Trends and Status of Harbor Seals in Washington State: 1978-99

By
Harriet Huber and Jeff Laake

In the first half of the twentieth century, the number of harbor seals (*Phoca vitulina richardsi*) in Washington State was severely reduced by a state-financed population control program, which considered harbor seals to be predators in direct competition with commercial and sport fishermen. Seals began to recover after the bounty program ended in 1960 and the Marine Mammal Protection Act was passed in 1972. From 1978 to 1999, biologists from the Washington Department of Fish and Wildlife (WDFW) and National Marine Mammal Laboratory (NMML) flew aerial surveys to determine the distribution and abundance of harbor seals in Washington. We used exponential and generalized logistic models to examine population trends and status relative to maximum net productivity level (MNPL) and carrying capacity (*K*). Since 1978, harbor seal counts have increased threefold, and estimated abundance has increased seven- to tenfold since 1970.

Under National Marine Fisheries Service (NMFS) management, Washington harbor seals are divided into two stocks: coastal and inland waters. For both stocks, the observed population size for 1999 is very close to the predicted carrying capacity (*K*). The current management philosophy for marine mammals that assumes a density-dependent response in population growth with MNPL > $K/2$ is supported by growth of harbor seal stocks in Washington waters. We expect that further monitoring of other pinniped and cetacean stocks will also support this concept. This study highlights the importance of long-term precise monitoring to help understand population dynamics and support management decisions.

Background

The U.S. Marine Mammal Protection Act (MMPA) of 1972 established criteria for man-

agement of marine mammals by NMFS and the U.S. Fish and Wildlife Service that required that marine mammal populations "should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part, and, consistent with this major objective, they should not be permitted to diminish below their optimum sustainable population." The intent of the MMPA was clear, but the language was too vague to provide an operational definition for management. Ecologist Dr. Lee Eberhardt suggested that optimum sustainable population (OSP) should be interpreted as the range of population sizes from the maximum size (carrying capacity (K)) down to the size which gives maximum productivity or maximum sustainable yield (MSY). NMFS adopted the definition for OSP as a population level between carrying capacity (K) and the population size which provided the maximum net productivity level (MNPL).

Defining OSP was a first step, but implementing the definition proved difficult for researchers because they lacked information about population parameters and sufficiently precise data. Difficulties in implementing an OSP management scheme led to the 1994 amendments of the MMPA that provided an alternative approach based on managing incidental take. In this approach, potential biological removals (PBR) must remain below a percentage of a minimum population size. In the present management scheme, an assessment of population growth rates and status relative to MNPL can be incorporated into the calculation of PBRs.

The utility of MNPL was questioned because it could not be measured precisely in a well-studied northern fur seal (*Callorhinus ursinus*) population. "Under ideal conditions, MNPL would be determined by accurate and precise monitoring of a discrete population unit during natural growth from some level well below MNPL … to a level above MNPL."[1]

Those "ideal conditions" are rare indeed, but they do exist for harbor seals in Washington State. The number of harbor seals residing in Washington State in the early 1970s was estimated to be 2,000-3,000. Beginning in 1978, Steve Jeffries of the WDFW began systematic surveys of Washington's harbor seal population; the surveys were continued through 1999 by the WDFW and NMML.

This 22-year time series provides a unique opportunity to describe population growth of a recovering and unharvested marine mammal population. Because harbor seals haul out onto land in discrete aggregations at specific times, we were able to count a large proportion of the population to provide a precise measure of population trend. We describe population growth using exponential and generalized logistic models and use the models to show that harbor seal populations in Washington are above MNPL and near carrying capacity. We tested our assumption that there was no temporal trend in the proportion of seals on shore during surveys by comparing proportion ashore data collected in 1991-92 with data collected in 1999-2000.

METHODS

Study Area

As managed by NMFS, harbor seals in Washington and Oregon have been separated into coastal and inland stocks because of differences in cranial morphology, timing of pupping, and genetics. The Washington inland stock includes all harbor seals in U.S. waters east of a line extending north-south between Cape Flattery on the Olympic Peninsula and Bonilla Point on Vancouver Island (Fig. 1). Harbor seals on the outer coast of Washington are part of a stock that includes seals in Oregon, from the Columbia River southward to the Oregon/California border. Interchange between inland and coastal stocks is unlikely. No radio-tagged seals from

