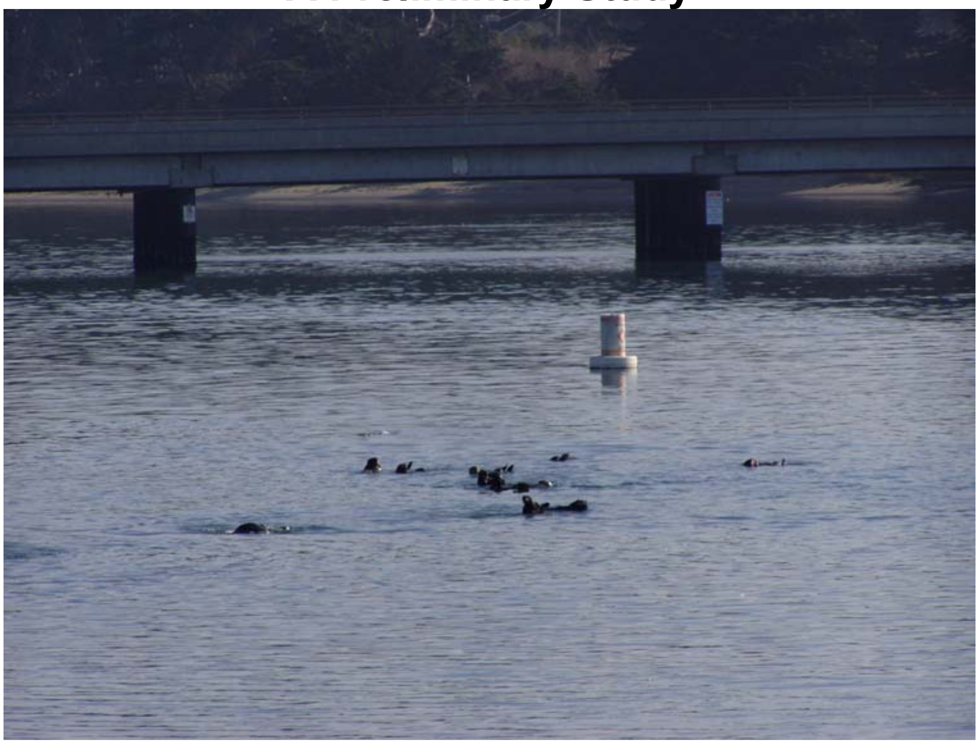
The effect of the Moss Landing Power Plant thermal discharge plume on sea otter behavior and distribution

A Preliminary Study



A report submitted to the Monterey Bay National Marine Sanctuary
Sanctuary Integrated Monitoring Network (SIMoN)
and
Monterey Bay Sanctuary Foundation

March 15, 2006

Gena B. Bentall, M. Tim Tinker
Department Of Ecology and Evolutionary Biology
University of California Santa Cruz
Santa Cruz, CA 95060

Table of Contents

List of Tables

List of Figures

The effect of the Moss Landing Power Plant thermal discharge plume on sea otter behavior and distribution: A preliminary study

Gena B. Bentall, M. Tim Tinker

Introduction

The Monterey Bay National Marine Sanctuary (MBNMS), which stretches from Marin County to Cambria, includes all coastal marine waters extending out an average of 50 kilometers from shore, and also includes some estuarine habitat. In particular, Elkhorn Slough, a large estuary adjacent to the town of Moss Landing, represents a unique and valuable natural resource within MBNMS. A recent upgrade to the cooling system of the Moss Landing Power Plant (MLPP), currently owned and operated by Duke Energy North America, required permits from the MBNMS and other agencies. The MBNMS is interested in determining the effects, if any, of the modified thermal discharge plume on surrounding marine organisms and their associated habitats. In 2003 researchers at Moss Landing Marine Laboratories (MLML) initiated a project funded by the Sanctuary Integrated Monitoring Network (SIMoN) to provide the first quantitative evaluation of the ecosystem impacts of thermal discharge into Monterey Bay from MLPP. Although the MLML study is ongoing, field observers noted the presence of sea otters at the thermal plume. However, the sampling design of the initial study did not include otter-related observations and analyses, and so further investigation of these observations was deemed necessary.

The southern sea otter (*Enhydra lutris nereis*) is a federally listed Threatened species that ranges from approximately Half Moon Bay in the north to just south of Point Conception, California. Subsequent to its near extirpation by the maritime fur trade in the 18th and 19th centuries, the southern sea otter has recovered at a rate well below what has been seen in other recovering sea otter populations (Estes et al. 2003a). This slow population growth has been attributed to high levels of mortality, primarily due to disease (Kreuder et al. 2003, Jessup et al. 2004), but other factors including depletion of preferred prey items in high density regions may also be important (Estes et al. 2003a). Due to their high metabolic requirements (Costa 1978), sea otters are known to be strongly affected by the abundance and quality of their prey, principally benthic invertebrates (Estes and Palmisano 1974). As sea otter densities increase within a region, preferred prey such as urchins, abalone and large *Cancer* spp. crabs become depleted, forcing otters to turn to other, less energetically profitable prey to meet their caloric demands (Estes 1990). There is increasing evidence that sea otters respond to this reduction in food availability by increasing individual diet specialization, resulting in the development of alternative foraging strategies (Estes et al. 2003b, Tinker 2004). Sea otters in the high-density range center regions (including the Moss Landing area) have been shown to be foraging specialists, with individual otters specializing in a small subset of the population level diet. As a result of this diversification, the diet composition of certain types of specialists may include higher frequencies of filter-feeding invertebrates such as mussels, clams and worms, species known to be bio-accumulators of both disease pathogens (bacteria, viruses, protozoal parasites) and anthropogenic contaminants (Jessup et al. 2004, Kannan et al. 2004, Conrad et al. 2005).

Pathological examination of beach stranded sea otter carcasses has revealed infectious disease, in particular a suite of parasitic diseases, to be a primary cause of mortality (Kreuder et al. 2003, Jessup et al. 2004). Elevated levels of contaminants have been detected in sea otter tissues and they are additionally affected by bacterial and viral pathogens (Jessup et al. 2004, Kannan et al. 2004). The exact mechanism of infection has yet to be definitively determined, but many of these pathogens have been found to accumulate in the tissues of filter-feeding invertebrates, in particular mussels (*Mytilus* and *Modiolus* spp.) (Jessup et al. 2004, Conrad et al. 2005).

