Chapter 137
Potential Uses of Anthropogenic Noise as a Source of Information in Animal Sensory and Communication Systems

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Abstract Although current research on the impact of anthropogenic noise has focused on the detrimental effects, there is a range of ways by which animals could benefit from increased noise levels. Here we discuss two potential uses of anthropogenic noise. First, local variations in the ambient-noise field could be used to perceive objects and navigate within an environment. Second, introduced sound cues could be used as a signal for prey detection or orientation and navigation. Although the disadvantages of noise pollution will likely outweigh any positive effects, it is important to acknowledge that such changes may benefit some species.

Keywords Ambient-noise imaging • Acoustic daylight • Prey detection • Acoustic landmark

1 Introduction

All sensory systems are affected by noise when acquiring information from the environment. Current research on the effects of noise has focused on the detrimental effects and how animals deal with interference from noise (Brumm and Slabbekoorn 2005). Recent concerns about sound pollution have led to several studies on the effects of anthropogenic noise on animals (see reviews by Nowacek et al. 2007; Barber et al. 2009; Slabbekoorn et al. 2010). At its most extreme, noise pollution can have pronounced population-level consequences such as lethal beaked whale strandings in relation to Navy sonar exercises (Tyack 2009). Other more common effects are temporary or permanent damage to the auditory system, avoidance responses leading to changes in local abundance and distribution, masking of

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communication or other sound cues used as information sources, distraction from relevant signals, increased stress levels, hypertension, and decreased reproductive success (Nowacek et al. 2007; Barber et al. 2009; Chan et al. 2010). Thus, noise is now seen as a major environmental problem that requires mitigation strategies.

Although most studies highlight the detrimental effects of noise, increased noise levels can also be beneficial to some species. There is now a much greater recognition of how animals use sounds outside of direct signal exchanges. Eavesdropping on conspecific and other species' communication signals or movement sounds are much more widely used as sources of information about predator or prey presence and habitat choice than previously assumed (Deecke et al. 2002; Barber et al. 2009).

Similarly, anthropogenic noise can be beneficial to some species depending on context and how others react to it. For example, prey of greater mouse-eared bats (*Myotis myotis*; Schaub et al. 2008) and western scrub jays (*Aphelocoma californica*; Francis et al. 2009) experience a decrease in predation pressure due to predators avoiding increased local noise. Similarly, masking of movement sounds by anthropogenic activity may decrease foraging success in predators benefiting prey species (Barber et al. 2009). Conversely, this acoustic crypsis could also allow predators to avoid detection by prey and increase their foraging success (Chan et al. 2010).

Although these examples are seen as the main possible benefits of noise in the recent literature, there is a range of mechanisms by which animals could potentially benefit from noise. Here we discuss two other potential uses of sound. First, local variations in the ambient-noise field could be used to perceive objects and navigate within an environment. Second, introduced sound cues could be used as a signal for prey detection or serve as acoustic landmarks for orientation and navigation.

2 Use of Local Variation in the Ambient-Noise Field to Detect Objects

One potential information stream provided by anthropogenic noise is from detectable differences within the ambient-noise field. Variation in the ambient-noise field can provide information on an object through the presence of an "acoustic shadow." In the visual domain, one way to detect objects is to use the differences in illumination (i.e., shadows and reflections) created between an object and a directional point source such as the sun. In the acoustic domain, there is often no dominating source of illumination, and the noise field is typically made up of a myriad of different natural and anthropogenic sources. However, in some cases, the ambient-noise field will contain localized sound sources such as snapping shrimp on fringing reefs or breaking waves around isolated rocks. In such circumstances, reflectors may cause acoustic shadows that would manifest as local attenuations in the noise field. Directional hearing and sound source segregation could allow an organism to detect the change in the ambient-noise field and detect the object.