---

[1]Ragen, T.J. 1995. Maximum net productivity level estimation for the northern fur seal (*Callorhinus ursinus*) population of St. Paul Island, Alaska. Mar. Mammal Sci. 11:275-300.
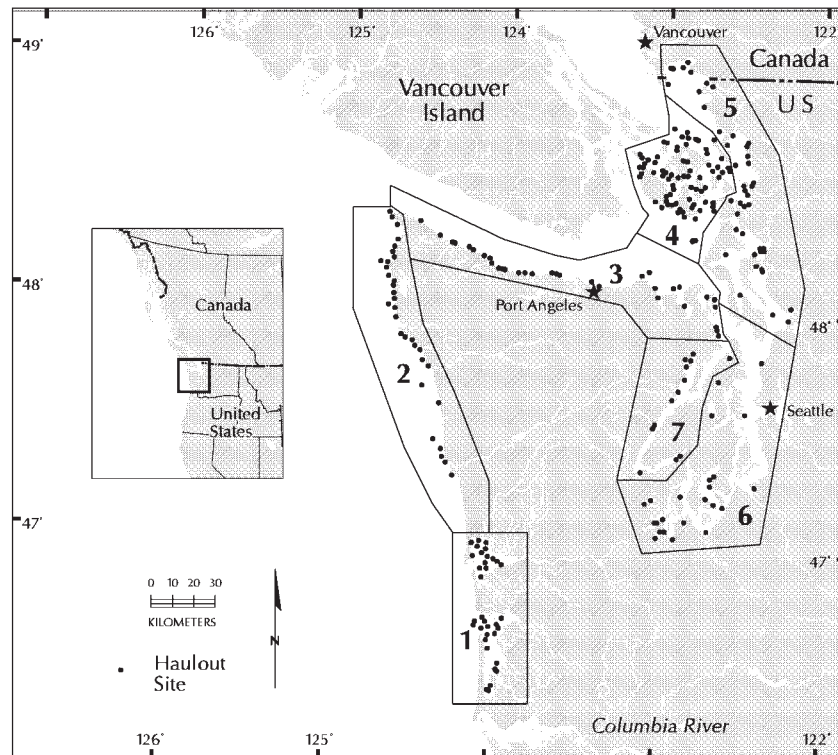
Figure 1. Map of harbor seal haul-out sites and survey regions for Washington coastal and inland stocks. The Washington coastal stock includes Coastal Estuaries (1) and Olympic Peninsula (2). The inland stock includes Strait of Juan de Fuca (3), San Juan Islands (4), Eastern Bays (5), Puget Sound (6), and Hood Canal (7).

the inland stock (n = 140) have been observed in coastal areas or vice versa (n = 188). We divided harbor seal haul-out sites in Washington into seven survey regions: Coastal Estuaries, Olympic Coast, Strait of Juan de Fuca, San Juan Islands, Eastern Bays, Puget Sound, and Hood Canal (Fig.1). Survey regions were determined by timing of pupping and a geographic area that could be surveyed within a 3-4 hour tidal window.

Survey Methods

Surveys were flown at low tide during the pupping season when maximum numbers were onshore. All known haul-out sites were surveyed and potential new sites were exam-ined on each census. Because of differences in timing of pupping, surveys were flown in late May to mid-June for the coastal stock and August through September for the inland stock. Surveys were scheduled as closely as possible (tides permitting) to the time when peak numbers of pups were expected to be present. All surveys took place within a week of the peak of pupping for each region. Surveys were flown between 2 hours before low tide to 2 hours after low tide in a single engine plane at 700 to 800 feet altitude at 80 knots. The total number of seals (including pups) present at each site was counted from photographic slides.

At least two to three surveys were scheduled for each region during annual survey

windows, though some surveys were canceled because of bad weather. A complete survey of each region was attempted in 1 day; if this was impossible because of weather or disturbance, surveys from 2 or 3 days were combined.

Population Growth Models

Two simple non-age-structured deterministic models of population growth were considered to represent the growth in the harbor seal stocks: exponential and generalized logistic. These models are discrete in nature with an annual time step to represent the annual pupping pulse. In each case, the population size (N_t) in year t is expressed in terms of the population size (N_{t-1}) in year t-1 plus growth (new individuals), which is some fraction of N_{t-1}. Exponential growth assumes the population grows without limit at a constant annual rate (R_{max}):

$$N_t = N_{t-1} + N_{t-1}R_{max} \qquad (1)$$

Clearly, the exponential model cannot be true forever, but populations can experience exponential growth prior to approaching K. Therefore, it can be used as a null model to test for density dependence. In the generalized logistic growth model, the rate of increase is a function of the population size relative to the maximum population size K:

$$N_t = N_{t-1} + N_{t-1}R_{max}\left[1 - \left(\frac{N_{t-1}}{K}\right)^z\right] (2)$$

Annual net production is simply the difference in consecutive population sizes and the maximum net productivity level (MNPL) is the value of N_{t-1} at which annual net production is maximized. As N_{t-1}/K ranges between 0 and 1, the realized per capita growth rate values range between R_{max} and 0.

