

Sea Otter Foraging in Elkhorn Slough

Uriel Osvaldo García

ABSTRACT

Elkhorn Slough has changed in sea otter population density since 1995 and as a result, may have altered benthic macro-invertebrate populations due to increased predation pressure. The goal for this observational study was to document sea otter foraging behavior and prey choice. One otter was observed at a time until it was lost from sight or left the research area. As the otter foraged, I documented the time the sea otter dove and surfaced. I also recorded if the otter was successful or unsuccessful in acquiring prey. If the sea otter was successful in the dive, I approximated the size of the prey item in relation to the paw and tried to identify the organism to the species. The observed diet of the otters consisted mostly of clams, followed by crabs, $p\text{-value} = 2.43e-12$. Sea otters in the region were observed to have a 53% success rates in foraging and successful dives by male otters were significantly longer than female successful dives, $p\text{-value} = 0.31$. The observed sea otters spent about 67% of the time foraging, 13% grooming dives, 6.8% traveling, and approximately 5.6% of the time nervously grooming. This is interesting because sea otters may have developed a strategy that maximizes the ratio of caloric intake and energy expenditure while decreasing intraspecific competition or that bivalve have become more abundant in Elkhorn Slough.

KEYWORDS

Enhydra lutris, Optimal Foraging theory, specialization, theory of profitable location, Density Dependence

INTRODUCTION

Competing organisms can deplete resources from the environment and drive the less competent organisms to death (Tilman et al 1981). Although high population densities may be beneficial to some organisms (Ashbrook et al 2010), high population density is a limiting factor resulting from the increased level of competition (Newton 1998). Density dependence is the decrease in per capita growth rate of a population when the population is large and the increase in per capita growth when the population is small (Balasuriya 2010, Knape and de Valpine 2012). The carrying capacity of an environment, e.g. food availability, usually limits population growth for most organisms (Hassell 1975). Therefore, it is important for an organism and its species to be competitive in survival traits, such as foraging tactics, and sexual reproduction.

Optimal Foraging theory assumes that organisms streamline their resource acquisition process. Under this assumption, organisms select prey to minimize energy expenditure and maximize a net increase of calories (Bone and Moore 2008, Lacher et al 1982, Schoener 1971). For example, predators may become specialized and primarily target a single species, or forage in profitable locations (Stephens and Krebs 1986, Tinker et al 2008). This latter idea, the patch model, assumes foraging organisms move to other patches when the intake rates of any patch decreases to the average rate of the entire habitat (Prins and van Langevelde 2008).

Enhydra lutris (sea otters) are an endangered species and studies show that they are optimal intake predators (Jolly 1997). *E. lutris* would rather spend energy feeding on large volumes of food than a few big-sized prey items that require more energy to acquire. Sea otters have to consume a quarter of their weight in food every day to maintain their body temperature at 100° F without blubber and as a result, they can easily deplete the easy-to-get species such as the Pismo clam in a year (Kvitec et al 1988). *E. lutris* fully depends on its aquatic environment for its prey which consists of crabs, sea urchins, clams, tube worms and some species of fish (Feinholz 1998, Yeates et al 2007). Population densities have increased from twenty one in 1985 to approximately 80 otters in the slough daily from 2006 to 2009 (Dr. Jim Harvey, *pers. comm.*).

Increasing sea otter density may affect otter foraging habits, and the population and size distribution of their prey. Elkhorn Slough may not be able to provide sufficient resources to accommodate the large otter population. There are few formal studies that quantify their current

population, prey choices and the sea otters' use of the slough. This study will focus on the sea otter's diet and foraging behavior at their currently high densities.

METHODS

Study area

Elkhorn Slough is located west of the Santa Cruz mountain range and 100 miles south of San Francisco CA (**Fig.1**) ($36^{\circ}48'46.67''$, $121^{\circ}46'45.59''$). Elkhorn slough is an estuarine slough, soft bottomed marshy area where sea-water and freshwater mix. This area is protected by NOAA and the California Department of Fish and Game. Elkhorn slough is important because it is the third largest estuary in California and home to 7.7% of the *E. lutris nereis* population (Maldini unpublished data). *E. lutris* use this area for foraging, resting and reproducing.

