Sound Production and Reception in Southern Sea Otters (*Enhydra lutris nereis*)

Asila Ghoul and Colleen Reichmuth

1 Introduction

The rapidly increasing pressure of human activity in coastal and pelagic marine environments has led to concern regarding the effects of anthropogenic noise on marine mammals. Recent studies dealing with acoustic communication and behavioral responses to sound along with investigations of auditory anatomy, acoustic sensitivity, and noise impacts have established a knowledge base that has proven vital to regulators charged with determining safe sound exposure limits for some cetaceans and pinnipeds (Southall et al. 2007). Comparable data are presently unavailable for sea otters (*Enhydra lutris*), which have been largely ignored in the context of this issue. To date, only one study has addressed the bioacoustics of *Enhydra lutris* from the standpoint of sound production and communication (McShane et al. 1995), and there have been no formal anatomical, physiological, or behavioral studies of sound reception in this species. Due to the lack of available data, decision makers must use less than optimal, indirect evidence to evaluate the potential effects of anthropogenic noise on *Enhydra lutris*. This information comprises mainly unpublished technical reports describing observed behavioral reactions to various noise sources; most of these studies are not systematic and none of them consider auditory sensitivity to airborne or waterborne sound sources (Richardson 1995). To begin addressing the critical data gaps that exist concerning the bioacoustics of *Enhydra lutris*, we used a twofold approach to systematically evaluate captive individuals of this species as both sound emitters and sound receivers. We opted to begin these studies in air because these amphibious marine mammals spend a majority of their time at the water's surface where they carry out many important life functions, including those related to communication.

A. Ghoul (✉)
Long Marine Laboratory, Department of Ocean Sciences, University of California
Santa Cruz, Santa Cruz, CA 95064, USA
e-mail: asila@ucsc.edu

C. Reichmuth
Long Marine Laboratory, Institute of Marine Sciences, University of California
Santa Cruz, Santa Cruz, CA 95060, USA
e-mail: coll@ucsc.edu

A.N. Popper and A. Hawkins (eds.), *The Effects of Noise on Aquatic Life*,
Advances in Experimental Medicine and Biology 730, DOI 10.1007/978-1-4419-7311-5_35,

2 Sound Production

Currently, the only available information regarding the significance of sound to *Enhydra lutris* comes from observations of vocal communication. Southern sea otters (*Enhydra lutris nereis*) produce a range of aerial vocalizations in different social contexts. However, sound production underwater has never been observed, and there is no information on how aerial calls may be transmitted beneath the water's surface. Although many of the vocalizations emitted by *Enhydra lutris nereis* are thought to be used for short-range communication at the surface, scream calls are relatively loud signals with potentially large effective communication distances. These harsh calls are most commonly produced by mothers and their young when separated from one another and can be heard by human listeners up to 1 km away (McShane et al. 1995). The ranges over which these signals may be detected by conspecifics is unknown, in part because the source levels of these calls have not been measured.

To obtain quantitative measures of the source level and full spectral content of scream vocalizations, we recorded these aerial calls from adult females and dependent pups at close range (1–3 m) in a captive setting. Vocalizations were analyzed to determine duration, frequency range, dominant frequency, and source sound pressure level (SPL), given here as root mean square decibels (dB_{RMS}) re 20 μPa. Durations varied from 0.5 to 2 s, and all screams were harmonic in structure and extremely broadband, with energy extending above 60 kHz. Dominant frequencies ranged from 6 to 8 kHz in screams from adult females and from 4 to 7 kHz in screams from dependent pups. Source level measurements from all age and sex classes showed a high degree of variability both within and between individuals and ranged from 50 to 113-dB SPL re 20 μPa.

The extremely wide bandwidth of these contact calls raises questions about what portion of the signals are available for functional communication in natural settings. Specifically, frequencies above 10 kHz represent only a small percentage of the total energy contained in these signals, and these high-frequency components are likely to undergo high transmission loss when emitted in air. To estimate potential communicative ranges, the source level and frequency range characteristics measured in this study must be considered in the context of vocal behavior and combined with direct information on auditory sensitivity and the frequency bandwidth of hearing in this species.

