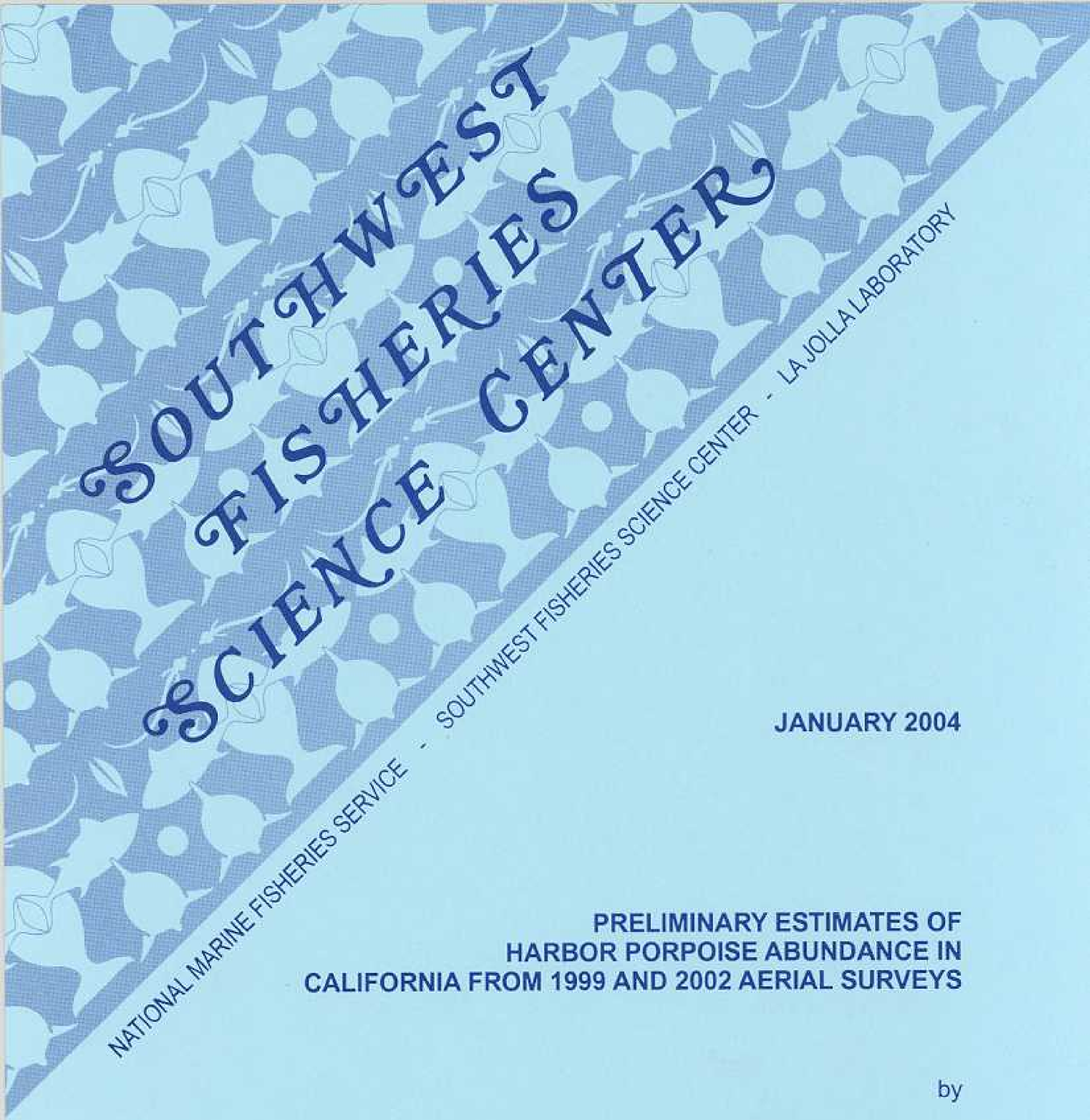

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PRELIMINARY ESTIMATES OF HARBOR PORPOISE ABUNDANCE IN CALIFORNIA FROM 1999 AND 2002 AERIAL SURVEYS

by

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Table of Contents

Abstract 1
Introduction 1
Methods 2
Results 6
Discussion 7
Acknowledgments 8
Literature Cited 8

Tables

1. Effort summary, line-transect parameters, and porpoise density and abundance estimates by geographic stratum. Corrected estimates of abundance include correction for g(0), the probability of detecting a porpoise on the trackline. 10