Data collection materials and methods

I collected my data in the summer of 2011 and winter 2011-2012 with the help of interns and friends. The observations lasted usually about two hours or until no sea otter was in the research area for over forty five minutes. More specifically, my research area was at a public observation deck on the North shore of the slough (**Fig. 2**). The observations were made using West Marine Raiatea binoculars and a BARSKA 18-36x50mm spotting scope in the mornings and by noon. The observations were recorded on a copy data sheet used in (Jolly 1995). Variables recorded in the data sheet included date, location, observer, dive time, surface time, behavior, prey success, prey type, prey size, level of grizzle, and gender. I added visibility as a variable to the data sheet because there were days with heavy fog.

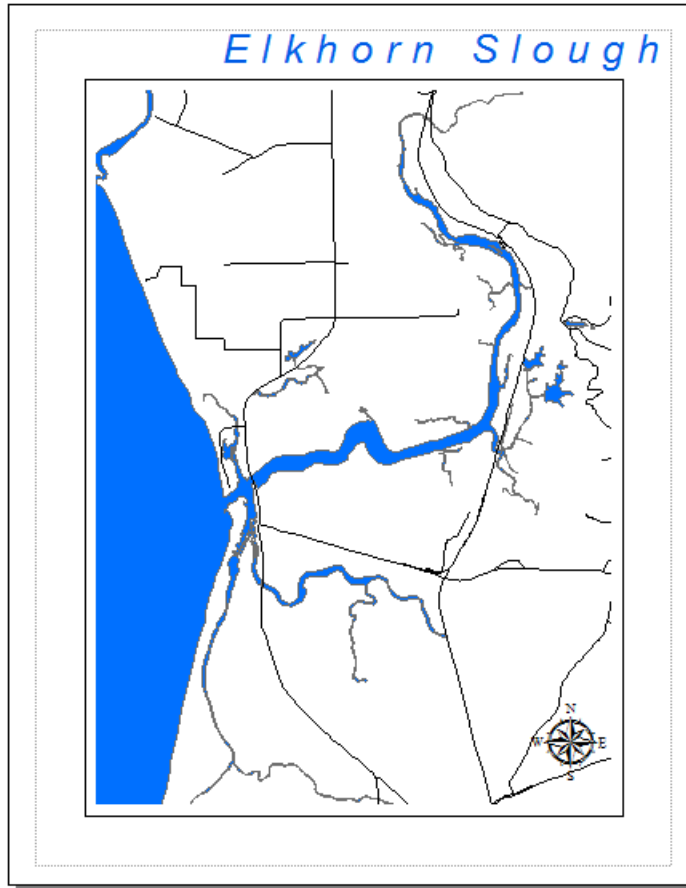


Figure 1. Aerial map of Elkhorn Slough.



Figure 2. Research Area. Grey blue area is the area visible from the observation deck.

Visibility at the research site varied from bad, to good and excellent. A “bad” visibility day was on days in which the visibility was less than 100m, or could see about halfway into the slough. A “good” day was having a visibility of 100m to 270m and an “excellent” day was having a visibility greater than 270m, on these days Highway 1 and the ocean were clearly visible.

For the foraging observations I recorded the time of dive to the second. The dive was recorded as a success if the otter surfaced with prey and as a failure if no prey was observed. In the case of a successful dive, the prey was identified to the species if possible, if not it was identified as its taxa, such as clam or crab.

The prey size was coded as an integer representing its size in comparison to the paw of an average sea otter, 5 cm across (Jolly 1997, Kvitek et al 1993). A one signifies equal to the size of its paw; a two signifies twice the size of paw etc. There was no zero in the prey size category because prey size cannot be zero times the size of a paw. A .5 signifies smaller than the otter’s paw.

Data analysis

I used R to perform my data analysis and models.

RESULTS

Prey size and type

I observed the diet of the otters to be 64.9% of bivalves, 9.4% of crabs, 2.36% were fat innkeeper worms and of the diet was 23.22% unknown (**Fig. 3**).



of the fat-innkeeper worm was one paw, or approximately 5cm. The mean size of the Washington clam was 2.038 paws, or about 10.19 cm and gaper clam was 2.364 paws, 11.82 cm.

