Ecosystems Mission Area—Species Management Research Program

Prepared in cooperation with the U.S. Fish and Wildlife Service and the U.S. Navy

Southern (California) Sea Otter Population Status and Trends at San Nicolas Island, 2020–2023

Open-File Report 2023–1071

U.S. Department of the Interior
U.S. Geological Survey

Cover. A sea otter feeds on a mussel in the intertidal. Photograph by Joe Tomoleoni, September 30, 2018. Photograph used with permission.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Energy	
kilocalorie (kcal)	4.184	kilojoule (kJ)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.47105	acre

Datums

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

CI	confidence interval
COVID-19	coronavirus disease 2019
ESA	Endangered Species Act
GIS	Geographic Information Systems
GLM	generalized linear models
LOESS	locally estimated sum of squares
MMPA	Marine Mammal Protection Act
NDAA	National Defense Authorization Act
SNI	San Nicolas Island
SE	standard error
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USN	U.S. Navy

Southern (California) Sea Otter Population Status and Trends at San Nicolas Island, 2020–2023

By Julie L. Yee[1], Joseph A. Tomoleoni[1], Michael C. Kenner[1], Jessica A. Fujii[2], Gena B. Bentall[3,4], Michelle M. Staedler[1], and Brian B. Hatfield[1]

Abstract

The population of southern sea otters (*Enhydra lutris nereis*) at San Nicolas Island, California, has been monitored annually since the translocation of 140 southern sea otters to the island was completed in 1990. Monitoring efforts have varied in frequency and type across years. In 2017, the U.S. Navy and the U.S. Fish and Wildlife Service initiated a southern sea otter monitoring and research plan to determine the effects of military readiness activities on the growth or decline of the southern sea otter population at San Nicolas Island. The southern sea otter is the only subspecies of sea otter in California (hereafter, "sea otter"). The monitoring program, at its basic level, includes seasonal surveys of population abundance, distribution, and foraging activity. From 2020 to 2023, we measured a 10-percent per annum increase in population abundance (95-percent confidence interval =0–20 percent), with 146 total individuals as of April 2023. Coinciding with the recent population growth, the sea otter distribution, which previously tended to concentrate on the island's west end during 2003–2006 before shifting toward more use in the north and south sides during 2017–2019, appears to have shifted again during 2020–2023 to concentrate at the island's east end. Forage data were collected between February 2020 and April 2023. There was a total of 773 forage dives in 60 forage bouts, with most of the identified prey on successful dives (n=401) recorded as sea urchins (66 percent), followed by bivalves (15 percent), snails (12 percent), and crabs (5.2 percent). Two lobsters and three abalone also were identified among the sea otter prey. Estimates of energy intake rates averaged 14.0 kilocalories per minute (95-percent confidence interval =10.8–17.2 kilocalories per minute). Monitoring data from the past two decades indicate that sea otters at San Nicolas Island have maintained a steady pattern of energy intake and population growth characteristic of a robust population, including a sixfold growth between 2000 and 2023. There was no conclusive evidence of density-dependent effects based on these patterns; however, estimates of energy intake rates for 2020–2023 were slightly lower than previous estimates from 2017 to 2019. Additionally, subtidal monitoring results at four sites around San Nicolas Island indicated that counts of purple sea urchins (*Strongylocentrotus purpuratus*) have increased between 2003 and 2023, whereas sea otter foraging surveys completed during the same period revealed that some sea otters have shifted toward higher consumption of purple sea urchins and bivalves compared to red sea urchins (*S. fransicanus*), which generally are the preferred larger prey of sea otters. These results contribute to the understanding of population dynamics and to the conservation and planning of future monitoring and research of sea otters at San Nicolas Island.

Introduction

The southern sea otter (*Enhydra lutris nereis*), also known as the California sea otter, is a subspecies of sea otter (*E. lutris*) native to California. Before the fur trade of the 18th and 19th centuries, sea otters were estimated to range from 150,000 to 300,000 individuals along the continental shelf of the northern Pacific Ocean from Japan through Mexico (Bodkin, 2015). Sea otters were extensively hunted for their fur during that period and were nearly extinct by the time of their protection under the North Pacific Fur Seal Treaty of 1911. The California population was believed to be extirpated until a remnant group of about 50 southern sea otters was discovered near Big Sur, California. The population of southern sea otters is listed as threatened under the Endangered Species Act of 1973 (ESA) and considered depleted under the Marine Mammal Protection Act of 1972 (MMPA). The surviving California population of sea otters gradually increased in range and number, reaching about 1,500 individuals by the mid-1980s. However, concerns remained about the survival of this population because of the narrow range of its habitat, particularly if an oil spill were to occur. The U.S. Fish and Wildlife Service (USFWS) developed a program to reintroduce as many as 250 southern sea otters to

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[3]Sea Otter Savvy.

[4]Moss Landing Marine Laboratories.

San Nicolas Island (SNI), California, as a reserve population (USFWS, 2012). Despite the translocation of 140 southern sea otters between 1987 and 1990, fewer than 20 sea otters were counted at SNI for nearly a decade thereafter (table 1). Most of the translocated animals disappeared, but many returned to the mainland population, and some moved to and stayed in other areas (Rathbun and others, 2000; Hatfield 2005). From the beginning of the translocation, the USFWS and later the National Biological Survey and U.S. Geological Survey (USGS) monitored the status and trends of the SNI population. Spring and fall surveys were done in all years, with the spring survey at SNI taking place within a few weeks of the mainland California sea otter census; as many as four surveys were done at SNI in some years.

The U.S. Navy (USN) owns SNI and supported the translocation of southern sea otters to the island with a provision that defense-related actions were exempt from ESA consultation requirements (Public Law 99-625). After the USFWS declared the translocation program a failure in 2012, additional provisions for military readiness activities were legislated through the National Defense Authorization Act (NDAA) for Fiscal Year 2016. As required by the NDAA, the USN and the USFWS, in coordination with the USGS, developed a monitoring and research plan for the study of southern sea otters in the military readiness areas of SNI and San Clemente Island, which are among the California Channel Islands (appendix 1). The southern sea otter is the only subspecies of sea otter to occupy California (hereafter, "sea otter"). Of the two islands, sea otters are currently (2023) only known to occupy SNI. Consequently, all monitoring efforts within this research program were focused at SNI.

The military readiness area monitoring and research plan aims to "monitor interactions between military readiness activities and the sea otter population" (appendix 1). The plan defines three tiers of monitoring in order of increasing responsiveness to triggers that can indicate an effect to the SNI sea otter population from military readiness activities. The population is currently (2023) monitored in accordance with tier 1 ("basic monitoring and research"), in which the objectives are to (1) monitor and analyze population trends at SNI; (2) monitor and analyze subtidal benthic communities and assess effects of sea otter recovery on food dynamics; and (3) determine factors affecting population change, including relative contributions of density-dependent factors (changes in per-capita prey abundance) and density-independent factors (for example, shark mortality or military readiness activities) to variations in growth rates. The plan prescribes a strategy in which any new military readiness activities that could affect sea otters would trigger increased (tier 2) monitoring ("operational monitoring"). Additional (tier 3) monitoring ("advanced monitoring") is triggered if, in addition to new military activities, one of the following three events occur: (1) a dead moribund or stranded sea otter is found with injuries consistent with military activities; (2) the population trend decreases by more than 10 percent from the average trend during the preceding 3-year period for at least 2 consecutive years for reasons unattributable to density dependence; or (3) the total sea otter population drops below 75. As of August 2023, tier 2 and tier 3 responses have not been triggered.

Table 1. Count of independent sea otters and pups at San Nicolas Island, California, during spring surveys from 1990 through 2023. Spring surveys were cancelled during 2020 and 2021 due to the coronavirus disease 2019 pandemic restrictions.

Year	Independents	Pups	Total
1990	14	3	17
1991	14	2	16
1992	10	2	12
1993	7	4	11
1994	10	4	14
1995	9	4	13
1996	12	4	16
1997	16	0	16
1998	12	2	14
1999	18	3	21
2000	21	2	23
2001	21	5	26
2002	22	5	27
2003	33	5	38
2004	27	4	31
2005	22	3	25
2006	36	5	41
2007	26	4	30
2008	22	3	25
2009	27	6	33
2010	38	7	45
2011	44	6	50
2012	48	10	58
2013	54	8	62
2014	59	9	68
2015	54	7	61
2016	92	12	104
2017	72	9	81
2018	81	14	95
2019	109	12	121
2022	119	2	121
2023	134	12	146

The USGS addresses the objectives of tier 1 by doing seasonal sea otter population and foraging surveys and semi-annual subtidal surveys of the kelp habitat community consistent with long-term monitoring programs and by developing quantitative models that describe patterns of population change in relation to environmental variables. This report presents information and analyses of data collected from February 2020 through April 2023 and is an update to an earlier report (Yee and others, 2020) that covered the seasonal sea otter surveys from February 2017, the time of initiation of the military readiness area monitoring plan, to February 2020. New information collected by the long-term subtidal kelp monitoring program is presented in a separate report (Kenner and Tomoleoni, 2021). Herein, we evaluate sea otter population abundance, distribution around SNI, and foraging activity, and we compare those findings to those from previous survey periods, 2003–2006 and 2017–2019, when comparable types of monitoring were done. We present sea otter density maps with annual imagery snapshots of kelp distribution around SNI. We also analyze foraging success, including prey compositions and energy intake.

Kelp beds are underwater thickets of a type of large brown algae that provide habitat and food resources for a community of fish and invertebrate species, including sea urchins (*Strongylocentrotus*), snails, and other species that provide forage for sea otters. Kelp forests are a type of kelp bed in which certain kelp species, such as giant kelp (*Macrocystis pyrifera*), grow to form tall underwater forest structures that support the associated community. Kelp canopy refers to the blades or fronds of multiple kelp plants when they form a layer near the water's surface that shades the ocean bottom and is visible from above water. Kelp canopy that has emerged at the water's surface, also known as surface kelp, is where sea otters typically concentrate when resting; however, sea otters also can be found away from canopies. In this report, we use the terms "kelp beds" for historically persistent kelp and probable areas of sea otter distribution, "kelp forests" when referencing subtidal surveys of species in kelp communities at permanently marked transects where kelp forests have historically occurred, "kelp canopy" when describing kelp at or near the surface where it is visible from above water, and "surface kelp" when referencing areas with kelp on the water surface where it is associated with resting sea otters.

Methods

In this section, we describe the protocols used at SNI to survey and analyze sea otter population abundance and spatial distribution, the subtidal kelp forest ecosystem, and sea otter foraging activity and outcomes. For summary and descriptive purposes, we divided the nearshore habitat surrounding SNI into nine survey areas grouped into four sections (fig. 1): (1) west end (areas 1–3), (2) north side (areas 4–6), (3) east end (area 7), and (4) south side (areas 8–9). Area 3 is completely offshore between areas 1 and 2 and nicknamed "The Boilers" for an expansive rocky outcrop with kelp beds 2–3 kilometers from shore that give the illusion of boiling water. Sea otter surveys were done in all nine areas, whereas subtidal surveys of kelp forests were done at four sets of permanently marked transects, with one set done in each of the four sections (area 1 on the west end, area 5 on the north side, area 7 on the east end near Daytona, and area 8 on the south side near Dutch Harbor).

Population and Distribution Surveys

From 2017 through 2023, winter surveys of sea otters were done in early to mid-February, spring surveys in mid to late April, summer surveys in July, and fall surveys in late October to early December (as weather conditions and island access permitted). Seasonal surveys were suspended from spring 2020 through spring 2021 due to limited access of USGS personnel to the island during the coronavirus disease 2019 (COVID-19); only one fall survey was completed in December 2020, and it was done with a reduced survey team. Seasonal surveys were resumed in summer 2021 and have continued uninterrupted to 2023, except for the winter 2023 survey, which was cancelled after strong storms caused extended road closures and poor overall survey conditions.

Surveys were completed following similar protocols as the annual range-wide southern sea otter census in California (Hatfield and others, 2019), with the exception that an experienced observer surveyed alone at SNI (whereas a principal observer usually surveys with an assistant during the mainland range-wide census), and there were usually two or three attempts to count the entire island on different days of the survey trip. For each survey day, each observer was assigned to a section of the island spanning one or more of the nine survey areas (fig. 1). Each observer was equipped with a high power 50–80X spotting scope (Questar Inc., New Hope, Pennsylvania) and binoculars (10X). The observers started at one end of their assigned section and selected an observation point that provided good vantage of a viewable segment of habitat. In most cases, observers used the same counting locations year after year, for consistency. The observers scanned the segment with unaided eye and with binoculars for sea otters or objects that were suspected to be sea otters. Large groups, distant areas, and suspicious objects were scanned with the spotting scope. After sufficient time elapsed (15–30 minutes, depending on viewing conditions and extent) to make a thorough count of all sea otters in the first surveyed segment of habitat, the observer moved to another location that provided good viewing of the next segment of habitat, contiguous with the first segment. This process was repeated until the entire section was counted.

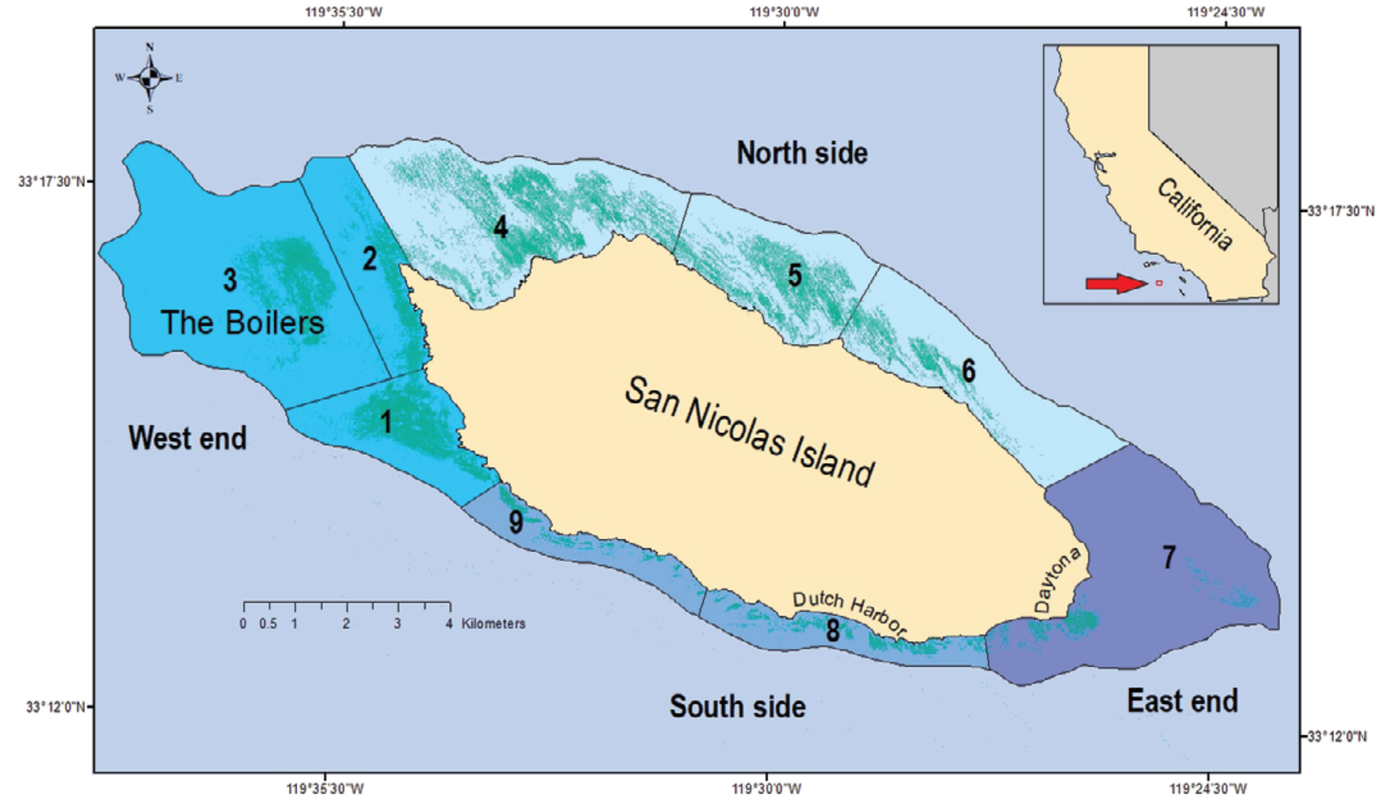

Figure 1. Sea otter habitat within a 30-meter isobath around San Nicolas Island, California. Sea otter counts are tallied into nine naturally distinct and contiguous survey areas numbered from 1 to 9 and grouped into four sections (blue shades). Mapped kelp canopies (shaded dim green) are derived and merged from aerial imagery taken in the fall seasons of 2017–2019.

