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JUNE 1994

AN ASSESSMENT OF THE 1994 STATUS

OF HARBOR PORPOISE IN CALIFORNIA

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NOAA Technical Memorandum NMFS

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CONTENTS

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ABSTRACT

The status of harbor porpoise in California is reviewed with emphasis on the effect of set gillnet fisheries on the population. Movement of porpoise on the U.S. west coast appears limited, and it is recommended that porpoise in central California (where the fishery is located) be managed as a separate stock. Previous population estimates are reviewed and new estimates are made based on aerial surveys conducted in 1988-93 and based on correction factors developed by Calambokidis et al. (1993b). During this period the population size is estimated to be 4,120 (C.V. = 0.22; 95% C.I. = 2,689-6,313) in central California and 9,250 (C.V. = 0.23; 95% C.I. = 5,943-14,397) in northern California.   Available data are insufficient to detect trends in population size or estimate growth rates in these areas. The status of the central California population relative to carrying capacity or OSP (optimum sustainable population) is unknown, but the population has probably been reduced by fishery mortality. The status of the northern California population is estimated to be within the OSP range. In the early 1980s, mortality in set gillnet fisheries for halibut was in excess of 200 harbor porpoise per year in central California, but estimates since 1987 have been less than 100 per year.

INTRODUCTION

Harbor porpoise (Phocoena phocoena) are killed incidentally in set gillnet fisheries in central California. An assessment of the status of harbor porpoise in California was conducted in 1990 (Barlow and Hanan, in press) in conjunction with a world-wide review of the status of porpoises (Donovan and Bjorge, in press). Additional information has accumulated since that time. In this paper, we present a brief review of new information which has a bearing on the status of harbor porpoise in California, and we summarize the conclusions of the 1990 assessment in the format that was agreed upon at the 1992 West-Coast Pinniped Assessment Workshop (Lowry et al. 1992, Barlow et al. 1993). Because previous estimates of porpoise abundance are approximately 7 years old, we also analyze 1988-93 aerial survey data to make a revised estimate of harbor porpoise abundance for California.

POPULATION AND STOCK STRUCTURE

Biological Basis for Populations

Harbor porpoise appear to have more restricted movements along the western coast of the continental U.S. than along the eastern coast. Regional differences in pollutant residues in harbor porpoise indicate that they do not mix freely between California, Oregon, and Washington (Calambokidis and Barlow 1991). That study also showed some indication of regional differences within California (although the sample size was too small to allow much inference). This pattern stands as a sharp contrast to the situation on the eastern coast of the U.S. and Canada where harbor porpoise appear to migrate seasonally from as far south as the Carolinas to the Gulf of Maine and Bay of Fundy (Polacheck et al. 1990). Early genetic analyses did not show any significant differences between samples from California and Washington (Rosel and Haygood 1992), but more recent analyses with larger sample sizes do show significant differences (Rosel, Haygood, and Dizon, ms. in prep.). Our interpretation of these two studies is that porpoises on the west coast are not pan-mictic or migratory, and movement is sufficiently restricted that genetic differences have evolved.

Recommended Stocks for Management Purposes

In their assessment of harbor porpoise, Barlow and Hanan (in press) recommend that the animals inhabiting central California be treated as a separate stock for management purposes. The justifications given for this were 1) fishery mortality of harbor porpoise is limited to central California, 2) movement of individual animals appears to be restricted within California, and consequently 3) fishery mortality could cause the local depletion of harbor porpoise if central California is not managed separately. Because the recent genetic studies have confirmed that movement on the west coast is limited, we again find sufficient support for treating harbor porpoise in central California as a separate stock for management.