Previous studies have named Moss Landing among several “high-risk” sites for parasitic (in particular, protozoal-related) infection and mortality (Kreuder et al. 2003, Conrad et al. 2005). It is possible that sea otters in the Moss Landing region are acquiring these parasites through their consumption of bio-accumulating invertebrates and, thus, monitoring the quality and consumption of these prey species may be of interest in understanding the links between diet and parasitic infectious disease. In 2005, there was an increase in the number of individual sea otters utilizing the area inside and immediately outside the Moss Landing Harbor/ Elkhorn Slough area (Figure 1), with resting group sizes of 20 to 45 animals regularly observed. The foraging efforts of this group appear to have been concentrated mostly within the harbor and estuary, but it is likely that, as prey become depleted, they will expand their foraging efforts to include the region outside the harbor mouth where the MLPP thermal discharge plume is located. While no recent surveys have been conducted of the invertebrates on and around the discharge structure, observational evidence indicates that abundant invertebrates, including mussels, have colonized the hard surface (P. Raimondi, personal communication). Sea otters discovering this food source might be expected to exploit these potential prey species, particularly those individuals that already specialize on mussels, with the result that the plume could impact their behavior and movements. In accordance with the goal of the MBNMS to determine the effect, if any, of the MLPP thermal discharge plume on surrounding marine organisms, our preliminary study included the following objectives:

1. Determine if any spatial bias exists with regards to the distribution of sea otters outside of Moss Landing Harbor, such that they disproportionately utilize the area of the thermal plume from the MLPP.
2. Document the behavior of sea otters occurring within the plume area (PL) and compare with behavior of otters in nearby non-plume areas (NPs).
3. Document the diet of any sea otters feeding within the PL and compare with the diet of otters feeding in NPs.

Methods:

<u>Study site:</u>

Observational data on sea otter distribution and behavior in and adjacent to the Moss Landing thermal plume were collected from the balcony of the

Monterey Bay Aquarium Research Institute (MBARI) building (Figure 2). The outflow from the thermal plume creates substantial turbulence which can clearly be observed from the MBARI location. Our comparative experimental approach (i.e. contrasting the plume area, or PL, with control non-plume areas, or NPs) necessitated the designation of one PL site and two NP sites, NP 1 being the southernmost site and the farthest from the harbor mouth and NP 2 being the northernmost site, nearest the harbor mouth. Each of these sites was designated as a circular patch of sea surface approximately 65 m in diameter. In order to avoid confounding effects due to differences in bottom habitat structure or bathymetric features, we selected NP sites that were at an equivalent depth to the PL site and at 100 m to the north and south (Figure 2). The three sites ranged between 150 and 250 meters from the shoreline. Designated sites were close enough to each other to ensure similar habitat types yet sufficiently distant to ensure that otters feeding within a NP site could not possibly be diving to capture prey from the plume outflow. The presence of the large, dynamic group of sea otters inside the Moss Landing Harbor could potentially create biases associated with the proximity of the harbor mouth to the group's resting area and the tendency of some otters to feed on prey inhabiting the artificial rocky substrate of the jetty. By choosing one NP site to the north and one NP site to the south, we controlled for these potentially confounding effects. Assessments of distances between sites, bathymetry and proximity to the harbor mouth were confirmed and adjusted using ArcView 3.2.

Testing for Spatial Bias in Sea Otter Distribution

Data collection sessions were conducted by two field personnel between November 3 and January, 2005 for a total of 22 scan days. Each session lasted approximately two hours, and the time of day for each session was randomized to avoid any bias associated with diurnal patterns, and all daylight hours were represented approximately evenly in the final data set. Observations were conducted from shore using high-powered Questar telescopes (50-80x magnification; Questar Corp., Isanti, MN). The observers first identified the PL site (based on visual assessment of surface turbulence), and then used compass bearings in conjunction with laser range finders to identify the two NP sites, based on distance and direction from the observation point. For the first hour of each session, instantaneous scan sampling of sea otter distribution and abundance was conducted (Altmann, 1974). Scans were conducted as follows: one minute scan of NP 1, followed by a one minute scan of PL, followed by a one minute scan of NP 2. In each one minute scan, all sea otters present within the sites were recorded. This sequence was repeated 15x over a one hour period. After the 1 hour scan session, a second hour was spent collecting foraging and telemetry-based data (see below).

For each independent sea otter observed during the shore-based scans, the following information was documented:

- Activity/ Behavior
- Time of Day

- Age-class, sex, ID tag (if present) and reproductive status (pup/no pup), whenever possible

Behavior was categorized hierarchically: first as active or inactive, then further designated using an ethogram of nine descriptive behavior categories (Gelatt et al. 2002). Prior to analysis, behaviors were condensed to four broad categories in order to achieve suitable sample sizes: feeding, swimming, resting (inactive), or other active (all other active behaviors).

Foraging Behavior

Foraging data were collected by methods identical to those currently in use in all California sea otter studies (Estes et al. 2003b, Tinker 2004, Tinker et al. 2004). After a scan session was completed, a single foraging otter was selected arbitrarily from within the PL site for collection of detailed foraging/diet data (if there was at least one foraging otter available). A second foraging otter was selected arbitrarily from within one of the two NP sites, again conditioned upon at least one subject being available. For both of the two selected focal otters, we used the Questar telescope and collected the following data:

- Start and finish time of data collection
- Precise location (using GPS)
- Sub-surface and surface time intervals for each dive
- Prey identification (to lowest possible taxon) for each dive
- Number of prey items captured per dive
- Prey size estimate (maximum linear dimension), per prey item, per dive

These foraging parameters were recorded for each focal otter for a 30 minute time period (designated as a feeding bout). In cases where a 30 minute bout was not possible, we attempted to record a minimum of 10 consecutive feeding dives.

Supplementary data: Individual trends

The data collection protocols described above provided cross-sectional data on sea otter habitat use, behavior and diet in the PL and NP areas. However, because there were known to be tagged otters in the vicinity of Moss Landing, we took the opportunity to collect longitudinal data from these marked individuals, with the view that such longitudinal data collected over the entire study period might provide further insight into individual patterns of habitat use related to the thermal plume. Accordingly, after the scans and foraging data collection were completed each day, we visually searched the entire vicinity of the plume area for marked individuals: telemetry equipment was also used to detect otters implanted with VHF radio transmitters (Tinker et al. 2004). Additionally, any tagged otters that were observed during scan or foraging sessions were noted. For any tagged otters that were detected, we recorded precise location (using compass, range finder and GPS) and behavior, following established protocols.

