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Estimating the Historical Abundance of Sea Otters in California

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Prior to commercial exploitation, the estimated abundance of sea otters (Enhydra lutris) in the North Pacific Ocean was between 150,000 (Kenyon 1969) and 300,000 (Johnson 1982). Sea otters historically ranged from Baja California along the Pacific coast northward to Prince William Sound, Alaska; southwestward along the Alaska Peninsula, throughout the Aleutian Islands, Pribilof Islands, and Commander Islands to Kamchatka; and then southward through the Kuril Islands to Sakhalin and Hokkaido (Kenyon 1969; see Anderson, this issue). Prior to commercial exploitation in California, sea otters occupied the waters off the entire coast of California. The population was estimated to have included between 16,000 to 18,000 animals (California Department of Fish and Game (CDFG) 1976a). Due to a lack of suitable alternatives, this estimate has become the best available estimate of the current carrying capacity (K) of sea otters in California. Further, because the range of sea otters is currently discontinuous between California and Washington, evidence that sea otters in California should be afforded sub-specific status (U.S. Fish and Wildlife Service 1996; see Anderson et al., this issue), and a lack of alternative historical estimates of abundance for sea otters along the west coast of the United States, the 16,000 to 18,000 abundance estimate has also been used as the best available estimate of K for the population of sea otters referred to as southern (or California) sea otters.

The objective of this paper is to refine the 1976 estimate of K for sea otters in California. To some, estimating K for a population that currently occupies less than 250 miles of coastline in central California and includes approximately 2,400 animals (U.S. Fish and Wildlife Service 1996) may seem pointless; however, having a reliable estimate of K is important for the following reason. Under the provisions of the Marine Mammal Protection Act, a population is considered depleted if its current abundance level is below a range of population sizes referred to as the optimum sustainable population (OSP) level (Gerrodette and DeMaster 1990; see Baur et al., this issue). As Congress intentionally left the definition of OSP vague, an operational definition has evolved where the lower end of the OSP range is assumed to occur at approximately 60% of the maximum population size the environment will support (i.e., K). Therefore, from a management perspective, it is important to have a reliable estimate of K.

Unfortunately, estimating K is very difficult. As noted by Gerrodette and DeMaster (1990), there are only a handful of methods that can be applied to this problem: (1) back-calculating historical abundance levels, based on a current estimate of abundance, a history of human-related annual removals, and information regarding the relationship between abundance and net productivity; (2) using historical estimates of abundance that were made prior to the onset of commercial exploitation; or (3) directly estimating the current carrying capacity, based on information about factors which limit population growth. All of these require information that is typically not available. For sea otters in California, techniques Numbers 1 and 2 are easily dismissed as there are no reliable abundance estimates from the 1700s, and there is no reliable information on the catch history of sea otters from the late 1700s until the early 1900s.

At first blush, one might also abandon the approach of estimating current K based on knowledge regarding factors that limit or regulate population growth. Fortunately, the recovery of sea otters has occurred primarily as a result of range expansions initiated by peripheral groups of males (Riedman and Estes 1990), where the core density of adult males and females, juvenile females, and dependent pups has remained relatively constant in the center of the range. Therefore, it should be possible to estimate K by having an estimate of the equilibrium density of sea otters per linear mile of coastline or square mile of available habitat from the central portion of their current range and knowing the amount of available habitat in the state (Gerrodette and DeMaster 1990).

Methods

Table 1. Summary of geographical areas in California suitable for sea otters, where each area has been assigned a habitat type (and associated equilibrium density- D_i). The surface area (nm^2) for a particular geographical area was calculated, assuming a maximum feeding depth of 130 ft (40 m). The number of otters per area was calculated as the product of Di and area.