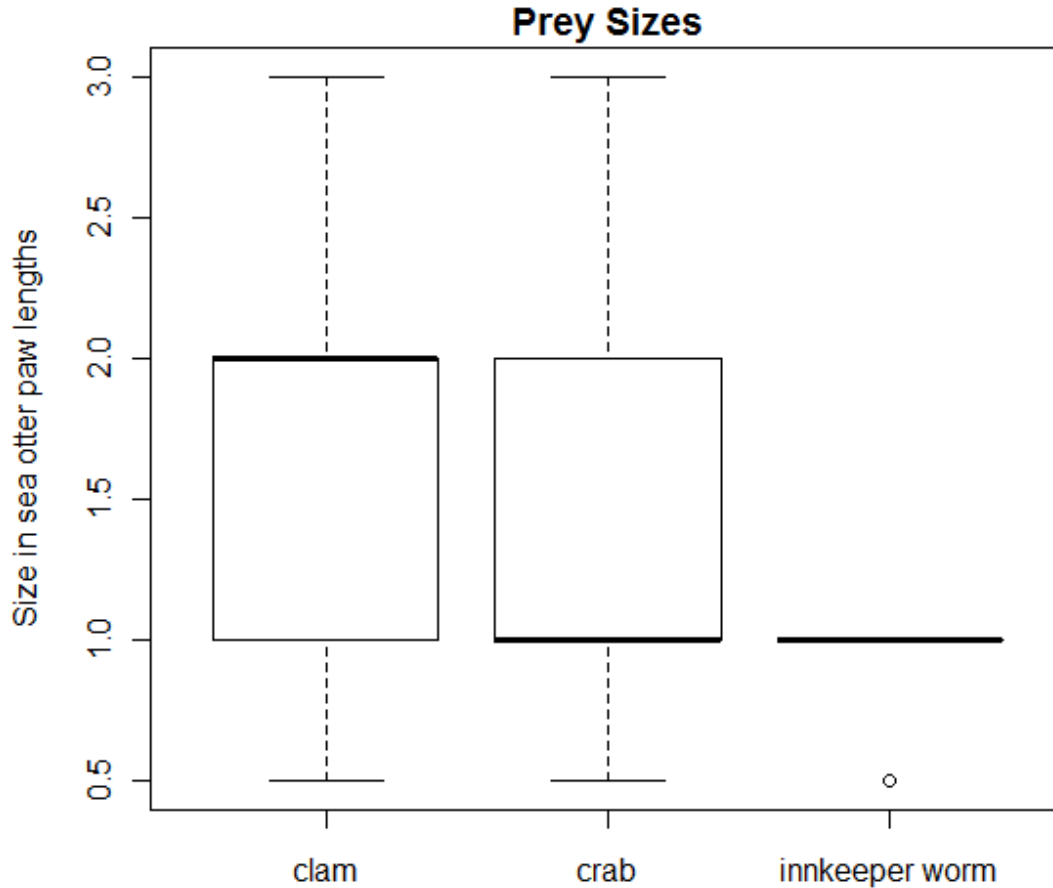


Figure 5. Prey Size in otter paws.

Foraging success

The study I conducted consisted of 393 dives; 53.18% of the dives were successful, 41.73% were unsuccessful and 5.09% were unknown (**Table 1**). The average dives between males and females were compared statistically by an Analysis of Variance model, aov, and compared by a Tukey HSD test. The males and females differed by 15.79 sec. (table1) with p-value of 0.0031335 (**Fig. 6**) but the male to unknown differences or female to unknown gender were both not significant.

Table 1. Summary of Successful Dive in seconds. Unsuccessful dives were excluded from the calculations in this table.

	Mini mum	1 st Qu.	Me dian	M ean	3 rd Qu.	Ma x.
Male	1.00	31. 75	61. 50	56. 53	82. 25	104. 00
Fema le	1.00	28. 00	48. 00	46. 55	61. 00	100. 00
unkn own	1.00	31. 75	50. 00	49. 80	68. 00	101. 00