Another way of gathering information using the acoustic ambient-noise field is with "acoustic daylight" or "'ambient-noise imaging" (ANI). Objects can be detected using incoherencies within the ambient-noise field as a main source of illumination (thus providing acoustic daylight; Buckingham et al. 1992). In this case, reflective objects will modify the ambient-noise field, creating a source of information that can be extracted through different methods. In engineering applications, imaging of reflective objects has been achieved by focusing scattered sound onto a paraboloid reflector, essentially creating an "acoustic lens" (Buckingham et al. 1992). More accurate pictorial images can be created by using a paraboloid reflector in conjunction with a hydrophone array that enables beam forming and mapping of relative intensities in each beam (Epifanio et al. 1999). Acoustic daylight imaging has led to the successful development of a computerized detection system, ADONIS, capable of using ambient noise to detect underwater objects (Epifanio et al. 1999). This system was able to detect various objects including 1-m-wide neoprene and corrugated steel targets, a swimming diver, and 113-L polyethylene drums filled with air, wet sand, and seawater at distances of at least 40 m (Epifanio et al. 1999).

In animals, the use of ambient noise for object imaging would be limited by having only two ears functioning as receivers. Although spatiotemporal integration and directional hearing could solve some of these issues, real imaging such as in engineering applications is unlikely to be possible. Nevertheless, the basic forms of ANI, such as for the detection of large obstacles, have been successfully shown in humans (Ashmead and Wall 1999). Some additional evidence suggests that human subjects were capable of determining an object's size (Gordon and Rosenblum 2004) and shape (Rosenblum and Robart 2007) in a continuous broadband noise field.

To date, no study has directly investigated whether animals use this information. However, based on theoretical models, it has been suggested that animals are capable of using acoustic daylight imaging for navigation and object detection (Potter 1997). Some empirical studies may also point toward such abilities even though alternative explanations cannot be ruled out. Blinded rats (Riley and Rosenzweig 1956) and seals in darkened environments (Oliver 1978) have been shown to perform well in navigation and obstacle avoidance experiments. It is possible that changes in the ambient-noise field were used for navigation. However, it is also possible that the seals detected hydrodynamic disturbances, using their vibrissae to navigate (as shown in Dehnhardt et al. 2001).

The ability to utilize ambient noise may also explain the presence of advanced auditory capabilities in fish species that do not produce sounds themselves (Fay 2009). For example, the goldfish (*Carassius auratus*) does not use any known form of sound communication, but it has a very acute sense of hearing (Fay 1998). Rather than being used for communication, it is possible that the fish use their sensitive hearing to exploit ambient-noise information. Although this possibility has not been well investigated, Lewis and Rogers (1992) demonstrated that fish have the potential to use ambient noise to detect other fish. They successfully conditioned fish to discriminate between artificial Gaussian noise fields, either without any scattering or with scattering similar to that which would occur from resonance in swim bladders (Lewis and Rogers 1992).

Anthropogenic noise could enhance or impede ANI. In situations where anthropogenic noise sources are highly localized, they may increase incoherencies in the noise field and therefore provide additional acoustic “illumination,” resulting in improved object detection capabilities for animals. However, it is also possible that anthropogenic noise sources can reduce inhomogeneity in a noise field by interfering with natural point sources or could mask localized ambient-noise cues and prevent the perception of certain types of reflection patterns.

Currently, few studies have addressed the use of acoustic daylight imaging by animals. It is therefore difficult to predict how specific anthropogenic noise sources would affect an animal’s perception. Further research investigating the abilities and detection sensitivities of animal species of interest would be valuable.

3 Use of Noise as a Signal for Prey Detection

Many species use passive listening to movement sounds to detect and capture prey (e.g., dolphins, Gannon et al. 2005; bats, Schaub et al. 2008). Through learning, animals can associate specific sound stimuli with food availability. This would be most obvious where anthropogenic noise indicates prey patches. In the marine environment, anthropogenic noise from fishing boat engines, pingers, sonar, and acoustic deterrent devices used on fish farms could be used by predators to locate prey, resulting in a “dinner bell” effect. Marine mammals have been found to be attracted by such sounds (Chilvers and Corkeron 2001; Thode et al. 2007), occasionally even to sounds introduced with the intention of deterring them (Bordino et al. 2002). In wild populations, higher incidences of predation at fisheries with acoustic deterrent devices (ADDs) may be attributed to learned associations between sound and prey (Jefferson and Curry 1996). ADDs produce loud sounds that are believed to cause avoidance responses in species such as seals that depredate fish farms. Although seals that have not previously been exposed to these avoid them, seals that have experience finding fish at that location quickly habituate to ADD sounds (Götz and Janik 2010, 2013). Through operant conditioning, ADDs can be associated with the presence of fish and then act as a dinner bell, potentially attracting seals to the area.