Data Analysis

Resulting data were compiled into a Microsoft Access database form prior to analysis. Categorical variables relevant to each recorded observation, or “fix”, were location (PL, NP 1 and NP 2), time of day (TOD), tide height and behavior. Time of day was designated as AM for scan sessions completed before 12:00

noon, and as PM for scan sessions begun after 12:00 noon. Tide height data (in feet) corresponding to the hour of each scan session were collapsed into arbitrarily determined categories: tides ≤ 3 feet were designated as L (low) and tides > 3 feet were designated as H (high). Plume vs. non-plume areas were tested for differences in sea otter utilization (i.e. number of fixes) using Pearson chi-square statistics. In order to account for the confounding effect of site proximity to the harbor mouth, an additional chi-square test was conducted based on the expectation that frequency of observations should be negatively related to the distance to the harbor mouth. This was accomplished by fitting a simple linear model to the relative frequency of fixes at the three sites using distance to harbor mouth as a predictor variable, and then using this model to generate the expected number of hits (Table 1). The relative frequency of fixes were further analyzed by cross classifying location (PL, NP 1, NP 2) with the categorical variables tide height and TOD using two way contingency tables.

For each foraging bout, we simultaneously contrasted all recorded feeding behavior parameters – dive success rate, dive time/surface time, proportion of prey types, abundance and size class – between the PL and the NPs using multivariate discriminant analysis, to determine whether feeding behavior differs between the sites overall and to identify the key parameters that define such differences. We then used two way contingency tables to test for variation in diet composition (i.e. differences in the relative frequency with which prey types were observed) between PL and NP areas. Prey types were condensed into five comprehensive classes for analysis.

The Type I error rate (α) was set to 0.05 for all statistical tests and, in the case of non-significant results, power analysis was used to determine if the given sample size was sufficient to detect a “large effect” (*sensu* Cohen 1988).

Results

Spatial Bias

There was a significant effect of location on the frequency of observations of sea otters in the three study sites ($\chi^2 = 6.89$, df = 2, p = 0.03). Elimination of the site with the greatest mean deviation (NP 1) from the analysis indicated that this result was primarily driven by the infrequency of observations in NP 1, the site most distant from the harbor mouth (Figure 3). When a chi-square test was conducted using linear distance from harbor mouth as a co-variate, the deviation of frequencies from expected was no longer significant (Table 1). After controlling for the effect of site variation, there was a marginally significant effect of time of day ($\chi^2 = 5.0$, df = 2, p = 0.08) (Figure 4), with more otters observed at all three sites during morning (AM) hours. Tide was not a significant predictor of activity overall ($\chi^2 = 2.78$, df = 2, p = 0.25, power = 0.30) although two of the sites (PL and NP2) did show a tendency towards greater utilization at high tide (Figure 5).

Behavior results

Of the behaviors recorded during scan sessions, 95% were active with feeding being the most frequently observed overall (Figure 6). The results of the two-way contingency table showed no significant association between site and behavior category ($\chi^2 = 5.9$, df = 4, p = 0.21, power = 0.48).

Individual data

Sightings of tagged individual sea otters in the vicinity of the PL and NP sites were extremely rare. On two occasions, marked male sea otters were observed swimming and feeding near the north jetty (Figure 2). Both male otters had been tagged and monitored regularly by the Monterey Bay Aquarium Sea Otter Research and Conservation (SORAC) staff but no longitudinal data relevant to their use of the plume area were obtained during this study.

Foraging Behavior

Twelve foraging bouts (six PL, six NP) were collected for a total of 114 known outcome foraging dives. Foraging bouts for which <10 dives had been recorded were excluded, leaving ten bouts for analysis. Seven different prey types were recorded (Figure 7), with six out of seven occurring in both PL and NP sites. In the nine bouts where the sex of the foraging otter could be identified, the sex was determined to be male (six sub-adults, three adults). No female otter was identified in any of the sites for the duration of the study.

Discriminant analysis resulted in poor performance at correctly classifying foraging bouts into plume and non-plume site categories (Wilks' lambda = 0.293, F-ratio = 0.301, df = 8, p = 0.894). A jack knifed re-sampling of the data correctly classified bouts as NP 40% of the time and PL only 20% of the time. Success was improved by limiting the analysis to sub-surface time, surface time and mean number of prey items (jack knifed classifications correct 80% of the time, Table 2). This analysis suggested that animals feeding at the plume had longer dives and post-dive surface times, during which they handled and consumed relatively more prey items than at non-plume areas.

There was a significant relationship between site and diet composition, as measured by the relative frequency of four main prey classes: mussels, non-mussel bivalves (clams), decapods (*Cancer* crabs) and worms ($\chi 2 = 8.8$, df = 3, p = 0.03). However, the worm prey class (in this case, entirely *Urechis* sp., or fat innkeeper worms) was only recorded during a single bout, and when worms were excluded from the analysis the difference in diet composition was no longer significant (worm prey class excluded: $\chi^2 = 3.05$, df = 2, p = 0.21). We caution that these results are somewhat equivocal, as the foraging sample size we were able to obtain for this study was small and Chi-square power analysis indicated that the statistical power of this test to detect a significant effect was 22%.

Discussion

The results of this preliminary study provide evidence that sea otters are using the area within and immediately surrounding the Moss Landing power plant thermal plume in a non-random fashion. However, the infrequent observations of sea otters within the non-plume control site 1, the site most distant from the harbor mouth, was the primary driver of this effect, and we were unable to reject the alternate hypothesis that the observed habitat-use differences simply reflected a decreasing level of utilization as distance from the harbor mouth (and thus distance from the main resting location) increased. In particular, it appears that sea otters tend to emerge from the harbor mouth during feeding bouts, and preferentially feed near the rocky jetties, which likely represent favorable habitat for many of their invertebrate prey. The location of the plume relative to the harbor mouth will render problematic any attempt to distinguish any preference effect specific to the plume from the effect due to proximity to the rocky jetties. Indeed, the closeness of the jetty foraging areas to the plume may increase the probability that foragers discover the plume structure as a feeding patch.