2. Estimates of harbor porpoise abundance, coefficients of variation, and results of significance tests for differences in abundance by stock area in California for the periods 1997-99 and 1999-2002. Key: N = abundance estimate, CV = coefficient of variation for abundance estimate, *d* = difference between 1997-99 and 1999-2002 abundance estimates, CI_d = bootstrap confidence interval for *d*, with lower and upper 95% intervals, and *P* = probability value for observed difference, obtained using iterative boostrap confidence interval process (see Methods). 11

Figures

1. Aerial survey study area, showing harbor porpoise stock names and boundaries, California transect lines (bold), and harbor porpoise habitat (shaded) in this region from shore to approximately 200 m.
. . . . 12

2. Probability density function fit to perpendicular sighting distances for Beaufort sea states 0-2 and cloud cover ≤ 25%. The hazard rate model fit is shown (*f(0)* = 5.0057 km-1; χ^2 = 4.27, df = 9, *p* = 0.89). Sample sizes for each distance bin are also shown. 13

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ABSTRACT

Abundance estimates of harbor porpoise in California waters based on 1999 and 2002 summer/autumn aerial line-transect surveys are presented. Pooled estimates of abundance (CVs in parentheses) for both survey years by area are: **Morro Bay**, N = 1,656 (0.39); **Monterey Bay**, N = 1,613 (0.42); **San Francisco-Russian River**, N = 8,521 (0.38); and **Northern California**, N = 12,889 (0.38). A total of 24,679 (0.37) porpoise are estimated in California waters, the highest total to date from aerial line-transect surveys in this region. An updated abundance for the **Northern California/Southern Oregon** stock will not be available until results from 2002/2003 surveys in southern Oregon are available. No statistically significant differences in abundance were found for the periods 1997-99 and 1999-2002 for any of the stocks/areas.

INTRODUCTION

Four stocks of harbor porpoise are currently recognized in California waters, including one trans-boundary stock with Oregon (Carretta *et al.* 2002). The stocks (from south to north) are: (1) **Morro Bay**, from Point Conception to Point Sur; (2) **Monterey Bay**, from Point Sur to Pigeon Point; (3) **San Francisco-Russian River**, from Pigeon Point to Point Arena; and (4) **Northern California-Southern Oregon**, from Point Arena to Cape Blanco, Oregon (Figure 1). Stock boundaries are based on molecular genetic differences, pollutant concentration differences, density minima observed from aerial surveys, and known habitat discontinuities. Chivers *et al*. (2002) provides information on the molecular genetic methods used to discern small-scale population structure of harbor porpoise along the U.S. west coast. This document presents preliminary estimates of abundance for the **Morro Bay**, **Monterey Bay**, and **San Francisco - Russian River** stocks from 1999 and 2002 aerial surveys. An estimate of abundance for the northern California portion of the **Northern California/Southern Oregon** stock is also presented. An updated abundance for the **Northern California/Southern Oregon** stock will be estimated after results from 2002/2003 southern Oregon aerial surveys are available (National Marine Mammal Laboratory, in prep). Previous estimates of abundance for these stocks are presented in Carretta (2003).

METHODS

Harbor porpoise abundance is estimated from 1999 and 2002 summer and autumn aerial line-transect surveys in California waters. Two sets of transects, one inshore (out to the 90 m isobath) and another offshore (out to roughly the 200 m isobath) were surveyed to ensure that all harbor porpoise habitat was included in the surveys. Offshore transects extended to the 200 m isobath or to a fixed distance offshore (10 nmi offshore south of 37°N or 15 nmi north of this latitude), whichever is further. Standard line-transect methods were utilized (Buckland *et al.* 2001). Surveys were flown at an altitude of 198 m (650 ft) and an airspeed of 165-175 km/hr (90-95 kts). Two observers searched from bubble windows on either side of a twin-engine Partenavia high-wing aircraft, while a third observer searched from a belly port in the rear of the aircraft. Sightings were verbally reported to a data recorder who entered sighting and environmental information into a laptop computer receiving real-time GPS input. Further details on the survey methodology and aircraft are found in Forney (1995, 1999). Raw data were error-checked and formatted using a TRUEBASIC program (*HPASDIST.TRU*). Formatted transect data were then imported into the line-transect software program *Distance 3.5* (Thomas *et al*. 1998), which was used to estimate porpoise density and abundance. Only transect data collected under excellent survey conditions (Beaufort sea state #2, cloud cover #25%) were used in estimating porpoise abundance. The detection function, *f(0)*, was estimated by pooling all sightings from transect segments meeting these environmental criteria. As in previous analyses (Barlow and Forney 1994, Forney 1999, Carretta 2003), a truncation distance of 300 m was used, which results in the elimination of 29 (4%) of 783 porpoise sightings. Half-normal, uniform, and hazard-rate detection functions were fit to the perpendicular distance data using cosine, hermite polynomial, and simple polynomial series expansions, and the model fit with the lowest Akaike's Information Criterion (AIC) was selected to estimate density and abundance. Because observers may fail to detect small groups of porpoise at greater distances, mean group size can be biased upwards. For this reason, the size bias regression method in *Distance 3.5* was employed to test for and, if appropriate, correct group size bias. This method regresses the natural logarithm of observed group size against estimated $g(x)$, and, if the regression is significant at an alpha-level of 0.15, a corrected group size $\{E(S)\}$ is estimated by extrapolating the regression to zero perpendicular distance (Thomas *et al*. 1998). If the regression is not significant, then observed mean group size is used as $\{E(S)\}$. Porpoise abundance N_i was estimated for each geographic stratum using the equation