All sea otter observations were marked as "points" directly onto paper field maps, using the area's primary stationary features, such as the shoreline and offshore rocks, for spatial reference. Kelp canopies from an earlier year also were displayed on the maps for use as secondary reference features due to their tendency to persist; however, kelp contracts, expands, and shifts across months and years, making the kelp distributions somewhat less reliable than stationary features for marking the precise locations of sea otters for comparisons across surveys. The kelp features, however, allowed sea otter locations to be mapped relative to all available visual cues within the same survey, which reduced the chances of double-counting or undercounting when the observer moved to the next observation point.

To minimize double-counting or detection biases because of sea otter movements, each total island count included surveys of all nine areas of the island on one survey day. In addition to the sea otter locations, other data recorded directly onto the maps included the number of independent sea otters, number and relative age of pups (pups are classed as either small or large depending on the presence or absence of natal pelage, relative size, and behavior), behavior (resting, foraging, or other), group size, and micro-habitat type (open water or kelp). Time and general survey conditions also were recorded. Viewing conditions were rated from excellent to poor (coded 4=excellent, 3=very good, 2=good, 1=fair, 0=poor), and survey trips were done when fair or better conditions could be anticipated. Shore-based surveys are estimated to detect about 90–95 percent of the sea otters located in the nearshore area (Estes and Jameson, 1988), but distances exceeding 1-kilometer (km) offshore and factors such as viewing conditions, sea otter grouping, and behaviors can influence detectability. Surveys were repeated on multiple days during each seasonal survey trip to SNI, and the maximum single-day total was taken as the island-wide count to minimize undercounting due to detection biases.

Ecosystem Monitoring

Underwater divers performed subtidal monitoring of kelp forest species community composition at four sets of permanently established transects at SNI (areas 1, 5, 7, and 8) semi-annually in April and October in most years since October 1980. Information on these surveys through fall 2019 are reported in detail in Kenner and Tomoleoni (2021). Subtidal kelp forest monitoring was suspended in 2020 and 2021 due to the COVID-19 pandemic, was partially resumed in 2022, and was fully resumed by spring 2023. Because sea urchins are a primary prey item of sea otters, we examined the subtidal counts of red sea urchins (*Strongylocentrotus franciscanus*) and purple sea urchins (*S. purpuratus*) and compared their patterns during the same periods as the sea otter surveys.

In addition to subtidal kelp forest monitoring, we obtained multi-spectral digital island-wide imagery of the survey areas around SNI annually (during fall 2014 through 2019 and 2022). This work was contracted by the U.S. Navy and collected from aircraft by the Ocean Imaging Corporation (http://www.oceani.com). The digital imagery was recorded with 0.2 meter and 1.0 meter resolution as red, green, blue, and near-infrared bands, and pixels were subsequently classified into exposed or submerged giant kelp (*Macrocystis pyrifera*) canopies based on supervised learning algorithms. We obtained the georeferenced aerial imagery and kelp classifications in raster and shapefile format and used them with geographic information systems (GIS) to develop maps of sea otter distributions relative to areas with kelp canopy.

Foraging Surveys

Sea otter foraging data were collected during the same seasonal trips as the sea otter population surveys, opportunistically during the times that were not already dedicated to those population surveys. Observation methods followed well-established protocols (Estes and others, 1981; Ralls and others, 1995; Tinker and others, 2008). Field observations were done during daylight hours by teams of 1–2 observers that searched for foraging sea otters near enough to shore that they could be visually distinguished from other sea otter individuals. The sea otters were monitored using a 50–80X spotting scope. Foraging bouts, which are defined as contiguous sequences of feeding dives made by a focal sea otter, were observed until data from at least 20 dives in the bout were recorded or until visual contact with the focal sea otter was lost. The information recorded during these bouts included location, date and time, duration of the subsurface dive interval (dive time) and the post-dive surface interval (surface time) for each feeding dive (in seconds), outcome of each dive (in other words, whether or not prey was captured), species of prey captured, number and size of prey items, per-item handling time (number of seconds required to handle and consume each item), whether or not tools were used to handle the prey, and ambient conditions (including sea-state, wind, and so forth). Prey size was recorded as the estimated diameter of the shell or maximum body dimension (excluding appendages) and categorized into 5-centimeter incremented size-classes. Each 5-centimeter increment represents one typical sea otter paw-width and was subdivided further into thirds within that size-class for increased precision. For observations where prey could not be reliably identified to species, the items in question were assigned to the lowest possible taxonomic unit. Any items that could not be reliably categorized to any taxonomic level were listed as unknown prey, although size class and number of items were still recorded. Additional information recorded by observers included numbers of prey items that were carried over from a previous dive or stolen by or from the focal animal and, in the case of females with dependent pups, the amounts of these prey that were shared with the pups.

Analysis

Abundance and Trends

We graphically modeled trends in island-wide sea otter abundance using nonlinear regressions fitted by locally estimated sum of squares (LOESS). LOESS trends were fitted locally by the “geom_smooth” function of the “ggplot2” package in R statistical software using a default span of 0.75 of data observations (Wickham 2016; R Core Team, 2022). We used generalized linear models (GLM) on 3-year moving intervals to estimate variable rates of population growth across time beginning with the 1990–1993 interval and ending with the 2020–2023 interval. We modeled sea otter counts (C_t, for year t) within each interval by fitting a linear trend where replicate counts C_t vary according to an overdispersed Poisson model with mean $\mu_t = \exp(\beta_0 + \beta t)$ and variance $c\mu_t$. The multiplier (c) in the variance represents an overdispersion factor, in other words, the amount by which the variance of count data exceeds that of a standard Poisson distribution, in which both the mean and the variance are μ_t (McCullagh and Nelder, 1989). We used the estimated slope coefficient (β) to calculate and test multiplicative rates of annual change in population size, $\lambda = \exp(\beta)$, based on the mathematical equivalence between $\exp(\beta)$ and the ratio in expected counts between two consecutive years, that is, μ_{t+1}/μ_t. For the 2017–2023 years, we included replicate counts from all available seasons ($C_{t,s}$, for season s) and tested for seasonal differences in island-wide total counts. We calculated the pup-to-independent ratio by summing the counts of sea otter pups across surveys and dividing by the corresponding sum of counts of independent sea otters, and we multiplied this ratio by 100 to derive an index of the number of sea otter pups per 100 independent sea otters. We used R statistical software to complete all statistical analyses and the “ggplot2” package to create graphics (Wickham 2016; R Core Team, 2022).

Distributions

We used ArcGIS software (Environmental Systems Research Institute, Inc., Redlands, California) to illustrate and interpret the spatial distribution of sea otter locations around San Nicolas Island for the years 2020–2023 and to compare it with the previous period (2017–2019). We used GLM to statistically test for changes in distributions for the periods 2017–2019 and 2020–2023, among years within periods, and among seasons. We also tested for interaction effects. We modeled spatial distributions by aggregating sea otter locations from the high-count dates across multiple survey trips, and we used kernel density estimation techniques with a 2-km smoothing parameter to model spatially explicit estimates of relative sea otter density. We evaluated this density for the aggregation of nine seasonal surveys from February 2020 through April 2023, and we compared this density to that of 12 seasonal surveys completed in the previous period from February 2017 through November 2019. We used descriptive bar charts and circular charts that represent the periphery around SNI to analyze changes in sea otter distributions among the nine areas. For statistically analyzing changes in distribution, we aggregated the areas into four sections of the island (west end, north side, east end, and south side) to ensure adequate sample sizes within each area category, and we used GLM to test for significant changes in distributions among years and seasons.

Foraging

We categorized foraging data into years (2020–2023), seasons (winter, spring, summer, and fall), and sex (males, females, and unknown) and report foraging outcomes by these categories. We also examined prey composition within these categories in terms of the proportion of items within eight prey classes: (1) abalone, (2) bivalves, (3) crabs, (4) lobsters, (5) octopus, (6) snails, (7) urchins, and (8) other. However, for comparisons with the years of the previous periods, 2003–2006 and 2017–2019, sample sizes of the forage data collected from 2020 through 2023 were too small to calculate reliable estimates of prey composition and energy intake rates separately by year, and we combined all forage data from the years 2020–2023 for those comparisons. To obtain quantitative measures of the composition of various prey species and energy intake rates (kilocalories per minute), field counts of prey capture frequency and prey shell diameter were converted to estimates of consumed biomass and caloric content using species-specific formulas for converting prey diameter to wet edible biomass and kilocalories per gram (Oftedal and others, 2007). These data were then analyzed using a Monte-Carlo simulation procedure to estimate diet composition (in terms of the proportion of consumed biomass contributed by each prey group) and rate of energy gain or kilocalories consumed per minute of feeding (Tinker and others, 2008). The Monte-Carlo procedure incorporates sampling uncertainty and adjusts for recognized biases associated with direct observations of sea otter foraging; a detailed description of the algorithm is provided elsewhere (Tinker and others, 2012; Tinker, 2015). We also used the Shannon-Weiner index to compare diet diversity between the 2020–2023 period and the previous 3 years (from 2017 to 2019; Tinker and others, 2008).

Finally, during 2003–2023, we examined long-term trends in the abundance of sea urchins, which are a primary prey item of sea otters, at four sites around SNI where subtidal monitoring was done (Kenner and Tomoleoni, 2021). We estimated overall trends in red sea urchins and purple sea urchins, separately, by using the “lme4” package in R statistical software to fit linear mixed effects models on log-transformed urchin counts in relation to year, with random site effects to account for variations among sites (Bates and others, 2015; R Core Team, 2022).

Results

Abundance and Trends

Shortly after the translocation of 140 sea otters to SNI from 1987 to 1989, most of those sea otters disappeared from SNI, leaving a population of fewer than 20 sea otters during most of the first decade (table 1). However, this population had gradually grown to exceed 100 individuals by the time of the spring 2016 survey and continued to exceed 100 individuals in all 14 surveys from fall 2018 through spring 2023 (fig. 2). Current survey estimates average about 150 total individuals, which is a sixfold increase in the population since 2000 when sea otters numbered fewer than 25 (table 2; figs. 2, 3).

The sea otter count, as of the last spring survey in April 2023, was 146, which included 134 independents and 12 pups, and the estimated rate of population growth during the 2020–2023 period was $\lambda_{2023} = 1.10$ (95-percent CI =1.00–1.20), corresponding to a 10-percent annual growth rate during this period (95-percent CI = 0–20 percent). Annual population growth rates varied during the past three decades, with about half of the estimates and 95-percent CI exceeding 1, representing statistically positive annual growth, with most growth occurring after 2010 (figs. 2, 4).

The pup-to-independent ratio for surveys in the 2020–2023 period was 8.8 pups to 100 independent sea otters, which was lower than the pup-to-independent ratio for surveys in the previous period (2017–2019; 12 pups per 100 independent sea otters). Lower pup ratios are associated with periods following larger rates of growth as more juveniles and subadults recruit into the pre-breeding population.

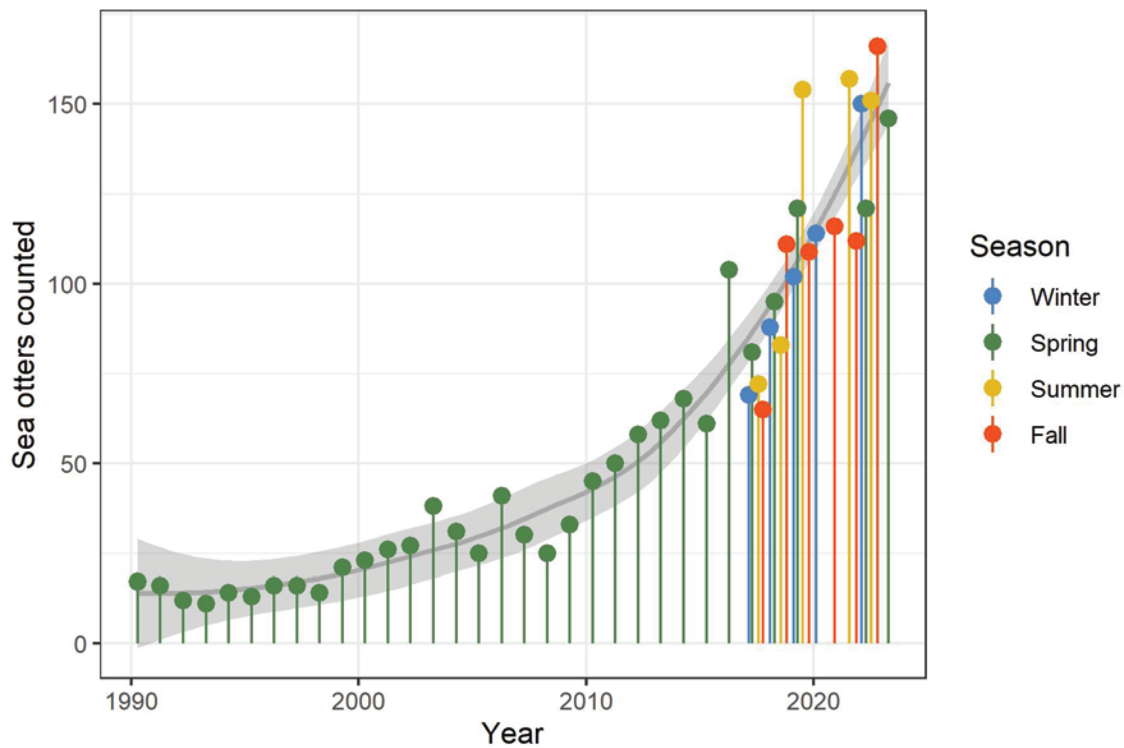

Figure 2. Number of sea otters counted at San Nicolas Island, California, during spring surveys from 1990 to 2023 (green pins) and seasonal surveys from 2017 to 2023 (multi-colored pins). Solid gray curve represents a smooth regression of the sea otter counts across years, fitted by the locally estimated sum of squares (LOESS) method and light gray-shaded by 95-percent confidence intervals. The LOESS regression was smoothed using a 0.75 proportion of the plotted data localized around each year.

