California Sea Otter Time Budgets and Population Growth Implications:

A comparative analysis of four study years

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ABSTRACT

Daily time budgets and activity patterns of sea otters (*Enhydra lutris*) were determined by scan sampling at 15 locations along the Big Sur coastline. Activities were determined by direct observation and categorized into appropriate units of behavior; resting, foraging and other. We compared this data to data collected in three previous studies to determine if percent time allocation of otter activity had changed for the studies conducted over the past twenty-four years. For every year a study was conducted, we calculated an average diurnal activity budget for the observed otters. In 2006 otters spent an average of 22% of the day foraging, 57% of the day resting and, 22% of the day engaged in other activities. When comparing across years we found no significant difference in percent time allocated for each activity, P=0.69. We compared diurnal activity patterns between 1986 and 2006, both studies showed peaks in foraging during the morning and afternoon with a period of resting mid day. This comparative analysis suggests that population growth of the California sea otter is not limited by food availability. This is consistent with three other studies conducted over the past twenty-four years (Estes et al 1986, Giles1988 and Buckelew 1998).

INTRODUCTION

In the 18th and 19th century, the California sea otter (*Enhydra lutris nereis*) suffered from over hunting that resulted in its near extinction (Riedman 1994). By the time they became protected the population of California sea otters had declined from an estimated 16,000-18,000 to 50 -100 individuals (Estes et al 1986). In a recent survey 2,735 otters were recorded between Half Moon Bay and Santa Barbra (USGS survey 2005). Currently, sea otters are protected as threatened species, and with favorable unoccupied habitat available throughout their range, their population growth rate should be similar to that of other otter populations (Laidre et al 2001). Studies show the sea otter population in California to be increasing at a rate 3 to 4 times below that of other otter populations in Alaska and British Columbia (Riedman 1994).

The California sea otter's disparate population growth rate may be the result of two factors that commonly limit population growth. One possible cause is the population has reached equilibrium density, and growth has become limited by food availability and competition (Laidre et al 2001). The second possibility is independent of population density. In this case the growth rate may be limited by factors such as human caused disturbance, entanglement, poaching or disease (Estes et al 1986, Gerber et al 2003).

Several techniques have been developed to assess the status of marine mammal populations (Estes et al 1986). One is based on the relationship between population growth and activity budgets. To explain this relationship, foraging theory states that net energy yield from feeding increases concurrently with increased time spent foraging (Estes et al 1986). As a result, reduction in food abundance, size or quality, will decrease foraging yield and result in increased time spent foraging. For example, a population at Amchitka Island known to be at equilibrium density shows increased foraging times when compared to populations below equilibrium density; 55% of daylight hours vs. 17% (Estes et al 1982).

Several previous studies have been conducted based on this assumption. All have found the California sea otter population to be below equilibrium density (Estes et al 1986, Giles 1988, and Buckelew 1998). This study addresses whether, or not, the California sea otter population has increased sufficiently as to have reached equilibrium density, or if density independent factors should be the focus of future protection efforts. If the activity time budgets show a significant change when compared to those of previous study years, population density will be supported as a significant factor in limiting population growth. If no significant change in activity time allocation is found future studies regarding density independent factors should be pursued.

METHODS

Site selection

All four study years analyzed in this comparison had been sampled along the Big Sur coast. Following a near extinction due to over hunting, this location was first re inhabited in the mid-40's (Estes et al 1986). We selected 15 contiguous coastal subsegments (viewing sights) from which sea otters could be observed with the use of binoculars and spotting scopes. Each observation site was composed primarily of rocky reef and kelp forest habitat. Both giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereoccystis leutkeana*) were present, with bull kelp as the principle surface canopy-forming species.

Sampling procedures

The number of days spent observing at each viewing site ranged from two to four depending on the year of the study. In the 1986 study, for example, one day (dawn to dusk) was spent in every viewing area during each sampling period, a total of four periods (Estes et al 1986). In order to compare across years, we conducted our observations from 6:30AM to 5:30 PM on two days in May of 2006. All observations for each year were taken between the months of April through July in order to control for seasonal changes in behavioral activity allocation.

Activity was estimated each year by scan sampling the viewing areas at 0.5-hour intervals with 7 to 10X binoculars and spotting scopes. Scans were done at a rate that minimized the chance of counting an otter twice and allowed for submerged otters foraging on a dive to be recorded upon surfacing. This time interval also allowed for observers to reliably identify unfamiliar behavioral patterns and record data manually (Packard and Ribic 1981).

The activity of each otter sighted was categorized into one of three categories: resting, foraging or other. We included in the "other" category, behaviors such as grooming and playing. These categories were chosen for two primary reasons: the categories of foraging and resting were the most pertinent to our question of time allocation and because the categories foraging and resting are sufficiently discrete to allow reliable recognition by observers (Packard and Ribic 1981). Behaviors were recorded based on the first activity observed for each otter observed during every scan.