Sea otter behavior, and in particular feeding behavior, was generally similar between plume and non-plume areas, although there was some indication that sea otters have slightly longer dives and collect more prey items per dive (on average) within the plume area. This trend might reflect differences in the types of prey collected in the plume area: while the limited sample size precluded a rigorous testing of diet differences between plume and non-plume sites, visual examination of the raw data suggest that some variation in diet does indeed exist between the site types. Plume foragers had a slightly higher frequency of occurrence of prey types associated with hard substrates, such as mussels and *Cancer* crab species, while non-plume foragers fed more commonly on soft-bottom species, including clams and, in one case, fat innkeeper worms. The hard substrate provided by the plume structure, as well as the discharge flow (Duke Energy 2000) likely provides favorable habitat for hard-bottom prey species within a soft-bottom (sandy) habitat. Tagged sea otters feeding within the Moss Landing Harbor and Elkhorn Slough areas have been observed feeding on a high proportion of mussels relative to other prey types (Figure 8). As individual sea otters are known to specialize in small subsets of the comprehensive population diet (Estes 2003, Tinker 2004) it is possible that the proximity of the plume to the harbor allowed otters specializing in the acquisition and handling of mussels and other hard-substrate species to “discover” the somewhat isolated plume-dependent habitat and begin exploiting this resource. Thermal discharge from electric-generating stations in Seal Beach, CA have been shown to attract aggregations of the stingrays (Hoisington and Lowe 2005), with warm water zones hypothesized to be approximating the ray’s disappearing estuarine habitat. In the case of the MLPP thermal plume, the hard substrate of the structure in combination with increased temperature and turbulence may approximate a rocky intertidal habitat favored by some sea otter specialists.

The detection of significant differences in diet composition and behavior between the plume and surrounding areas will likely require a more comprehensive study. The incorporation of seasonality and the fluctuating abundances of both sea otters and prey in the region will potentially have profound effects on foraging observations. As indicated by the power analysis, a larger sample of foraging bouts is necessary to increase the probability of detecting an effect. The opportunistic nature of the collection of foraging data often necessitates data collection over comparatively extended time periods in order to obtain a comprehensive sample.

Long-term changes in the distribution of sea otters in the Moss Landing area will likely affect the outcome of any further study. The complete absence of females across all observations is not surprising considering the characteristically male composition of the dynamic group currently occupying the Moss Landing

Harbor. Similar “male groups” occur sporadically within the southern sea otter range, most predictably at range fronts, and are known to vary in size from year to year or even season to season (Jameson 1989). The abundance of sea otters in the harbor has fluctuated dramatically over the last five years (Figure 1), and it is likely that the size and composition of this group will be tightly linked to the number of sea otters observed in the general vicinity of the plume (PL and NP sites included).

If indeed sea otters are feeding preferentially in the thermal plume, and on different prey types, what are the implications? The answer is likely dependent on the quality of the prey being consumed. Mussel species are known bio-accumulators of contaminants and pathogens known to infect sea otters (Fayer et al. 2004, Jessup et al. 2004, Conrad et al. 2005), however, links have yet to be made between prey specializations and susceptibility and virulence of these diseases. If mussels associated with the plume structure were found to be carrying a higher contaminant load than mussels from the nearby jetties, otters feeding in the plume may have a higher risk of exposure. The small spatial scale of the plume region would likely limit such a risk to an individual rather than a population-level issue.

Any effect of the MLPP thermal discharge plume on sea otter behavior, movement and/or health is tightly linked to the effect of the discharge and the discharge structure on the invertebrate species on which the sea otters feed. There has been no recent monitoring of either the benthic invertebrates adjacent to the plume or species colonizing the discharge structure and, as such, little is known of the species composition, or the effect of the thermal plume on invertebrate growth and physiology. Research conducted beyond the scope of this preliminary study should necessarily focus not only on a more comprehensive understanding of the effect of the plume on sea otter foraging behavior but, additionally, on the quality of the invertebrate prey colonizing the plume.

Acknowledgements

This work was supported by a contract from the Monterey Bay Sanctuary Foundation through the Sanctuary Integrated Monitoring Network (SIMoN) program. The Santa Cruz field station of the USGS- Biological Resources Division provided equipment for the field portion of this study. The authors wish to thank to Alisha Kage for her assistance with data collection and experimental design. Steve Lonhart and Pete Raimondi were helpful in providing background information regarding the history of the thermal plume and Pete additionally provided statistical suggestions.

Literature Cited

Altmann, J. (1974) Observational study of behaviour: sampling methods. Behaviour, 49, 227-267.

Cohen, J. 1988. Statistical power analysis for behavioral sciences (2nd ed.) Hillsdale, NJ: Lawrence Earlbaum Associates.

Conrad, P. A., M.A. Miller, C. Kreuder, E.R. James, J. Mazet, H. Dabritz, D.A. Jessup, Frances Gulland, M.E. Grigg. 2005. Transmission of *Toxoplasma*: Clues from the study of sea otters as sentinels of *Toxoplasma gondii* flow in the marine environment. International Journal for Parasitology 35:1155-1168.

Costa, D. P. 1978. The ecological energetics, water and electrolyte balance of the California sea otter (*Enhydra lutris*). Ph.D dissertation. University of California, Santa Cruz, Santa Cruz, CA.

Duke Energy Moss Landing, LLC. 2000. Moss Landing Power Plant modernization project: Evaluation of proposed discharge system with respect to the thermal plan, Final Report.

Estes J. A., B. B. Hatfield, K. Ralls, J. Ames. 2003a. Causes of mortality in California sea otters during periods of population growth and decline. Marine Mammal Science 19(1):198-216.

Estes J. A., Riedman M. L., Staedler M. M., Tinker M. T., Lyon B. E. 2003b. Individual variation in prey selection by sea otters: patterns, causes and implications. Journal of Animal Ecology 72:144-155.

Estes, J. A. 1990. Growth and Equilibrium in Sea Otter Populations. Journal of Animal Ecology. 59: 385-401.

Estes, J. A., J. F. Palmisano. 1974. Sea otters: their role in structuring near-shore communities. Science 185:1058-1060.

Fayer, R., J.P. Dubey, D.S. Lindsey. 2004. Zoonotic protozoa: From land to sea. Trends in Parasitology. 20:531-536.

Gelatt, T. S., D. B. Siniff, J. A. Estes. 2002. Activity patterns and time budgets of the declining sea otter population at Amchitka Island, Alaska. J. Wildl. Manage 66(1):29-39.