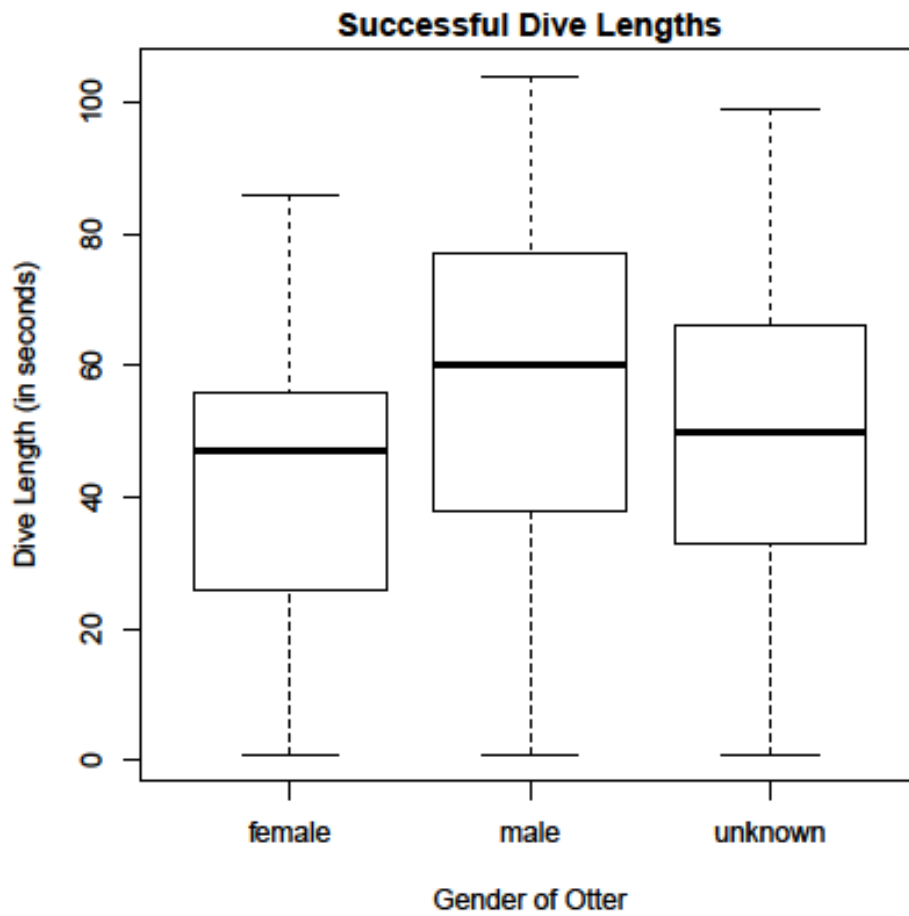


Figure 6. Successful Dive Length. I separated the dive duration results by sex of the otter.

DISCUSSION

Assuming that sea otters are optimal foragers and by observing their diet and consequently their prey choice, one can learn about the underlying abundance and diversity of the prey types (Jessup et al 2004). I tried to assess the health of benthic organism populations in Elkhorn slough that serve as prey to the southern sea otter. I analyzed data that would be indicators of imbalances in the system, such as heavy predation of benthic macro-invertebrates by looking into prey size, dive length, dive success, and prey type.

Prey size and type

The observed diet of the otters consisted mostly of clams, followed by crabs suggesting bivalves are still the preferred prey and relatively abundant in Elkhorn Slough (**Fig. 5**) (Jolly 1995, Maldini et al 2010). The mean size of the bivalves consumed by the otters suggests that the bivalves are not reaching the average size from other studies: Washington clams can grow to a length of 15 cm and the average size observed was about 10cm (Kvitek 1988), Gaper clams to a size of 14.8cm but the average size was approximately 11.82cm (Campbell and Bourne 2000). I included all bivalves in the “clam” category when I was unable to identify the species. Aside from sea otters increasing in population, sea otters in the region have been able to maintain about the same success rates in foraging (Jolly 1995). The success rates results may be balanced by an increased efficiency in specialized foraging tactics because specialization may reduce the overlap and competition for prey that has the highest calorie to energy expenditure ratio. This is interesting because this may have two reasons; the first reason may be that sea otters have developed a strategy that maximizes the ratio of caloric intake and energy expenditure while decreasing intraspecific competition. The other possible reason is that the bivalves have become more abundant in Elkhorn Slough.

Foraging success

The similar foraging success rates as (Jolly 1995) imply that the population of benthic prey is likely to have increased since 1995. Male otters were more successful than female otters but I

suspect it was because males display dimorphism and are larger; also, the study area is a non-territorial male area and there are fewer females than males (**Fig. 6**) (Maldini et al 2010). Dive length was not equal for all prey types perhaps as a result of a relation between the metabolic cost of a prey item and its caloric value (caloric value as a product of species of prey and its respective size). In my study, otters favored bivalves above the rest of the prey species perhaps because they are sessile and rich in calories (Kivitek 1998).