Data analysis

We implemented an analysis of variance to determine if sea otter time budgets had significantly changed over the past 23 years. We calculated a grand mean from the raw data and used an arcsine transformation to account for the difference in proportions between data collections. Values for each year were compared using a chi squared analysis to determine if there was a significant difference in percent time spent at each activity.

RESULTS

Time budgets

For each year a study was conducted we calculated an average daytime activity budget as shown in figure 1. The observed otters in the year 2006 spent an average of 22% of the day foraging, 57% of their day resting and 22% of their day engaged in other activities. (Figure 2) When comparing across years, we found no significant difference in percent time allocated for each activity, P=0.69.

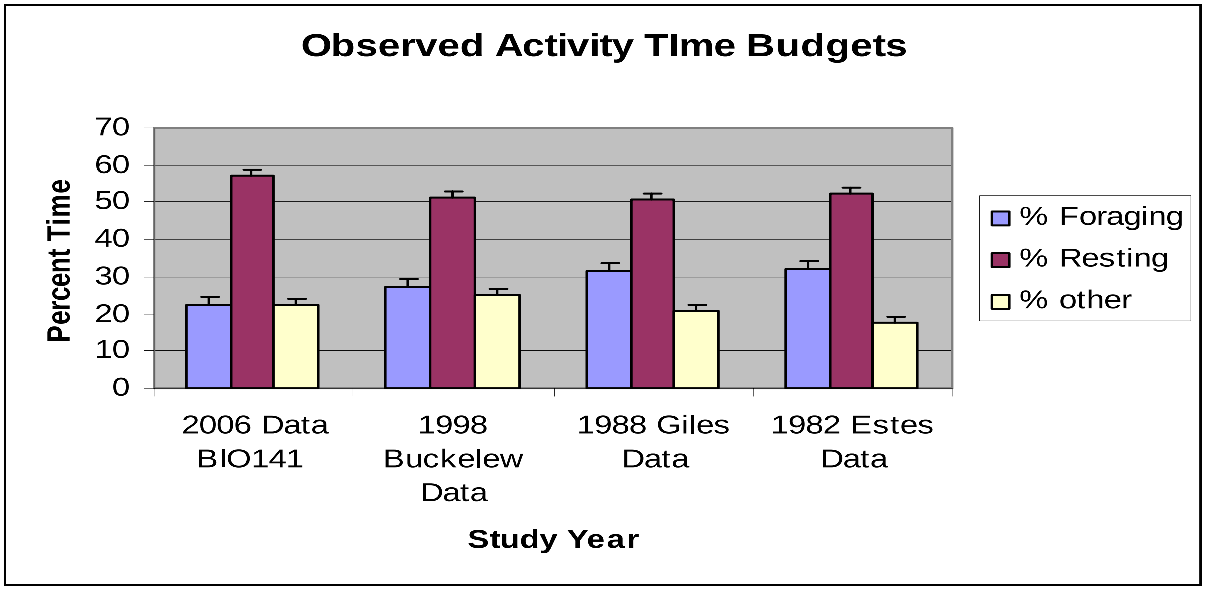


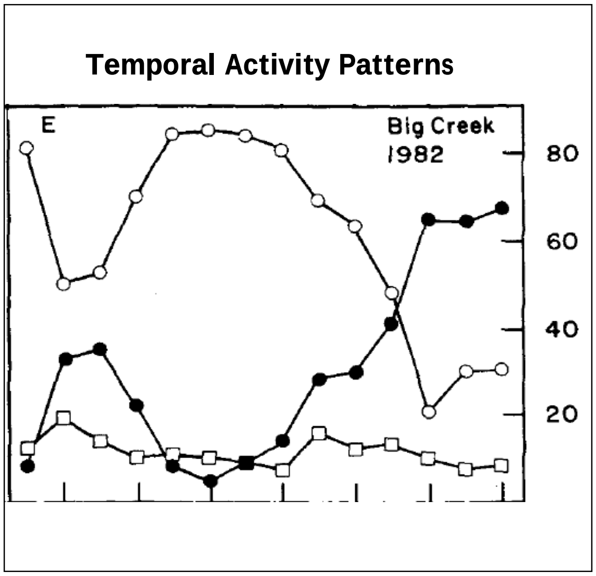
Figure 1: Graph of observed percent time spent at each activity for each year. These percents are based on mean average values for each activity each year a study was conducted.

	% Foraging	% Resting	% other
2006 Data BIO141	22.470297	57.25229	22.50731
1998 Buckelew Data	27.2747	51.3545	25.1041
1988 Giles Data	31.3064	50.7684	20.9634
1982 Estes Data	31.9481	52.535	17.4576

Figure 2: Observed % time spent in each activity.

