to Cape Mark															378[3]	202[2]	362[3]	389[2]
Total B.C.	70	67	74	116	345	370	354	582	668	590	969	1045	1300	1527	3180	2369	2809	3185

Additional central mainland coast counts used

Segment	1996	1998
Goose Group	88[3]	126[3]
McMullin Group to Cape Mark	171[3]	303[3]

SOURCES

1977: Bigg and MacAskie 1978
1978: Morris *et al*. 1981
1980: Farr unpubl.
1982: Bigg unpubl.
1984: MacAskie 1987
1987: Bigg and Olesiuk unpubl.
1988: Watson 1993
1989: Watson 1993, MacAskie unpubl.
1990: Watson 1993, Powers 1991 unpubl.
1991: Watson 1993
1992: Watson *et al*. 1997, BC Parks
1993: Watson *et al* 1997
1994: Watson *et al*. 1997
1995: Watson *et al*. 1997
1996: Watson unpubl.
1998: Watson unpubl.
2001: Watson, DFO
2002: Watson, DFO
2003: Watson, DFO
2004: Watson, DFO

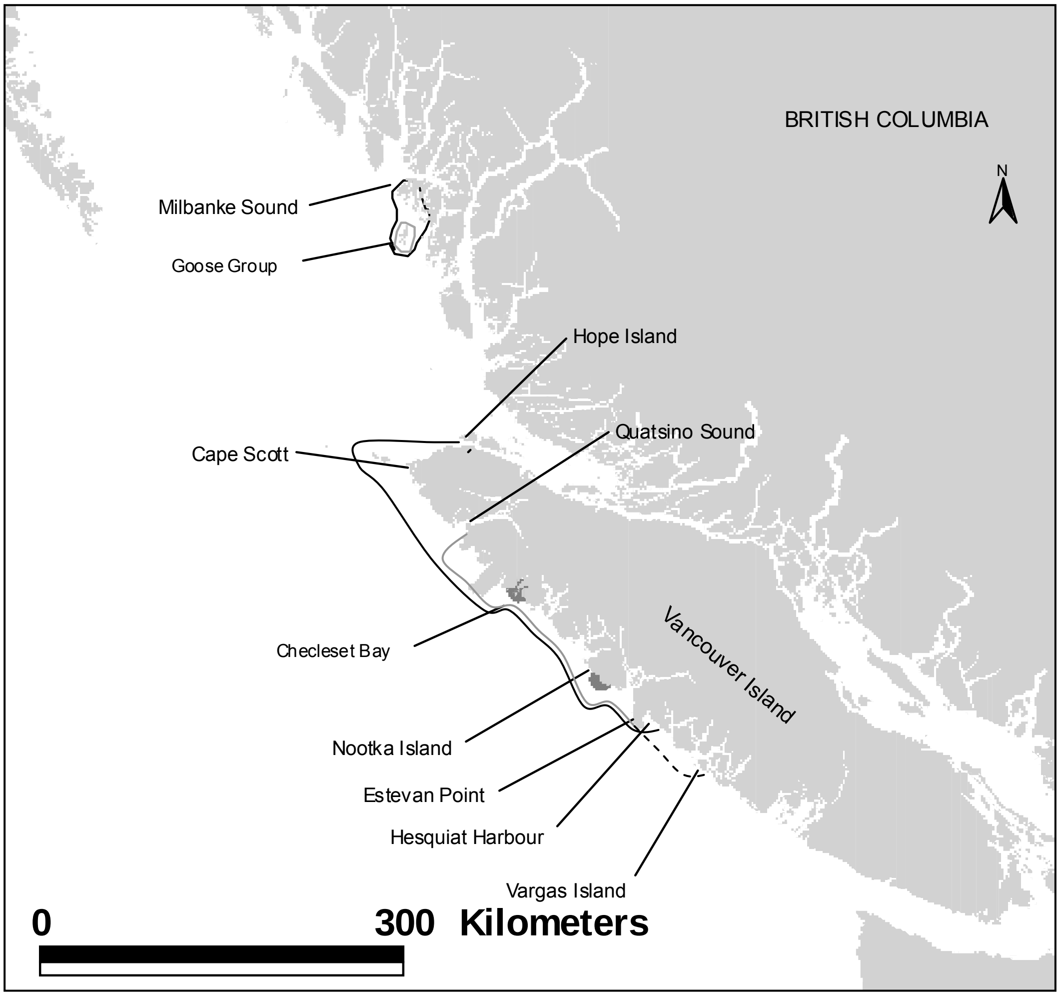

Figure 1. Distribution of sea otters in British Columbia and place names mentioned in the text. Shaded areas on Vancouver Island represent the range in 1977. Gray line represents the range by 1995, black line the range by 2001 and the dashed line, range expansion on Vancouver Island in 2004.