POPULATION SIZE

Previous Population Estimates

The number of harbor porpoise has been estimated previously for several regions within California (Dohl et al. 1983; Szczepaniak 1987; Barlow 1988; Barlow et al. 1988; Calambokidis et al. 1990). Barlow and Hanan (in press) reviewed these previous estimates and concluded that the best estimates of porpoise abundance could be obtained by combining the results of two of these studies. Estimates from Barlow (1988) are the best available for Regions 1, 2, and 4 (Fig. 1). The estimates from Calambokidis et al. (1990) are based on more sampling effort and therefore are better estimates for Region 3. Using these two sources, Barlow and Hanan (in press) estimate the 1987 abundance of harbor porpoise in central California (Regions 1, 2, and 3, which include all areas where harbor porpoise are caught in

gillnets) to be 3,274 (C.V. = 0.31). Abundance estimates for other regions are given in Table 1.

New Population Estimates

Since the review by Barlow and Hanan (in press), two other estimates have been made for the abundance of cetaceans in California which include harbor porpoise (Forney and Barlow 1993; Barlow 1993). These estimates were based on aerial and ship surveys (respectively) that were designed to estimate the abundance of offshore delphinids. Both studies were poorly designed to estimate the abundance of a very coastal species such as harbor porpoise. Confidence limits for both studies are so broad as to make the estimates meaningless; therefore, these studies cannot be used to revise population estimates for harbor porpoise.

However, updated population estimates can be made from a series of aerial surveys flown specifically for harbor porpoise in autumn of 1986 through 1993. Data from the 1986-90 surveys have been used to examine trends in the abundance of harbor porpoise (Forney, Hanan, and Barlow 1991). Abundance was not estimated previously from these data because of uncertainty about the large correction factor that must be used to estimate the fraction of submerged animals that are missed by aerial observers. New estimates of correction factors (with measures of statistical precision) are now available from recent work by Calambokidis et al. (1993b). Below we estimate the abundance of harbor porpoise in California based on the 1988-93 aerial surveys and on these new correction factors. We limit ourselves to data collected since 1988 in order to produce a current estimate of abundance, while maintaining a large enough sample size to produce a precise estimate.

Aerial surveys were flown at approximately 213m (700 ft) altitude on established transect lines which uniformly covered the region between the coast of California and the 50-fathom isobath (Fig. 2). [Two out of 26 transects in central California stopped at the 30-fathom isobath because the 50-fathom line was judged to be too far from shore for safe operation of that aircraft]. Transects in central California were flown each year except 1992. Transects in northern California were flown in 1989, 1990, 1991, and 1993. The aircraft, a Partenavia P-68, was equipped with bubble windows on each side and a belly window in the floor of the fuselage. Three observers searched continuously through the left, right, and belly windows. A fourth person served as data recorder. The 3 observers (and sometimes all 4 people) rotated positions every 30-60 minutes. Data were recorded on a laptop computer which recorded position information directly from a LORAN receiver. Sighting conditions (including altitude, Beaufort sea state, percent cloud cover, and a subjective measure of sighting condition) were recorded at the beginning of each transect and whenever conditions changed. Whenever a sighting occurred, the declination angle to the center of the group was measured as the group was abeam of the aircraft using hand-held clinometers (for right and left positions) or estimated based on pre-calibrated marks on the belly window. Additional details of the survey methodology are described by Forney et al. (1991).

Harbor porpoise abundance was estimated from these data using standard line-transect methods (Burnham et al. 1980; Buckland et al. 1993). The porpoise abundance for Regions 1 through k was estimated as

$$N = \sum_{i=1}^{k} \frac{A_i \; n_i \; S_i \; f(0)}{2 \; L_i \; g(0)} \qquad (1),$$

where

A_i	=	size of the study area in Region i,
n_i	=	number of sightings in Region i,
S_i	=	mean group size in Region i,
$f(0)$	=	sighting probability density at zero perpendicular distance,
L_i	=	length of transect line completed in Region i, and
$g(0)$	=	probability of seeing a group directly on the trackline.

