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Migration Patterns of Adult Male California Sea Lions (*Zalophus californianus*)

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PREFACE

This report presents the results of the first satellite tracking study of adult male California sea lions (*Zalophus californianus*) and it is the first to fully describe the species' migration in terms of timing, distance, duration, and the diving and swimming behavior of individuals. Earlier reports or studies on the movements or migration of California sea lions did not utilize satellite or VHF telemetry data so the results were not definitive or detailed. Several more recent studies, as cited later in this report, have utilized satellite tracking to investigate the movements of male California sea lions, however these studies did not focus on migration and describe only short-distance movements during the non-migration period (Weis et al. 2006, Wright et al. 2010). Another study completed in 2016 involved satellite tracking of adult male sea lions captured in Puget Sound, Washington, as part of a U.S. Navy funded effort to investigate the abundance and movements of sea lions around U.S. Navy facilities. The study in 2016 did not document migration and the results have not yet been published.

In our study, nine satellite instruments were attached to adult male sea lions from 1995 to 2000. The primary objective of the study was to document the southbound migration of California sea lion males. Seven of the instruments deployed were also dive recorders. The instruments were all deployed in late March to early June, just prior to the southbound migration, in order to maximize the likelihood that the instruments would stay attached during the full southbound migration period. Eight of the nine sea lions completed the full southbound migration to rookeries off southern California. One also completed a full northbound track. These data allowed us to calculate for the first time average daily swimming distances, maximum 24-hour travel distances, and resting and diving activity.

The data provided in this paper answer many of the basic life history questions for this species which prior to this study had only been inferred. For example, the route taken by this species during the migration demonstrates the coastal migration route along the continental shelf. Other questions such as how fast do they swim, how far can they swim per day, how deep do they dive, and do they feed during the migration are answered in this report and no longer need to be left to speculation. This report provides a reference for future researchers conducting studies on this species, or other migratory species where satellite telemetry is utilized. Finally, the information in this report is important for resource management agencies, conservation organizations, and even defense agencies who are in constant need of accurate data in order to make informed decisions concerning the environment and human activities. Even though this study was completed in 2000, the information that we present is still timely and important to future researchers because the results of this study have not been presented before.

CONTENTS

ABSTRACT

The migration and movement patterns of male California sea lions (*Zalophus californianus*) were investigated to determine the timing and distance of the migration. Nine adult male sea lions were instrumented with satellite-linked instruments in Puget Sound, Washington, before the southbound migration between 1995 and 2000. Eight migrated to rookeries off southern California, and one remained at a haul-out site in Oregon. The southbound migrations were generally inshore, within 5-20 km of the coast, over the continental shelf and averaged 25 days in duration. The mean distance traveled during the southbound migration was 2,027 km. Maximum 1 day travel distances for individual sea lions ranged from 119 to 235 km. All of the sea lions stopped 2-5 times at haul-out sites along the migration route, presumably to rest, and spent 1-2 days at each site before resuming their migration. One complete and one partial northbound migration track were also logged. The complete northbound track covered 1,940 km and took 30 days including stops at haul-out sites. Diving data indicated that sea lions were actively feeding during both north and south migrations. Most dives (83%) during the migration were less than 50 m deep and less than 2 minutes in duration. Maximum dive depths were 475 m and maximum duration was >13 minutes.

INTRODUCTION

Migration is a key ecological process by which marine mammals move from one location to another for a variety of reasons including breeding, foraging, nursing their young, and avoiding climactic extremes. In the case of California sea lion (*Zalophus californianus*) males, the southbound migration appears to be to participate in reproductive social behaviors on the rookeries and for foraging and hauling out behavior during the northbound component. Although the species has been well studied throughout its range their migration patterns have not been well documented nor well described. Most descriptions of migration for this species are based on anecdotal reports which lack specific data concerning migration parameters.

This report describes for the first time the migration of male California sea lions using satellite tags and provide specific information about the migration including the location, timing, distance, destination, and behavior of individuals during migration.

The California sea lion ranges along the west coast of North America from central Mexico to southern British Columbia, Canada (Scheffer 1958, Bigg 1988). The U.S. stock of California sea lions breeds almost exclusively on the Channel Islands off southern California with pupping and breeding occurring during summer months. The California sea lion population has undergone a dramatic recovery over the last 60 or more years due to elimination of commercial hunting, bounty programs, and from protection offered by the Marine Mammal Protection Act of 1972 (Mate 1976, Cass 1985, Boveng 1988[1]).

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[1] Boveng, P. 1988. Status of the California sea lion population on the U.S. west coast. Administrative Report LJ-88-07 (unpublished). 26 p. Available from SWFC, P.O. Box 271, La Jolla, CA 92038

California sea lions were not common or abundant in Pacific Northwest waters until the 1970s due to the historic reduction in the population (Bigg 1973, 1988; NMFS 1997). Over the last 35 plus years, as the population continued to recover, the species appears to have reinhabited what may have been their former feeding range in the Pacific Northwest (Guiguet 1971, Bigg 1988). In the inland waters of Washington State, aggregations of California sea lions were first observed in 1979 near the city of Everett (Everitt et al. 1980).

The most recent population estimate for the U.S. stock is 297,000 (Caretta et al. 2015). Females, which nurse pups for up to 11 months tend to remain near the southern breeding islands year-round (Morejohn 1968, Odell 1981, Melin et al. 2000), whereas males appear to move northward in August after the breeding season (Peterson and Bartholomew 1967). Orr and Poulter (1965) described seasonal movements of males indicating distinct peaks in abundance at Año Nuevo Island off central California during the fall, winter and spring, corresponding to northward and southward movements to and from the breeding colonies. Mate (1976) documented the migration of California and Steller sea lions (*Eumetopias jubatus)* along the Oregon coast and recorded evidence of northward movements into these waters. These early studies of California sea lions did not have the benefit of modern technology for capturing, permanently marking, and instrumenting of individuals, thereby making it difficult to track individual animals in real time. Improvements in techniques for capturing and branding large otariids (Jeffries et al. 1995[2]) and improvements in VHF radio and satellite telemetry allow

[2] Jeffries, S.J., P.J. Gearin, M.E. Gosho, and M.T. Wilson. 1995. Capture, marking and handling of adult male California sea lions. Abstract from the 11th Biennial Conference on the Biology of marine mammals, 14-18 Dec. 1995, Orlando, FL.

for more detailed investigations on the movements and migration patterns of this species. Movement and diving behavior of male California sea lions was recently described in relation to anomalous oceanographic conditions off central California, however this paper did not report on migration (Weise et al. 2006). Movements of satellite-instrumented California sea lion males captured in the Columbia River were reported by Wright et al. (2010). These authors focused on within-season movements in and around the Columbia River but did not discuss detailed migration patterns.