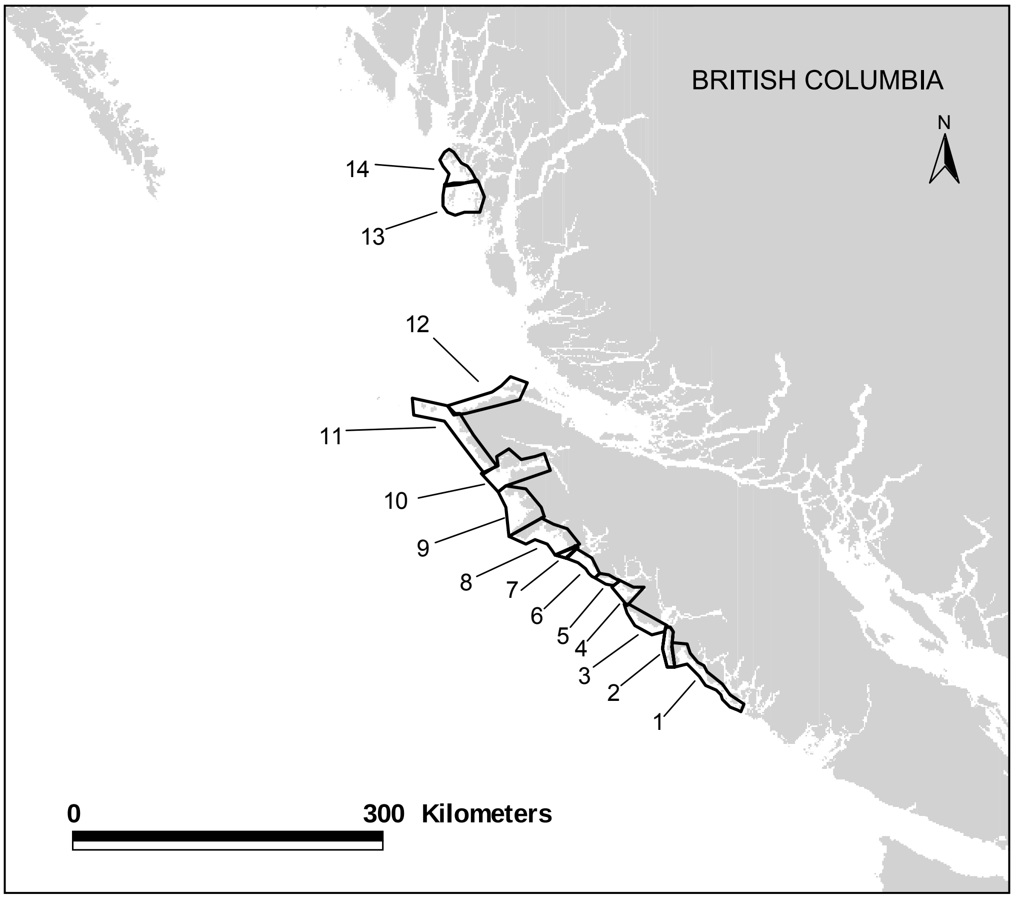

Figure 2. Sea otter survey segments. 1. Clayoquot Sound, 2. Estevan Peninsula, 3. Nootka Island, 4. Nuchatlitz Inlet, 5. Catala Island, 6. Kyuquot Sound, 7. Mission Group, 8. Checleset Bay, 9. Brooks Bay, 10. Quatsino Sound, 11. Kains to Cape Scott, 12. Queen Charlotte Strait, 13.Goose Group, 14. McMullin Group to Cape Mark.