The parameter $f(0)$ was estimated by fitting the perpendicular distances from all sightings pooled over all Regions using the hazard rate model (Buckland 1985). Declination angles were "smeared" by adding a uniformly-distributed random number between +5 and -5 degrees (Butterworth 1982). Because each stochastic realization of the smearing resulted in abundance estimates that differed slightly (+/- 3%), we used the median of 5 estimates made using different random numbers. We used ungrouped perpendicular distances that were estimated from these declination angles and altitude. Sightings made more than 300m from the transect line included only 5% of all sightings and were truncated to improve the fit of the hazard rate model (Fig. 3). The parameter $g(0)$ was estimated as the fraction of porpoise that were seen by aerial observers in an experiment conducted in the San Juan Islands, Washington using the same aircraft and methods that we used (Calambokidis et al. 1993b). They found that 30.4% of harbor porpoise within 100m of the transect line were seen by aerial observers working under good sighting conditions (< 25% overcast and Beaufort sea states of 0-2). They estimated $g(0)$ to be 0.324 (C.V. = 0.173), which is very close to the value of 0.312 which was calculated based on observed porpoise dive patterns (Barlow et al. 1988) and which was used to estimate harbor porpoise density from previous aerial surveys (Barlow et al. 1988).

Previous studies have shown that aerial sighting rates for harbor porpoise are highest during calm conditions with clear skies (Forney et al. 1991). It is likely that more harbor porpoise are missed on the transect line when seas are rough and when skies are cloudy. Analyses were therefore limited to transects conducted when sea states were Beaufort 2 or less and when cloud cover was less than 25%. These conditions correspond approximately to conditions under which $g(0)$ was estimated (Calambokidis et al. 1993b). Any additional limitations on sea state (e.g. limiting observations to Beaufort 0-1) are likely to introduce a positive bias because these extremely calm conditions occurred most commonly in protected areas near shore which are also likely to have higher porpoise density. We investigated the possibility of estimating $f(0)$ separately for each Region, but Akaike's information criteria (AIC) indicated that a better fit was obtained by pooling Regions.

Coefficients of variation and confidence intervals were estimated using a bootstrap method (Efron 1982). The sightings associated with consecutive segments of search effort (under sighting conditions given above) were combined to form a set of m subsamples of 25 nmi (46 km) of search effort. A total of m subsamples were then drawn randomly with replacement from this set of effort segments, and a pseudo-population size was estimated. For each bootstrap sample, the probability of detecting trackline groups, g(0), was estimated as a random number between 0 and 1 drawn from the probability distribution of a binomial ratio with a mean of 0.324 and a coefficient of variation of 0.173. This process was repeated 1000 times, and the C.V. of the estimated population size was calculated as the standard error of the 1000 pseudo-population sizes divided by the estimated population size. The 95% confidence intervals were based on the bootstrap C.V., assuming a log-normal distribution (Buckland et al. 1993).

For each Region, estimates of population size and coefficients of variation are given in Table 1, and full details of the estimation plus log-normal confidence intervals are given in Table 2. These most recent estimates are not significantly different from previous estimates but are more precise. This is obviously related to the greater number of kilometers surveyed compared to previous estimates. The current estimate for central California (Regions 1-3) is 4,120 (C.V.= 0.22), which compares to the best previous estimate of 3,274 (C.V.= 0.31). The closeness of these two estimates is perhaps surprising given that the surveys used entirely different methods (aerial vs. ship surveys) which may have different inherent biases. The current abundance estimate for northern California is 9,250 (C.V. = 0.23). Recent estimates of harbor porpoise abundance along the Northwest Pacific coast have been stratified by state (Calambokidis et al. 1993a). To facilitate combining our estimates with these, we have also presented a pooled estimate of 13,370 (C.V. = 0.18) for the entire state of California (Tables 1 and 2).