We provide a detailed analysis and interpretation of the migration and movement patterns of adult male California sea lions from the northern feeding areas to the southern rookeries. Specific objectives were to describe the migration in terms of seasonal timing, distance, duration, location, and eventual destination. In addition, migratory activities such as resting, feeding, and transit times are described.

MATERIALS AND METHODS

The migration and movements of adult male California sea lions were monitored by branding, tagging, and instrumenting individuals with VHF radio tags and satellite-linked time-depth recorders (SLTDRs). Adults are defined here as sea lions that are sexually mature, though not necessarily physically or socially mature. Sea lions were captured on floating haul-out traps deployed at Shilshole Bay near Seattle, Washington (47°40.80 N, 122° 24.66 W) (Fig. 1). After sea lions were captured, they were moved from the trap platform onto a 10 × 3 m barge where they were sorted into one of two transfer cages for handling. Sea lions were weighed, measured, and hot iron branded on the dorsal rump area with unique numbers. Sea lions also were tagged on each foreflipper with numbered plastic tags (All flex USA Inc., Dallas, TX). The combination of the brand and flipper tags made individuals readily identifiable when resighted.

Satellite instruments were deployed on nine adult male California sea lions from 1995 to 2000 between March and June before the onset of the southbound migration. Seven of the instruments were satellite-linked time depth recorders (SLTDRs) and two were SPOT tags (Wildlife Computers, Bellevue, WA) which provided only position data. The satellite instruments were set in an epoxy resin mold and glued to the dorsal pelage of each sea lion using 5-minute epoxy. A VHF radio tag was attached alongside the satellite housing unit to assist in locating animals and recovering instruments at a later date. The satellite instruments were programmed to transmit location data twice daily, 0200 to 0500 hours and from 1100 to 1400 h. The instruments also were programmed to record wet or dry status used to determine if the animal was on-land and at-sea for each position.

Location data obtained from satellites were summarized by the Service ARGOS (Landover, Maryland, USA) (Service ARGOS 1996). A quality code is assigned to each location based upon the estimated accuracy of the location relative to the true position of the animal. Locations were classified as Z, B, A, 0, 1, 2, 3, indicating poor to good quality locations. The potential error of a location was 150 m for quality level 3 locations, 350 m for quality level 2 locations, and 1,000 m for quality level 1 locations. The potential error for quality levels 0, A, B, and Z was not estimated by Service ARGOS.

All quality level Z locations were discarded before analysis. Each location was then inspected to determine if it should be retained for the analysis. The locations were considered on a point-to-point basis using a maximum swim speed of 3 m/s (Feldkamp et al. 1989, Ponganis et al. 1990) and the elapsed time between consecutive locations to determine whether the location was within the swimming capabilities of the animal. Locations were discarded if the distance between the two points was greater than the possible travel speed of the animal.

To minimize dependence among locations, only one location was selected for each day for each sea lion. When more than one location was obtained for the same day, the location with the best quality was used in the analysis. If multiple locations on the same day had the same quality, a single location was randomly chosen.

The SLTDR data uploaded to satellites contained binned information for depths and duration of dives producing histograms of these metrics. Instruments had to be recovered in order to obtain archived detailed dive depth and dive time data. The data were transmitted to the satellite every 6 hours. These data were available for all animals and did not require recovery of the instrument. In 1995, the SLTDR was programmed to record dives in a series of bins from 8 to 800 m at 100 m intervals. Movements less than 8 m in depth from the surface were not recorded by the instrument because they were not considered dives. In 1996, dive bins were from 8 to > 300 m at 50 m intervals. In 2000, dive bins used ranged from 8 to > 300 m at intervals of 4 to 50 m between bins. Similarly, dive duration was recorded in a series of duration bins ranging from 1 to 20 minute intervals. Larger adult male sea lions weighing more than

250 kg were selected for the satellite tracking studies to maximize the likelihood that the animals would migrate back to rookery locations. A kernel density plot was constructed which shows the distribution of the sea lions by density, illustrating locations of varying usage along the coast.

RESULTS

Migration Patterns

The sea lions captured and instrumented during the migration study (1995-2000) were released back into Puget Sound the day of capture (Table 1). The movements of these individuals in local waters in the spring between the end of March and early June indicate that they remained in Puget Sound until the onset of migration (Fig. 1). Once the sea lions left Puget Sound they moved rapidly out of the Strait of Juan de Fuca and then south along the Pacific coast.

The weight of the nine animals fitted with satellite instruments ranged from 270 to 492 kg. The deployment time (Table 1) is the date when the instrument was first attached to the sea lion to the date when the last signal was received. The mean deployment time for the nine sea lions was 70 days (range 38 to 108 days). Eight of the nine sea lions instrumented with satellite tags completed the full southbound migration from Puget Sound, Washington, to rookery sites in southern California (Table 1, characterized in Fig. 2). The other sea lion migrated only as far south as Cape Arago, Oregon (Fig. 3). This animal was unusual in that he did not depart Puget Sound until early July, much later than the other individuals. Data from that sea lion was not used to calculate migration parameters for the group. The track line for the only instrumented sea lion to complete both the southward and northward migrations is illustrated in Figure 4. Four of the sea lions that completed the southbound migration ended their migration at San Nicolas Island (33° 13 .98 N, 119° 30 W) (Fig. 2A) and four at San Miguel Island (34° 01.99 N, 120° 24 W) (Fig. 2B). All of the sea lions traveled along the coast over the continental shelf, 5-20 km offshore (Figs. 2 and 3). The mean transit time for the eight sea lions was 25 days (range 18-38 days). The mean deployment date for the instruments was 15 May, the mean migration departure date was 28 May and the mean arrival date at the rookery sites was 23 June (Table 1). The mean distance traveled during the southbound migration was 2,027 km (range 1,792 to 2,342 km). The actual distance traveled during the southbound migration for each sea lion was probably much greater than the calculated mean because these distances were calculated as the straight-line distance between two positions. All sea lions deviated from a straight-line transit during the migration, many making offshore forays, presumably to feed. Maximum 24-hour travel distances for individual sea lions are provided in Table 1.