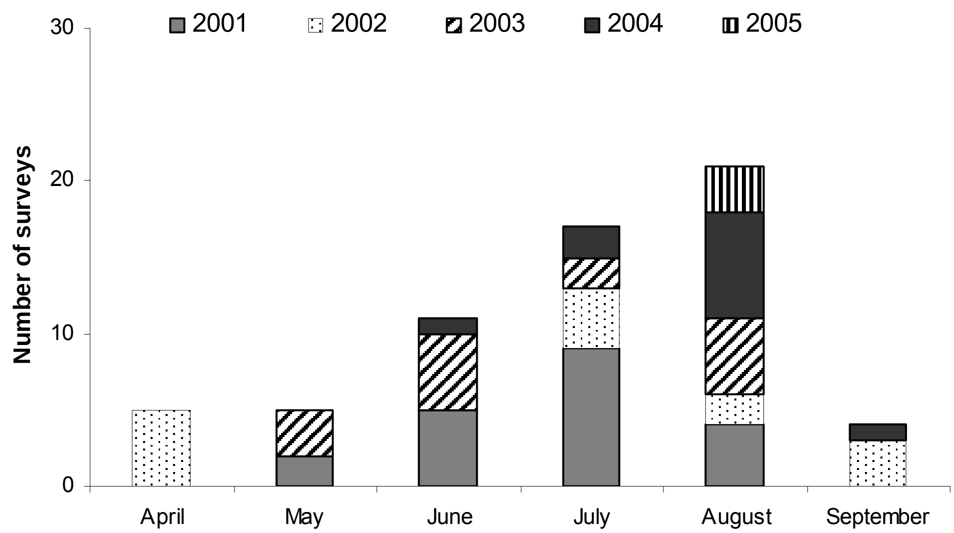

Figure 3. Seasonal distribution, by month, of surveys conducted 2001 - 2005 and used in this analysis.

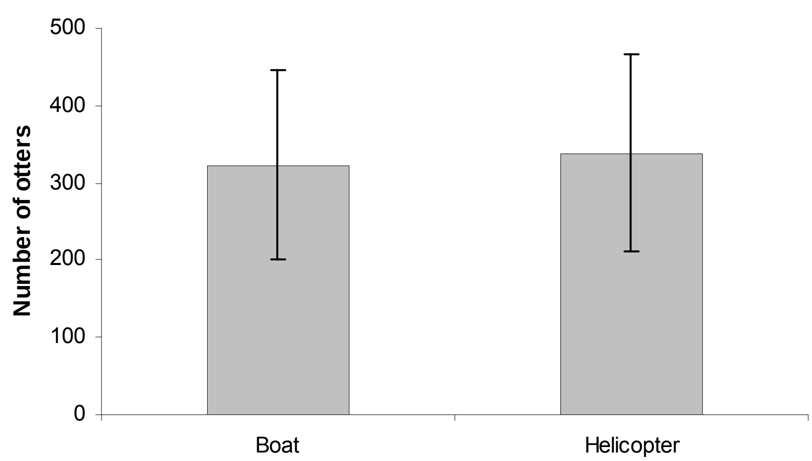

Figure 4. Comparison of the results of boat and helicopter counts of the same segments, conducted during the same year, in *Good* to *Excellent* conditions. The means are not significantly different ($t_{(0.05,4)}$ = -0.32, Error bars = ± 1 *SE*).

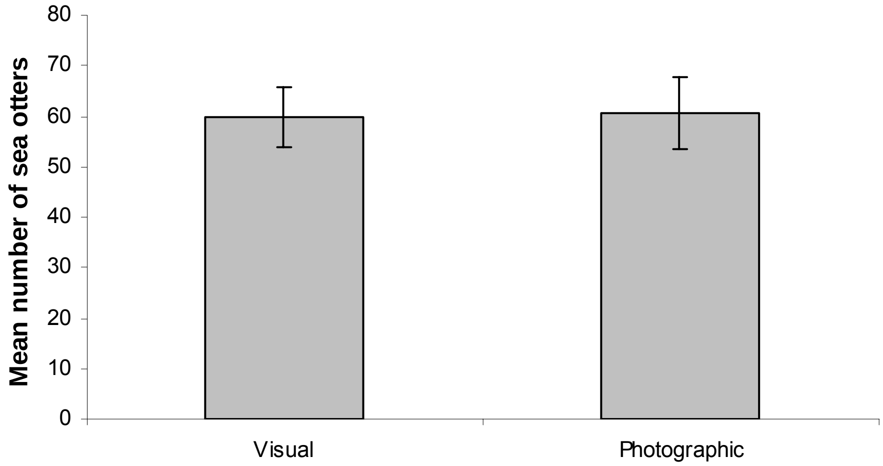

Figure 5. A comparison of visual and photograph counts taken simultaneously of rafts during helicopter surveys. The means are not significantly different ($t_{(0.05,41)} = 0.76$, Error bars = ± 1 *SE*).

