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Review

The emerging significance of bioacoustics in animal species conservation

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ABSTRACT

This review reports on the effects of human activities on animal acoustic signals published in the literature from 1970 to 2009. Almost 5% of the studies on variation in animal communication tested or hypothesised on human impacts, and showed that habitat fragmentation, direct human disturbance, introduced diseases, urbanization, hunting, chemical and noise pollution may challenge animal acoustic behaviour. Although acoustic adaptations to anthropogenic habitats have been documented, human impacts have most often generated neutral variation or potential maladaptive responses. Negative impacts have been postulated in the sexual signals of fishes, amphibians, birds, and mammals; these are concerning as any maladaptive alteration of sexual behaviour may have direct bearings on breeding success and ultimately population growth rate. Acoustic communication also facilitates other vital behaviours influenced by human-driven perturbations. Bat and cetacean echolocation, for instance, is disrupted by noise pollution, whereas bird and mammal alarming is also affected by introduced diseases and hunting. Mammal social signals are sensitive to noise pollution and hunting, and birds selecting habitats by means of acoustic cues are especially vulnerable to habitat loss. Anthropogenic intervention in these cases may have a negative impact on individual survival, recruitment and group cohesion, limiting rescue-effects and triggering Allee effects. Published evidence shows that acoustic variation may be used as an early-warning indicator of perturbations even when not directly affecting individual fitness. Acoustic signalling can be studied in a broad range of ecosystems, can be recorded, analyzed, synthesised and played back with relative ease and limited economic budget, and is sensitive to many types of impacts, thus can have great conservation significance.

Contents

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1. Introduction

Communication, the way organisms convey information to each other, is the gel that holds animal societies together: it facilitates reproduction, provides information on individual identity, status, mood and intentions (Bradbury and Vehrencamp, 1998). As it includes a substantial proportion of the behavioural repertoire of animal species, communication behaviour can become an important driver of several aspects of species biology, affecting the evolution of life histories and genes.

Along with several other animals, humans share the use of sounds as the principal means of exchanging information. Many vertebrates (bony fishes, amphibians, reptiles, birds, mammals) and invertebrates (insects, spiders, crustaceans, nematodes) make sounds (or vibrations) for a variety of reasons, mostly for courtship and agonistic behaviours, but also for more complex social communication (Hauser, 1997; Owings et al., 1998). Many birds (oscines, some sub-oscines, trochilids and psittacines) and some mammals (cetaceans, primates, bats) may acquire important components of their acoustic repertoires by copying others, while this behaviour is thought to be innate in the other taxonomic groups (Kroodsma and Baylis, 1982; Janik and Slater, 1997). As an example, birdsong was the first 'cultural' trait (i.e. acquired through social learning) to be described in non-human animals, based on evidence dating back to Aristotle (Laland and Galef, 2009).

Acoustic signals are particularly well suited for studying the evolution of animal communication because of the relative ease with which sounds can be recorded and analyzed, synthesised and played back with efficiency (Gerhardt and Huber, 2002). Animal sounds have indeed served as models to address essential evolutionary questions, such as the way sexual selection operates and intervenes in speciation processes and the way natural selection shapes animal interactions (Kroodsma and Miller, 1996). In spite of being the target of many evolutionary studies, the role of animal vocalizations has been less significant in applied ecological research (Terry et al., 2005). Until the last decade, their use has been limited to acoustic surveys and censuses to detect vocal species of birds, mammals, amphibians and insects. Bioacoustics has also been used to generate basic demographic variables through the vocal identification of individuals, or estimate species occurrence and richness in those cryptic taxa characterized by species-specific acoustic signals (see also Caro (1998), Vaughan et al. (1997), Gaunt and McCallum (2004)).

More recently, bioacousticians have begun to tackle the questions of how human activities challenge the communication systems of animal species, what are the stochastic or deterministic mechanisms involved (natural, sexual or social selection processes), and what information of conservation significance can be derived by studying animal sounds (Rabin and Greene, 2002; Slabbekoorn and Ripmeester, 2008; Laiolo et al., 2008). A similar drive determined the development of '*Conservation Behaviour*', a discipline that combines applied and baseline research to address the behavioural mechanisms that influence the fate of populations and species (Curio, 1996; Buchholz, 2007; Caro, 2007).

The aim of this review is to collect recent literature on the impact of human activities on animal communication, and provide an overview of the potential of bioacoustics in conservation science. Based on published evidence, I discuss the type of information that could be extracted from animal sounds which may be relevant to species conservation and population ecology, and highlight a series of troublesome cases, in which acoustic variation may cause conservation problems and affects population persistence. Finally, I discuss how acoustic signals can be used in conservation studies as early-warning indicators of ongoing human-driven perturbations or to monitor population processes.

2. Bibliographic search

The overview is based on a Thompson's ISI Web of Science search of journals within the subject categories of 'Zoology', 'Ecology', 'Multidisciplinary Sciences', 'Behavioural Science', 'Acoustics', 'Biology', 'Marine and Freshwater Biology', 'Evolutionary Biology', 'Ornithology', and 'Environmental Science' from 1970 to 2009. As a variety of human impacts has been proven to affect animal communication and no single search term could define them, I started with a broad search of the terms CALL or SONG or VOCAL* or ACOUST* and VARIATION, and refined the search to the subject categories mentioned above. I checked 1711 papers on acoustic communication variation, and identified those titles and abstracts with conservation relevance (see also Section 3).

By checking literature, I classified human-driven effects according to the potential consequences for individual fitness or population persistence, on the basis of the conclusions of the authors themselves. I found that some species deal well with anthropogenic change and adapt their communication system to the novel conditions imposed by humans. In contrast, other species respond maladaptively, with deleterious consequences for individual fitness (such as reduced survival or mating success). In other cases, human-driven variation is neutral, e.g. differentiation does not affect individual fitness.

3. Results

I found that 53 papers explicitly focused on human-driven alterations (excluding review papers). For simplicity, I refer to these studies as 'Conservation Bioacoustics' papers. In the remaining titles of the search, I paid special attention to those of a more descriptive nature, which dealt with intra-specific acoustic variation. I searched here for inadvertent comparisons among natural and anthropogenic habitats, populations separated by anthropogenic barriers or differently affected by human impact. I found that 23 of the 406 descriptive papers read (5.7%) speculated on some anthropogenic causes to explain the patterns of acoustic variation found, as an alternative to other ecological or evolutionary hypotheses. Although these studies do not directly address conservation issues in the title, nor sometimes in the abstract, they do testify to the pervasiveness of human impact even in many behavioural study fields, which in theory tends to restrict the sources of variation to those of evolutionary significance.

The number of papers testing or hypothesising on human impact was therefore 76, less than 5% of the studies on variation in animal communication behaviour. Literature is summarized in Table 1, which reports the type of anthropogenic impact, the underlying mechanisms (internal mechanisms, demographic processes, etc.), the taxon affected, and the potential problems derived from acoustic variation. The types of impact were diverse: noise pollution (47.3% of papers), habitat fragmentation and degradation (40.8% of papers), direct human disturbance (2.6%), hunting (2.6%), chemical pollution (2.6%), introduced diseases (1.3%) and