One complete northbound migration track was recorded for sea lion No. 17 (Fig. 4), and one partial northbound track was logged for sea lion No. 255 (Fig. 2A). For the remaining six sea lions, the satellite instruments either failed or fell off before beginning the northbound migration. Sea lion No. 17 spent from 26 June to 29 July at San Nicolas Island and then began migrating north. He arrived at Folger Island, British Columbia, Canada, on 28 August and the last satellite transmission was on 29 August. This complete northbound migration took 30 days and covered 1,940 km. Sea lion No.255 departed San Miguel Island on 31 July 2000 and arrived at Cape Mendocino, California, on 13 August. The last transmission was received on 26 August at

Cape Mendocino. The activities of sea lions during the migration can be categorized into three general behaviors: traveling or transit, resting, and feeding. Each sea lion showed some variability in these behaviors. Most sea lions hauled out multiple times (Table 2) along the route presumably to engage in social interactions or to rest (Fig. 3), some more frequently than others. Five of nine of the sea lions also appeared to deviate from the inshore migration route one or more times during the migration by making offshore feeding forays (Figs. 2 and 3). The relative use of offshore feeding areas and inshore haul out or resting sites is shown in Figure 3.

Transit and Haul Out Activity

The southbound migration route was generally inshore along the continental shelf within 5-20 km of the coast (Fig. 2). A general pattern emerged when comparing the migration tracks for the nine sea lions, which indicated 2-5 days of active transit followed by 1-2 days of resting at coastal haul-out sites (Table 2). Cape Arago, Oregon, appeared to be one of the most frequently used haul-out sites during the southbound migration, as eight of nine sea lions stopped there (Table 2). The haul-out sites used most frequently by migrating sea lions were relatively evenly spaced out along the coast at distances of 200-250 km (Fig. 3). Sea lions used these rest site stops during both the south and north migrations. Sea lion No. 17 completed the southbound migration in the shortest period of time, in 18 days from Puget Sound to San Nicolas Island, despite making three rest stops (Table 2, Fig. 4). The northbound migration for sea lion No. 17 took 13 more days than the southbound trip and included at least four resting site stops (Table 2).

Diving and Feeding Activity

Dive data were obtained from seven of the nine sea lions. In 2000 one of the SLTDRs was recovered and data archived in this SLTDR allowed us to calculate the daily maximum and mean dive depths and duration for this animal. The diving data obtained via satellite from the 1995 (n = 1) and 1996 (n = 2) sea lions was not used in the analysis because the dive bins were programmed in intervals too large to be useful for describing diving behavior. However, the distribution of dive depths and durations from these data were similar to the 2000 data. In 2000, four sea lions showed differences in diving behavior before the migration and during the migration. Before the migration, sea lions were feeding within the Puget Sound basin where depths average 137 m and range to 283 m. The Puget Sound is comparably deeper than along the migratory route over the continental shelf. During the migration, 75% of all dives (n = 1,942) were less than 20 m in depth, whereas within Puget Sound, 41% (n = 12,163) were less than 20 m (Fig. 5). Conversely, within Puget Sound, 44% of the dives were greater than 100 m but during migration only 12% were greater than 100 m (Fig. 5). However, the deepest dives recorded were during the migration when individual sea lions made offshore feeding forays in deeper waters. Many of the offshore feeding areas were near or over submarine canyons (Fig. 3). The deepest dive recorded was 475 m by sea lion No. 255 (Fig. 6), which was determined from archived dive data from the recovered instrument. These data indicate that many dives during the southbound migration exceeded 150 m with little diving activity associated with the time spent at the rookery (Fig. 6). Although we were not able to correlate specific dives with real time in this study, we can infer from the dive data that sea lions were actively foraging during both the south and northbound migrations. It is assumed in this study that any dive deeper than

8 m was a foraging dive where the individual was searching for prey. Dives shallower than this were considered migratory traveling behavior. If this is a valid assumption, then it appears that sea lion males were foraging during much of the migration because 75% of their dives were between 8 and 20 m in depth.

The duration of dives during the migration reflected the generally shallow dive depths; 41% of all dives in 2000 (n = 1,942) were less than 2 minutes in duration (Fig. 7). Less than 2% of all dives in 2000 were greater than 10 minutes in duration. The maximum dive duration was >13 minutes but only 0.1% of dives were in this category. There were some differences in dive depth and duration for individual sea lions perhaps reflecting differences in migratory behaviors. For example, 86% of dives were less than 50 m and 96% were less than 2 minutes in duration for the two animals marked in 1996. In 1995, for the single animal, 99% of dives were less than 2 minutes in duration during the southbound migration and 100% of the dives were less than 100 m.

DISCUSSION

The migratory behavior of California sea lions differs from the movements of individuals in the Pacific Northwest during the late summer, fall, and winter. California sea lions begin arriving in the Pacific Northwest after their northbound migration from the California breeding colonies in late August. Aggregations of a few hundred to several thousand animals appear at haul-out sites along the coasts of Oregon, Washington, and British Columbia during the northward migration. In Washington, large aggregations of over 5,000 sea lions have been observed off the north coast in the fall, where they remain until early winter before moving into the inland waters of Washington and British Columbia (Marine Mammal Laboratory (MML), unpubl. data[3]). Large aggregations of over 2000 California sea lions have also been observed off western Vancouver Island during the fall (MML, unpubl. data[3]; Bigg 1988). Aerial surveys conducted throughout these areas indicate that most California sea lions move from outer coastal sites into the more protected inland waters of Puget Sound and the Strait of Georgia, British Columbia, in the winter. It is believed that these movements are in response to prey availability. In Puget Sound, the predominant prey is Pacific whiting (*Merluccius productus)* Pacific herring (*Clupea pallasii)* spiny dogfish (*Squalus acanthias)* and salmonids (National Marine Fisheries Service (NMFS) 1997). Counts of California sea lions in Puget Sound from 1979 to 1995 showed that numbers increased about 10-fold during this time (NMFS 1997).