$$N_i = \frac{A_i \cdot n_i \cdot f(0) \cdot E(S_i)}{2 \cdot L_i \cdot g(0)} \qquad (1)$$

where

A_i = size of study area in stratum i (in km^2),

n_i = number of porpoise groups detected in stratum i,

$f(0)$ = probability density function (km^{-1}) evaluated at zero perpendicular distance,

$E(S_i)$ = expected group size at zero perpendicular distance,

L_i = length of transect line (in km) surveyed in stratum i,

$g(0)$ = probability of detecting a porpoise group on the transect line.

The probability of detecting a trackline group of porpoise, ($g(0)=0.292$, $CV = 0.366$), is taken from the study of Laake *et al.* (1997), which also took place under excellent survey conditions, using the same aircraft type and survey methods as in this study.

Separate estimates of porpoise density and abundance are made for *inshore* and *offshore* strata within the following California regions: (1) **Morro Bay,** from Point Conception to Point Sur; (2) **Monterey Bay**, from Point Sur north to Pigeon Point; (3) **San Francisco-Russian River**, from Pigeon Point to Point Arena; and (4) **Northern California**, from Point Arena to the California/Oregon border. Combined estimates of porpoise abundance for *inshore* and *offshore* strata are made for each geographic region. Variance estimates of all density estimates and encounter rates were estimated empirically using the *DISTANCE 3.5* analysis engine. Log-normal 95% confidence intervals of abundance estimates were calculated using the Satterthwaite procedure, described in Buckland *et al*. (1993), where

$$\hat{N}_{L95\%} = \hat{N}/C \quad (2)$$

$$\hat{N}_{U95\%} = \hat{N} \cdot C \quad (3)$$

and

$$C = \exp\left\{ t_{df(0.025)} \cdot \sqrt{\log_e\left(1 + \left[cv(\hat{N})\right]^2\right)} \right\} \quad (4)$$

Coefficients of variation (CVs) of combined *inshore* and *offshore* strata were calculated as the square root of the sum of the squared CVs of the encounter rate (*n/L*), group size (*E(S)*), sighting probability density function *f(0)*, and probability of detecting a porpoise group on the trackline, *g(0)* (Equation 5).

$$CV\ N = \sqrt{CV^2\,\frac{n}{L} + CV^2 E(S) + CV^2 f(0) + CV^2 g(0)} \qquad (5)$$

Because the variance components *f(0)* and *g(0)* were common to all strata, they were removed when calculating the variance of the sum of stratum estimates, then reincorporated into the final variance estimate for combined *inshore* and *offshore* strata.

Confidence intervals for combined *inshore* and *offshore* estimates were calculated by generating a log-normal distribution of 5000 values with a mean equal to $N_{\text{inshore}} + N_{\text{offshore}}$ and associated CV, from which 95% confidence intervals were determined using the percentile method.