Hoisington, G., C. G. Lowe. 2005. Abundance and distribution of the round stingray, *Urobatis halleri*, near a heated effluent outfall. Marine Environmental Research 60:437-453.

Jameson, R. J. 1989. Movements, home range and territories of male sea otters off central California, USA. Marine Mammal Science 5:159-172.

Jessup, D. A., M. Miller, J. Ames, M. Harris, C. Kreuder, P. A. Conrad, J. A. K. Mazet. 2004. Southern sea otter as a sentinel of marine ecosystem health. EcoHealth 1: 239-245.

Kannan, K., N. Kajiwara, M. Watanabe, H. Nakata, N.J. Thomas, M. Stephenson, D.A. Jessup, S. Tanabe. 2004. Profiles of polychlorinated biphenyl congeners, organochlorine pesticides, and butyltins in southern sea otters and their prey. Environmental Toxicology and Chemistry. 23(1):49-56.

Kreuder, C. M., M. A. Miller, L. J. Lowenstine, M. D. Harris, T. E. Carpenter, P. A. Conrad, D. Jessup, J. K. Mazet. 2003. Recent causes of mortality in southern sea otters (*Enhydra lutris nereis*). Journal of Wildlife Disease. 39:495-509.

Reidman, M. L. and Estes J. A. 1990. The sea otter (*Enhydra lutris*): Behavior, ecology and natural history. U. S. Department of the Interior Fish and Wildlife Service Biological Report 90(14).

Tinker, M. T. 2004. Sources or variation in the foraging and demography of the sea otter, *Enhydra lutris.* PhD dissertation, University of California, Santa Cruz, Santa Cruz, CA

Tinker, M. T., D. P. Costa, D. H. Monson, Y. Tremblay, K. Ralls, J. A. Estes. 2004. Dive behavior and activity budgets in the southern sea otter. Chapter 6 *in* M. T. Tinker, J. A. Estes, K. Ralls, T. M. Williams, D. Jessup, D. B. Costa, eds. Population dynamics and biology of the California sea otter (*Enhydra lutris nereis*) at the southern end of its range. A report prepared for the Minerals Management Service.

Tables

Table 1 Observed and expected counts of sea otters in the three plume-related sites. Counts represent totals of all observational "hits" for the 22 one-hour scan sessions.

	NonPlume 1	NonPlume 2	Plume	Total
Observed	27	45	49	121
Expected (no bias)	40	40	40	
Pearson's χ^2 statistic	$\chi^2 = 2.8$, df = 2, $p = 0.24$			
Expected (harbor mouth bias)	30	40	50	
Pearson's χ^2 statistic	$\chi^2 = 6.9$, df = 2, $p = 0.03$			

Table 2 Summary of Discriminant Analysis results

Canonical Discriminant Functions

	Raw coefficient	Standardized coefficient
	Function 1	Function 1
Constant	-11.4647902	
Mean Sub-surface (Dive) Interval	0.0720578	1.5682645
Mean Surface Interval	-0.078332	-2.4756406
Mean Number of Prey Items	9.8472543	1.8665064

Classification Functions

	Non-Plume	Plume
Constant	-55.8421218	-91.8642121
Mean Sub-surface (Dive) Interval	0.6089367	0.8353406
Mean Surface Interval	-0.7695187	-1.015636
Mean Number of Prey Items	114.3953656	145.3351977

Classification Matrix

	Non-Plume	Plume	% correct
Non-Plume	5	0	100
Plume	1	4	80
total	6	4	90

Jack knifed Classification Matrix

	Non-Plume	Plume	% correct
Non-Plume	4	1	80
Plume	1	4	80
total	5	5	80

Wilks' Lambda= 0.245

Approx. F= 6.17 df = 3 p = 0.029

Eigenvalues = 3.085

Canonical correlations = 0.869

Figures

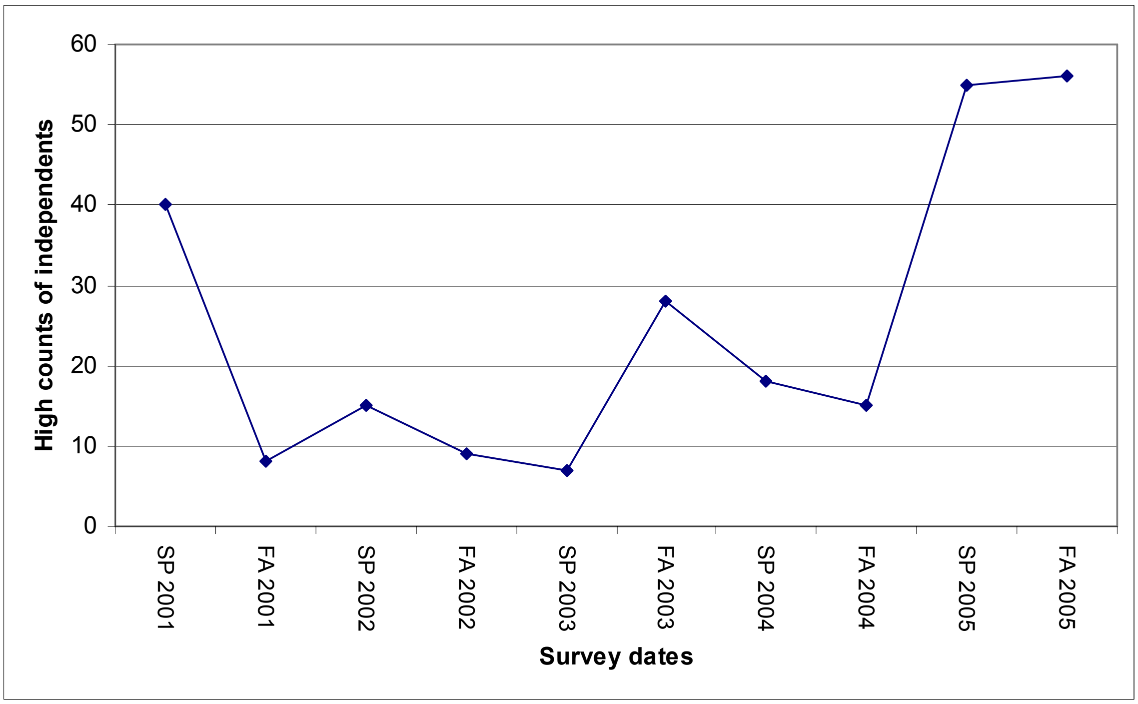


Figure 1 High counts of independent sea otters within Moss Landing Harbor and Elkhorn Slough from 2001-2005. SP = spring survey, FA = fall survey. Courtesy Brian Hatfield, USGS California biannual sea otter census.