It should be stressed that the above abundance estimates only refer to harbor porpoise within the 50-fathom isobath. Barlow (1988) found that the vast majority of harbor porpoise in California were within this depth range. However, Green et al. (1992) found that 19% of harbor porpoise seen during aerial surveys of Oregon and Washington were between the 100m and 200m isobaths (55 to 109 fathoms). Subsequent observations on ship surveys in California have confirmed that harbor porpoise do occur in deeper shelf waters (NMFS unpubl. data). The abundance estimates presented above are likely to underestimate the total abundance of harbor porpoise in California by a small, but non-trivial amount. This bias cannot be corrected without additional information.

POPULATION GROWTH RATES AND TRENDS

Trends in Abundance

An analysis of a 1986-90 time series of aerial surveys was conducted to examine trends in harbor porpoise abundance in central California (Forney et al. 1991). That study showed

that although there was no statistically-significant evidence for either a increase or decline, the statistical power after only 5 years was insufficient to detect a consistent change of 10% per year. Indeed, it is likely to require 10 years of data to yield a high probability of detecting a 10% annual rate of change. Additional data were collected in 1991 and 1993 but have not been analyzed to date. We conclude that there is currently no evidence for either increasing or decreasing trends in harbor porpoise in central California; however, this does not mean the population is necessarily stable.

Growth Rate at MNPL

The actual growth rate has never been measured for any harbor porpoise population. Based on what are argued to be biological limits of the species (ie. females give birth first at age 4 and produce one calf per year until death), the theoretical maximum conceivable growth rate of a closed harbor porpoise population was estimated as 9.4% per year (Barlow and Boveng 1991). [Woodley and Read (1991) calculate a maximum growth rate of approximately 5% per year, but their argument for this being a maximum (i.e. that porpoise survival rates cannot exceed those of Himalayan thar) is weak.] Maximum growth rates are likely to be attained only under the best of conditions with little or no intraspecific competition. The growth rate when a population is at its maximum net productivity level (MNPL) is necessarily greater than zero and less than the maximum rate. The range of possible values is so large, however, that we conclude that the growth rate of harbor porpoise at MNPL is unknown for all populations.

STOCK STATUS RELATIVE TO OSP AND K

OSP Determination

The goal of the Marine Mammal Protection Act is to maintain optimum sustainable population (OSP) levels for all species. OSP has been interpreted to mean a population size that is greater than the maximum net productivity level for that population. For marine mammals, this is thought to be greater than 60-85% of their carrying capacity (K).

For central California, Barlow and Hanan (in press) calculate the status of harbor porpoise relative to K using a technique called back-projection. They calculate the population could be as low as 30% or as high as 97% of K, depending on the choice of input parameters. They conclude that there is no practical way to reduce the range of this estimate. New information does not change this conclusion. The status of harbor porpoise populations in central California must be treated as unknown.

In northern California, harbor porpoise have not been subject to high levels of gillnet mortality or of anthropogenic mortality from other sources. The northern California population is assumed to be at OSP.

Condition Indices

There are no biological parameters that have been correlated with population condition or status in harbor porpoise.

CURRENT BIOLOGICAL REMOVALS

Incidental Take

The incidental capture of harbor porpoise is largely limited to set gillnet fisheries in central California (coastal setnets are not allowed in northern California, and harbor porpoise do not occur in southern California). Harbor porpoise mortality in halibut gillnets has been estimated for the years 1969 through 1993 (Table 4) based on direct observation of a subset of gillnet hauls from 1983 to 1993. An increase is seen during this time period to a maximum annual catch of 200-300 porpoise in the late 1970s and early 1980s. The decrease in annual mortality since the mid-1980s was primarily the result of decreased fishing effort (Perkins et al. 1994).

Subsistence Take

There are no subsistence takes from harbor porpoise populations in California.

Illegal Killing

The intentional killing of harbor porpoise is not likely. Harbor porpoise do not feed on fish that are caught in gillnets or on troll lines and therefore are not likely to earn the wrath of fishermen. Even if they did, harbor porpoise surface cryptically and avoid vessels making them a difficult target for intentional shooting.