3 Sound Reception

In the absence of any quantitative measures of hearing capabilities in *Enhydra lutris*, we developed a simple behavioral approach to conservatively estimate the upper and lower frequency limits of the auditory system. This controlled exposure experiment (CEE) began as a part of a larger project aimed at investigating hearing sensitivity of *Enhydra lutris nereis* and was designed to provide estimates of the aerial frequency range of hearing from multiple captive subjects in a relatively short period of time.

The design of the CEE called for subjects to be exposed to 1-s pure-tone stimuli while resting calmly in an acoustically mapped enclosure. The subjects were not trained for active participation in this study. Exposures were only presented when the subject was in a relaxed behavioral state, with its head above water. Behavior during and immediately after each sound exposure was compared with baseline behavior to determine if a positive response was observed. Blank exposures, during which no sound was present, were included as control trials and responses were evaluated in the same manner. The auditory stimuli were presented at fixed source SPLs of 80–100 dB re 20 μPa, generating received levels exceeding 70 dB re 20 μPa. Sessions were remotely conducted by an experimenter who viewed the animals on high-definition video. Each session was recorded, and

both sound exposures and blank exposures were identically visually marked using video editing software. Responses to both trial types were later scored by blind observers. Statistically reliable differences in exposure versus blank conditions were used to determine audible frequencies between 0.125 and 45.3 kHz.

These data revealed an upper frequency hearing limit extending to at least 32 kHz and a low-frequency limit below 0.125 kHz, results that are generally consistent with comparable data for other carnivores, including some terrestrial mustelids (Heffner and Heffner 1985). Reasonable estimates of frequency bandwidth of hearing will allow decision makers, for the first time, to identify or exclude potential sounds of concern when evaluating *Enhydra lutris nereis* in the context of environmental noise impacts. These data also improve understanding of vocal communication by suggesting that the portion of vocalizations below 32 kHz are most likely to contain biologically relevant information.

4 Summary

Because of their dependence on a highly restricted coastal habitat, *Enhydra lutris* is especially vulnerable to a variety of different environmental and anthropogenic threats. This species is presently listed as threatened and is protected throughout the northern and southern portions of its range. Resource managers are presently faced with uncertainty when responding to and prioritizing potential threats to these animals due to insufficient understanding of the factors that may disturb or disrupt normal behavior patterns both above and below the water's surface. The objective of these studies was to obtain direct measurements of the source characteristics of vocalizations and the limits of auditory reception in *Enhydra lutris*. These data are necessary to form a basic but essential understanding of bioacoustics in this species. To further develop this knowledge base, psychoacoustic profiles of aerial and underwater hearing sensitivity as a function of sound frequency are imperative to adequately consider sea otters alongside other marine mammals within the issue of anthropogenic noise impacts. These studies are presently ongoing in our laboratory. As these coastal-living carnivores have only recently transitioned to a marine lifestyle, an improved understanding of their acoustic communication and auditory adaptations will also provide insight into their evolutionary biology and behavioral ecology as well as the evolutionary pressures shaping underwater perception in marine mammals.

Acknowledgments This work was conducted with permission of the United States Fish and Wildlife Service (Permit MA186914) and the University of California Santa Cruz Institutional Animal Care and Use Committee and with support from the United States Bureau of Ocean Energy Management, Regulation and Enforcement, Washington, DC.

References

Heffner RS, Heffner HE (1985) Hearing in mammals: The least weasel. J Mamm 66:745–755.

McShane LJ, Estes JA, Riedman ML, Staedler MM (1995) Repertoire, structure and individual variation of vocalizations in the sea otter. J Mamm 76:414–427.

Richardson WJ (1995) Documented disturbance reactions. In: Richardson WJ, Greene CR Jr, Malme CI, Thomson DH (eds) Marine mammals and noise. Academic Press, San Diego, CA, pp 241–324.

Southall BL, Bowles AE, Ellison WT, Finneran JJ, Gentry RL, Greene CR Jr, Kastak D, Ketten DR, Miller JH, Nachtigall PE, Richardson WJ, Thomas JA, Tyack PL (2007) Marine mammal noise exposure criteria: Initial scientific recommendations. Aquat Mamm 33:412–522.