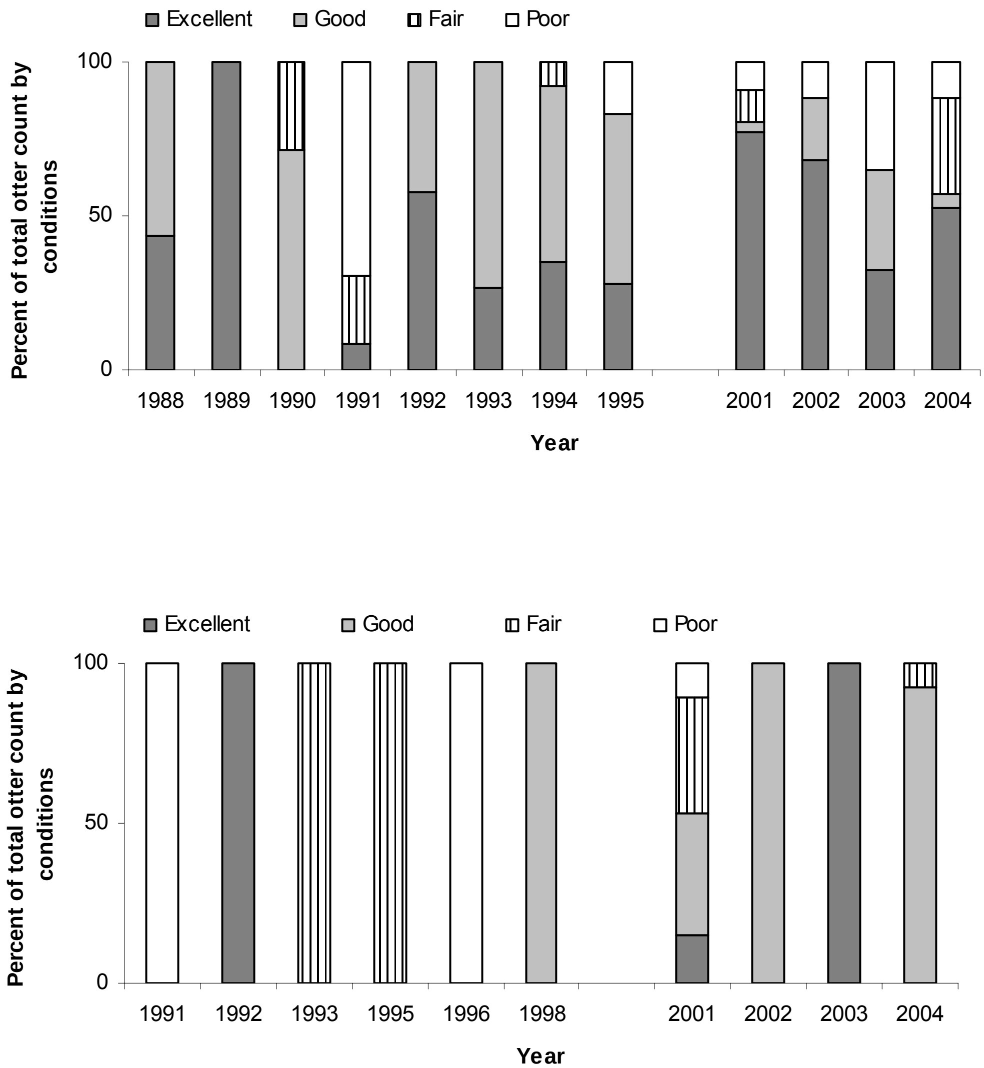

Figure 6. Percent of total annual sea otter counts by survey conditions. Top panel: Vancouver Island, 1988 -1995 and 2001 - 2004. Bottom panel: central mainland coast, 1991 - 1998 and 2001 - 2004.