	Geographical Location	Habitat	Area (nm^2)	Number Otters
1	Mexican border - Pt. Loma	sandy	46	55
2	Pt. Loma - Bird Rock	sandy	10	12
3	Bird Rock - Pt. La Jolla	rocky	7	92
4	Pt. La Jolla - Corona Del Mar	rocky	64	845
5	Corona Del Mar - Pt. Fermin	sandy	118	140
6	Pt. Fermin - Palo Verdes Pt.	mixed	6	42
7	Palo Verdes Pt. - Pt. Dune	mixed	80	556
8	Pt. Dune - Pt. Mugu	rocky	12	159
9	Pt. Mugu - Ventura	sandy	83	99
10	Ventura - Pt. Conception	mixed	62	431
11	Pt. Conception - Rocky Pt.	mixed	19	132
12	Rocky Pt. - N. Pt. Pedernales	mixed	8	56
13	N. Pt. Pedernales - Santa Ynez River	mixed	10	70
14	Santa Ynez River - Purissima Pt.	rocky	2	26
15	Purissima Pt. - Lions Head	sandy	35	42
16	Lions Head - Pt. Sal	mixed	16	111
17	Pt. Sal - Shell Beach	sandy	48	57
18	Shell Beach - Pt. San Luis	rocky	4	53
19	Pt. St. Luis - Hazard Canyon	rocky	22	291
20	Hazard Canyon - Cayucos Pt.	sandy	33	39
21	Cayucos Pt. - Monterey	rocky	117	1546
22	Monterey - Capitola	sandy	75	89
23	Capitola - Sandhill Bluff	mixed	7	49
24	Sandhill Bluff - Ano Nuevo Pt.	rocky	7	92
25	Ano Nuevo Pt. - Pt. San Pedro	mixed	93	646
26	Pt. San Pedro - Pt. Lobos	sandy	93	111
27	Pt. Lobos - Bodga Head	mixed	102	709
28	Bodega Head - Fort Bragg	rocky	97	1281
29	Fort Bragg - Cape Vizcaino	rocky	35	462
30	Cape Vizcaino - Pt. Delgado	mixed	54	375
31	Pt. Delgado - Punta Gorda	sandy	30	36
32	Punta Gorda - Cape Mendocino	mixed	23	160
33	Cape Menocino - Trinidad Head	sandy	124	148
34	Trinidad Head - Patricks Pt.	rocky	21	277

35	Patricks Pt. - Klamath River	sandy	63	75
36	Klamath River - Pt. St. George	rocky	71	938
37	Pt. St. George - Oregon Border	sandy	47	56
38	Channel Islands	rocky	210	2774
39	San Francisco Bay	sandy	321	382

The maximum number of sea otters that the marine environment in California will support (K) was estimated by first determining the equilibrium density of sea otters in each of three habitat types, and then determining the amount of each habitat type that exists in California.

The following values for equilibrium density were made using survey data as of 1992 (Marzin and DeMaster 1992): (1)13.21 otters per square nautical mile (nm^2; nm=1,852 m) for rocky habitat; (2) 6.95 otters per nm^2 for mixed habitat; and (3) 1.19 otters per nm^2 for sandy habitat. The equilibrium density of otters for sandy habitats was based on the density of sea otters in Monterey and Morro Bays. The equilibrium density of sea otters in mixed habitat was based on the density between Año Nuevo and the Santa Maria River, while for rocky habitat the estimate was based on the number of sea otters between Cayucos Point and Monterey Bay.

The amount of area available to sea otters in California by habitat type was estimated based on the assumption that sea otters cannot effectively forage in water depths greater than 130 ft (40 m). This threshold was selected based on Ralls et al. 1995, where they reported that juveniles, which usually forage in water deeper than adults, typically do not feed in water deeper than 160 ft (49 m). In a preliminary exercise to estimate K, it was determined that the estimate was relatively insensitive to the choice of the depth contour between 30 ft (9 m) and 160 ft. For example, if the 160 ft contour had been selected as the offshore boundary, the resulting density would be lower than if the 130 ft contour had been selected, but the available habitat for the former would be increased relative to the latter, and the resulting estimate of available habitat would have been similar. The estimate of surface area out to a depth of 130 ft and along the entire California coastline, including the Channel Islands and San Francisco Bay (SFB), was estimated using the FORTRAN subroutine SPHAREA (Forney 1988).

Thirty-nine discrete areas were identified off the coast of California, ranging in size from 2 nm^2 to 321 nm^2, and a habitat type was assigned to each area (see Table 1). The specific characterization of an area as being sandy, mixed or rocky was done by one of the authors (RJJ) based on information provided in nautical charts and personal experience.

Table 2. Estimated number of sea otters that could be supported by habitat type.

Habitat Type	Density ($/nm^2$) (D_i)	Area (nm^2> (A_i)	Number of Otters (A_i*D_i)
1. Rocky	13.21	669	8,837
2. Mixed	6.95	480	3,336
3. Sandy	1.19	1,126	1,340
Total		2,275	13,513

Following the procedure described above, the total area available to sea otters was estimated to equal 2,275 nm^2. By habitat type, the following areas were calculated: rocky (669 nm^2), mixed (480 nm^2), and sandy (1,126 nm^2). Based on these results, almost 50% of the available habitat for sea otters in California is low quality, while less than 30% of the available habitat is high quality.