The behavior I observed coincides with literature because sea otters do have to devote most of their time foraging to upkeep their demanding metabolism (**Fig. 4**) (Feinholz 1998, Maldini et al 2010) followed by grooming behavior. Grooming behavior is important to the otter because they are the only marine mammals without blubber and depend on the layer of air trapped in their thick fur after grooming (Jolly 2005, Tinker 2007).

Broader Implications

Optimal foraging theory

Prey switching is more common after sea otters have depleted the most profitable prey species or until the preferred prey reaches a low critical value (Stephens & Krebs 1986) and as a result, dietary specialization is then most clearly observed (Bentall 2005, Tinker 2004, Newsome et al 2009, Tinker 2008). I did not account for foraging patterns that may be matrilineal during weaning and rearing (Estes et al. 2003). I found that although the size of prey has decreased an amount that was not statistically significant, the prey choices were statistically different from each other and that indicates that bivalves are still the prime choice, followed by crabs and innkeeper worms.

Density dependence

The competition of organisms for resources plays a crucial role in the success of these organisms. Sea otters in Elkhorn slough compete for benthic macro-invertebrate prey, and space; since they are protected by federal law, sea otters in the slough have no threat aside from human introduced pathogens (Miller et al 2009). According to (Bentall 2005, Jessup 2010, Stephens & Krebs 1986, Tinker 2004, Tinker 2008), given that sea otters still have the luxury to specialize in their diet by consuming clams; my study suggests that the high density of otters has not maxed

out the carrying capacity of otters at the slough. This research was effective in finding the key otter foraging patterns to compare to (Jolly 1995) but it was inadequate in addressing if *E. lutris* at Elkhorn Slough is changing the populations of clams and other prey items.

Limitations

One limitation in my study was difficulty in identifying individual otters. This became a problem when I wanted to test for individual behavioral traits in foraging and assuming independence in every observation day. Since this research spanned in the course of little over a season, my results are not representative of a full year and in general one would want to do these surveys every few years and see how otters are doing. It was difficult to identify the species of prey items smaller than the paw of the otter. This information is a limitation to the research because this systematic error could have shed light on a species of prey that has been heavily predated upon or a species of prey not documented in literature. Also, many times sea otters would surface facing away from me and I could not identify the prey species, or size.

Further Work

Based on the results of my thesis, I would like to focus more on finding how sea otters at Elkhorn Slough were able to maintain similar success rates in the same area when the population density of the sea otters has increased. I would suggest improving the sampling technique by observing sea otters from a kayak instead of staying in one location and using telemetry to track individuals by their dive and surfacing times. This would insure different individual otters and areas of the slough where otters feed most commonly.

ACKNOWLEDGEMENTS

This thesis is dedicated to all my family, friends, and colleagues. More specifically to my parents, brothers, aunts and uncles as well as the greatest friends: Nick Rodriquez, Jahzeel Flores, Alejandro Ramirez, Juan Velasquez, and Jose and Mario Palomera. Also, I would like to thank the Creepers work group, the Moffit/GIS cave dwellers, Melissa Eitzel, Tina Mendez, Kurt

Spreyer, and Seth Shonkoff for all their help and support in the production of this thesis. My thesis would have been impossible to finish without the help of Ron Eby, Robert Scoles, Wendolyne Valdez, Jesus De Haro, Omar García, the interns of ESNRR and my mentor, Jim Harvey. Thank you Ron for all the equipment and time you set apart to help me. Another great help was my friend and student mentor Jesus Miguel Diaz. Thank you Jesus for always pushing me to strive for the best and all the good advice you gave me. Huge thanks to the Marco Antonio Firebaugh for the funding and additional help in the formulation of this thesis. Lastly and most importantly, I want to thank God, without his help nothing would be possible. Thank you all for your helping hands and willing minds; I hope I have made you all proud.