Current research using artificial sound sources to mark fish, such as the ocean-tracking network (http://oceantrackingnetwork.org/; Cooke et al. 2011), could also be influenced by such an effect. Many of these studies use acoustic coded transmitters (also known as pingers) that typically emit an ultrasonic acoustic signal that is inaudible to fish but is audible to many marine mammal predators (Bowles et al. 2010). If the signal is detectable, the sound would be associated with the presence of prey and could cause increased predation through a learned dinner bell effect. Alternatively, marine mammal predators may initially avoid fish fitted with a pinger, thus reducing the predation of tagged fish. In either case, such tag effects cause significant differences in the mortality of tagged compared with untagged fish and therefore lead to erroneous conclusions when studying fish behavior and survival rates.

Most of the studies illustrating the use of anthropogenic sound as a signal for prey detection are opportunistic. It is currently unclear to what extent acoustic cues affect prey detection or how long it would take for a predator to make an association between novel sound and an associated food source in its natural environment. However, the first results show that some predators like bottlenose dolphins (*Tursiops truncatus*) use fish communication sounds to detect prey aggregations (Gannon et al. 2005). Thus, more controlled studies investigating the role of anthropogenic acoustic information in prey detection are needed.

4 Use of Noise as a Signal in Orientation

Although noise can be used to navigate within an environment, it can also be used as a signal to mark specific locations. Apart from the effects of habituation and sensitization, the role of learning in reactions to noise is often overlooked. However, changes in the acoustic environment of an animal may be used to inform the receiver about the features relevant to its survival. Animals may use novel noise sources as an indicator of locations of interest and therefore are vulnerable to changes in the noise field.

This is particularly a concern with the introduction of anthropogenic noise. Sounds of ocean features such as reefs have been found to inform fish of their location (Simpson et al. 2005). For example, several species of reef fish have been shown to be attracted to the location of artificially simulated reef sounds, especially during larval stages (Leis et al. 2003; Simpson et al. 2004). Damselfish (*Pomacentrus* sp.) have been found to develop a preference for settling locations that have the same soundscape as the one that they experienced as larvae (Simpson et al. 2010). Additionally, ocean noise caused by waves or currents is suspected to be an important cue in the migration and orientation behavior of marine mammals (Richardson et al. 1995). Introduced anthropogenic noise may mask other such signals and affect navigation.

Stationary anthropogenic noise sources an also be used as a navigational signal or acoustic beacon. This can be advantageous or of concern depending on when and for how long noise is introduced into the environment. Exposure to anthropogenic noise may lead an animal to use the novel sound source as a signal, functioning as an acoustic landmark for orientation. However, when the sound is removed or relocated, this could confuse animals and create navigation errors. Currently, very little is known about the role of acoustic landmarks in animals, but there are numerous examples of the use of visual landmarks in navigation (for example, honey bees, *Apis mellifera*, Cheng et al. 1987; domestic dogs, *Canis familiaris*, Milgram et al. 1999; desert ants, *Cataglyphis fortis*, Collett 2010;). It is difficult to predict what role anthropogenic noise sources may play in animal navigation. Additionally, no information is available on the time it would take for an animal to associate locations with a novel sound source or how relocation of a sound source would affect its use as a beacon. Thus, future research investigating the role of anthropogenic sound in navigation would be valuable.

5 Conclusions

At present, very little is known about how animals utilize sound information other than that from species-specific sounds. Our ability to evaluate the effects of anthropogenic noise on a population level is hampered by a lack of understanding of how animals deal with noise. It is often assumed that noise can only compromise the fitness of animals. Although the disadvantages of noise pollution will likely outweigh any positive effects, it is important to understand how learning and perceptual mechanisms might be influenced by noise. Rare studies acknowledge that noise may have no effect or might even benefit some species.

We focused here on the use of ambient noise for acoustic daylight imaging, in which ambient noise from anthropogenic sources could help to illuminate the environment and aid sensory perception, and the use of anthropogenic sound as a signal marking locations for navigation or prey detection. The effects on species distribution and composition at locations of increased noise levels may create further advantages for selected species. To assess the role these effects might play, further work is needed on how animals use sound and react to it, especially concerning the sensitivities for perception and learned associations with sound.

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