Table 2. Count of independent sea otters and pups at San Nicolas Island, California, during seasonal surveys from winter 2017 through spring 2023, by area.

Season	Year	Month	Area of count (independents + pups)									Island count		
			1	2	3	4	5	6	7	8	9	Independents	Pups	Total
Winter	2017	2	2 + 0	0 + 0	12 + 0	9 + 1	1 + 0	0 + 0	1 + 0	37 + 6	0 + 0	62	7	69
Spring	2017	4	3 + 0	0 + 0	11 + 0	20 + 3	8 + 0	0 + 0	13 + 4	13 + 2	4 + 0	72	9	81
Summer	2017	7	10 + 0	5 + 0	31 + 2	5 + 2	4 + 0	0 + 0	0 + 0	9 + 4	0 + 0	64	8	72
Fall	2017	10	36 + 5	1 + 0	9 + 3	6 + 0	3 + 0	0 + 0	1 + 0	1 + 0	0 + 0	57	8	65
Winter	2018	2	30 + 2	1 + 0	18 + 5	19 + 1	4 + 0	0 + 0	1 + 0	6 + 0	1 + 0	80	8	88
Spring	2018	4	12 + 2	0 + 0	2 + 0	31 + 5	15 + 0	1 + 0	2 + 1	16 + 6	2 + 0	81	14	95
Summer	2018	7	12 + 1	10 + 0	33 + 5	5 + 1	9 + 0	2 + 0	1 + 0	4 + 0	0 + 0	76	7	83
Fall	2018	10	22 + 2	24 + 0	32 + 3	10 + 1	1 + 0	0 + 0	2 + 0	0 + 0	9 + 5	100	11	111
Winter	2019	2	8 + 2	2 + 1	2 + 0	18 + 3	19 + 0	0 + 0	3 + 0	32 + 11	1 + 0	85	17	102
Spring	2019	4	20 + 4	17 + 1	0 + 0	23 + 1	29 + 0	0 + 0	8 + 2	4 + 1	8 + 3	109	12	121
Summer	2019	7	32 + 3	4 + 0	45 + 5	9 + 0	31 + 3	2 + 0	6 + 1	6 + 0	6 + 1	141	13	154
Fall	2019	10	29 + 7	0 + 0	26 + 0	4 + 0	29 + 1	4 + 0	6 + 1	2 + 0	0 + 0	100	9	109
Winter	2020	2	2 + 0	3 + 0	6 + 1	37 + 5	13 + 1	7 + 0	11 + 0	20 + 4	3 + 1	102	12	114
Fall	2020	12	47 + 12	2 + 0	19 + 3	7 + 1	1 + 1	0 + 0	21 + 0	1 + 0	1 + 0	99	17	116
Summer	2021	7	37 + 5	0 + 0	12 + 0	31 + 2	3 + 0	6 + 0	57 + 0	2 + 0	2 + 0	150	7	157
Fall	2021	11	47 + 10	4 + 0	0 + 0	2 + 0	0 + 0	1 + 0	35 + 0	2 + 1	7 + 3	98	14	112
Winter	2022	2	5 + 0	2 + 0	39 + 6	13 + 1	1 + 0	4 + 0	47 + 0	21 + 6	5 + 0	137	13	150
Spring	2022	4	13 + 1	0 + 0	22 + 0	11 + 1	0 + 0	4 + 0	40 + 0	20 + 0	9 + 0	119	2	121
Summer	2022	7	17 + 1	0 + 0	43 + 5	21 + 3	5 + 1	0 + 0	43 + 0	7 + 2	3 + 0	139	12	151
Fall	2022	10	14 + 2	11 + 2	56 + 5	18 + 1	2 + 1	1 + 0	45 + 0	3 + 0	5 + 0	155	11	166
Spring	2023	4	14 + 2	0 + 0	9 + 1	8 + 1	0 + 0	11 + 4	55 + 1	35 + 3	2 + 0	134	12	146

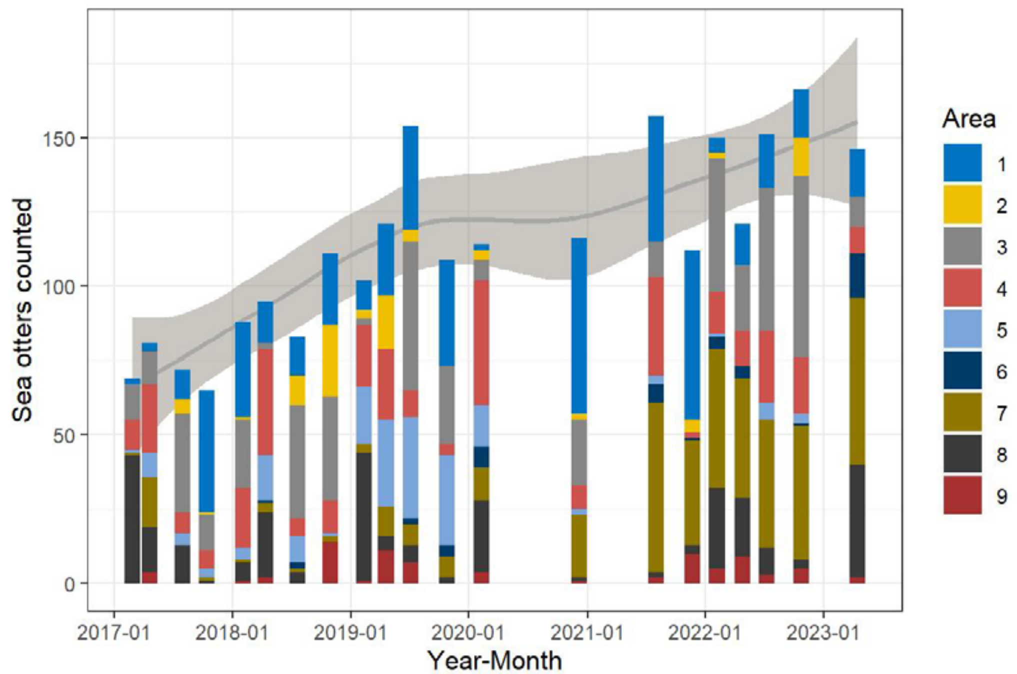

Figure 3. Number of sea otters counted at each of the 9 areas at San Nicolas Island, California, during 21 seasonal surveys from February 2017 to April 2023. Solid gray curve represents a smooth regression of the total sea otter counts in relationship to year, fitted by the locally estimated sum of squares (LOESS) method (gray line), and light gray-shaded with 95-percent confidence intervals. The LOESS regression was smoothed using a 0.75 proportion of the plotted data localized around each year. Count data are presented in table 2.

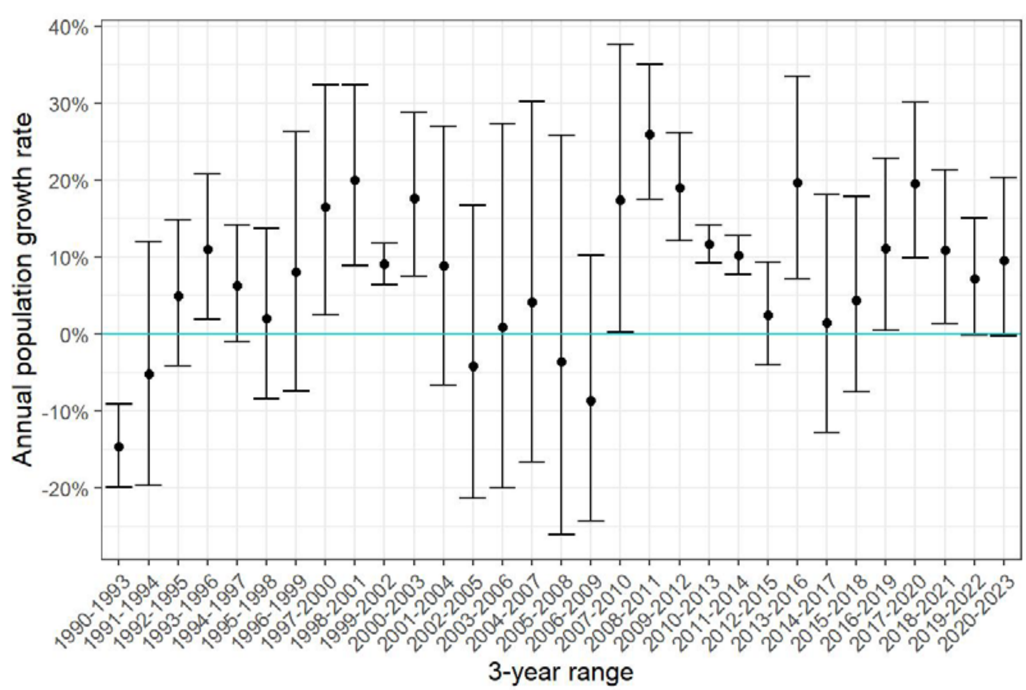

Figure 4. Estimated rates of annual population growth of sea otters at San Nicolas Island, California, during 3-year moving windows from 1990 to 2023, with 95-percent confidence intervals. Positive rates represent population growth, whereas negative rates represent population decline. Confidence intervals that overlap with 0 represent insufficient evidence to conclude growth or decline.

Densities and Distributions

We compared the densities and distributions of sea otters during surveys from the 2020–2023 period with those of the 2017–2019 period. Sea otter locations were aggregated across all surveys during each period to develop kernel density surfaces representing the relative density of cumulative counts (fig. 5). In these maps, sea otters appear to have shifted from concentrations distributed around the island, primarily at the west end (areas 1–3) and north side (areas 4 and 5) during 2017–2019, to a large concentration at the east end (area 7) during 2020–2023, leaving less dense concentrations in the west and northwest.

The maps on figure 5 also display sea otter densities overlaid with kelp canopy distributions derived from aerial imagery collected during the last fall within each respective sea otter survey period. Surface kelp changes significantly over the seasons, with the maximum extent typically occurring in the fall. Kelp surveys were done once annually and were scheduled in the fall with the intent of capturing images of the maximum extent of kelp canopy for that year. After winter storms, the area of surface kelp is largely reduced, and the distribution changes seasonally. Thus, these kelp distributions are not strictly representative of where kelp beds were across the other seasons when sea otter surveys were done, but they are an indicator of where kelp beds had the most potential to be present.

Radial plots (also known as radar or spider plots) provide a graphical summary of the distribution of sea otters counted around the perimeter of the island (Bion, 2020; Nakazawa, 2023). The nine areas defined on figure 1 are arranged on circular plots in the general cardinal direction as they are oriented around the island (figs. 6, 7). Most of the population distribution, which was formerly concentrated on the island's west end (areas 1 and 3), expanded and increased on the north and south side during 2017–2020 but has since concentrated more toward the southeast end (areas 7 and 8) during the past several years (fig. 7).

Radial plots display the distribution of sea otter use around the island as it varied seasonally and by year (fig. 7). Areas 1 and 3, which include The Boilers, on the west end have consistently had among the largest sea otter counts in the summer and fall from 2017 through 2022. From summer 2019 through winter 2020, areas 4 and 5 combined had a visible spike in sea otter use, starting in area 5 and then shifting more to area 4. The south side of the island did not have much use except sometimes at area 8 near the east end (area 7) where sea otter use has increased from 2020 to 2023, mostly in the spring but also in the summer and fall. Area 6, which is on the eastern end of the north side, where there is almost no kelp, has had very few sea otters in all seasons and years.

Spatial density maps for each of the four seasons reflect these seasonal spatial distribution patterns in greater detail for the recent years (from 2020 through 2023; fig. 8). Sea otters continued to frequent areas at the island's west end in all seasons and years. However, during 2020–2023, sea otters were observed to aggregate in higher concentrations near Daytona (in area 7 at the east end), notably in spring, summer, and fall, and they were observed near Dutch Harbor in area 8, on the south side in spring.

To estimate and test seasonal differences in the spatial distribution of sea otters generally, we aggregated sea otter counts within the west end, north side, east end, and south side sections (fig. 1). We detected significant differences in distribution among sections between the 2017–2019 and 2020–2023 periods ($\chi^2_3 = 40.3, p < 0.0001$) and season ($\chi^2_9 = 54.6, p < 0.0001$), but there was no significant evidence of trends among years within either of the two periods ($\chi^2_3 < 5.3, p > 0.15$) or interaction effects between period and season ($\chi^2_9 = 9.1, p = 0.42$). Concentrations of sea otters were on the west end each season, in areas associated with historically persistent kelp, but concentrations tended to be lowest in winter or spring (figs. 8, 9). Despite indications that sea otter distributions expanded to both the north and south sides of the island during the 2017–2019 period, when the south side was formerly defined to include area 7 (Yee and others, 2020), there was little indication that this pattern of growth on the north side continued into the 2020–2023 period (figs. 5, 6, 7, 8). However, large concentrations of sea otters continued to persist and grow in area 7, herein referred to as "the east end," and in area 8 of the south side during the 2020–2023 period (area 7; figs. 5, 6, 7, 8, 9).