Research and Live Capture

There have been no research or live-capture takes of harbor porpoise that would remove animals from the population in California.

ACKNOWLEDGEMENTS

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Table 1. Estimates of harbor porpoise abundance in California from studies by Barlow (1988), Calambokidis et al. (1990), and 1988-93 aerial surveys. Lengths of completed transects and coefficients of variation are given for each estimate. Regions refer to sections of the coast shown in Figure 1. Northern California includes Region 4 and the portion of Region 5 that is south of the California/Oregon border. The pooled estimate for central California includes Regions 1, 2, and 3.

	1984-85 Ship Surveys Barlow et al. 1988			1987-89 Ship Surveys Calambokidis et al. 1990			1988-93 Aerial Surveys (this study)		
	Abund.	km	C.V.	Abund.	km	C.V.	Abund.	km	C.V.
Region 1	96	378	0.54	-	-	-	265	3,662	0.30
Region 2	1459	197	0.61	-	-	-	1,778	2,564	0.25
Region 3	112	175	1.04	1,719	452	0.29	2,077	1,413	0.37
Region 4	7909	209	0.60	-	-	-	-	-	-
Region 5	4806	285	0.36	-	-	-	-	-	-
Northern California	-	-	-	-	-	-	9,250	2,581	0.23
Pooled Estimates:									
Central California	1667	750	0.54	3,274*	1,027*	0.31*	4,120	7,637	0.22
California	-	-	-	-	-	-	13,370	10,219	0.18

*Pooled estimates of Regions 1-3 for 1987 were based on a combination of 1984-85 and 1987-89 ship surveys (Barlow and Hanan, in press).

12

Table 2. Abundance estimates and log-normal confidence intervals for harbor porpoise in California based on the 1988-93 aerial surveys. Regions are shown in Figure 1. Northern California is defined as Region 4 plus that part of Region 5 south of the California/Oregon border. The pooled estimate for central California includes Regions 1, 2, and 3. Study areas were defined as the area between the shore and the 90m depth isobath and were estimated using the method of Forney (1988). Estimates of f(0) were based on pooling all Regions. Estimates of g(0) were as given by Calambokidis et al. (1993b).

	Number Groups n	Mean Group Size S	Study Area A km^2	Trans. Length L km	f(0) km^{-1}	g(0)	Porpoise Density km^{-2}	Pop. Size N	Log-Normal Lower 95% C.I.	Upper 95% C.I.
Region 1	40	1.60	1,985	3,662	4.984	0.324	0.13	265	148	475
Region 2	143	2.16	1,917	2,564	4.984	0.324	0.93	1,778	1,096	2,885
Region 3	58	2.16	3,049	1,413	4.984	0.324	0.68	2,077	1,032	4,180
N. Calif.	394	1.75	4,504	2,581	4.984	0.324	2.05	9,250	5,943	14,397
Pooled Estimates:										
Central California			6,951	7,637				4,120	2,689	6,313
California			11,455	10,219				13,370	9,442	18,933

13

Table 3. Estimated mortality of harbor porpoise in halibut gillnet fisheries in central California. Fishing years are April 1 through March 31 (1969-88), April 1 through December 31 (1988), and January 1 through December 31 (1989-92).

Fishing Year	Porpoise Killed	Source
1969/70	28	Barlow and Hanan (in press)[1]
1970/71	21	Barlow and Hanan (in press)[1]
1971/72	46	Barlow and Hanan (in press)[1]
1972/73	62	Barlow and Hanan (in press)[1]
1973/74	19	Barlow and Hanan (in press)[1]
1974/75	39	Barlow and Hanan (in press)[1]
1975/76	77	Barlow and Hanan (in press)[1]
1976/77	96	Barlow and Hanan (in press)[1]
1977/78	74	Barlow and Hanan (in press)[1]
1978/79	124	Barlow and Hanan (in press)[1]
1979/80	179	Barlow and Hanan (in press)[1]
1980/81	226	Barlow and Hanan (in press)[1]
1981/82	283	Barlow and Hanan (in press)[1]
1982/83	222	Barlow and Hanan (in press)[1]
1983/84	303	Diamond and Hanan (1986)
1984/85	226	Hanan et al. (1986)
1985/86	226	Hanan et al. (1987)
1986/87	197	Hanan and Diamond (1989)
1987/88	34	Konno (unpubl.)
1988/89	91	Perkins et al. (1994)
1989	92	Perkins et al. (1994)
1990	84	Perkins et al. (1994)
1991	38	Perkins et al. (1992)
1992	44	Julian (1993)
1993	12	Julian (1994)