The tracking of sea lions with SLTDRs revealed the extreme mobility of these animals during the migration. The maximum 24-hour travel distance during the migration was 235 km, and six of the nine animals instrumented had one day travel distances of at least 176 km.

The hypothesized foraging behavior of sea lions during the migration as evidenced from the dive data is that sea lions are continuously and opportunistically searching for prey as they transit between the Pacific Northwest and their breeding islands. When transiting in shallow inshore waters they appear to make periodic foraging dives. In addition, most sea lions appear to make offshore foraging trips into deeper waters to search for prey while migrating.

The timing of the southbound migration appears to be closely related to the onset of breeding on the southern California rookeries which generally occurs from 20 May to 20 July. The mean departure date of breeding aged males from Puget Sound was 28 May and the mean

[3] Marine Mammal Laboratory, NOAA, NMFS, Alaska Fisheries Science Center,7600 Sand Point Way NE, Seattle, WA 98115

arrival date on the rookeries was 23 June. The trigger mechanism which initiates the migration is unknown but could be a function of day length, hormones, or both.

California sea lion males exhibit a more coastal north-south migration pattern compared to Steller sea lions and northern fur seals (*Callorhinus ursinus*). The male California sea lion migration spans at least 19 degrees of latitude from 33˚ N to 51˚ N and is characteristically inshore over the continental shelf. The migration is also rapid and confined to a few months a year, averaging 25-30 days in duration each way. The result of this migratory pattern is that male California sea lions spend approximately 10 months per year away from the rookery islands in southern California. Steller sea lions do not exhibit a highly synchronized migration as do male California sea lions but appear to disperse widely during the post-breeding season (Loughlin et al. 1987*a*). Adult male Steller sea lions demonstrate northward movements during fall and winter in both the Bering Sea and in the southeastern portion of their range (Kenyon and Rice 1961, Mate 1973). Northern fur seals from the Bering Sea rookeries exhibit a distinctly pelagic migration pattern which lasts approximately 8 months (Loughlin et al. 1987*b*, Loughlin et al. 1992, Ream et al. 2005). Female and young male northern fur seals migrate as far south as California and are found along the continental shelf and slope but remain pelagic until they return to the breeding rookeries (Loughlin et al. 1987*b*, 1992). Adult male northern fur seals do not migrate far south, remaining in the Bering Sea and Gulf of Alaska during the non-breeding season (Kenyon and Wilke 1953). Northern fur seal migration may also be correlated with oceanographic features such as the Alaska Gyre, the North Pacific Current, and sea-surface temperatures (Ream et al. 2005). California sea lion adult males, like northern fur seal and

Steller sea lion males, appear to spend the majority of time away from breeding rookeries, however, California sea lion males are distributed in more coastal waters and haul-out areas.

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Table 1. -- Timing, distance and duration of the southbound migration for California sea lions tagged with satellite instruments in Seattle, Washington, from 1995 to 2000.

Number	Mass (kg)	Deployment date	Departure date	Arrival date	Net days	Distance (km)	Maximum one day distance (km)	Destination island
17	492	8 June 1995	8 June 1995	26 June 1995	18	1,959	177	San Nicolas Island
117	272	7 June 1996	14 June 1996	4 July 1996	20	1,792	119	San Nicolas Island
321	392	7 June 1996	8 June 1996	1 July 1996	23	2,066	143	San Nicolas Island
55	363	7 April 2000	4 May 2000	2 June 2000	29	1,990	176	San Miguel Island
168	299	2 May 2000	11 May 2000	18 June 2000	38	2,342	199	San Nicolas Island
220	301	26 April 2000	22 May 2000	18 June 2000	25	1,958	235	San Miguel Island
567	301	2 May 2000	1 June 2000	25 June 2000	24	2,133	203	San Miguel Island
255	289	25 May 2000	3 June 2000	28 June 2000	25	1,975	176	San Miguel Island
Mean	**339**	**15 May**	**28 May**	**23 June**	**25**	**2,027**	**-**	
425	270	30 March 2000	2 July 2000	10 July 2000	8	637	43	Cape Arago, Oregon

Table 2. -- Rest sites used by California sea lions during the south (●) and northbound (◘) migration between Washington State and California breeding colonies. ●-Resting site-southbound. ○-Final southbound destination. ◘- Resting site-northbound.

Location	Sea lion No.567	Sea lion No.425	Sea lion No.168	Sea lion No.220	Sea lion No.55	Sea lion No.17	Sea lion No.117	Sea lion No.321	Sea lion No.255
Race Rocks		●						●	●
Waadah Island	●							●	
Cape Alava				●	●				●
Columbia River			●						
Cascade Head	●		●		●	● ◘			
Cape Arago	●	○	●	●	●	◘	●	●	●
St. George Reef	●		●			◘			
Cape Mendocino				●		●		●	● ◘
Año Nuevo Is.					●	◘			
Monterey Bay			●			◘			
San Miguel Is.	○			○	○	● ◘	●		○
San Nicholas Is.			○			○	○	○	