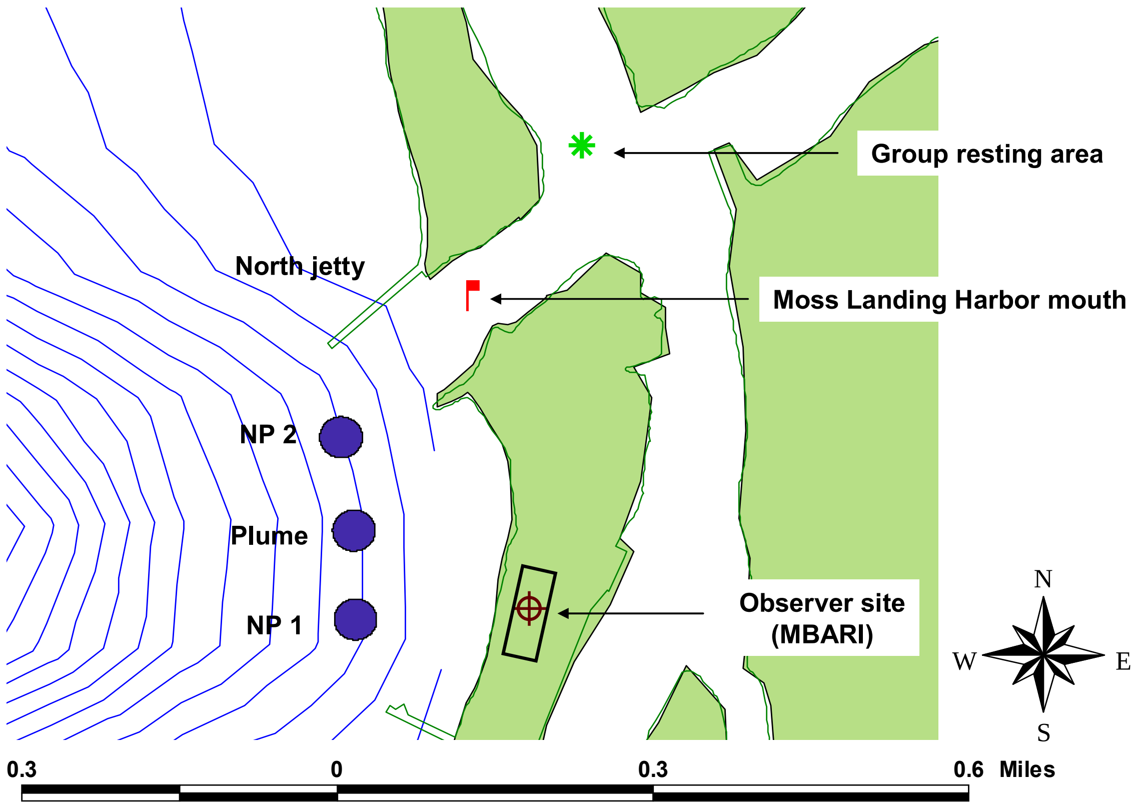


Figure 2 Map of the region of study indicating the location of the three plume-related sites relative to the observer site and the Moss Landing Harbor.

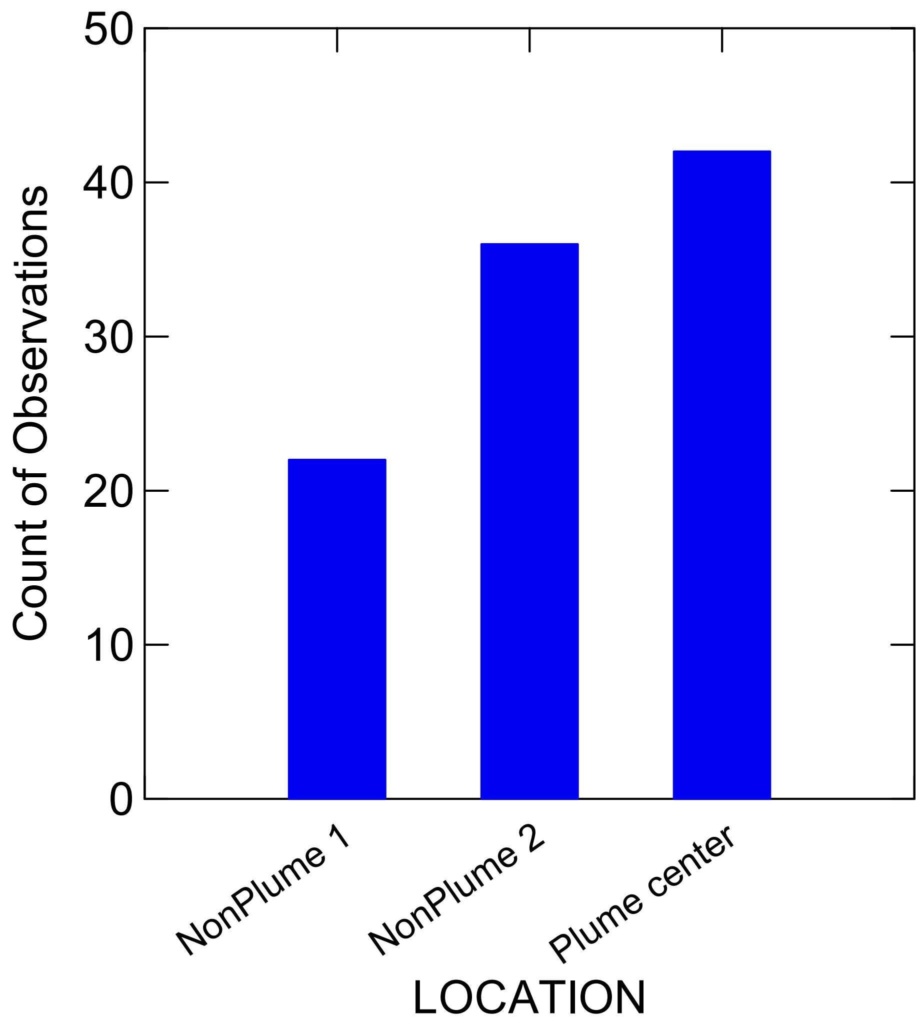


Figure 3 Frequency of observations of sea otters in each of the three study sites. Counts are based on totals for each of the 22 independent scan sessions.