LITERATURE CITED

- Ashbrook K., S. Wanless, M. P. Harris, and K. C. Hamer. 2010. Impacts of poor food availability on positive density dependence in a highly colonial seabird. *Proceedings of the Royal Society Biological Sciences Series B* 277:2355-2360.
- Balasuriya S. 2010. Invasions with density-dependent ecological parameters. *Journal of theoretical biology* 266:657-666.
- Bentall, G. B. 2005. Morphological and behavioral correlates of population status of the southern sea otter, *Enhydra lutris nereis*: A comparative study between central California and San Nicolas Island. M. A. thesis, University of California Santa Cruz.
- Estes J. A., M. L. Riedman, M. M. Staedler, M. T. Tinker, and B. E. Lyon. 2003. Individual variation in prey selection by sea otters: Patterns, causes and implications. *Journal of Animal Ecology* 72:144-155.
- Feinholz D. M. 1998. Abundance, distribution, and behavior of the southern sea otter (*Enhydra lutris nereis*) in a California estuary. *Aquatic Mammals* 24:105-115.
- Hassell M. P. 1975. Density Dependence in Single Species Populations. *Journal of Animal Ecology* 44:283-296.
- Jolly, J. M. (1997). Foraging Ecology of the Sea Otter, *Enhydra lutris*, in a Soft-Sediment Community. M.S. Thesis University of California Santa Cruz, 1-61.
- Knape, J., and P. de Valpine. 2012. Are patterns of density dependence in the Global Population Dynamics Database driven by uncertainty about population abundance? *Ecology letters* 15:17-23. doi: 10.1111/j.1461-0248.2011.01702.x.

- Kvitek R. G., P. J. Iampietro, and C. E. Bowlby. 1998. Sea otters and benthic prey communities: A direct test of the sea otter as keystone predator in Washington State. *Marine Mammal Science* 14:895-902.
- Lacher T. E. J., M. R. Willig, and M. A. Mares. 1982. Food Preference as a Function of Resource Abundance with Multiple Prey Types an Experimental Analysis of Optimal Foraging Theory. *American Naturalist* 120:297-316.
- Maldini D., Ward C, Cecchetti A. and Riggan J. 2010. Southern sea otter diet in a soft sediment community *Journal of Marine Animals and Their Ecology*. 3:27-36.
- Miller, M. A., B. A. Byrne, S. S. Jang, E. M. Dodd, E. Dorfmeier, M. D. Harris, J. Ames, D. Paradies, K. Worcester, D. A. Jessup, and W. A. Miller. 2010. Enteric bacterial pathogen detection in southern sea otters (*Enhydra lutris nereis*) is associated with coastal urbanization and freshwater runoff. *Veterinary research* 41:1. doi: 10.1051/vetres/2009049.
- Newsome, S. D., M. T. Tinker, D. H. Monson, O. T. Oftedal, K. Ralls, M. M. Staedler, M. L. Fogel, and J. A. Estes. 2009. Using Stable Isotopes to Investigate Individual Diet Specialization in California Sea Otters (*Enhydra Lutris nereis*). Retrieved May 11, 2012, from <http://si-pddr.si.edu/dspace/handle/10088/8057>.
- Newton I., P. Rothery, and L. C. Dale. 1998. Density-dependence in the bird populations of an oak wood over 22 years. *Ibis* 140:131-136.
- Nicholson A. J. 1954. An outline of the dynamics of animal populations. *Australian Jour Zool* 2:9-65.
- Prins, H. H. T., and F. van Langevelde. 2008. *Resource ecology: spatial and temporal dynamics of foraging*. Springer, Dordrecht. Retrieved from <http://edepot.wur.nl/137130>.
- R Development Core Team (2010). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL <http://www.R-project.org/>.
- Stephens D. W., J. R. Krebs. 1986. *Monographs in Behavior and Ecology Foraging Theory*. .
- Tilman D. 1981. Tests of Resource Competition Theory using 4 Species of Lake Michigan Usa Algae. *Ecology (Washington D C)* 62:802-815.
- 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., G. Bental, and J. A. Estes. 2008. Food limitation leads to behavioral diversification and dietary specialization in sea otters. *Proceedings of the National Academy of Sciences of the United States of America* 105:560-565.
- Yeates, L. C., T. M. Williams, and T. L. Fink. 2007. Diving and foraging energetics of the smallest marine mammal, the sea otter (*Enhydra lutris*). *The Journal of experimental biology* 210:1960–1970. doi: 10.1242/jeb.02767.