The shape of the growth curve and the per capita production curve is governed by the exponent z, which determines the timing of the density dependent effect and the position of MNPL relative to K. The standard logistic curve is obtained when $z = 1$: per capita production is a linear function of N and MNPL/K = 0.5. If $z > 1$, per capita production is a concave (downwards) non-linear function of N and MNPL/$K > 0.5$ and if $z < 1$, per capita production is a convex (concave upwards) non-linear function of N and MNPL/$K < 0.5$. An approximate relationship between MNPL/K and z is given by:

$$MNPL / K \approx (z+1)^{-1/z} \qquad (3)$$

Incorporating z into the growth model is important for harbor seal populations because long-lived marine mammals are expected to demonstrate the strongest density dependent effect close to K ($z > 1$). However, in most cases survey data have not been sufficiently precise to estimate z adequately. The parameters R_{max} and z have a strong negative correlation in the model and diametrically opposed parameter values can yield nearly identical population trajectories for portions of the overall trajectory (Fig. 2). Without precise population estimates, z will almost surely be poorly estimated. The correlation between R_{max} and z is lessened by observing the population over a wide-range of growth. Discriminating between the two models in Figure 2 would be nearly impossible if the population were observed from year 10 and beyond. However, if it was observed from year 0, the parameters could be estimated more precisely as the two models imply different starting population sizes.

Growth Model Fitting

We based the growth models on our survey count data. Fitting growth models to the harbor seal count data involved finding parameter values which provided the "best fit" to the data. The best fit depended on the assumed statistical model for the observed data. We used deterministic population growth models (i.e., given the parameter values, the popula-

tion size in year N_t determined exactly the size in year N_{t+1}) but our count of harbor seals represented only a proportion of the population because some seals were always in the water and consequently missed by the aerial surveys. An estimate of the proportion of seals on land (p) during surveys was determined using VHF radio tags in three areas in the coastal stock and three areas in the inland stock in 1991 and 1992 . If we had estimated the proportion ashore for each region in each year, the growth model could have been based on estimates of population size. We fitted growth models to the count data and our inference to population growth depends on the assumption that there was no temporal trend in the proportion of seals on shore during surveys. We tested that assumption by comparing proportion ashore data collected in 1991-92 with data collected in 1999-2000 (see section on Proportion Ashore).

The parameters of the growth model are R_{max}, K, z, and an intercept N_0, which is an initial size of the population onshore for some arbitrarily chosen time designated as $t = 0$. We used only the counts to fit the growth models but to express initial population size (N_0) and carrying capacity (K) in terms of the population we multiplied N_0 and K by the correction factor (CF) of 1.53 to account for seals in the water during surveys. The parameters R_{max} and z remain unchanged by the constant scaling but would be affected by any trends in p_t.

One of the complications in the harbor seal data was missing counts. While it was not necessary to have a count for each year, ideally, for any one year the entire range should have been counted completely. However, in certain instances some regions were not surveyed due to bad weather, disturbance, logistical problems, or lack of funding. In other instances, surveys were begun in one region and then expanded into other regions over time. For example, the Coastal Estuaries in Washington were surveyed as early as 1975 but surveys of the Olympic Coast region were not begun until 1980 (Table 1). Although there were some counts for inland waters for 1978, consistent counts for all regions in the
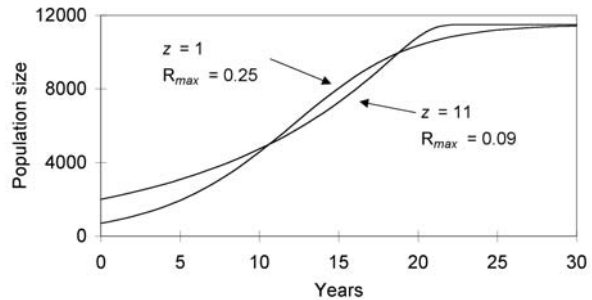

Figure 2. Two similar generalized logistic growth curves achieved by choosing different values for z, R_{max}, and initial population size.

inland waters stock did not begin until 1983. A simple solution was to limit counts to years in which seals were counted in all regions. However, this would have wasted valuable data and severely restricted the time frame of surveys.

Instead, we fitted separate growth curves for each of the seven regions (Fig. 1) using the counts that were available for each region. Fitting separate growth models to the regions used only observed data and allowed variation in the number of replicate counts between regions but required more parameters that applied to the regions and not the entire population. Any random movement between regions would create additional variation in counts and any directed movement (i.e., permanent emigration/immigration) would be reflected in the parameters of regional growth models.

Fitting the growth models separately for each region expanded the number of estimated parameters substantially. However, it's reasonable to hold some of the parameters constant for some or all of the regions. In general, z is difficult to estimate and it was unlikely that the data would support a different z for each region. Also, R_{max} was likely to be constant among regions unless there was a strong movement component. However, K and N_0 were unlikely to be constant across regions because of differences in region size and habitat quality.

We fitted a series of models for each of the five regions in the inland Washington stock and separately for the two regions in the

Table 1. Average annual counts for the two regions in the coastal stock and the five regions in the inland stock of Washington harbor seals for 1975-99.