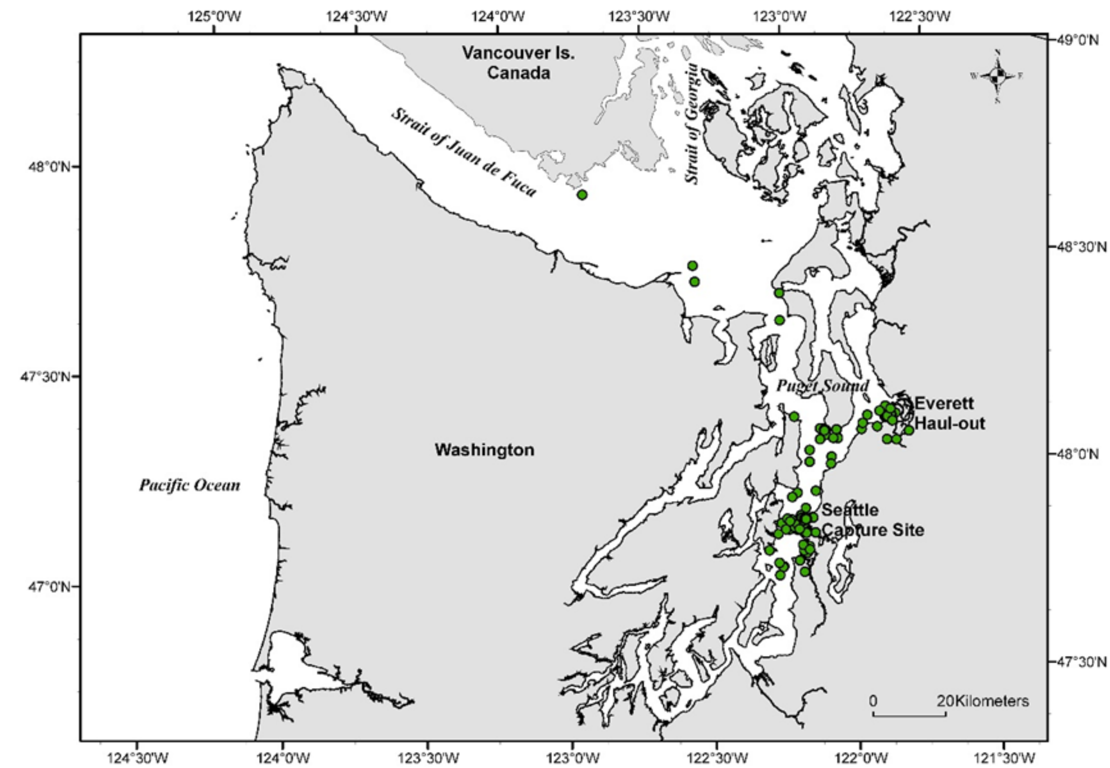

Figure 1. -- Satellite locations of California sea lions captured in 1995-2000 before the onset of migration. The capture location near Seattle, Washington, is shown.

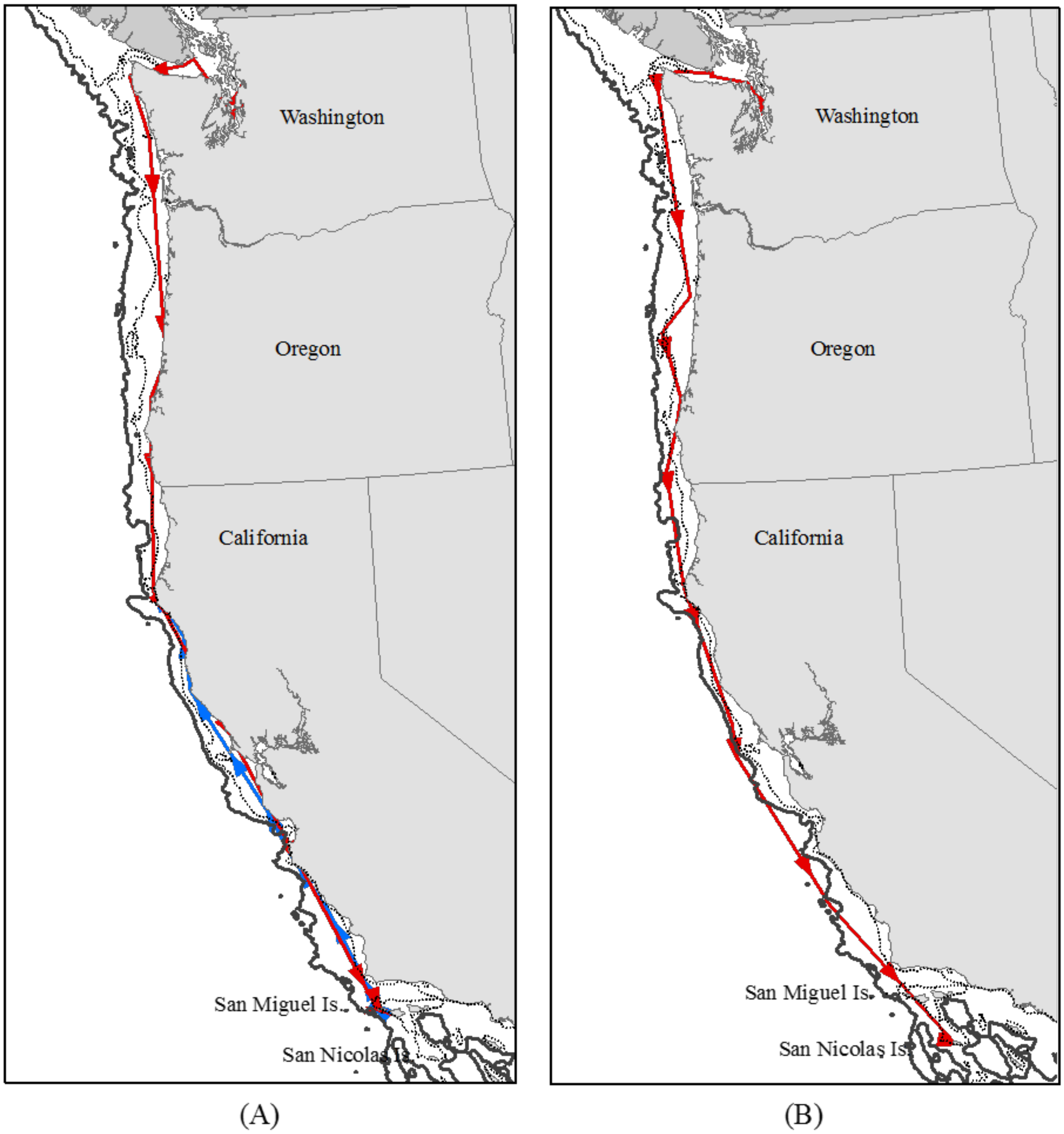

Figure 2. -- Typical southbound (red) migration tracks of California sea lions from Washington to San Miguel (A) and San Nicolas (B) Islands, California. One partial northbound track is shown in blue.