Results and discussion

The estimated number of sea otters that could be supported by the marine environment in California was 13,513 (see Table 2). The weighted average density of sea otters in California was approximately 5.9 sea otters per nm^2, based on an estimate of a total area of 2,275 nm^2. The estimate of K was based on the assumption that the habitat quality of SFB is the lowest density of the three habitat types (i.e., sandy habitat). If it were assumed that the habitat quality was intermediate between the sandy and rocky habitat types (i.e., mixed), the resulting estimate of sea otters that could be supported within SFB is 2,231 sea otters (321 nm^2 multiplied by 6.95 otters per nm^2). Incorporating this assumption into the estimate of K would increase the estimate to 15,362 sea otters. For a variety of reasons, it is difficult to predict the equilibrium density of sea otters in SFB, including uncertainty regarding the number of sea otters commercially harvested in SFB, the unknown impact of pollutants on the environment, and the unknown influence of fisheries on the benthos in SFB.

If we had assumed the equilibrium density of sea otters in California was equal to the existing density between Cayucos Point and Monterey Bay (i.e., 13.21 otters per nm^2), the resulting estimate of K would have been over 30,000 otters. This estimate is likely to be positively biased because the average quality of the habitat used to estimate the equilibrium density in "typical" rocky habitat is considerably better than the average quality of habitat throughout the state (Marzin 1996). In fact, based on our analysis, the average quality of habitat in waters off the coast of California is marginally less than the classification that we referred to as "mixed." It should also be noted that in the original estimate of K for sea otters in California by CDFG (1976a), it was assumed that: (1) the equilibrium density of sea otters was approximately 12 sea otters per nm^2, and (2) the amount of available habitat was approximately 1,300 to 1,500 nm^2. The 12 sea otters per nm^2 figure was derived by dividing the number of sea otters known to occur between Seaside and Morro Bay by the area between Seaside and Morro Bay out to a depth of 120 ft (California Department of Fish and Game 1976b). It was assumed in using the 12 sea otters per nm^2 that it accounted for all habitat types, including rocky, sandy, and mud bottoms (California Department of Fish and Game 1976b). Given that the average quality of habitat reported in this study was 5.9 sea otters per nm^2, the estimate of 12 sea otters per nm^2 should also be considered positively biased. Finally, while estimates of equilibrium densities of 10 to 15 sea otters per nm^2 (based on a maximum feeding depth of 180 ft (55 m)) have been reported in Alaska (Kenyon 1969), with short-term (i.e., non-equilibrium) density estimates reaching in excess of 50 animals per nm^2 (Palmisano and Estes 1977), it seems unreasonable in the face of the available information on the distribution and density of sea otters in California to use information on Alaska otters in estimating K for sea otters in California (California Department of Fish and Game 1976a, b).

Conclusions and recommendations

Under the existing Marine Mammal Protection Act, the southern sea otter population should be considered depleted as long as its abundance is less than 60% of K. At present, therefore, the best estimate of the lower bound for being depleted is 60% of 13,513, or approximately 8,100 animals.

We believe our preliminary estimate of between 13,500 and 15,400 animals is the best available estimate of K for sea otters in California at this time for the following reasons: (1) the current information on the existing density of sea otters was used; (2) equilibrium density estimates were stratified by habitat types and based on recent information regarding the distribution of sea otters in California; (3) estimates of maximum foraging depth were based on current information on foraging behavior, as determined from radio-telemetry; and (4) estimates of total habitat available were based on all of the available habitat types in California. Additional studies are needed to test the statistical validity of the assumed equilibrium density for each of the three habitat types and the reliability of the characterization of the coastal marine habitat. For example, it would be useful to have more recent estimates of the density for each habitat type, as well as estimates of the associated variance.

Finally, the technique described in this paper could be used to provide guidance as to the number of sea otters that might be expected to exist within a specified area. For example, the equilibrium number of sea otters that could occupy the area surrounding the Channel Islands or areas 11 through 25 (Pt. Conception to Pt. San Pedro) was estimated to equal 2,774 animals and 3,300 animals (see Table 1), respectively. An extensive application of this technique is reported in Marzin (1996).

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back to index