	Coastal stock		Inland stock				
Year	Coastal Estuaries	Olympic Peninsula	Strait of Juan de Fuca	San Juan Islands	Eastern Bays	Puget Sound	Hood Canal
1975	1,694						
1976	1,742						
1977	2,082						
1978	2,570		417	852	755	337	732
1979							
1980	2,864	1,639					
1981	4,408	1,677					
1982	5,197						
1983	4,416	2,359	883	1,688	1,347		
1984	4,203		1,025	2,308	1,727		
1985	6,008		1,288	1,859	1,416	732	
1986	4,807	1,789	849	2,193	1,613		
1987	7,600	3,204	1,016	2,179	1,751		
1988	6,796		1,518	2,847	1,902		
1989	6,475	3,667	1,402	2,884	1,839		
1990			1,142	3,157			
1991	8,681	3,832	1,238	3,510	1,939	891	1,206
1992	7,761	4,191	1,580	3,640	2,102	708	989
1993	8,161	3,544	2,154	4,524	2,175	972	592
1994	5,786	3,505	1,488	4,529	2,144	854	
1995	6,492	4,867	2,281	4,852	2,068		
1996	7,191	3,124	1,988	5,330	2,521	1,119	975
1997	7,643	4,221	2,284	4,277	2,008	1,060	695
1998			1,734	4,441	1,810	1,026	577
1999	7,117	3,313	1,752	3,588	1,873	1,025	711

Washington portion of the coastal stock. For each model we assumed that N_0 and K (for the logistic model only) were different for each region. We fitted exponential models that assumed R_{max} was constant or varied by region. Likewise, we fitted logistic models that assumed R_{max} and z were either constant or varied by region. After selecting the best logistic model for each stock, we also explored whether R_{max} and z varied by stock. We used the small sample Akaike Information Criterion (AICc) to choose the most parsimonious model (i.e., fewest number of parameters that adequately explains the data) with minimum AICc. We evaluated the model goodness of fit with the Kolmogorov-Smirnov test to examine whether the standardized residuals were normally distributed. For graphical display of the growth curve for each stock and the entire state we summed the predicted values across regions and for observed values, we summed the average of regional counts for years in which one or more counts were available for each region. To supplement the observed values for the entire state, we added predicted counts for a few years with missing counts in one or two areas.

Status Determination

We considered the coastal and inland harbor seal stocks to be at OSP if the predicted population size was above MNPL. This was most easily determined by comparing population sizes as a proportion of K, because (3) provides a simple computation of MNPL/K. For each parametric bootstrap, we compared $\hat{N}_{1999} / K$ to MNPL/K as given by (3). If fewer than 5% of the replicates were below MNPL/K then we concluded that the stock was at OSP. We also constructed bootstrap confidence intervals for $\hat{N}_{1999} / K$, MNPL/K, and $\hat{N}_{1999} / MNPL$. A similar approach was taken to investigate whether a spotted dolphin population was above or below MNPL.

Proportion Ashore

Our growth model based on seal counts would only reflect population growth if there was no trend in the proportion of seals ashore during the surveys. A trend could occur if, over the two decades of surveys, the seals spent more or less time ashore as the population increased. For example, seals could spend less time on shore because they needed to spend more time foraging as the population increased and food resources decreased. We examined whether the proportion ashore changed in Grays Harbor or Boundary Bay during the 1990s. VHF radio transmitters were applied to harbor seals in 1991 at Grays Harbor (coastal stock) and in 1992 at Boundary Bay (inland stock) to estimate the proportion of harbor seals ashore during those surveys. We applied the same techniques at Grays Harbor (GH) in 1999 and Boundary Bay (BB) in 2000. During each survey, all seals with active tags were determined either to be ashore or not. Using each seal as a sample, we modeled the number of surveys the seal was ashore using a generalized linear model based on a binomial distribution and logit link function. We fitted models that included four age-sex categories (adult female, adult male, pup and sub-adult), year (1991-92 versus 1999-2000) and region (GH or BB) and their interactions. Using the most general model with all interactions, we estimated an over-dispersion scale (residual deviance/df) to adjust model selection using minimum QAICc (quasi likelihood adjustment to AICc). We also examined whether any observed annual differences in the proportion ashore would influence our conclusion regarding population growth.