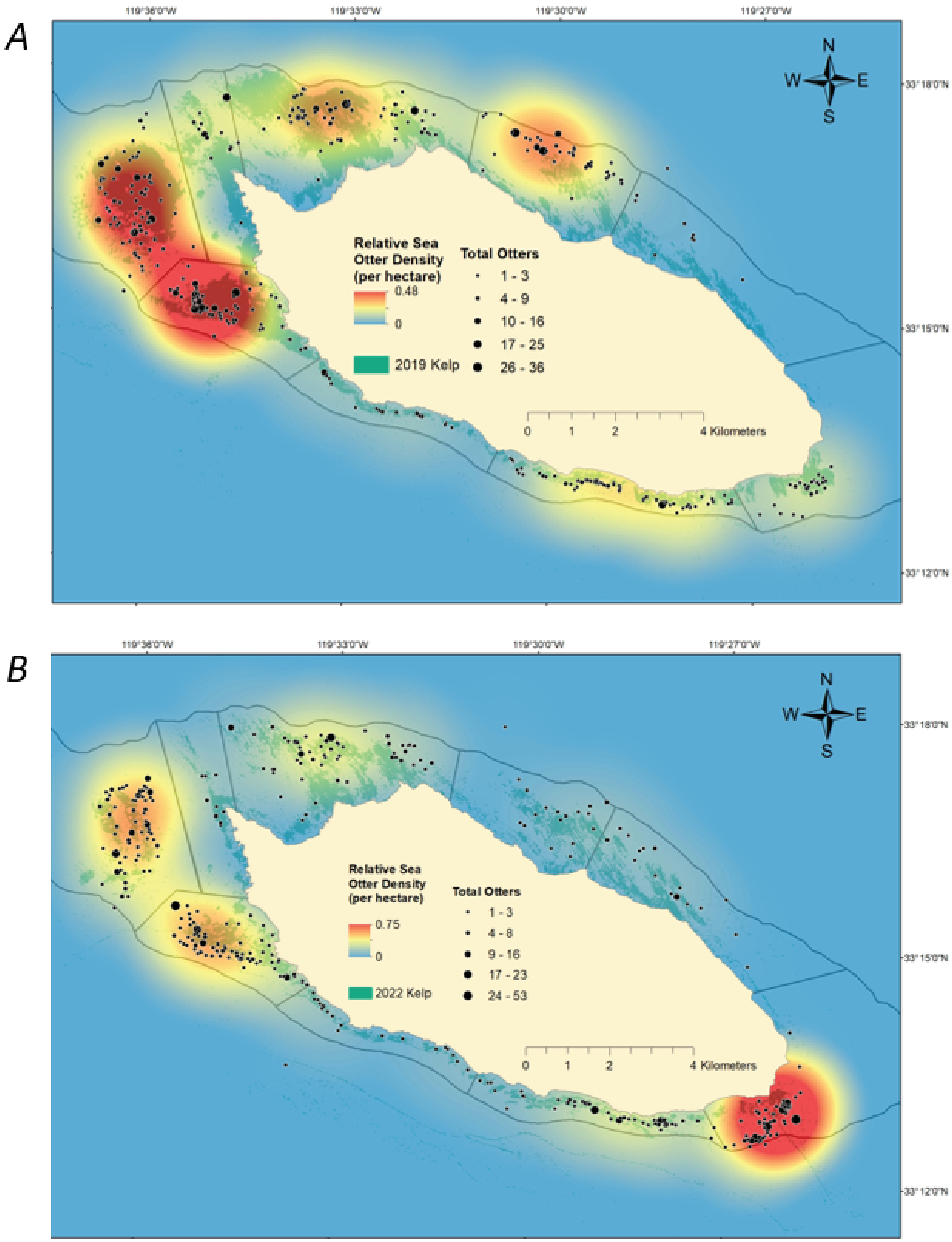

Figure 5. Relative sea otter density during seasonal surveys at San Nicolas Island, California, when combined from *A*, 2017 through 2019 (12 surveys); and *B*, 2020 through spring 2023 (9 surveys). Relative densities were spatially modeled using kernel density methods on the cumulative sea otters counted per hectare across surveys in each comparison period. Mapped kelp canopies (shaded dim green) are derived from aerial imagery taken in the fall seasons of 2019 and 2022.

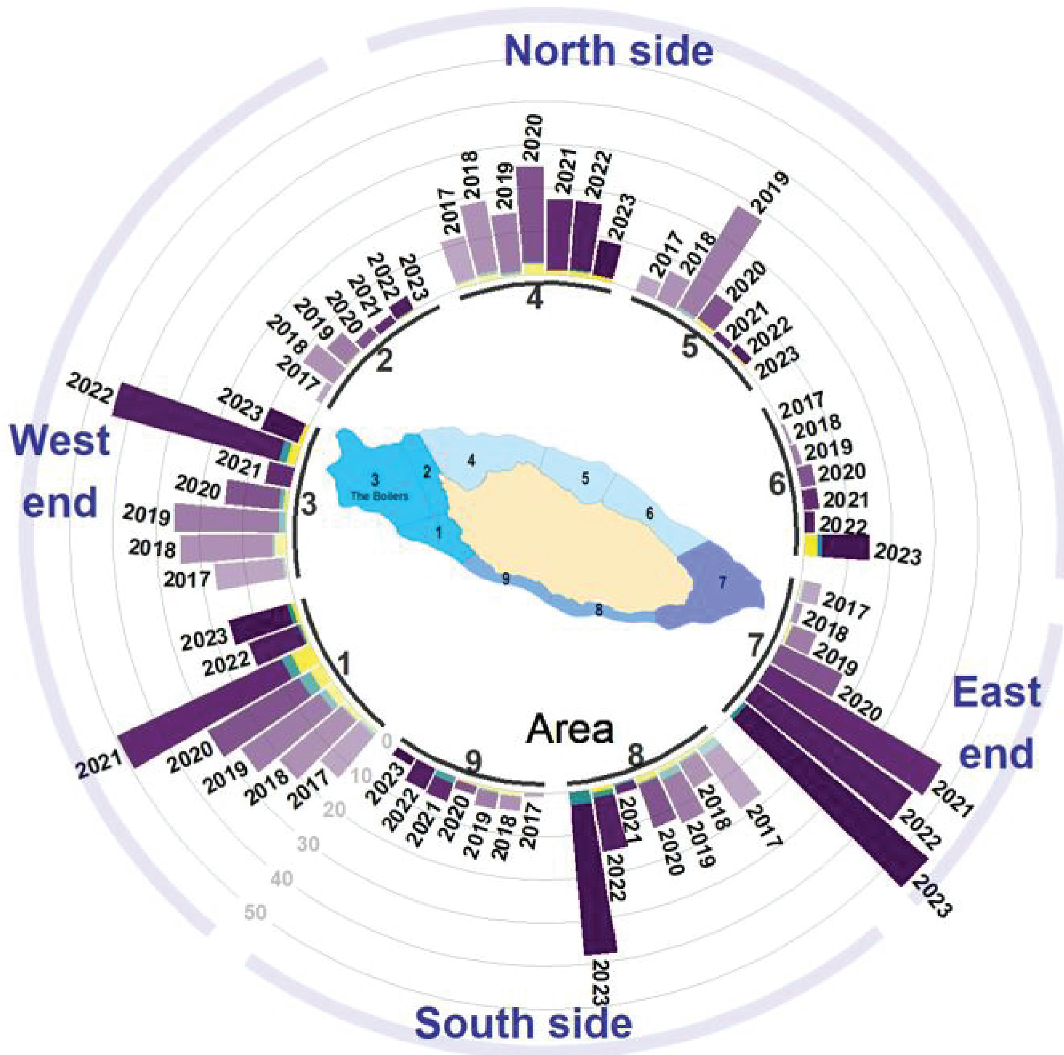

Figure 6. Average number of sea otters counted per year (2017–2023) at nine survey areas (see map inset for locations of numbered areas) around San Nicolas Island, California. Bars are grouped by area, color coded by age-size class (purple=adults, green=large pups, and yellow=small pups), and shades darken with later years (2017 is lightest and 2023 is darkest). Rotating clockwise around the cardinal directions of the island, starting at the southwest, areas 1, 2, and 3 represent the west end of the island; areas 4, 5, and 6 represent the north side; area 7 represents the east end; and areas 8 and 9 represent the south side.

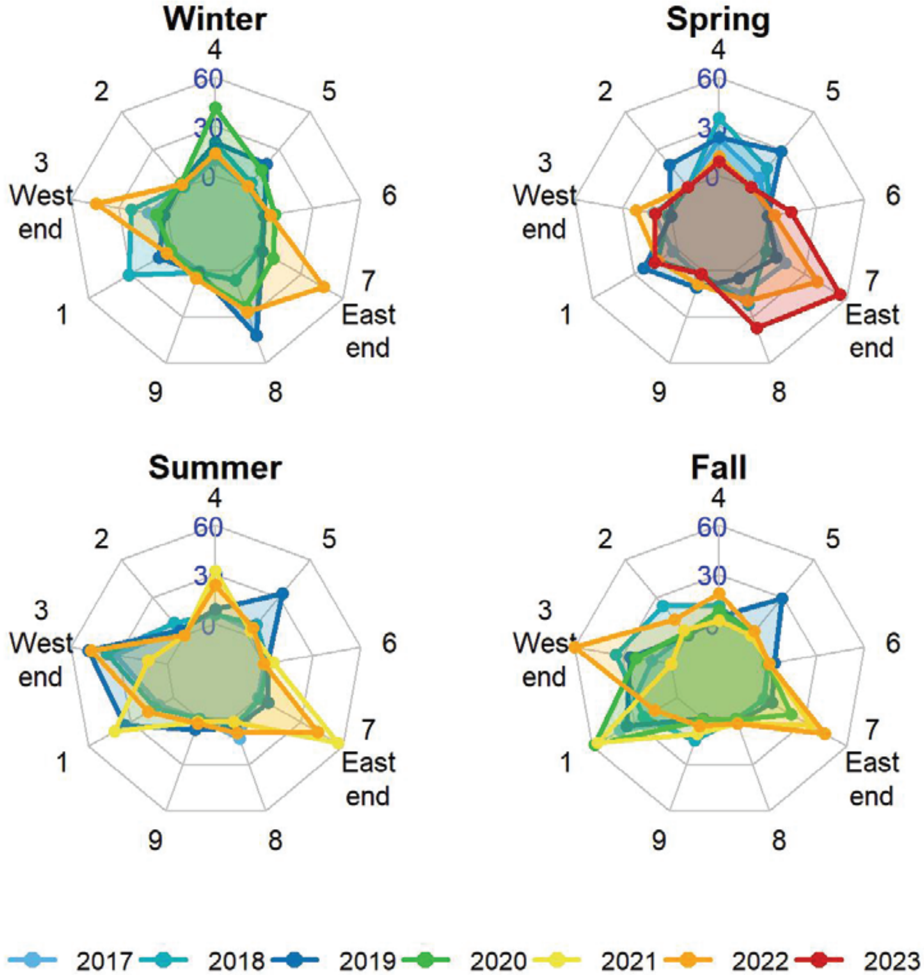

Figure 7. The abundance of sea otters around the periphery of San Nicolas Island, California, by season (winter, spring, summer, and fall), 2017–2023. Each plot displays the number of sea otters counted at nine areas around the island on the high-count date of each seasonal survey, for each year. The west end includes areas 1–3, with area 3 located between areas 1 and 2, and the east end consists of area 7. Concentric polygons represent a minimum count of 0 sea otters (inner polygon), a maximum count of 60 (outer polygon), and a middle value of 30.

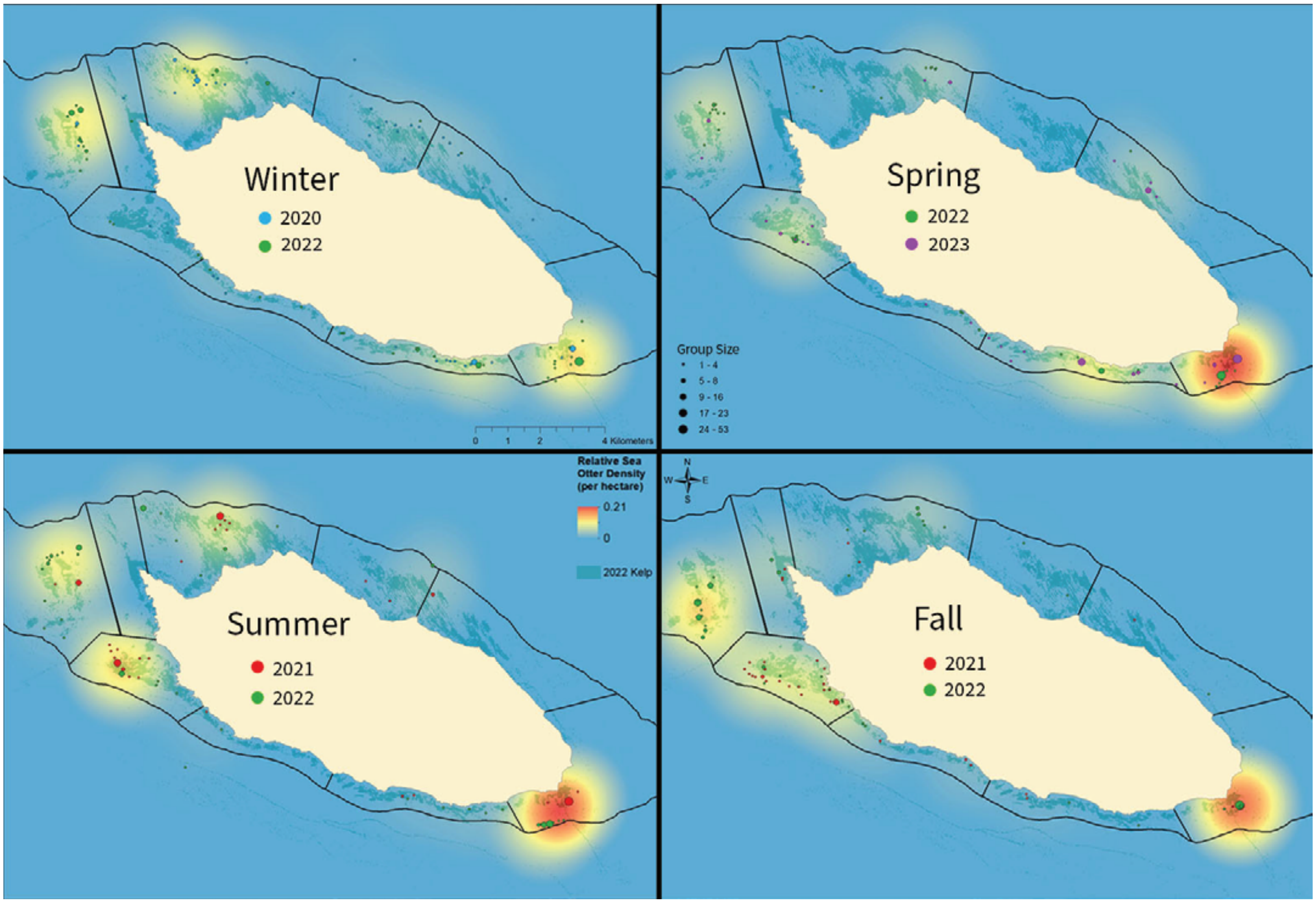

Figure 8. Seasonal distribution of relative sea otter density during surveys completed annually in winter (February), spring (April), summer (July), and fall (October/November) from 2020 to 2023, San Nicolas Island, California. Sea otter locations were aggregated across the two surveys for each season to develop kernel density surfaces representing the relative density of total counts distributed around the island. The same legends for group size and relative sea otter density apply to all seasons. Mapped kelp canopies (shaded dim green) are derived from aerial imagery taken in the fall season of 2022.