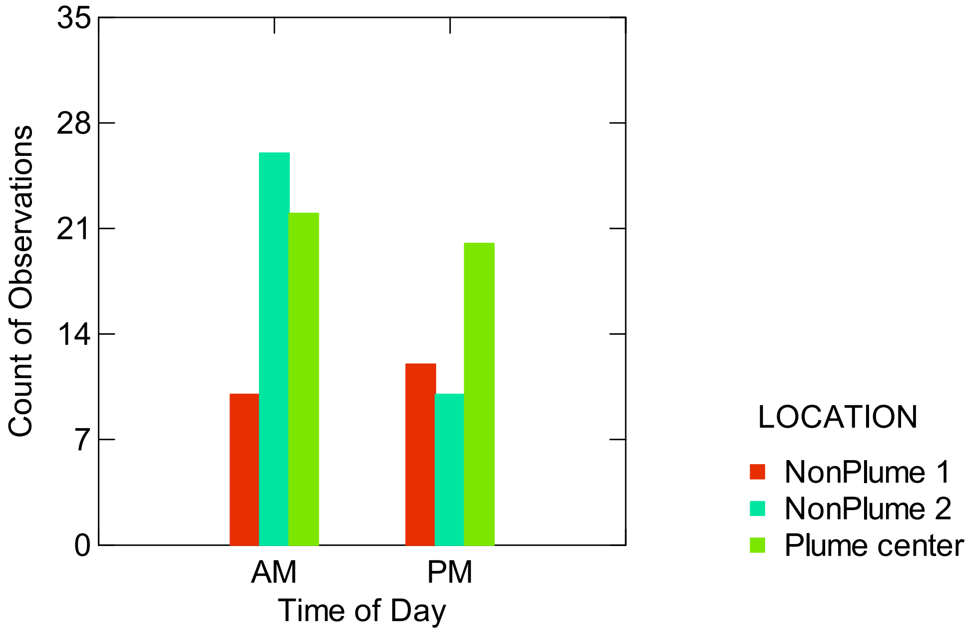


Figure 4 Frequency of observations by time of day in the three study sites. AM = 07:00-11:00; PM = 12:00-17:00.

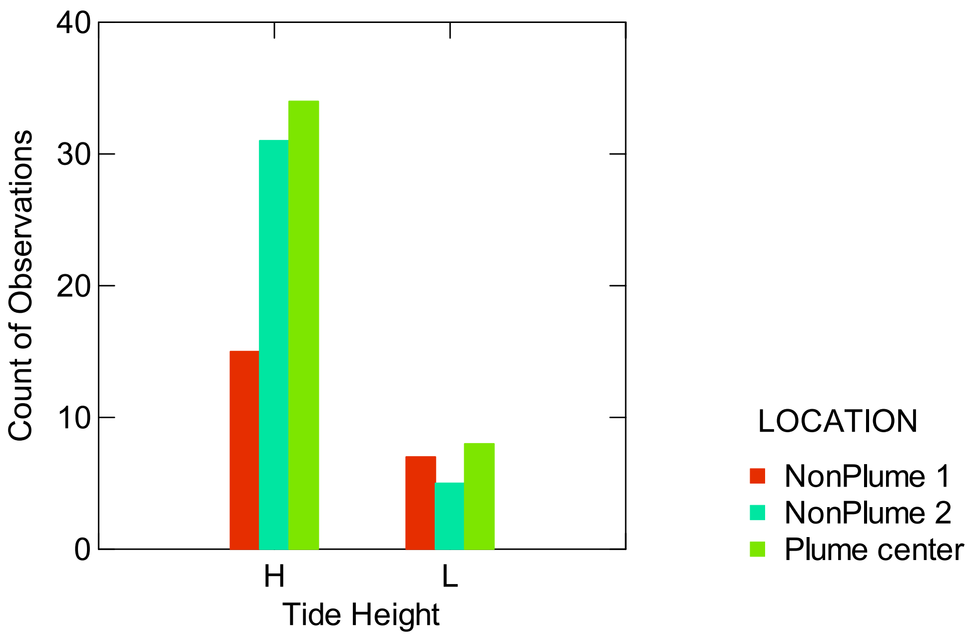


Figure 5 Frequency of observations by tide height in the three study sites. L = tides ≤3 feet; H = tides ≥ 4 feet.

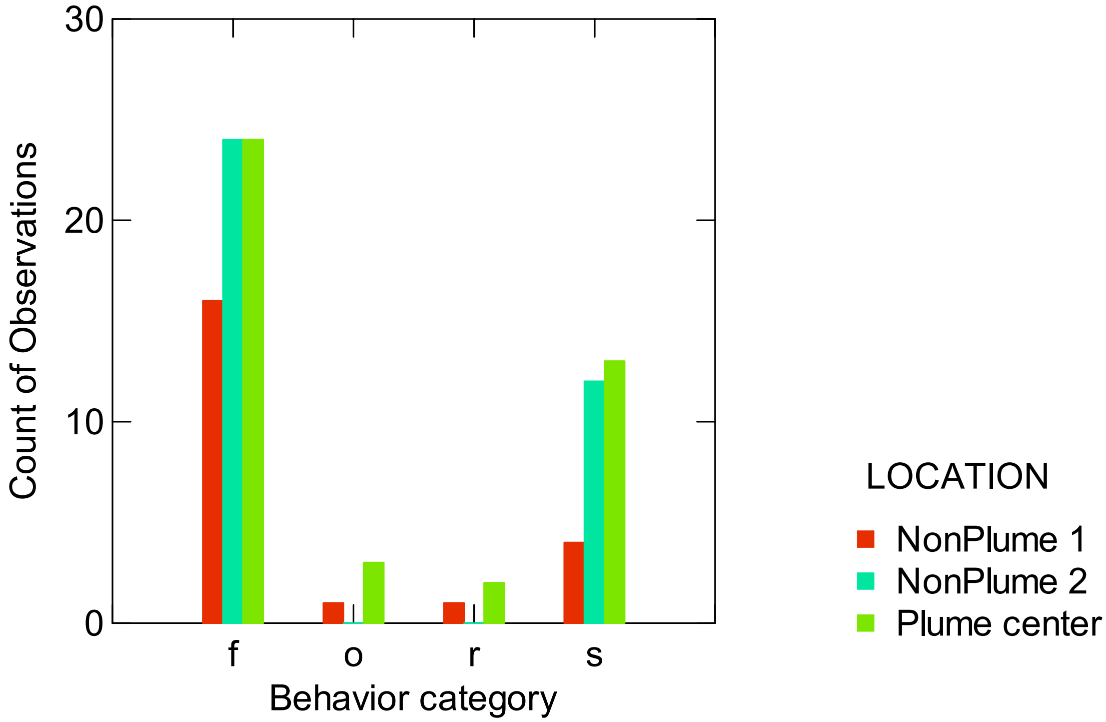


Figure 6 The frequency of observations within three behavior categories by study site. F = foraging, s = swimming, r = resting (inactive), o = all other active behaviors.