We compared abundance estimates obtained from 1997-99 surveys (Carretta 2003) with those obtained from 1999-2002 surveys statistically, using a *confidence interval of differences* approach proposed by Lo (1994) and adopted by Forney and Barlow (1998) and Carretta *et al.* (2001) for bootstrap confidence intervals. Commonly used comparative methods, such as those based on whether confidence intervals overlap or whether one population mean is included within the confidence interval of a second mean, have been shown to be biased, because "-levels do not approach the intended value of 0.05 (Lo, 1994). Therefore, we utilized a third method proposed by Lo (1994), based on the confidence interval of the difference (CI_d), between two population means. Through computer simulation, we generated 5,000 log-normal pseudoabundance estimates for 1997-

99 and 1999-2002 (N^*), using the mean estimate and CV from each respective survey period. The difference between pseudoestimates for each period was calculated as $d^* = N^*_{1997-99}$ minus $N^*_{1999-2002}$, and a 95% confidence interval of the differences (CI_d) was calculated from the 5000 d^* values using the percentile method. Estimates were considered significantly different if the resulting CI_d did not include zero. Following Forney and Barlow (1998), we estimated the significance level for this comparison by iteratively constructing a range of confidence intervals from the simulated data (i.e. 80%, 90%, 95%, 96%, 97%...) and we identified the threshold "-level (two-tailed) where the CI_d just included zero.

RESULTS

We detected 754 porpoise groups during 8,026 km of survey effort in Beaufort sea states of #2 and cloud cover #25%. A hazard rate key function provided the best fit to the perpendicular sighting distances (Figure 2). Model fit was good ($\boldsymbol{P}^2$ = 4.27, df =9, p = 0.89). Expected mean group size, *E(S)*, at zero perpendicular distance is used in place of observed mean group size for all inshore strata because the slope of the size-bias regression was significant in each stratum. There were too few sightings in the offshore strata to perform size-bias regressions, so average group size is used for these strata. Density and abundance estimates for each geographic stratum are given in Table 1.

There were no statistically significant differences in abundance between the 1997-99 and 1999-2002 survey periods for any stock/region, based on the confidence interval of differences (CI_d) between two population means (Table 2).

DISCUSSION

Abundance estimates for California waters were greater than 24,000 harbor porpoise, the highest total for this species from NMFS surveys dating back to the mid-1980s (Barlow 1988, Barlow and Forney 1994, Forney 1999, Carretta 2003). Offshore waters between 90 m - 200 m water depth accounted for approximately 8% (1,920) of the statewide estimate, based on six sightings during 854 km of survey effort. Most porpoise estimated for offshore waters (1,527) were in the **Northern California** stratum. No statistically significant differences in abundance were found for the periods 1997-99 and 1999-2002 for any of the stocks/areas. NMFS plans to monitor the abundance of harbor porpoise in California waters, with additional surveys planned every 3-5 years.

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Table 1. Effort summary, line-transect parameters, and porpoise density and abundance estimates by geographic stratum. Corrected estimates of abundance include correction for g(0), the probability of detecting a porpoise on the trackline.

1999-2002	No. of Groups n	Mean Grp Size s	Expect. Grp Size E(s)	Study Area A km2	Transect Length L km	f(0) km-1	Uncorrected Density D km-2	Uncorrected Abundance N	CV	Lognormal Lower 95% C.I.	Lognormal Upper 95% C.I.	Corrected Density D km-2	**Corrected Abundance N**	**CV**	**Lognormal Lower 95% C.I.**	**Lognormal Upper 95% C.I.**
Morro Bay Inshore	118	1.86	1.72	2,154	2,463	5.0057	0.207	446	0.14	342	582	0.709	**1,528**	**0.39**	**729**	**3,204**
Morro Bay Offshore	1	1.00	1.00	4,541	305	5.0057	0.008	37	0.70	10	136	0.028	**128**	**0.79**	**31**	**533**
Morro Bay (All)	119			6,695	2,767	5.0057	0.072	484	0.15	359	641	0.247	**1,656**	**0.39**	**730**	**3,183**
Monterey Bay Inshore	84	1.52	1.46	1,355	1,103	5.0057	0.291	394	0.18	277	560	0.995	**1,348**	**0.41**	**622**	**2,921**
Monterey Bay Offshore	2	1.50	1.50	2,154	209	5.0057	0.036	77	0.82	17	343	0.123	**265**	**0.89**	**53**	**1,309**
Monterey Bay (All)	86			3,509	1,312	5.0057	0.134	471	0.20	315	686	0.460	**1,613**	**0.42**	**675**	**3,353**
SFO Russian River (Inshore)	290	2.06	1.83	4,853	2,586	5.0057	0.513	2,488	0.10	2,055	3,013	1.756	**8,521**	**0.38**	**4,151**	**17,495**
SFO Russian River (Offshore)	0	-	-	5,035	135	5.0057	-	-	-	-	-	-	**-**	**-**	**-**	**-**
SFO Russian River (All)	290			9,888	2,721	5.0057	0.252	2,488	0.10	2,055	3,013	0.862	**8,521**	**0.38**	**4,151**	**17,495**
Northern CA (Inshore)	256	1.50	1.45	3,649	1,020	5.0057	0.909	3,318	0.10	2,701	4,074	3.114	**11,362**	**0.38**	**5,499**	**23,474**
Northern CA (offshore)	3	1.67	1.67	7,303	205	5.0057	0.061	446	0.46	181	1,102	0.209	**1,527**	**0.59**	**497**	**4,696**
Northern CA (All)	259			10,952	1,225	5.0057	0.344	3,764	0.11	3,018	4,670	1.177	**12,889**	**0.38**	**5,789**	**24,967**
California (All)	754			31,044	8,026	5.0057	0.232	7,206	0.07	6,252	8,306	0.795	**24,679**	**0.37**	**12,133**	**50,195**