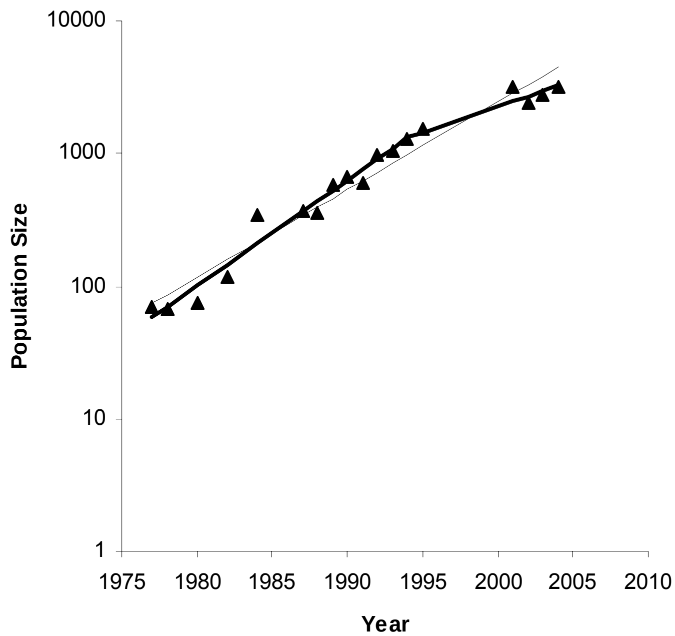

Figure 7. Trend in British Columbia sea otter population growth (Vancouver Island and the central mainland coast). Thin line is simple log-linear regression (growth 16.4% yr^{--1}, r^2 = 0.954, n =18). Thick line is piece-wise regression (growth 20.2% yr^{-1} until 1994 and 9.5% yr^{-1}, 1994 - 2004, r^2 = 0.978, n = 18).

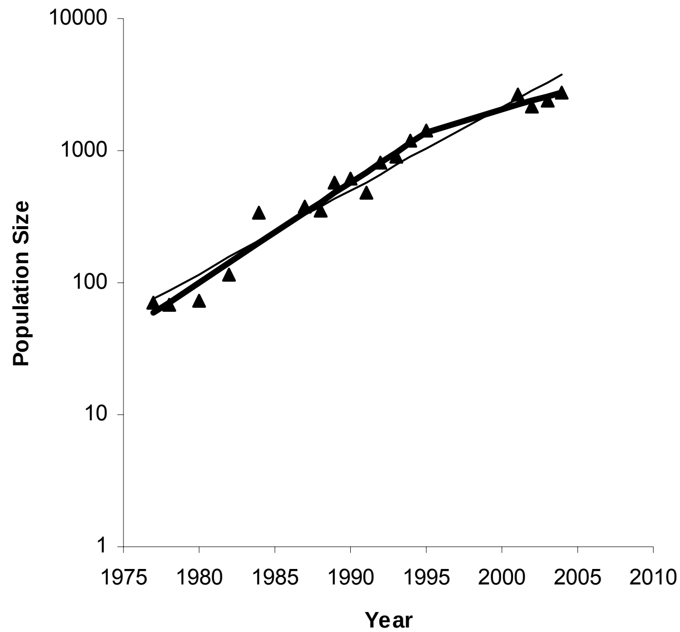

Figure 8. Trend in sea otter population growth on Vancouver Island. Thin line is simple log-linear regression (growth 15.6%yr^{-1}, r^2 = 0.950, n =18). Thick line is piece-wise regression (growth 19.1%yr^{-1} until 1995 and 8.0%yr^{-1}, 1995 - 2004, r^2 = 0.975, n = 18).

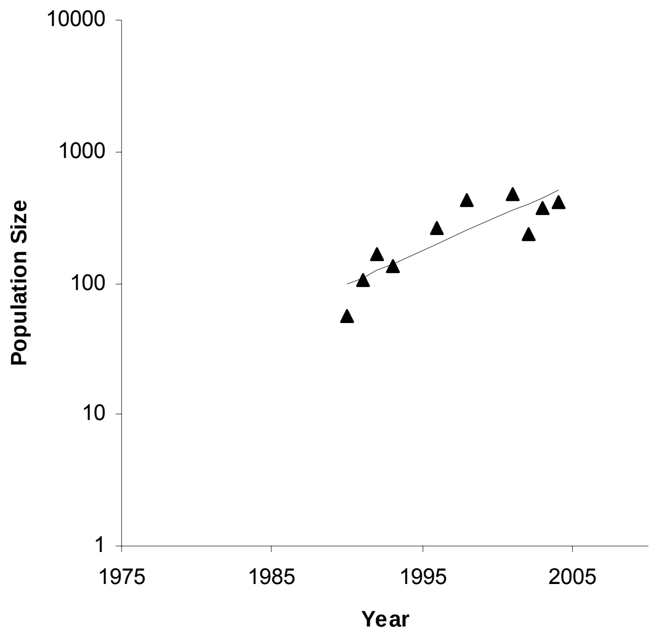

Figure 9. Trend in sea otter population growth on the central mainland coast. The line represents a simple log-linear regression (growth 12.4%yr^{-1} from 1990 - 2004, r^2 = 0.737, n = 10).