RESULTS

Aerial Surveys

In the 22 years from 1978 to 1999, counts of harbor seals in Washington State increased
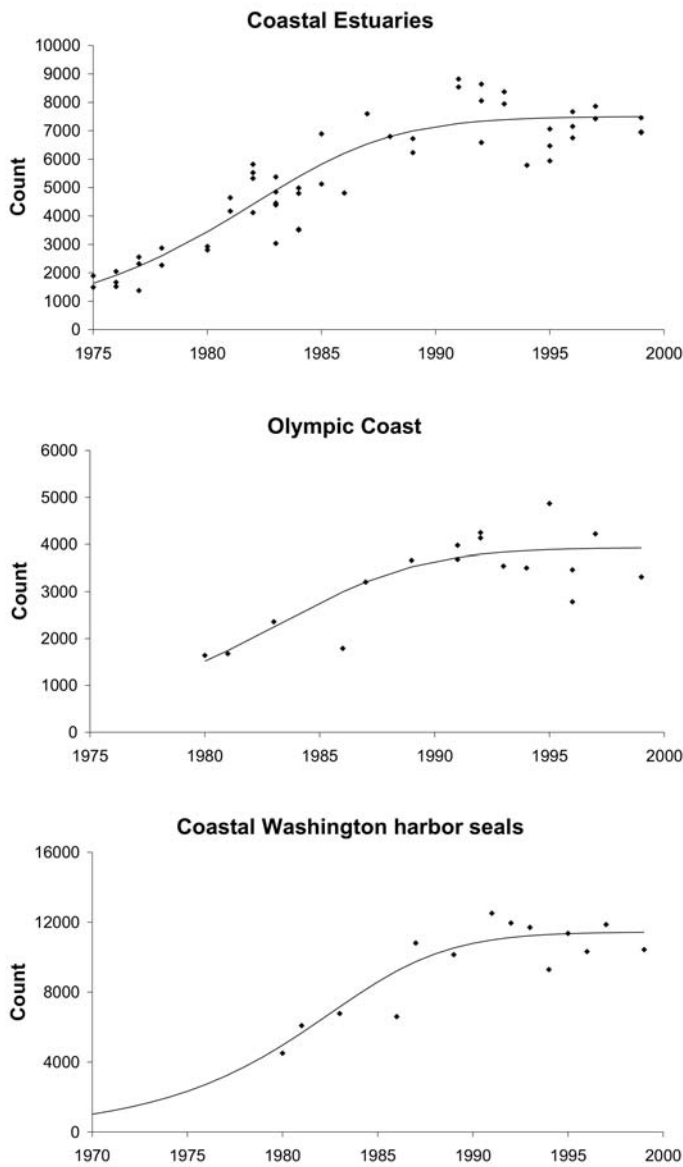
Figure 3. Generalized logistic growth curves for coastal estuaries and outer Olympic Peninsula coast regions, and their sum (Washington portion of coastal stock).

nearly threefold—from 6,786 to 19,379. The earliest surveys began in 1975 in the Coastal Estuaries (Table 1). By 1978 surveys had begun in all regions except the outer coast of the Olympic Peninsula where they began in 1980 (Table 1). Consistent surveys of inland waters did not begin until 1983 (Figs. 3, 4). Regions were not always surveyed annually nor were they surveyed an equal number of times per year. Population growth between 1978 and 1999 was not evenly distributed throughout all regions. Most growth occurred in the San Juan Islands and the Strait of Juan de Fuca and the least growth occurred in Hood Canal (Table 1).