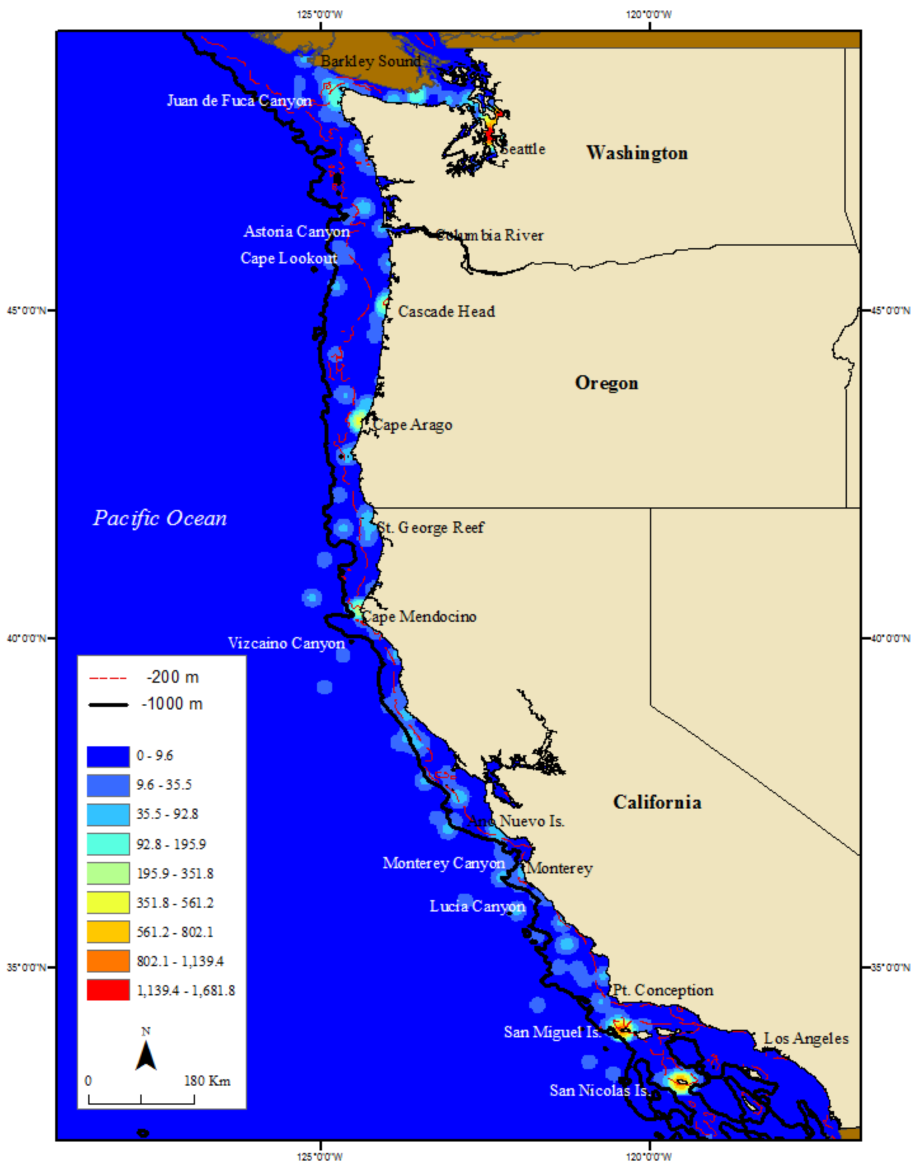

Figure 3. -- Kernel density plot of migrating California sea lion males (n = 9) that were instrumented in Seattle, Washington, during 1995, 1996, and 2000. Colors representing greater density correspond to sites where the sea lions were feeding or resting during their migrations primarily to and from San Miguel and San Nicolas Islands. Dashed lines indicates the 200 m isobaths (continental shelf). Solid black lines indicate the 1,000 m isobaths (continental slope).