[1] uncorrected by back-projection.

Figure 1. Regions used in estimating harbor porpoise abundance.
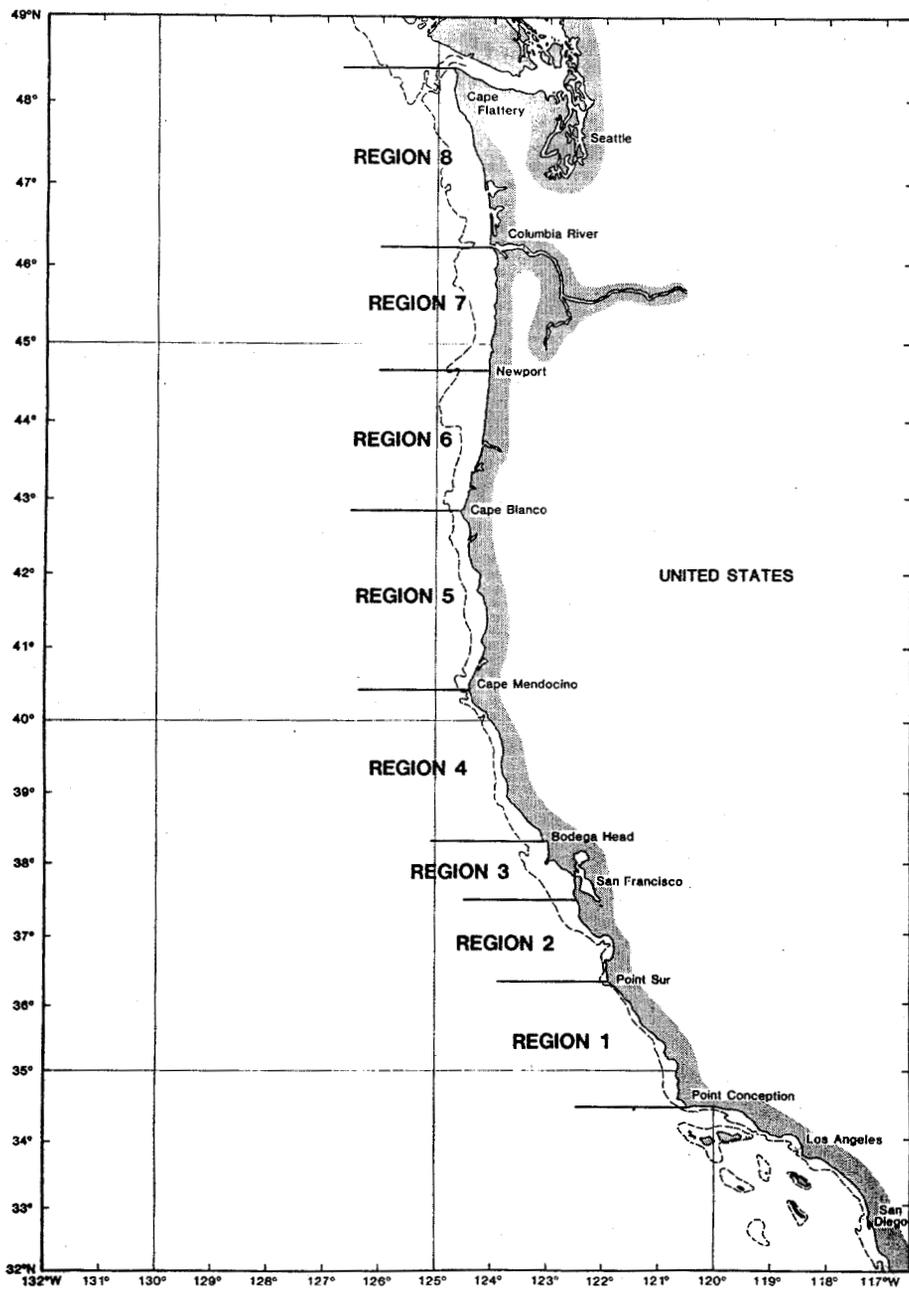