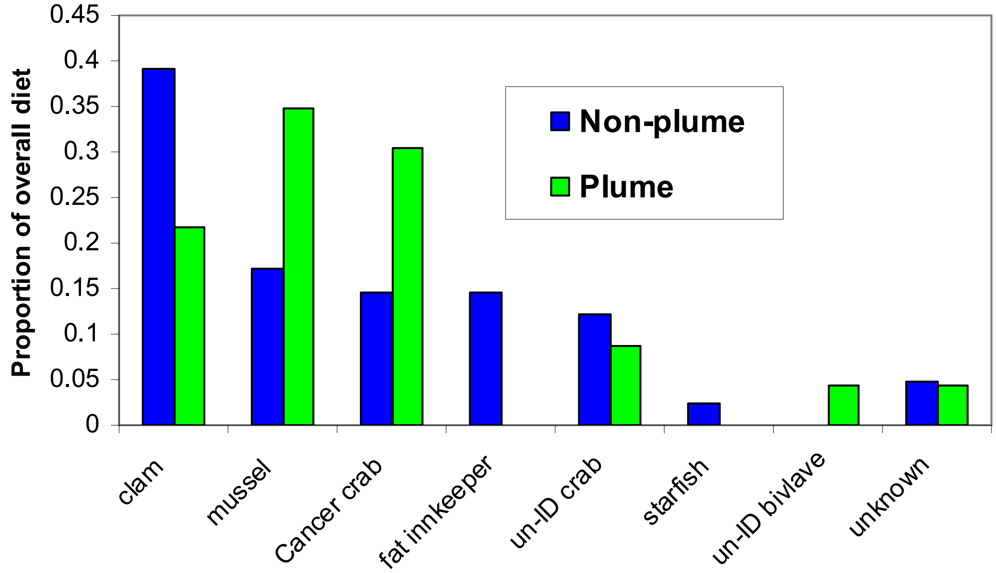


Figure 7 The diet composition of sea otters foraging in the plume and non-plume (NP 1 and NP 2 collectively) sites.

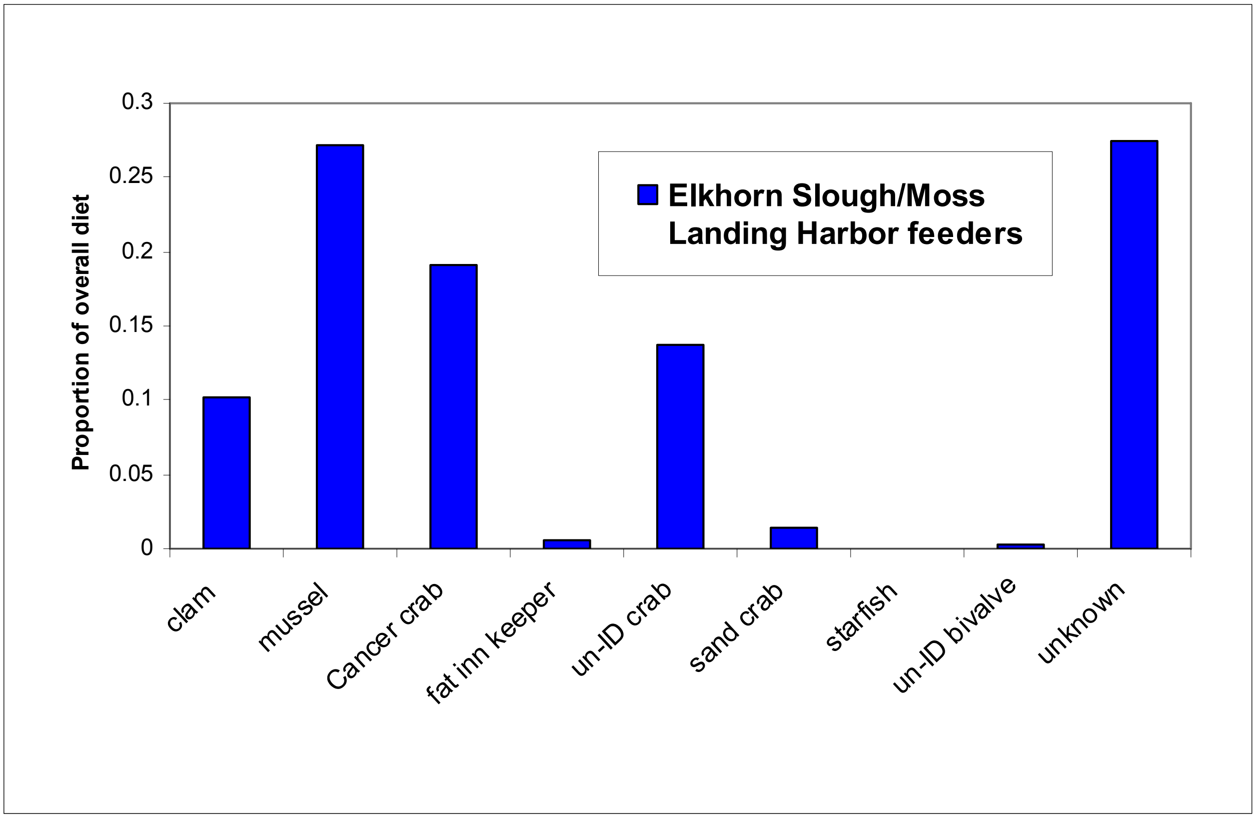


Figure 8 The diet composition of tagged sea otters foraging in Elkhorn Slough and Moss Landing Harbor from 1997-2006. Source: Monterey Bay Aquarium (SORAC)/ US Geological Survey.