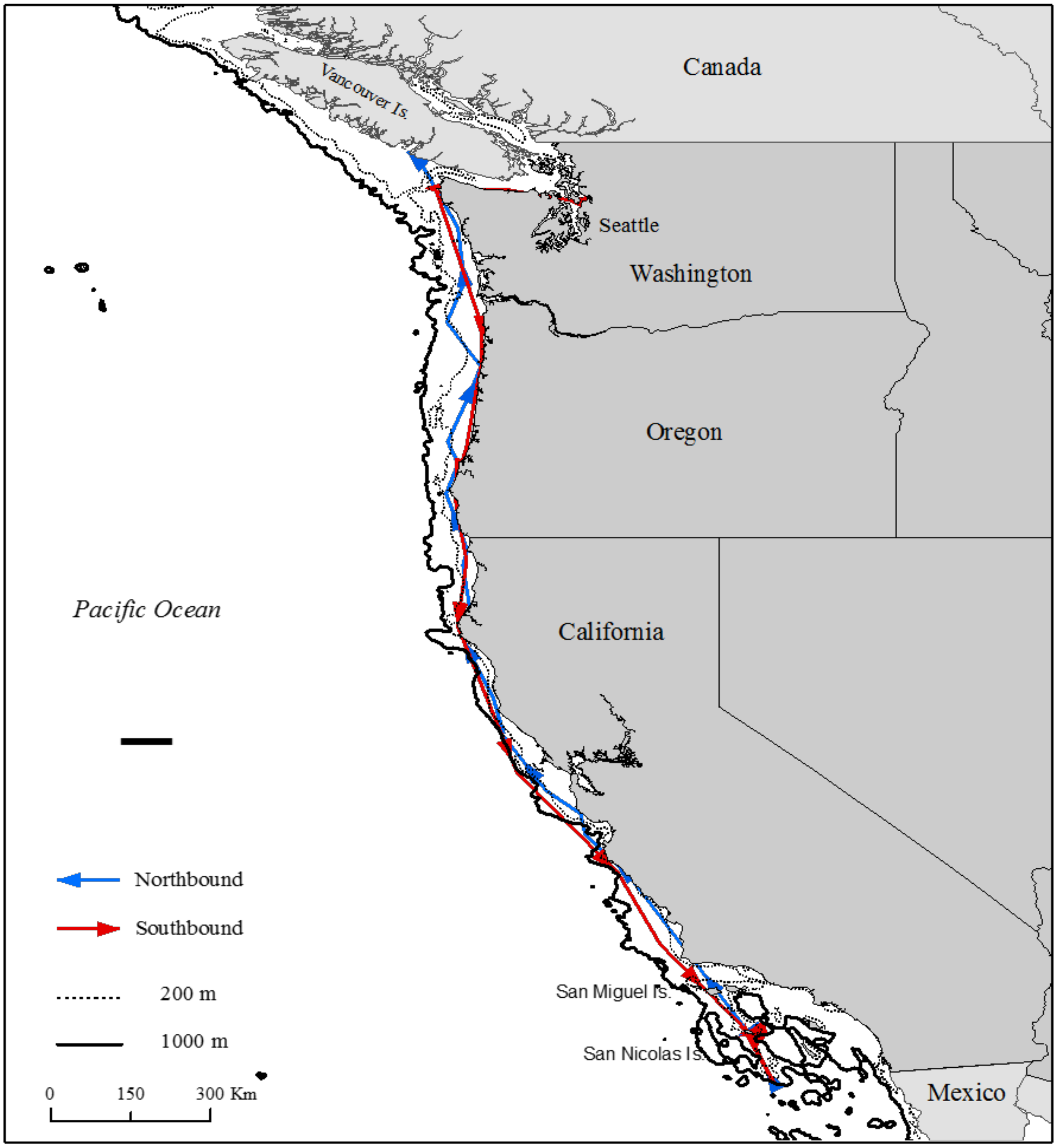

Figure 4. -- Southbound (red) and northbound (blue) migration tracks of California sea lion No.17 that was instrumented in Seattle, Washington, during 1995. This was the only sea lion that a complete round-trip migration was recorded.

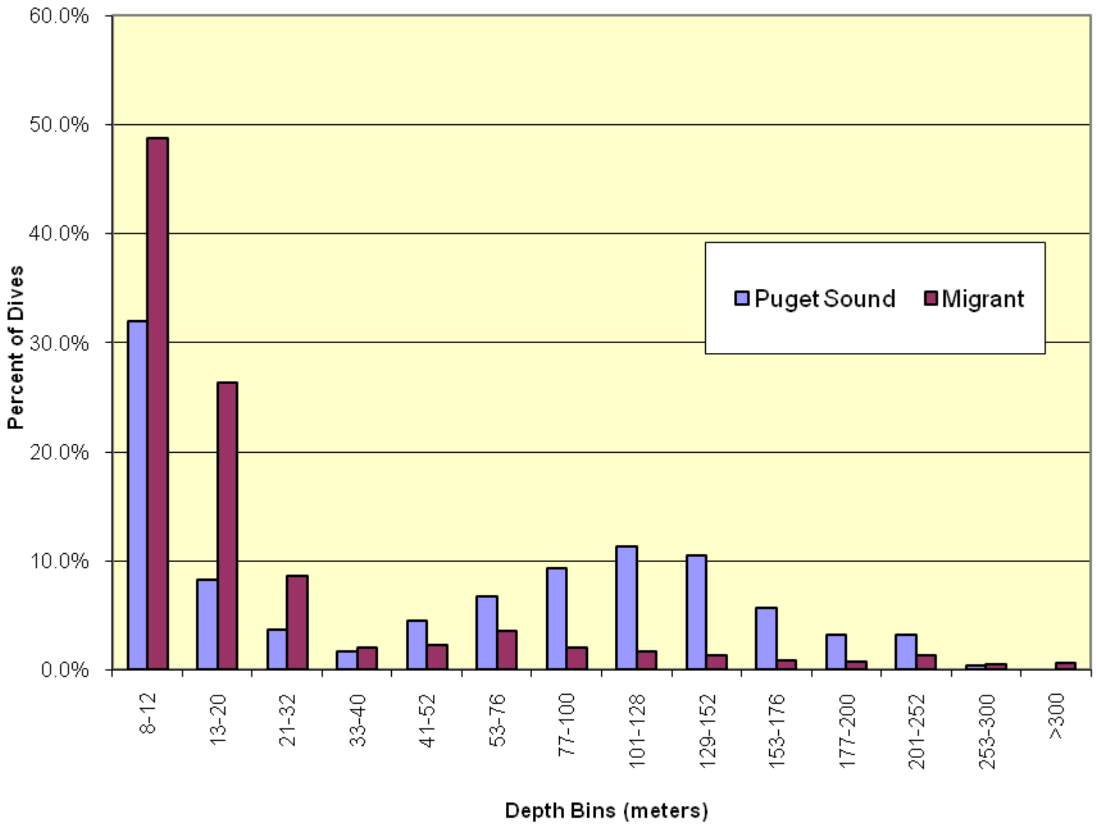

Figure 5. -- Dive profiles of migrant and non-migrant California sea lions during 2000.