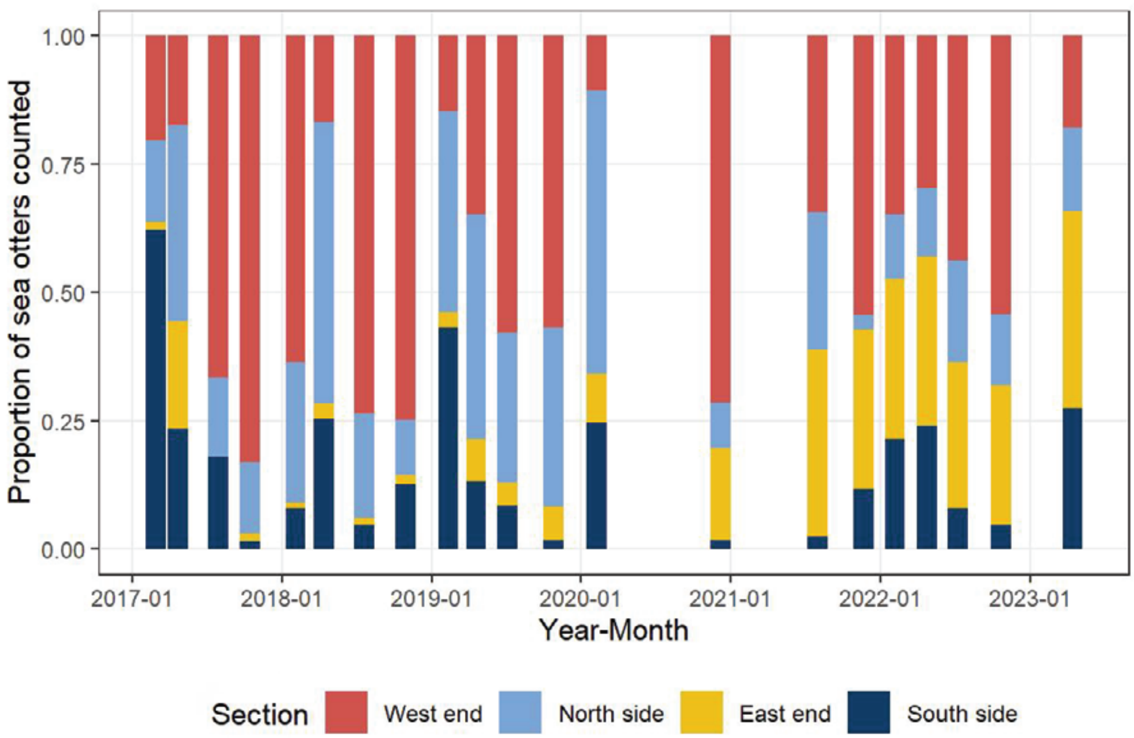

Figure 9. Proportional distribution of sea otters within four sections (west end=areas 1–3, north side=areas 4–6, east end=area 7, south side=areas 8–9) around San Nicolas Island, California, observed during seasonal surveys (winter, spring, summer, and fall) from winter 2017 through spring 2023.

Foraging

Sea otter foraging data were collected opportunistically as time and viewing conditions allowed. Consequently, the numbers of foraging observations varied by survey and location. A total of 60 sea otter foraging bouts were observed from winter 2020 through spring 2023, for a total of 773 diving observations (tables 3, 4). The amount of forage data collected from 2020 through spring 2023 was substantially less than that collected in the previous period 2017–2019 (2,581 dives) due to fewer surveys completed during the COVID-19 pandemic and sometimes poorer survey conditions. Most foraging bouts were recorded on the east end (70 percent) compared to the north side (18 percent), south side (7 percent), and west end (5 percent). Among all dives, 368 were observed on 21 female foraging bouts, 179 were observed on 15 male foraging bouts, and the remaining 226 were observed on 24 foraging bouts of unknown sex.

We classified identifiable prey species into taxonomic groups based on highest prevalence in the diet (urchins, bivalves, snails, crabs) or energetic content of less prevalent prey species (abalone, lobsters, octopus) and lumped all other species (other). Of the 587 successful dives observed during 2020–2023, 32 percent resulted in unidentified prey items (table 5). We used Monte-Carlo simulations to estimate the likely caloric values of unidentified prey based on partial data about the prey, such as their size and the lowest taxonomic level to which they could be identified. These simulations use empirical information about the likelihood of different prey species and the associated caloric values for their size class, based on the frequency with which specific species and sizes were identified in the data. This process enabled us to derive 95-percent confidence intervals to account for prey uncertainty. These simulations require robust sample sizes to provide sufficient information on prey. Because our foraging observations in the 2020–2023 period were fewer compared to those of previous years, we aggregated those data across years to calculate an average energy intake rate for the 2020–2023 period.

Sea urchins, including the red sea urchin (*Strongylocentrotus franciscanus*) and purple sea urchin (*S. purpuratus*), composed the majority (66 percent) of identified prey types among all successful diving outcomes, with the remaining successful diving outcomes comprised mostly of bivalves (15 percent), snails (12 percent), and crabs (5.2 percent; fig. 10). Three abalone, two lobsters, and one mollusk also were observed to be consumed (table 5). Bivalves comprised a larger proportion of prey in the 2020–2023 period than previously observed and were recorded for 61 dives from 11 bouts, including 1 bout where 21 rock jingles (*Pododesmus macroschisma*) and 3 clams were observed to be consumed and another 8 bouts where a total of 23 giant rock scallops (*Crassodoma gigantea*) were observed to be consumed.

Table 3. Number of sea otter foraging bouts surveyed by season, sex, age class, and section of San Nicolas Island, California, 2020–2023, summarized by year and for all years combined.

Sea otter foraging bouts	Year				All years
	2020	2021	2022	2023	
Total foraging bouts	12	10	34	4	60
Season					
Winter	10	0	20	0	30
Spring	0	0	0	4	4
Summer	0	9	5	0	14
Fall	2	1	9	0	12
Sex					
Females	4	1	13	3	21
Males	2	3	10	0	15
Unknown sex	6	6	11	1	24
Age class					
Adults	10	4	18	4	36
Aged adults	0	0	0	0	0
Sub-adults	1	2	13	0	16
Juveniles	0	0	0	0	0
Unknown age	1	4	3	0	8
Section					
West end (areas 1–3)	0	2	1	0	3
North side (areas 4–6)	2	4	4	1	11
East end (area 7)	9	4	27	2	42
South side (areas 8–9)	1	0	2	1	4

Table 4. Number of sea otter foraging dives observed by season and sex and diving outcomes at San Nicolas Island, California, 2020–2023, summarized by year and for all years combined.

Sea otter foraging dives	Year				All years
	2020	2021	2022	2023	
Total foraging dives	128	111	446	88	773
Season					
Winter	95	0	245	0	340
Spring	0	0	0	88	88
Summer	0	100	51	0	151
Fall	33	11	150	0	194
Sex					
Females	40	50	198	80	368
Males	41	26	112	0	179
Unknown sex	47	35	136	8	226
Outcomes					
Successful dives	115	96	308	68	587
Unsuccessful dives	7	11	105	18	141
Other	3	3	12	1	19
Unknown outcomes	2	1	9	1	13
Known outcomes	126	110	437	87	760
Known success or known unsuccess	122	107	413	86	728
Percentage success rate (successes/dives)	94.3	89.7	74.6	79.1	80.6
Mean dives per bout	10.7	11.1	13.1	22.0	12.9
Mean diving duration (seconds)	66	39.1	60.8	64.8	59.0
Mean surface interval (seconds)	56.3	53.0	47.2	47.6	49.6

Table 5. Number of successful dives with prey categorized into eight prey classes observed during foraging surveys at San Nicolas Island, California, 2020–2023.

Prey class	Year				All years
	2020	2021	2022	2023	
Abalone	0	0	3	0	3
Bivalve	0	0	31	29	60
Crab	2	0	12	7	21
Lobster	0	1	1	0	2
Mollusk	0	0	1	0	1
Octopus	0	0	0	0	0
Snail	13	0	27	8	48
Sea urchin	58	62	143	3	266
Unidentified	42	33	90	21	186
Total	115	96	308	68	587

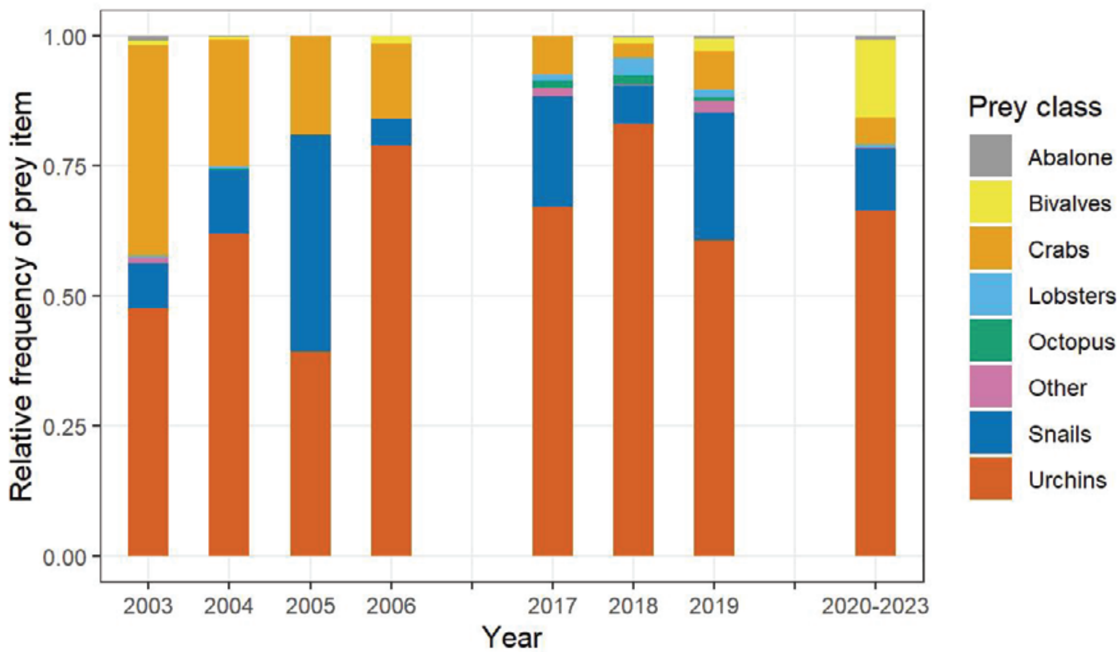

Figure 10. Relative frequency at which items from eight different prey classes were observed in sea otter diets during three periods of foraging surveys at San Nicolas Island, California, 2003–2006 and 2017–2019 (years shown individually and 2020–2023 years aggregated).

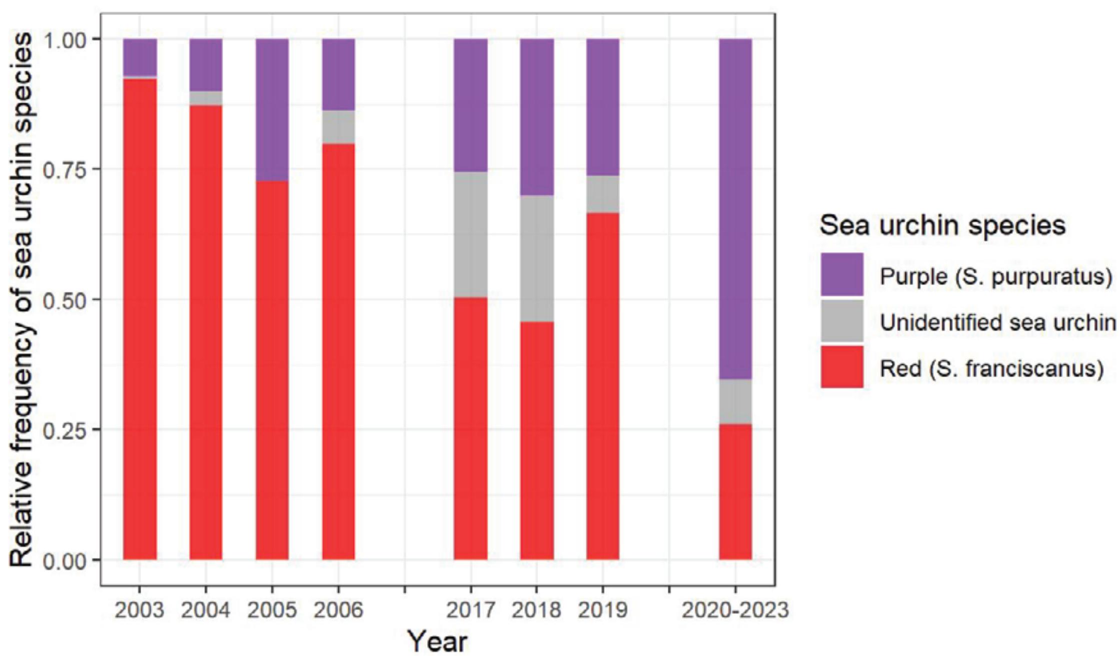

Figure 11. Relative frequency at which different species of sea urchins (*Strongylocentrotus*) were observed in sea otter diets during three periods of forage surveys at San Nicolas Island, California, 2003–2006 and 2017–2019 (years shown individually and 2020–2023 years aggregated).

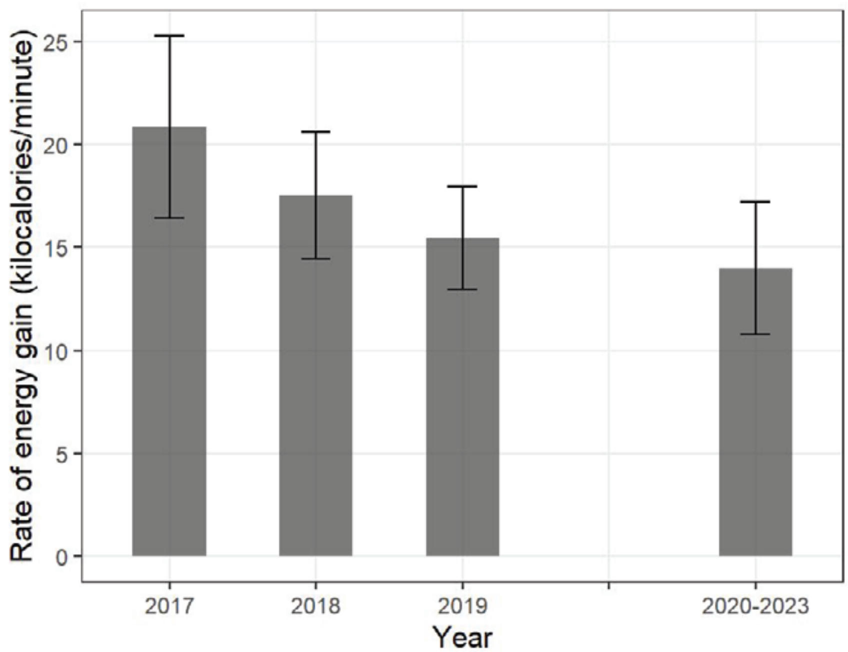

Figure 12. Rate of energy gain (kilocalories per minute with 95-percent confidence interval) for sea otters observed foraging during two periods of surveys at San Nicolas Island, California, 2017–2019 (years shown individually and 2020–2023 years aggregated).