15

Figure 2. Tracklines flown in 1988-93 and used in abundance estimation for central California (2a) and northern California (2b).
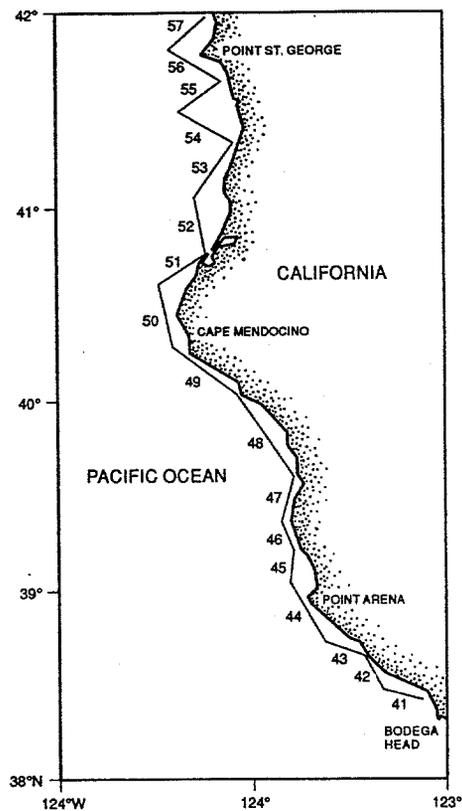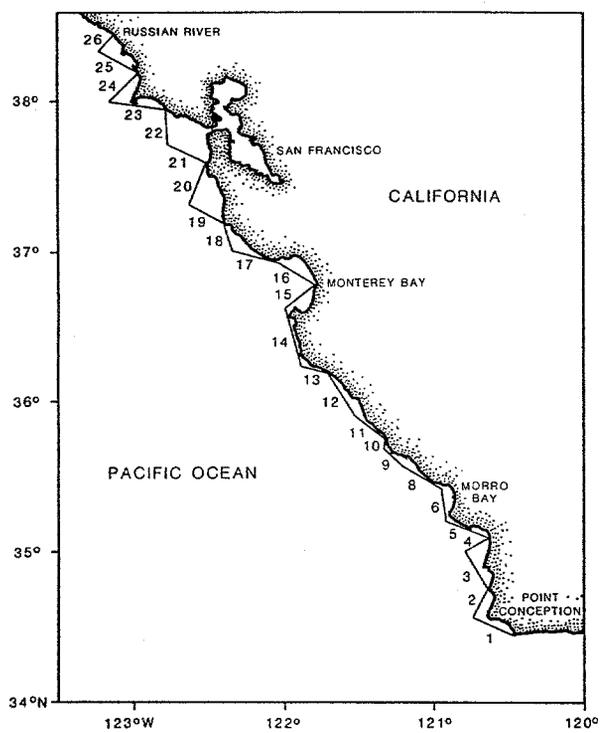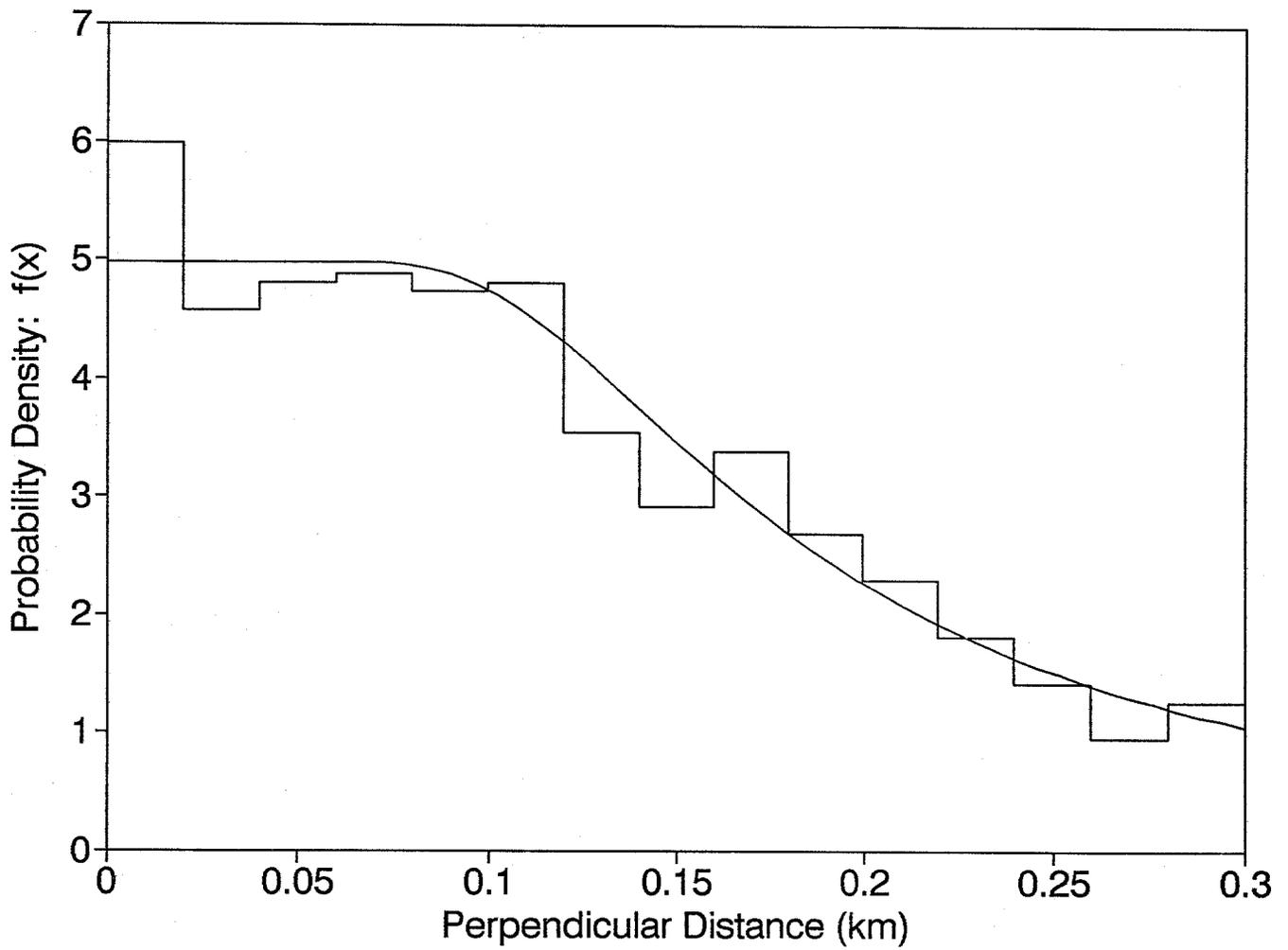
Figure 3. Fitted probability density distribution, f(x) km^{-1}, for perpendicular distances to sightings based on a Hazard rate model. The histogram represents the observed distribution of perpendicular distances.

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