Growth Model

The generalized logistic model with constant R_{max} and z was clearly the best model (Table 2) to describe the growth of the inland and coastal seal stocks. The large discrepancy in AICc between exponential and logistic models provides strong evidence for a density dependent response in population growth (Table 2). When we examined models that shared R_{max} and z parameters between stocks the choice was less clear. We selected the model with separate parameters for each stock because these stocks are genetically different and are unlikely to be demographically linked. As expected, the initial size and carrying capacity of the onshore population were estimated with reasonable precision, whereas lesser precision was achieved for R_{max} and z. The estimates of initial size using 1970 as the base year were quite consistent with counts for 1970-72, with the exception of the San Juan Islands region where our estimate was more than twice the original estimate. The growth curves demonstrate apparent slowing of the growth rate as numbers approached current carrying capacity (Figs. 3-5) and demonstrate a reasonable fit. Pooled standardized
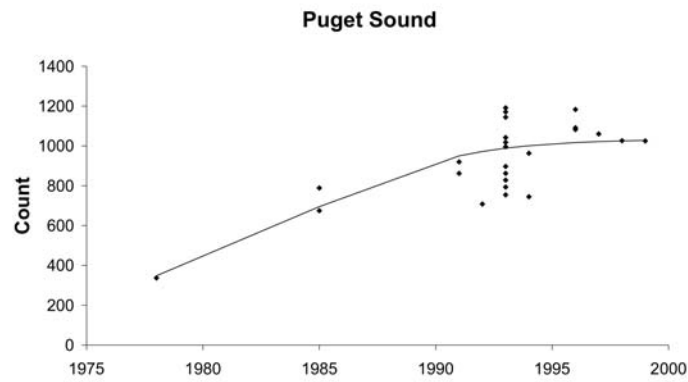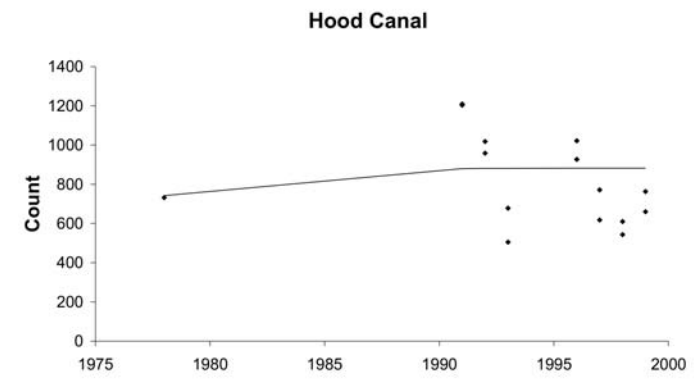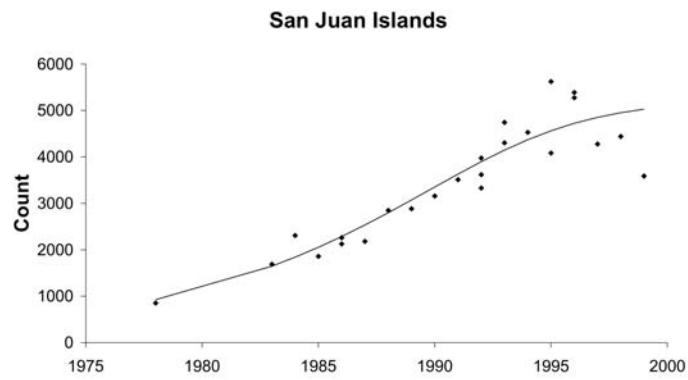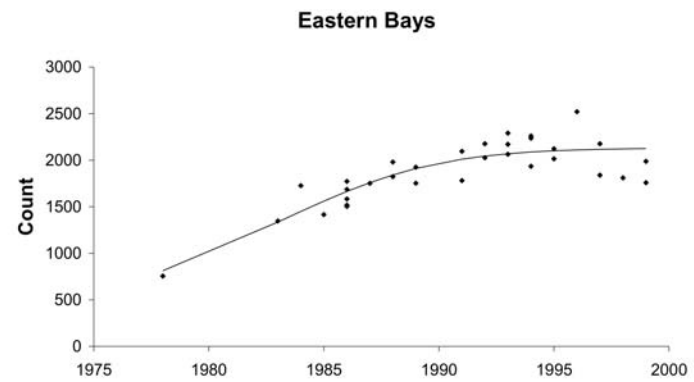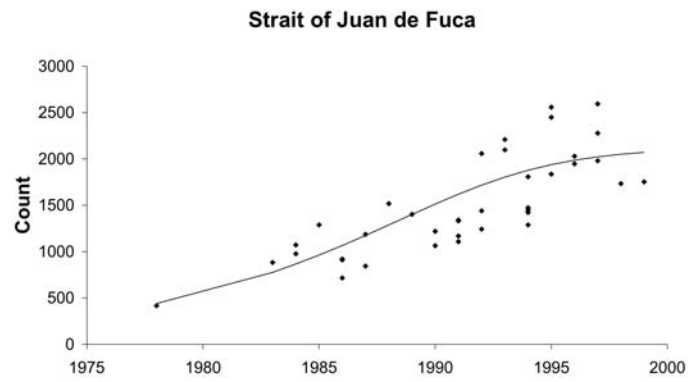
Figure 4. Generalized logistic growth curves for Strait of Juan de Fuca, Eastern Bays, San Juan Islands, Hood Canal, and South Puget Sound regions and their sum (inland Washington stock).
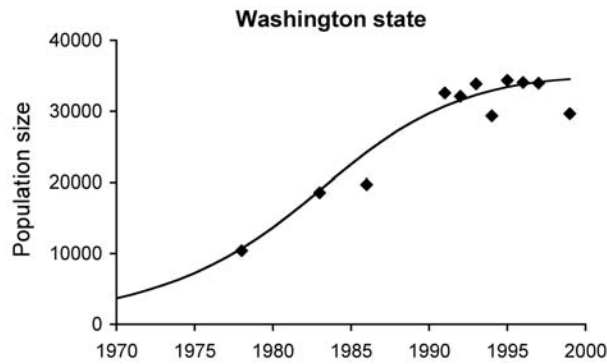
Washington state

Figure 5. Generalized logistic growth curve for harbor seals in Washington State expressed as population size. The observed values for 1978, 1983, 1986, 1994 and 1995 were supplemented with model predictions for regions with missing counts which accounted for 17%, 12%, 13%, 5% and 8% of the total abundance.

residuals did not differ from the assumed normal distribution (KS = 0.05, $P = 0.21$).

Status Relative to OSP

Although the evidence is not strong, the growth models of both stocks agree with the speculation that MNPL is indeed greater than 0.5 K (Table 3). The predicted population size for 1999 is very close to K for both stocks (Table 3), and none of the bootstrap replicates predicted a 1999 population size that was below MNPL. These results provide overwhelming evidence that both stocks in Washington are above MNPL and meet the guidelines for OSP. These stocks could decline or be reduced by 20% and they would still be above MNPL with a high degree of certainty (Table 3). The coastal stock recovered earlier than the inland stock as evidenced by the status of the stocks in 1990 (Table 3).