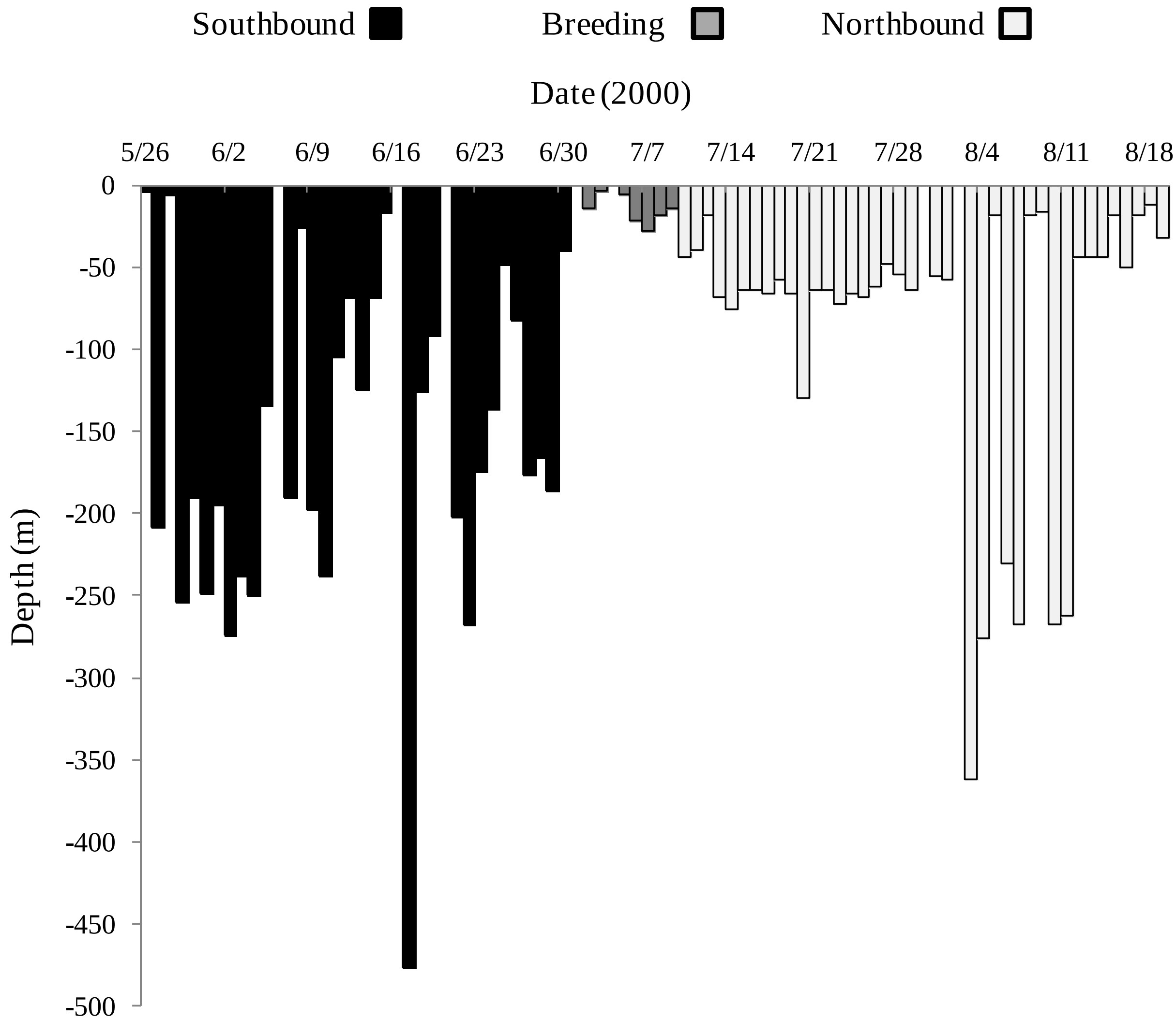

Figure 6. -- Daily maximum dive depths during the south and northbound migration and during the breeding season for an adult male California sea lion (No. 255).

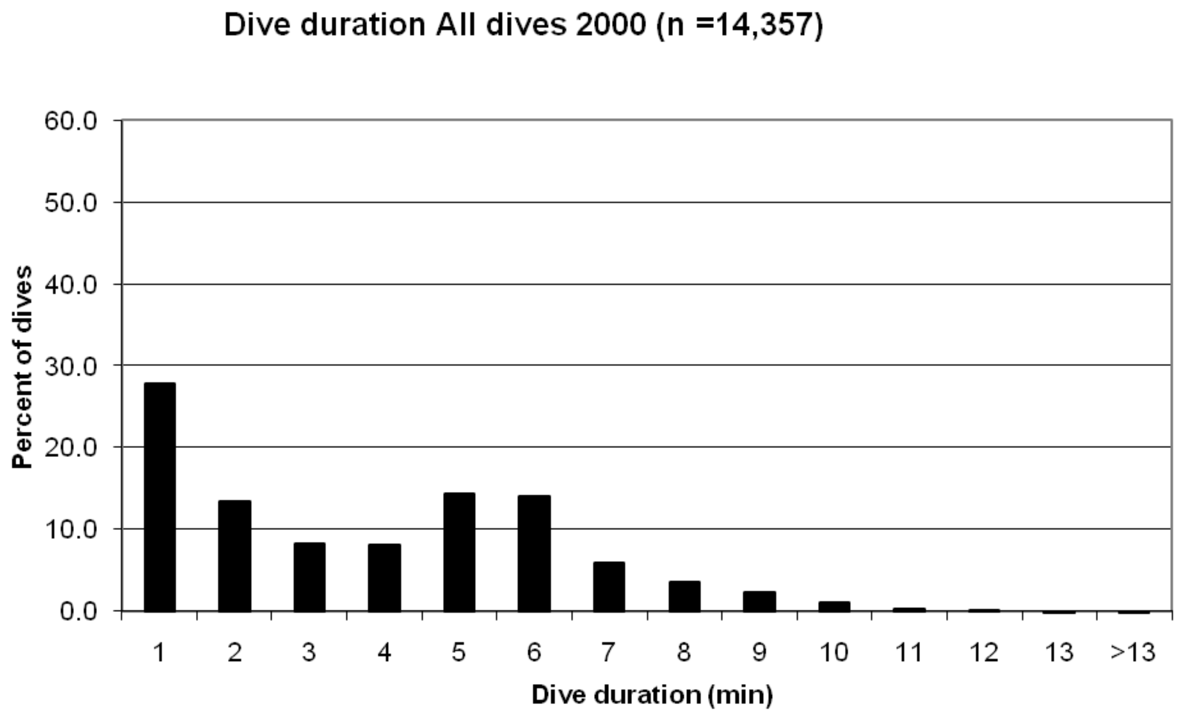

Figure 7. -- Duration of dives for California sea lion males in 2000 (n = 14,357).

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