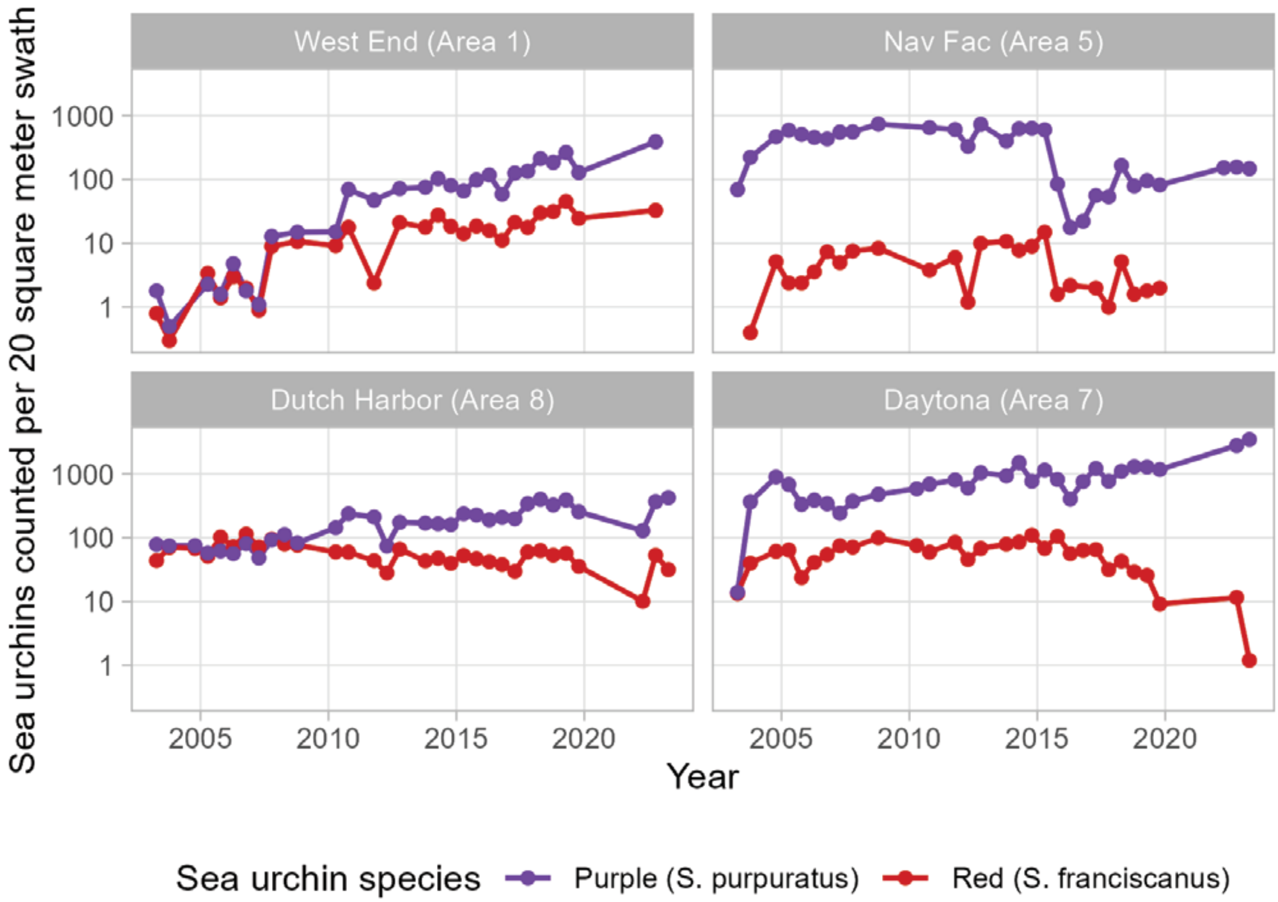

Figure 13. Trends in abundance of purple sea urchins (*Strongylocentrotus purpuratus*) and red sea urchins (*Strongylocentrotus franciscanus*; mean count per 20-square meter swath, shown on log scale) at four subtidal survey sites at San Nicolas Island, California, 2003–2023. Sites named "West End," "Nav Fac," "Dutch Harbor," and "Daytona" are described by Kenner and Tomoleoni (2021) and located in areas 1, 5, 8, and 7, respectively. Zero red sea urchins were counted in spring 2022, fall 2022, and spring 2023 subtidal surveys at the Nav Fac site and do not appear on the log-scale plot.

We examined the composition of sea urchin species, which is the most identified prey among successful sea otter foraging dives. Red sea urchins generally are larger (median diameter =53 millimeters, interquartile range [IQR; 25–75-percentile] = 41–65 mm) at SNI and thus have higher caloric value than purple sea urchins (median diameter =28 mm, IQR =21–36 mm; Kenner and Tomoleoni, 2020). Because sea otters are size-selective predators, they tend to prefer red sea urchins when larger size classes of red sea urchins are more available. As such, changes in the ratio of red to purple sea urchins consumed may correlate with prey availability. We inspected this ratio during the 2020–2023 period and compared it to ratios calculated annually from 2003 to 2006 and from 2017 to 2019 when similar sea otter foraging surveys were done at SNI. Results indicated a decreasing trend in the ratio of red to purple sea urchins consumed, detectable in 2017–2019, and pronounced by 2020–2023 (fig. 11).

Simulated estimates of energy intake rates averaged 14.0 kilocalories per minute (kcal/min; 95-percent CI =10.8–17.2) during 2020–2023. This estimated rate, slightly lower than the average rate that was previously estimated for 2019 (15.5 kcal/min; 95-percent CI =12.9–18.0), continues a declining trend of energy intake rate estimates beginning with 2017 (20.9 kcal/min; 95-percent CI =16.4–25.3; fig. 12; Yee and others, 2020); however, the confidence intervals of these estimates overlapped and did not conclusively indicate a decline. Dietary diversity trended positively from 2017 to 2018 and 2019 (Shannon-Weiner index [SWI] =0.67, 0.86 and 0.95, respectively), but this pattern of increase did not continue into 2020–2023 (SWI =0.81).

Subtidal monitoring at four sites surrounding SNI following the methods of Kenner and Tomoleoni (2021) showed variations in abundance and trends of sea urchins, by site and by species (fig. 13). Counts of red sea urchins increased by 1–2 orders of magnitude at the west end site but decreased by the same degree at the Daytona site on the east end. Because of these site differences, we did not detect an overall trend in the abundance of red sea urchins ($\chi^2_1 = 0.65, p = 0.42$). However, purple sea urchins experienced larger and more substantial increases over time ($\chi^2_1 = 31.1, p < 0.0001$) compared to red sea urchins, especially at the Daytona site in area 7 on the east end. Counts of purple sea urchins were larger than or close to those of red sea urchins across sites during the 2003–2006 period, when foraging survey results indicated that sea otters had consumed disproportionately high numbers of red sea urchins compared to purple sea urchins. However, by 2020–2023, purple sea urchins exceeded red sea urchins by 1–3 orders of magnitude across all sites, coinciding with the distributional shift of sea otters to the east end and the dietary shift toward higher relative consumption of purple sea urchins.

Discussion

Changes in the abundance and distribution of SNI sea otters were evident between 2017 and 2023. Population size grew at an estimated rate of 10 percent per year (95-percent CI =0–20 percent per year) during the 2020–2023 interval. This estimate is significantly positive but somewhat lower than the 22-percent per year rate of growth at SNI that was previously estimated for the 2017–2020 interval (95-percent CI =11–34; Yee and others, 2020) as well as those for other recovering populations in the Aleutian Islands, Alaska, British Columbia, and Washington (17.2–25.9 percent per year), which are among the maximum growth rates that can be achieved by sea otter populations (19.6–23.7 percent per year)–theorized based on the reproductive rates, ages of reproductive activity, and average lifespan of females (Estes, 1990). The sea otter survey at SNI in April 2023 yielded a count of 146 individuals (table 2). Sea otter distribution, which was formerly concentrated on the west end of the island during 2003–2006, expanded by 2019 to include more use of the north and south sides and further shifted during 2020–2023 toward a new and seasonally persistent concentration on the east end of the island. The distribution of the remaining sea otters oscillated seasonally toward more use of the north and south sides during summer and then traveled back to the west end during fall (fig. 7). Because sea otters tend to rest in surface kelp and often forage underneath among the kelp holdfasts, seasonal changes in kelp are likely to be an important driver of the seasonal variations in sea otter distributions that we observed. However, information on kelp distribution is currently (2023) limited to images collected annually in the fall. Whether or not these seasonal variations are related to changes in kelp distribution, the recent population growth, or both, might be determined by additional studies, such as increased collection and analysis of seasonal kelp patterns and an examination of historical data to determine if these seasonal changes in sea otter distributions also occurred before the recent population growth.

There were indications that energy intake from foraging activity might have slightly changed during the past several years, but fewer foraging observations collected in 2020–2023 resulted in wider and less precise confidence intervals for estimating energy intake rates. We aggregated the foraging data to estimate an energy intake rate for the period of 2020–2023, and we compared this rate to previously estimated rates for the years of 2017 through 2019 to examine potential changes. Foraging habits are known to change as sea otter populations increase and food resources become more difficult to obtain, and these density-dependent processes can signal that a population is approaching carrying capacity (Estes and others 2003; Tinker and others 2008; Tinker and others, 2012; Tinker and others, 2019). A decline in energy intake rate in conjunction with an increase in population size would be expected for a population that is beginning to experience density-dependent effects. The rate we measured (14.0 kcal/min) for 2020–2023 continued a trend of decreasing rates from 2017 through 2019 based on foraging data collected at SNI during those years, but confidence intervals overlapped too widely to statistically conclude a decline had occurred. Furthermore, these rates are close to other rates typically observed with recently established and rapidly growing populations at sites considered to have abundant resources (12–20 kcal/min; Tinker and others, 2019, fig. 28). By comparison, the intake rates for long-established and stable or slowly growing populations at sites considered to be resource-limited are estimated to be less than 10 kcal/min, which was exceeded by the 95-percent confidence interval limits for the estimates of energy intake at SNI.

The shift in urchin prey from large energy-rich red sea urchins toward smaller purple sea urchins between 2003 and 2023 indicates that a shift in the availability of the two urchin species has likely occurred. Subtidal monitoring at four sites around San Nicolas Island have shown long-term patterns in urchin counts (Kenner and Tomoleoni, 2021). The counts of purple sea urchins at these sites were consistently higher than counts of red sea urchins, sometimes by one or two orders of magnitude (fig. 13). This information, along with our findings of higher consumption of red sea urchins relative to purple sea urchins observed in foraging surveys from 2003 to 2006, is consistent with expectations that sea otters preferentially select larger red sea urchins instead of smaller purple sea urchins. However, a trend analysis of the subtidal data from 2003 to 2023 indicated a significant increase in the overall counts of purple sea urchins, whereas counts of red sea urchins remained relatively low. Additionally, from 2017 to 2019 to 2020–2023, seasonally persistent concentrations of sea otters developed at the island's east end where the highest counts of purple sea urchins were (fig. 13). It is unclear whether the dietary shift toward higher consumption of purple sea urchins is a consequence or a driver of the shift in distribution of sea otters toward the east end or how the overall increase in counts of purple sea urchins might have factored into these changes. Additional study would be needed to document if other patterns in foraging activity are changing and what the patterns might reveal about sea otter population growth and carrying capacity at SNI.

Foraging results should be interpreted cautiously because the nature of foraging surveys can introduce potential biases that do not occur with population survey counts. Survey effort at SNI prioritized counting sea otters, which occurred on days with the most optimal viewing conditions within each survey trip. Sea otters were systematically counted around the island as synchronously as possible, always within a day, to minimize detection errors due to sea otter movements. These daily surveys were repeated during multiple days each survey trip to minimize undercounting due to variable survey conditions, sea otter grouping, behavior, and detectability. The highest single-day count for each survey trip was considered a robust estimate of the population size. In contrast, foraging surveys were done opportunistically as time allowed, viewing conditions, and distance of foraging sea otter from shore. As a result, the amount of available foraging information is more limited and uneven across survey trips, locations, and individual sea otters. Because surveys during 2020–2023 were reduced by COVID-19, we aggregated foraging data to compute and compare energy intake rates by period. However, if foraging activity differs by sex or season, then those effects can potentially confound unbalanced aggregations of data when comparing other factors. Systematic biases also could exist. Foraging observations have an unavoidable bias toward prey acquired during daytime. Previous studies have shown that sea otter foraging bouts occur during day and night with equal frequency (Tinker and others, 2006). Additionally, during the 2003–2006 SNI studies, data obtained from implanted time-depth recorders indicated variation between daytime and nighttime dive characteristics that could result from sea otters seeking different prey nocturnally (Newsome and others, 2010). Furthermore, foraging observations require translation into energy intake values based on prey species and size, and unidentified items are translated into an average value for the size class. Accuracy of these translations depends on detailed and reliable information on the nutritional content of prey items, which have been documented by Oftedal and others (2007), although it remains a work in progress to update and expand these keys for different locations and periods.

Computerized simulations have demonstrated the information value of replicating seasonal surveys at SNI (Yee and others, 2020); however, the COVID-19 pandemic led to the suspension of four of the seasonal surveys that would have otherwise occurred during this reporting period. We did not find seasonal patterns in island-wide counts in either the previous (2017–2019) or current (2020–2023) periods, and the available replicate surveys were pooled to derive robust estimates of 10-percent annual growth. Current estimates of the population size average about 150 sea otters, representing a cumulative sixfold increase from counts that averaged about 25 in the early 2000s. Replicate seasonal surveys also revealed significant shifts in the spatial distribution of sea otters around SNI. From 2017 to 2023, sea otters began to aggregate in increasing concentrations on the island's east end where a boom in purple sea urchins has been observed (fig. 13; Kenner and Tomoleoni, 2021). Seasonal patterns in sea otter distribution also were significant; seasonal change in kelp distribution could be a potential driver of these shifts, but additional study would be needed to confirm this relationship.

Density-dependent processes, such as changes in sea otter foraging habits associated with changes in densities of sea otters, are known to occur for growing populations of sea otters as they deplete abundances of preferred prey resources and must increasingly compete for prey, generally indicated by reduced energy intake rates and increased dietary diversity. We did not find significant changes in the energy intake rates of foraging sea otters nor an increase in dietary diversity, but there were other signs that foraging patterns have potentially begun to change. We observed a pronounced trend from 2003 to 2023 of sea otters increasingly foraging on purple sea urchins instead of the preferred larger red sea urchins, as well as a proportionally higher consumption of bivalves in 2022 and 2023 than previously observed among sea otters at SNI. Annual subtidal surveys showed supporting evidence of an overall increase in purple sea urchins on the island's east end where sea otters now concentrate (Kenner and Tomoleoni, 2021). We also estimated slightly lower energy intake rates for 2020–2023 than estimated for the previous 3 years, continuing a pattern of decline, but the differences are small, and sample sizes were too small and confidence intervals were too wide to conclude significant change. A continuation of these monitoring efforts can provide further insights to the spatial and foraging dynamics of the growing population of sea otters at SNI and its relationship to the surrounding nearshore ecosystem.