Proportion Ashore

We tagged 29 seals and conducted five surveys at Grays Harbor (in the Coastal Estuaries) in 1999 and tagged 43 seals and conducted seven surveys at Boundary Bay (in the Eastern Bays) in 2000 (Table 4). The most

obvious differences in the proportions ashore (Fig. 6) were associated with the age and sex of the seal. As expected during the pupping season, adult males and subadults spent considerably less time ashore than adult females and pups. The full model with 16 parameters for age-sex, year, region and their interactions explained 59% of the deviance, and the residual deviance/df (124.82/113 = 1.11) suggested a minor amount of over-dispersion. The model with minimum QAICc included all of the main effects and two-way interactions (QAICc = 145.6), although a much simpler model with only age-sex, year, and their interaction had a similar value (QAICc = 145.8). The model with age-sex only (QAICc = 150.3) accounted for 63% of the explained deviance of the full model.

The influence of year was not consistent across the age-sex classes (Fig. 6). Relative to 1991-92, females and pups spent less time ashore in 1999-2000, whereas adult males and subadults spent more time ashore in those years. Most of the annual difference and the interaction resulted from shifts at Grays Harbor. We computed an annual average proportion ashore for all seals (Table 4) by weighting age-sex specific values by the expected age-sex proportions of seals in the population which adjusted for differences in sample sizes between the age-sex classes across years. The largest decrease in the av-
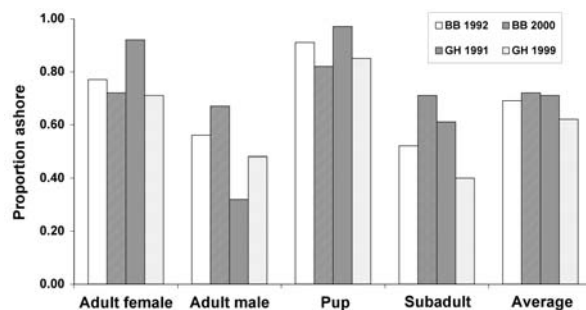

Figure 6. Average proportion ashore for radio-tagged seals in each of the 4 age-sex categories and a weighted average (Table 4) for Boundary Bay (BB) in 1992 and 2000 and Grays Harbor (GH) in 1991 and 1999.

Table 2. Model selection results for exponential and generalized logistic growth models of the inland and coastal stocks of harbor seals in Washington. In addition to R_{max} and z the number of parameters m includes initial size and carrying capacity (for logistic models) for each region.

Stock	Model	R_{max}	z	m	AICc
Inland	Exponential	Constant	n/a	6	26.8
		Region	n/a	10	-3.8
	Gen. Logistic	Constant	Constant	12	-39.9
		Region	Constant	16	-28.7
		Constant	Region	16	-28.6
		Region	Region	20	-13.9
Coastal	Exponential	Constant	n/a	3	68.7
		Region	n/a	4	70.9
	Gen. Logistic	Constant	Constant	6	20.5
		Region	Constant	7	23.3
		Constant	Region	7	23.5
		Region	Region	8	25.0
Both	Gen. Logistic	Constant	Constant	16	-20.2
		Stock	Constant	17	-19.3
		Constant	Stock	17	-20.4
		Stock	Stock	18	-19.9

Table 3. Parameter estimates for status determination of inland and coastal stocks of harbor seals in Washington with bootstrap standard errors and 95% confidence intervals.

Parameters	Stock	Estimate	Standard error	95% Confidence interval
MNPL / K	Inland	0.60	0.064	0.51 - 0.77
	Coastal	0.56	0.066	0.49 - 0.74
$\hat{N}_{1999}$ / K	Inland	0.98	0.025	0.90 - 1.00
	Coastal	1.00	0.004	0.99 - 1.00
$\hat{N}_{1990}$ / K	Inland	0.76	0.046	0.65 - 0.84
	Coastal	0.94	0.034	0.88 - 1.00
$\hat{N}_{1999}$ / $MNPL$	Inland	1.63	0.14	1.29 - 1.85
	Coastal	1.78	0.18	1.35 - 2.01

erage proportion ashore occurred at Grays Harbor with very little change at Boundary Bay.

DISCUSSION

Aerial Surveys

Haul-out behavior of harbor seals varies with season; in general, the highest number of seals are ashore during annual pupping and molt seasons and lowest numbers are ashore during the winter. For that reason, most researchers interested in long-term trends schedule assessment surveys during either pupping or molt season. Other variables such as height of tide, time of day, weather, and disturbance also affect haul-out patterns. The proportion ashore during a pupping survey will depend on tide state, timing relative to peak pupping, age, sex, and reproductive condition of seals using the haulout. There are several approaches to obtain maximum counts and to reduce variability in counts within a chosen season. Some researchers have surveyed during a broad range of time and tide conditions and adjusted counts for date and tide height after the fact. In this study, we have reduced variability in our counts by restricting our surveys within a narrow window adjusted for the peak of the pupping season in each survey region and to low tides between -2.0 and + 2.0 feet.