Table 2. Estimates of harbor porpoise abundance, coefficients of variation, and results of significance tests for differences in abundance by stock area in California for the periods 1997-99 and 1999-2002. Key: N = abundance estimate, CV = coefficient of variation for abundance estimate, *d* = difference between 1997-99 and 1999-2002 abundance estimates, CI_d = bootstrap confidence interval for *d*, with lower and upper 95% intervals, and *P* = probability value for observed difference, obtained using iterative boostrap confidence interval process (see Methods).

Stock area	$N_{1997\text{-}99}$	CV	$N_{1999\text{-}2002}$	CV	*d* ($N_{1997\text{-}99}$ - $N_{1999\text{-}2002}$)	CI_d L95%	U95%	*P* value
Morro Bay	932	0.41	1,656	0.39	-724	-2,358	562	0.29
Monterey Bay	1,603	0.42	1,613	0.42	-10	-2,001	1,958	>0.99
San Francisco - Russian River	6,674	0.39	8,521	0.38	-1,847	-10,760	6209	0.61
Northern CA	13,436	0.39	12,889	0.38	547	-14,151	15,694	0.97

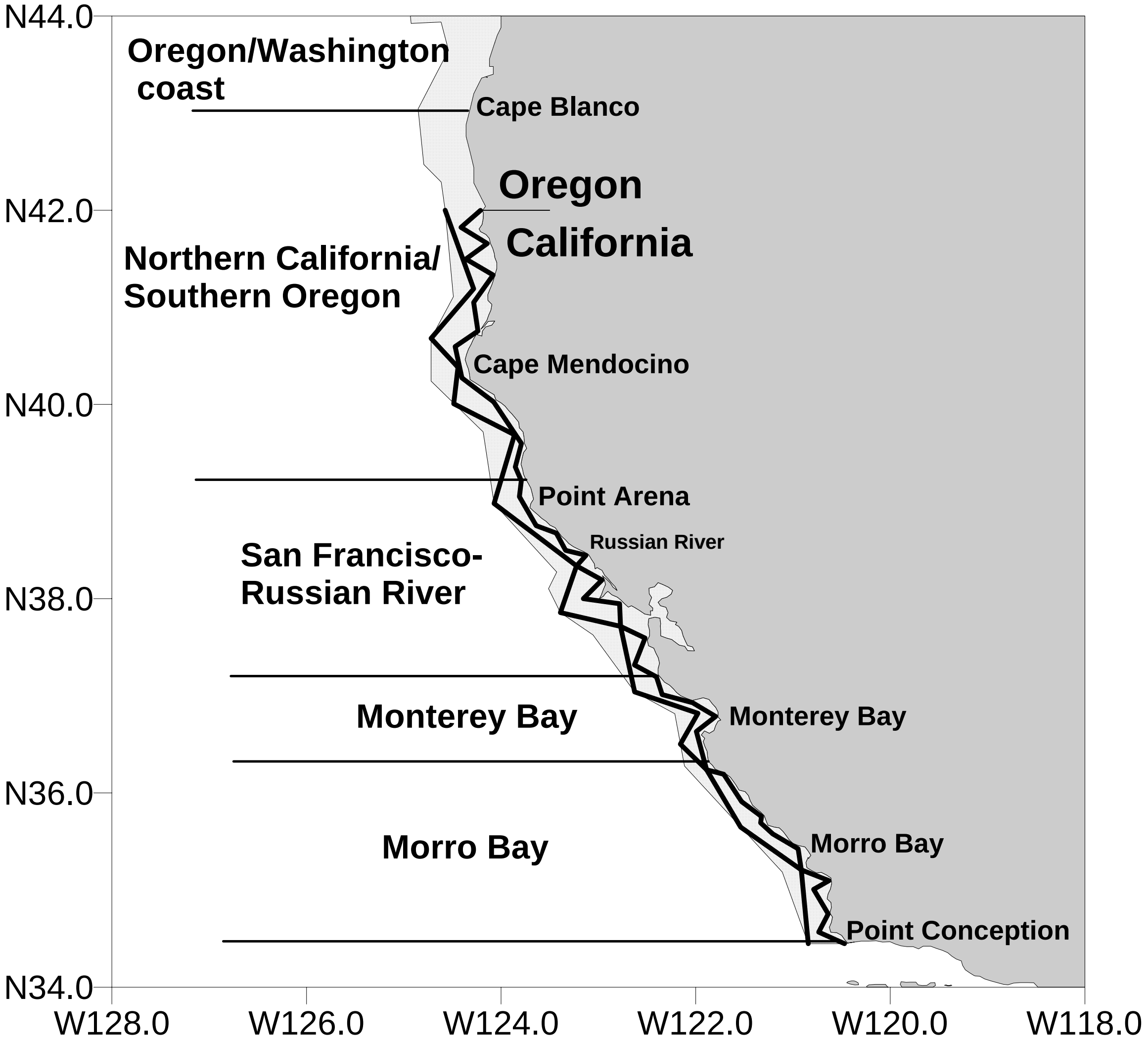

Figure 1. Aerial survey study area, showing harbor porpoise stock names and boundaries, transect lines (bold), and approximate range of harbor porpoise from shore to 200 m in this region (shaded). Inshore transect lines were repeated 2-6 times each year and offshore transect lines were repeated 1-2 times.

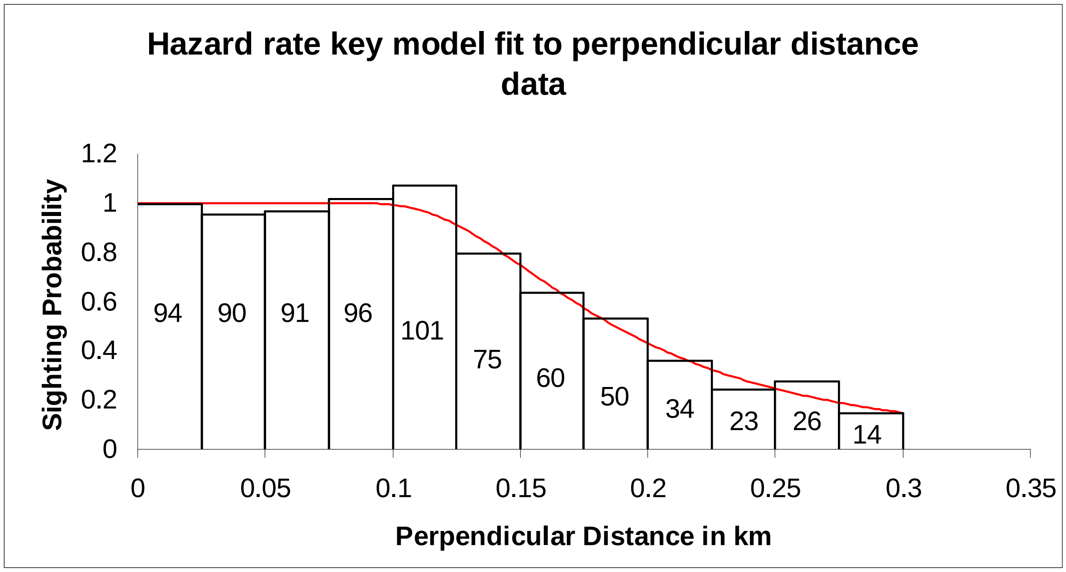

Figure 2. Probability density function fit to perpendicular sighting distances for Beaufort sea states 0-2 and cloud cover ≤ 25%. The hazard rate model fit is shown. $f(0) = 5.00$ km^{-1}; $\mathbf{P}^2 = 4.27$, df = 9, $p = 0.89$. Sample sizes for each distance bin are also shown.