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Appendix 1. Figures of Pages from the Monitoring and Research Plan for Southern Sea Otter Military Readiness Area

U.S. Navy and U.S. Fish and Wildlife Service
in coordination with
U.S. Geological Survey

I. INTRODUCTION

The National Defense Authorization Act for Fiscal Year 2016 (NDAA) includes provisions directing the Secretary of the Navy to establish Southern Sea Otter Military Readiness Areas (Areas) at San Nicolas Island and San Clemente Island (Figure 1). Military readiness activities[1] conducted within these Areas are subject to certain exemptions under the Endangered Species Act of 1973, as amended (ESA) and Marine Mammal Protection Act of 1972 (MMPA). Specifically, with respect to the ESA, Sections 4 and 9 do not apply to the incidental taking of any southern sea otter in the Areas in the course of conducting a military readiness activity, and any sea otter within the Areas is to be treated for the purposes of section 7 as a member of a species that is proposed to be listed as endangered or threatened under the ESA. With respect to the MMPA, Sections 101 and 102 do not apply with respect to the incidental taking of any sea otter in the Areas in the course of conducting a military readiness activity.

The NDAA also specifies monitoring requirements for these Areas:

(1) IN GENERAL.—The Secretary of the Navy shall conduct monitoring and research within the Southern Sea Otter Military Readiness Areas to determine the effects of military readiness activities on the growth or decline of the southern sea otter population and on the nearshore ecosystem. Monitoring and research parameters and methods shall be determined in consultation with the U.S. Fish and Wildlife Service (USFWS).
(2) REPORTS.—Not later than 24 months after the date of the enactment of this section and every three years thereafter, the Secretary of the Navy shall report to Congress and the public on monitoring undertaken pursuant to paragraph (1).

This document contains the research and monitoring plan for the San Nicolas Island Military Readiness Area (SNI Area). Required research and monitoring in this plan are tiered, using population status (increasing, stable, or decreasing) and changes in military readiness activities as triggers for the level of research and monitoring proposed.

Because sea otters do not yet occur at San Clemente Island and may not occur there for decades, preparation of a monitoring plan for the San Clemente Island Military Readiness Area (SCI Area) will not occur until at least three sea otters are present for at least twelve consecutive months or at least one female with a pup is detected. Marine and nearshore natural resource studies and monitoring activities currently occur in the areas around SCI to monitor for other species and habitats of concern. These studies and monitoring events will suffice to detect the presence and persistence of sea otters should they occur in the SCI Area in order to inform at what point a monitoring program under the law will be triggered. This document will be

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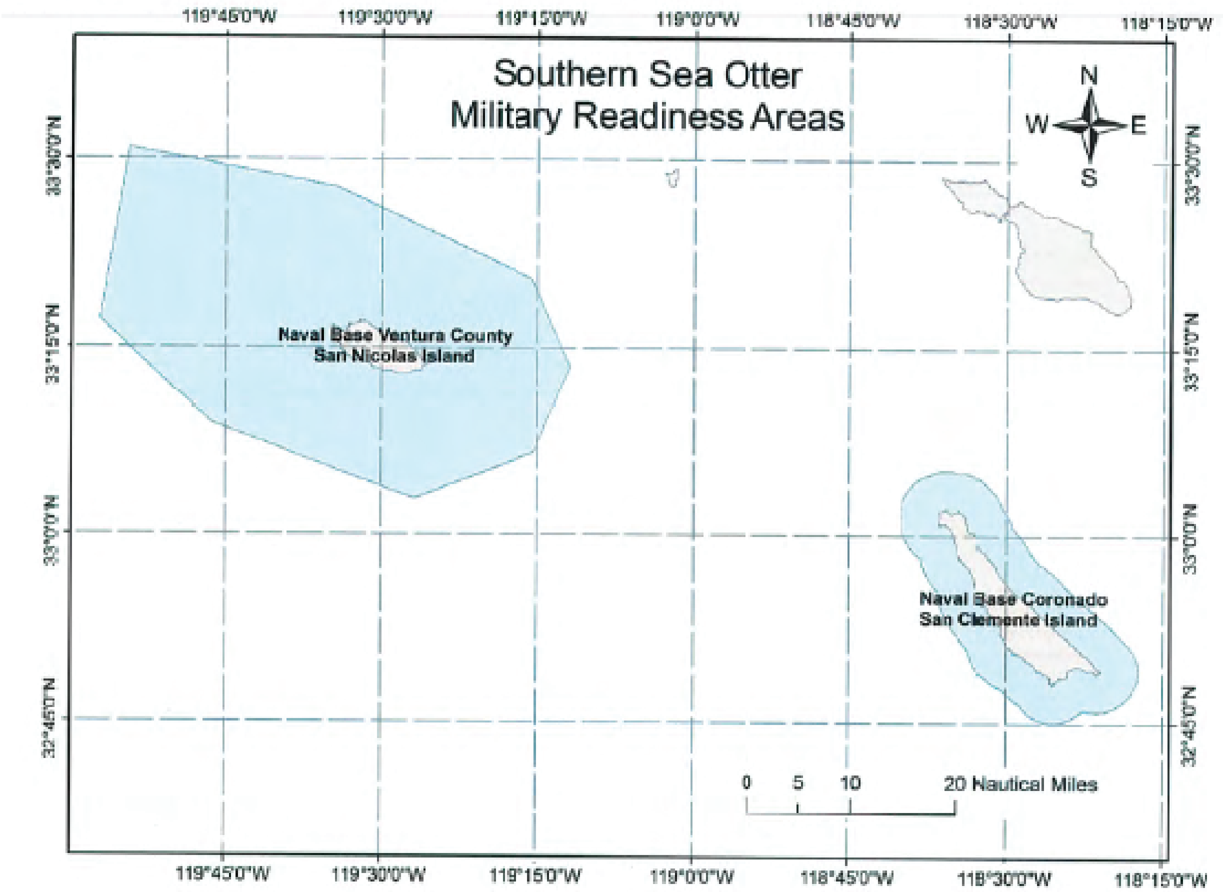
[1] According to the NDAA, "The term 'military readiness activity' has the meaning given that term in section 315(f) of the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (16 U.S.C. 703 note) and includes all training and operations of the armed forces that relate to combat and the adequate and realistic testing of military equipment, vehicles, weapons, and sensors for proper operation and suitability for combat use."

Figure 1.1. Page 1 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

Sea Otter Military Readiness Areas Monitoring Plan August 2016

reviewed by Navy and USFWS every three years after completion of reports to ensure the plan continues to adequately monitor interactions between military readiness activities and the sea otter population.

Figure 1. Southern Sea Otter Military Readiness Areas.



II. MONITORING AND RESEARCH PLAN FOR THE SNI AREA

The monitoring plan outlined below and in Figure 2 contains three tiers. The first tier is Basic Monitoring, which represents monitoring and research required given the current status of the sea otter population and currently occurring military readiness activities. Tier 1 efforts will continue as long as military readiness activities remain constant. The second tier is Operational Impact Monitoring. This higher level of monitoring would be required for any new military readiness activity[2] with a potential to impact sea otters or sea otter habitat. The third tier is Advanced

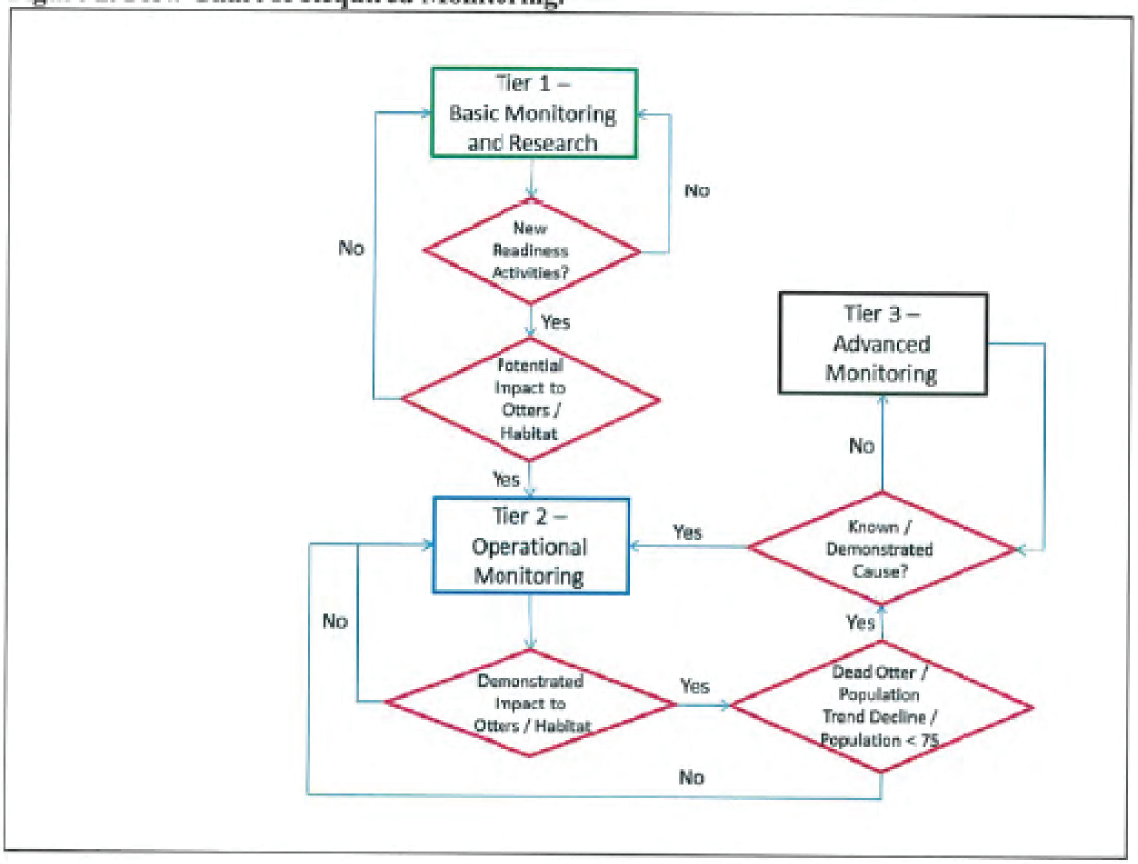
[2] For the purposes of this plan, a new activity is any activity that would require preparation of an Environmental Assessment or Environmental Impact Statement under NEPA with an area of potential effect within sea otter habitat. Existing activities are described in current NEPA documentation (Appendix 1).

Figure 1.2. Page 2 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

Sea Otter Military Readiness Areas Monitoring Plan August 2016

Monitoring, which is triggered if new military readiness activities, as described in Tier 2, are occurring and any of the following conditions is also met: (1) a single dead, moribund, or stranded sea otter with injuries consistent with impacts from the activity (as determined by an independent pathologist) is detected; (2) the sea otter population trend at SNI decreases by more than 10% from the average SNI sea otter population trend over the preceding three-year period[3] for at least two consecutive years for reasons that cannot be reasonably attributed to anticipated density-dependent reductions in growth (see Tier 1, objective 3); or (3) the total sea otter population at SNI drops below 75. If additional funding or outside partnerships allow, Tier 2 and Tier 3 monitoring may occur even if military readiness activities and sea otter population trends remain stable.

Figure 2. Flow Chart of Required Monitoring.



[3] A 10% decrease in population trend would be determined after correcting for observer or measurement error, using State-Space model analysis of the survey time series or comparable method. Using the current average annual population increase of 1.1, for example, a 10% decrease would lead to no increase in population between years (rate of 1.0).

Figure 1.3. Page 3 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

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a. **Tier 1 Basic Monitoring and Research**

1. **Objectives for Tier 1 monitoring**

The overarching monitoring goal articulated in the NDAA (to determine the effects of military readiness activities on the growth or decline of the southern sea otter population and on the nearshore ecosystem) can be split into four specific objectives that, taken together, will ensure that this broader goal is achieved. These Objectives are:

1. *Monitor and analyze population trends at San Nicolas Island.* Data on trends in sea otter abundance are necessary to assess effects of various stressors on the population. In addition to conducting regular surveys, data will be analyzed using dynamical demographic models to infer baseline population parameters (i.e., annual growth rates and environmental variability). Such data are necessary but not sufficient on their own to determine *causes* of population trends.

2. *Monitor and analyze subtidal benthic communities and assess impacts of sea otter recovery on food web dynamics.* Another core dataset necessary for evaluating impacts on nearshore ecosystem health (with respect to sea otter populations) is monitoring data on benthic subtidal communities, including trends in abundance of foundational species such as kelp and key invertebrates such as urchins and abalone. These data should be analyzed using dynamical multi-species food web models in order to interpret the interacting effects of bottom-up forces (e.g., temperature, wave events) and top-down forces (e.g., increasing predation from sea otters).

3. *Determine the factors affecting population change. Specifically, assess the relative contributions of density-dependent factors (changes in per-capita prey abundance) and density-independent factors (e.g., shark mortality, military readiness activities) to variation in growth rates.* Extensive research on sea otter populations in California has demonstrated that the most common factor leading to localized reductions in population growth is density-dependent resource limitation. The rate of growth of a local population is generally high at low population densities (as has been the case at San Nicolas over the past 20 years) but will slow as populations approach local carrying capacity. The ultimate factor limiting growth is per-capita prey abundance, although resource-limitation may be manifested as increased mortality due to disease and emaciation. Therefore, in order to assess whether some other putative threat is influencing population trends at a given location (e.g., shark bite mortality, entanglement in fishing gear, contaminant exposure, etc.), it is necessary first to account for the role of density-dependent factors. Sea otters are almost unique among marine mammals, in that it is possible to accurately infer population status from a number of easily measured indices, including behavioral parameters (foraging success, percent time feeding), individual body condition, and direct measurements of the abundance and size distribution of key prey species, such as sea urchins. By tracking these indices over time, it has been possible in central California to determine the causal role of density-dependent resource limitation in slowing population growth, and this determination should be even more feasible at San Nicolas due to the existence of better baseline data sets. Achieving this objective will be critical for making a meaningful assessment of the effects of other factors on population growth, including military readiness activities.

Figure 1.4. Page 4 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

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4. *Describe habitat use by sea otters at San Nicolas and identify habitats necessary for vulnerable life history stages and behaviors.* Sea otters typically exhibit highly localized patterns of habitat use, which can vary by activity type and by demographic group. For example, resting activity generally occurs in dense kelp canopies, though not all kelp beds are used equally, and certain kelp beds are highly preferred by certain demographic groups (sub-adult males, or females with pups). In contrast, foraging activity more typically occurs along the outer margins of kelp beds and off of emergent rocks. Furthermore, the limited home ranges of most sea otters means that habitat utilization can vary at the scale of kilometers. Understanding home range and habitat use patterns is therefore critical for determining which specific areas around San Nicolas may be most sensitive in terms of the potential for military readiness activities to affect sea otter behavior or health. For example, an area used as resting habitat by reproductive females will be far more sensitive (in terms of the potential to affect population growth) than areas used for feeding by males.