Corrections for Proportion Ashore

Harbor seal haul-out behavior varies by age, sex, and reproductive condition of seals. During pupping season, adult females and nursing pups spend 90% to100% of their time on shore during the 4 to 6 week nursing period. After weaning, pups spend an increased amount of time in the water and haul out only infrequently, whereas males and subadults are on shore during 40% to 60% of surveys. The annual molt period occurs 6 to 8 weeks after the pupping season, at which time seals undergoing molt spend a higher proportion of time on shore. Adult females molt first, then adult males, so that as the molt period progresses, the age and sex structure of seals on shore changes. These differences in haul-out behavior have strong implications for timing of surveys and the use and interpretation of correction factors associated with seasonal surveys.

We did find changes in the proportion of seals ashore during our surveys in 1991-92 and in 1999-2000; however, these changes do not invalidate our conclusions regarding growth and status of harbor seal stocks in Washington. The largest decrease in the proportion ashore occurred at Grays Harbor, declining from 0.71 to 0.62. However, the count of seals reflected this change decreasing from 8,681 in 1991 to 7,118 in 1999. If we apply the individual annual correction factors (Table 4), we get estimates of 12,285 and 11,548, respectively. Thus, the population estimates are even closer than the counts, which is consistent with our conclusion that the population stabilized during the 1990s. At Boundary Bay there was very little difference in the average proportions ashore, but the counts were not as consistent, decreasing from 797 in 1992 to 564 in 2000. However, these values are consistent with a lack of growth during the 1990s. We believe the leveling trend in seal abundance is real and not an artifact of a change in proportion of seals hauled out during surveys.

Trends and Status

Because the analysis was based on counts of seals ashore during a survey, the estimated carrying capacity (K) and initial population size (N_0) represent only a proportion of the entire population. To get estimates of the true population size, K and N_0 must be scaled by a correction factor (the inverse of the proportion ashore). Using the correction factor of 1.53, we estimated that during 1999 Washington coastal stock contained 15,958 harbor seals (95% CI = 13,645 to 18,662) and the inland stock contained 13,692 seals (95% CI = 11,707 to 16,012). Because there are no records of the pre-exploitation population size in Wash-

Table 4. Comparison of proportion of radio-tagged seals ashore during surveys at two sites 1991/1992 and 1999/2000. 1991/1992 data from Huber et al. (2001). The average proportion ashore was computed as a weighted average of the age-sex specific proportions using an assumed structure of 31% adult females, 26% adult males, 23% pups and 19% subadults.

	Grays Harbor		Boundary Bay	
	1991	1999	1992	2000
Active radio tags	33	29	24	43
Adult female	9	9	7	14
Adult male	7	7	5	16
Pup	8	8	7	8
Subadult	9	5	5	5
Number of surveys	4	5	5	7
Average proportion ashore (p)	0.71	0.62	0.69	0.72
Correction Factor ($1/p$)	1.42	1.62	1.44	1.38

ington, whether the present population is more or less than before is unknown. Changes that might have lowered the carrying capacity include decreases in fish stocks which are harbor seal prey such as hake and herring, reduced habitat, and increased disturbance. However, we have shown that both stocks of Washington harbor seals are above MNPL and are near the current carrying capacity of the environment.

Management Implications

Management implications for harbor seal stocks in Washington are quite clear. If formally determined to be at OSP, NMFS could return management authority for harbor seals to Washington State, if requested. It has been suggested that local selective removals of seals should be considered at river mouths where endangered or threatened salmonids co-occur if harbor seals are consuming and threatening fish populations of concern. From our analysis, selective removal of harbor seals around river mouths is unlikely to affect the status of harbor seal populations in Washington State. It is evident that harbor seal stocks in Washington could decline by 20% and still be above MNPL.

The current management philosophy for marine mammals that assumes a density-dependent response in population growth with MNPL $> K/2$ is supported by growth of harbor seal stocks in Washington waters. We expect that further monitoring of other pinniped and cetacean stocks will also support this concept. It is also clear from our analysis that it was not possible to determine that harbor seals in Washington had reached MNPL until several years after the fact. This study highlights the importance of long-term precise monitoring to help understand population dynamics and support management decisions.

This article is based on an article appearing in the January 2003 issue of the Journal of Wildlife Management cited as follows: Jeffries, S.J., H. R. Huber, J. Calambokidis, and J.L. Laake. 2003. Trends and status of harbor seals in Washington State: 1978-1999. Journal of Wildlife Management. 67 (1): 208-219.

The study was initiated by S.J. Jeffries at the Washington Department of Fish and Wildlife in 1975.