Activity patterns

The diurnal activity pattern consisted of peaks in foraging in the morning and afternoon. In 1986 and 2006 the number of resting otters was found to be inversely related to the number of foraging otters (Estes et al 1986). Data on this correlation was not available for 1988 or 1998. Morning foraging peaked around 0700 hours and declined around 0800 hrs. In the afternoon foraging peaked around 1400 hours and declined by 1700 hrs. (Figure 3) This is similar to the study observations in 1986. No changes in activity patterns were evident.



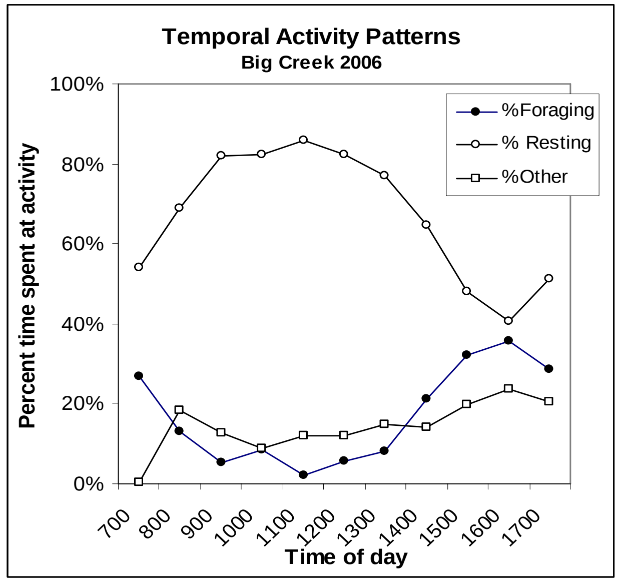


Figure 3: Temporal activity patterns of sea otters in Big Sur, CA. The first graph represents data collected in 1986 and the second 2006.

DISCUSSION

The compilation of data collected during these four years suggests that the population of otters along the Big Sur coast is not limited by food availability and that the population is still below equilibrium density. Based on optimal foraging theory and the relationship between population growth and activity budgets, increased time foraging should be observed, if the population has reached equilibrium density. The percentage of time otters allocate to foraging during daylight hours is found to differ between populations. Increased time foraging is found in populations above equilibrium density (Estes et al 1982). The Big Sur population currently spends two times less time foraging than known populations above equilibrium density (Gerber 2003). This percent time allocated to foraging suggests that the net energy yield from feeding is consistent, with no significant decrease in foraging yield among study years. In agreement with foraging theory, equilibrium density has not been reached and is not the limiting factor for the disparate population growth rate.

In comparing foraging patterns observed in this study with those of other otter populations at and below equilibrium density, we found foraging patterns to be the same with morning and afternoon peaks in foraging. The observed peaks and lows in activity may result from short duration rises in metabolism and increased resting VO_2 (Costa and Kooyman 1984). Metabolism returns to post absorptive levels 4-5 hours after feeding. This digestion pattern is consistent for all populations and may explain the trends in resting and foraging behavior observed in populations, regardless of equilibrium status.

We recognize several potential confounding factors in this study. First, estimates of percent time spent foraging based on radio transmitters are significantly higher than estimates based on visual scan sampling during daylight hours (Ralls and Siniff 1990). Ideally activity time budgets should be for a full twenty-four hour day, and not limited to daylight hours (Estes et al 1986). However this potential bias is consistent for all studies compared in this paper and should not influence the results. Second, observation bias against foraging otters may exist due to dive time and the impossibility of observing submerged otters. Observers in our 2006 study were also inexperienced in determining foraging behavior from grooming and other related behaviors and may have categorized a higher percentage of behaviors as other than experienced or better equipped observers would. These biases were minimized by the length of time allowed per scan as well as the use of guides to help distinguish between behaviors. Third, activity due to local habitat variation may influence activity records based on observation location. We controlled for this by choosing contiguous viewing sites and sampling from a relatively large expanse of coastline.

California's sea otter population is not increasing as rapidly as other otter populations in the Pacific ocean (Riedman et al 1994). This disparate population growth rate is perplexing due to the availability of unoccupied and favorable habitats occurring throughout the range of the California otter population. Density dependence has not been found to significantly limit the population growth. This result is based on the comparison of the time budget analyses from several years, p=0.69. This result is further supported by a recent study on the carrying capacity of the California sea otter. Based on density, range and area of available habitat carrying capacity was estimated to be 15,941 (95%CI 13,538-18,577) (Laidre et al 2001). This estimate is well above recent population estimate of 2,735 otters (USGS survey).

Future studies regarding what factors are limiting population growth are crucial to the protection and maintenance of a healthy otter population along the California coast. Based on this analysis, research projects should focus on the effects of density independent factors in order to determine if any of them are currently limiting the rate of population growth of the California sea otter. If density independent factors can be determined as drivers for the disparate sea otter population growth rates, action can be taken to further protect the sea otter population in California. This would allow for a population growth rate more representative of a healthy population of sea otters below equilibrium.

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