2. Proposed Study Plan for Tier 1 Monitoring

To achieve the above four objectives, a multi-faceted approach consisting of the following tasks is proposed:

Task 1, Objectives 1 and 4. Population Surveys (All Years). An effective survey program for monitoring trends in sea otter abundance at San Nicolas Island is already in place: since the late 1980s, the USGS has annually conducted between two and four island-wide exhaustive sea otter counts, which are compiled in a GIS-compliant data set on abundance and distribution (see Tinker and Hatfield 2015). Surveys are currently conducted twice per year (spring and fall) to provide key data on trends in total abundance and also distribution of sea otters around the island. The frequency of these island-wide surveys would be increased to four times per year for the next four years to provide a higher resolution data set on seasonal variation in distribution and habitat use. These surveys would also provide initial data on important habitat areas around SNI. After four years, power analysis of the existing data can be performed to determine whether reduced effort at two surveys per year will be sufficient for accurate estimation of trends and achievement of other objectives (see Tasks 2 through 4).

Task 2, Objectives 2 and 3. Ecosystem Monitoring (All Years). As with Task 1, subtidal monitoring and kelp canopy monitoring programs are already in place, with twice-annual subtidal surveys conducted by USGS for the past 35+ years (Kenner et al., 2013) and annual kelp canopy surveys conducted by the Navy. For USGS subtidal monitoring, data on the relative abundance of benthic invertebrates, kelps, and fish are collected from seven permanent subtidal sites using standardized SCUBA methods. The resulting data set represents one of the most comprehensive and long-term time series on subtidal ecosystem dynamics worldwide. It can be used to infer the effects of physical disturbance (e.g., large wave events or El Niño conditions) and food-web perturbations (e.g., the recovery of sea otters, disease outbreaks) on community structure and dynamics. For Navy kelp canopy monitoring, multi-spectral kelp canopy images are collected annually via aircraft overflight, processed to determine both surface and subsurface kelp canopy to a 30 cm resolution, and input into a GIS dataset. Subtidal monitoring surveys and kelp canopy overflights would continue at the current frequency.

Figure 1.5. Page 5 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

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Task 3, Objectives 3 and 4. Collection of Foraging Data from Untagged Sea Otters (Years 1-2). A number of key indices for determining the population status of sea otters can be assessed from observational data on sea otter feeding. As food resources become more limiting, sea otter diets become more diverse at the population level and more specialized at the individual level, and the average rate of energy gain decreases (Tinker et al., 2008(b), 2012). Two of these indices (diet diversity and rate of energy gain) can be measured using standardized methods for collecting feeding data from untagged sea otters following previously established protocols (Tinker et al., 2008(b)). Earlier studies of sea otter diet and foraging behavior (1987-93, 2004-07), can be compared with current data to determine how sea otter prey choice and foraging success have changed over the last decade. These data will provide one important step towards achieving *Objective 3* and will also allow us to collect baseline data on sea otter distribution, behavior, and habitat use (*Objective 4*). They will also be invaluable for planning future capture and tagging operations, if needed (refer to Tier 3). Foraging data collection will occur concurrently with regular surveys for distribution and abundance (*Task 1*).

Task 4. Data Integration, Analysis, and Reporting (All Years). All field data collected will be entered in a geo-referenced Access database. Population dynamics will be analyzed using published methods to model sea otter populations (Clark and Bjørnstad, 2004; Tinker, 2015; Tinker et al., 2006). Data on sea otter locations and habitat use will be analyzed in GIS using spatial tools and compared with ecosystem and habitat data. Statistical analysis may include logistical regression (habitat use vs availability), Maximum Entropy Models and General Additive Model (GAM). A series of high resolution GIS digital maps will be created to summarize all spatial data and analysis results and to facilitate identification of important habitats for sea otters (habitats most frequently used for feeding and resting).

To evaluate ecosystem-effects of sea otter populations at San Nicolas Island (*Objective 2*), an existing Ecopath mass-balance food web model for sea otters and kelp forests will be modified by combining the dietary data collected during this project and the concurrent subtidal monitoring data (see Kenner et al., 2013), and projections of food web dynamics in response to sea otter predation will be conducted using Ecopath/Ecosim. Community interaction matrix approaches will be used to analyze and forecast food web dynamics. Both approaches will allow us to estimate the range and magnitude of ecosystem services associated with the recovery of sea otters.

b. Tier 2 Operational Monitoring

1. Objective for Tier 2 Monitoring

Operational monitoring under Tier 2 would be required for any new military readiness activity with a potential to impact sea otters or sea otter habitat. At present there are no proposed new military readiness activities with potential to impact sea otters or sea otter habitat and there are no data suggesting continuing activities demonstrate significant disturbance effects. Furthermore, the existence of a measurable disturbance effect would not by itself imply an impact on population growth (indeed, the relatively rapid rate of population growth at San Nicolas Island compared to the mainland population over the past 20 years would suggest that there have been minimal or no effects of disturbance on sea otter populations to date). Rather, the benefit of examining this question would be to provide useful data on the types of disturbance that elicit a response and the contexts in which effects on behavior or energy expenditure are most likely to

Figure 1.6. Page 6 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

occur. Such information could be useful for planning purposes in future military readiness activities and for identifying potential problems before they occur.

I. *Assess the effects of disturbance on behavior and energetics.* In order to determine whether new military readiness activities have the potential to affect sea otter populations, it will be helpful to elucidate the likely mechanisms by which such an effect would occur. Specifically, certain types of activities may elicit a behavioral response (disturbance) and possibly impact individual energy expenditure (depending on the magnitude of response to the disturbance).

2. Proposed Study Plan for Tier 2 Monitoring

To achieve this objective, the following task is proposed for new military readiness activities at SNI with a potential to impact sea otters or sea otter habitat:

Task 1. Real-time Monitoring of Sea Otter Reactions. For any new military readiness activity with a potential to impact sea otter behavior, real-time monitoring of sea otter responses to the activity will occur. To detect behavioral responses and distinguish these from background levels of activity, a "Before-After-Control-Impact" (BACI) design will be used. The BACI experimental design requires sampling to be conducted at both control sites and "impact" (treatment) sites at repeated intervals before and during/after the activities in question. Behavioral sampling will be conducted using one of three methods: (1) If possible, sea otters will be monitored by Navy biologists using high-power telescopes from shore, after receiving training from USGS biologists in standardized scan-sampling methods for measuring the behavior of sea otters. Training will cover basic scan sampling protocols and the categorization of behaviors using standard sea otter ethograms. Note that direct monitoring can occur only if sea otters are present in areas visible by telescope and outside hazard patterns that preclude human presence; (2) Unmanned aerial vehicles (UAVs) may be used to observe sea otters either farther from shore or during events when hazard patterns preclude human presence. UAVs will be equipped with high-resolution video cameras that allow the observation of behavioral changes. In the case of this option, Navy personnel will work with USGS biologists to validate UAV data collection techniques via comparisons with data collected by human observers; (3) If in place, archival data logging tags described under Tier 3 monitoring would replace the previous two methods (see below).

c. <u>Tier 3 Advanced Monitoring</u>

1. Objective for Tier 3 Monitoring

Advanced monitoring would be required in the event that new military readiness activities as described in Tier 2 are occurring and any of the following conditions is also met: (1) a single dead, moribund, or stranded otter with injuries consistent with impacts from the activity (as determined by an independent pathologist) is detected; (2) the sea otter population trend at SNI decreases by more than 10% from the average trend over the preceding three-year period for at least two consecutive years for reasons that cannot be reasonably attributed to anticipated density-dependent reductions in growth (see Tier 1, objective 3); or (3) the total sea otter population at SNI drops below 75. This monitoring would focus on providing a more detailed analysis of habitat use, emigration (if occurring), and reactions to specific activities. If no substantial effect from military readiness activities on sea otter health is detected and a reason for

Figure 1.7. Page 7 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

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the declining growth trend is known (e.g., shark bite mortality or food limitation, as substantiated by other monitoring), Tier 3 monitoring would not be required.

After a second consecutive year of change by more than 10% from the current sea otter population trend following the occurrence of new military readiness activities, the Navy will secure funds as quickly as possible to initiate any advanced monitoring requirements. Advanced monitoring will begin when these new funds become available. Advanced monitoring may also benefit earlier objectives, as described, and will be supported prior to the Tier 3 trigger if additional funding or partnerships become available.

2. Proposed Study Plan for Tier 3 Monitoring

To achieve this objective, the following tasks are proposed:

Task 1. Capture, Tagging, and Sampling. In compliance with all applicable Federal laws and statues, a sample of approximately 25 sea otters at San Nicolas Island will be captured and tagged, following methods utilized for many similar studies in the past, including one conducted previously at San Nicolas Island (Tinker et al., 2008(a)). Captures are conducted by a highly experienced and uniquely trained sea otter capture team using specialized closed-circuit SCUBA methods (Ames et al., 1983). Divers swim out from small skiffs, guided by radio transmissions form the skiff operator and shore-spotters, and position underneath a potential resting sea otter. The divers then swim upwards and entrap the resting animal in a Wilson trap attached to an underwater propulsion device. The captured animals are then transported back to a support vessel for processing by a veterinary team.

All captured animals will be anaesthetized and tagged and will receive comprehensive health exams and bio-sampling. Each animal is equipped with colored flipper tags for visual identification, a surgically implanted VHF transmitter for radio tracking, and a time-depth recorder (TDR) for bio-logging of diving activity. VHF frequencies will be deconflicted with Navy working frequencies to avoid any mission impact. Analysis of morphometric data and health parameters, and comparison of these with other sub-populations in California and with previously captured animals at San Nicolas Island (2005-07), will also contribute towards accomplishing Tier 1, *Objective 3*.

Task 2. Telemetry-based Monitoring of Tagged Animals (2Years). After release, study animals will be monitored regularly (using standardized VHF telemetry protocols) by shore-based observers. This phase will continue for two years past tagging (pending support for follow-on work). Field personnel will conduct shore-based daily surveys of the study site using standard telemetric protocols (triangulation on radio signal using VHF telemetry receivers and visual identification using 50-80X Questar spotting scopes: see Tinker et al., 2006, 2008) to locate all study animals within the study area and record precise GPS position, survival, reproductive status, and instantaneous behavior. Attempts will be made to re-sight all study animals at least five times per week. A series of intensive focal-animal observation sessions will be established to collect detailed behavioral data. During these 12-hour focal animal monitoring sessions, data will be recorded at 10-minute intervals on the individual's activity state, diet, dive behavior, distance-to-shore and fine-scale movements (habitat use). Whenever study animals feed during these activity sessions, continuous data will be recorded on dive/surface intervals and prey capture rates and handling times following previously established protocols (Tinker et al., 2008(b)). The anticipated schedule of focal-animal observation sessions is two sessions per

Figure 1.8. Page 8 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

week, with a goal of obtaining three sessions for each study animal. These data, and comparisons with similar data from other populations, provide additional information for characterizing habitat use patterns (Tier 1, *Objective 4*), fcraging success and status with respect to prey resources (Tier 1, *Objective 3*), and predator-prey interactions and ecosystem impacts (Tier 1, *Objective 2*).

Task 3. TDR Retrieval and Analysis. After two years of deployment, a second capture operation will recapture previously tagged otters. Recaptured animals will undergo another surgery in order to retrieve the implanted TDR (containing two years of bio-logged diving and temperature data), and a second set of morphometric and bio-health samples will be collected. *Note that at this time a subcutaneous networking tag programmed for short-distance communications and data sharing between otters (and between otters and a buoy equipped with a data retrieval unit) would be implanted.* Data from the retrieved TDR units will be downloaded and analyzed, following established methods, in order to obtain detailed information on time-activity budgets, foraging behavior and diving depth, and reproductive parameters, thereby contributing to Tier 1, *Objectives 3 and 4*. Because the data on behavior have a high resolution (2-second interval between depth readings), it will be possible to relate changes in activity to specific events that occurred over the two-year period, thereby contributing to the Tier 2 objective of identifying reactions to specific events. Existing Navy data on operational dates and times will be used to cross-reference with TDR data.

Figure 1.9. Page 9 of Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

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IV. LITERATURE CITED

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Figure 1.10. References for Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

Appendix 1
List of Current Navy NEPA documents
San Nicolas Island

Document Title	Date	Brief Description
Environmental Assessment Directed Energy Test Facilities at San Nicolas Island	2015 Jun	Directed Energy test facility construction and operations
Environmental Assessment/Overseas Environmental Assessment Point Mugu Sea Range Expansion of Unmanned Systems Operations	2015 Feb	Increased use of both unmanned aerial vehicles and unmanned surface vehicles on the Sea Range
Environmental Assessment Point Mugu Sea Range Countermeasures	2014 Jul	Use of various countermeasures, including guns, directed energy, chaff, flares, and others on the Sea Range
Final Environmental Assessment for Obtaining California Sea Lions for Service in the Navy Marine Mammal Program	2012 Dec	Collection of live sea lions from San Nicolas Island
Final Environmental Assessment/Overseas Environmental Assessment Laser Testing and Training Naval Air Warfare Center Weapons Division Sea Range, Point Mugu, California	2010 Jun	Testing and training with lasers at Point Mugu and San Nicolas Island
Final Environmental Assessment SSM-1 KAI Missile Testing at San Nicolas Island	2007 Mar	Testing and training with Japanese Defense Forces missile system
Environmental Assessment FOCUS Cable Repair – San Nicolas Island, CA	2003 Sep	Repair of undersea fiber optic cable
Arrow System Improvement Program Environmental Assessment	2003 Nov	Testing and training with Israeli Defense Forces missile system
Final Environmental Impact Statement/Overseas Environmental Impact Statement Point Mugu Sea Range	2002 March	Programmatic coverage for Sea Range testing and training activities
Construction and Operation of a Supply Pier on San Nicolas Island	2002 Sep	Pier constructions at San Nicolas Island
Final Environmental Assessment/Overseas Environmental Assessment Harpoon BLOCK II Development Test 2 on the Point Mugu Sea Range	2001 Dec	Testing and training with Harpoon missile systems on Sea Range
Addendum to the EA for Tomahawk Flight Test Operations on the West Coast of the United States	2000 Nov	Addition of a soft-landing area on San Nicolas Island for Tomahawk missile system testing and training.
Final Environmental Assessment - Tomahawk Flight Test Operations on the	1998 Oct	Testing and training with Tomahawk missile systems on

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Figure 1.11. Page A-1 of appendix 1 for Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

Document Title	Date	Brief Description
West Coast of the United States		the Sea Range
Environmental Assessment Non-warhead Standoff Land Attack Missile (SLAM) Expanded Response (ER) Developmental Test & Evaluation Firings San Nicolas Island, Ventura County, California	1997 Oct	Construction and operation of an inert (non-warhead) target site on San Nicolas Island
Environmental Assessment of the Use of the Outer Sea Test Range for the Shock Trial of The DDG 53	1994 Apr	Shock trial for a specific Navy Destroyer
Environmental Assessment, Fiber Optic Communication Undersea System (Focus)	1989 Mar	Installation of an undersea fiber optic cable between Point Mugu and San Nicolas Island

Figure 1.12. Page A-2 of appendix 1 for Monitoring and Research Plan for Southern Sea Otter Military Readiness Area.

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