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Review paper

Reducing bycatch in gillnets: A sensory ecology perspective

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ABSTRACT

Sensory capacities and perceptual challenges faced by gillnet bycatch taxa result from fundamental physiological limits on vision and constraints arising within underwater environments. To reduce bycatch in birds, sea turtles, pinnipeds and blue-water fishes, individuals must be alerted to the presence of nets using visual cues. Cetaceans will benefit but they also require warning with cues detected through echolocation. Characteristics of a visual warning stimulus must accommodate the restricted visual capacities of bycatch species and the need to maintain vision in a dark adapted state when foraging. These requirements can be provided by a single type of visual warning stimulus: panels containing a pattern of low spatial frequency and high internal contrast. These are likely to be detectable across a range of underwater light environments by all bycatch prone taxa, but are unlikely to reduce the catch of target fish species. Such panels should also be readily detectable by cetaceans using echolocation. Use of sound signals to warn about the presence of gillnets is not recommended because of the poor sound localisation abilities of bycatch taxa, cetaceans excepted. These warning panels should be effective as a mitigation measure for all bycatch species, relatively easy to deploy and of low cost.

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1. Introduction: the problem of gillnet bycatch

Bycatch of seabirds in gillnet fisheries is a worldwide problem that is estimated to result in the deaths of at least 400,000 birds annually (Lewison et al., 2014; Zydelis et al., 2013). This rate of bycatch is thought to be unsustainable for some species, and there is evidence that in some localities gillnet bycatch has resulted in severe reductions in the numbers of breeding birds (Osterblom et al., 2002; Regular et al., 2013). Bycatch is also a well-established issue for other animals groups including sea turtles (Chelonioidea), pinnipeds, cetaceans and blue water fish (Tunas *Thunnus spp.* and billfish *Istiophoridae* and *Xiphiidae*) (Fritsches and Warrant, 2006; Lewison et al., 2014; Myers and Worm, 2003; Reeves et al., 2013; Wallace et al., 2013). It is recognised that there is an urgent need to reduce this bycatch, but at the same time, in order to obtain support and adoption by the fishing industry, it is desirable not to reduce the efficiency of gillnet fishing. Spatial and temporal closures of fisheries have a role to play in managing the impact of gillnets (Regular et al., 2013), but these may be difficult to establish and enforce. Thus, technological solutions to gillnet bycatch, of which there are currently few, are sought as important additions to the suite of prospective management measures. Ideally a technological solution is sought that will be effective for all bycatch species and is easy to deploy.

This review is a contribution towards the achievement of that aim. It provides an analysis of the sensory ecology of bycatch-gillnet interactions. The aim is to understand the factors which predispose animals to become entangled in gillnets as bycatch and to suggest how this understanding can be used to reduce bycatch.

Sensory ecology has been variously defined but can be summarised as, "The investigation of the information that underlies an animal's interactions with its environment" or "How organisms acquire and respond to information" (Dusenbery, 1992; Stevens, 2013). A sensory ecology approach has provided insights into the bases of many broad classes of interactions between animals and their environments, especially with respect to foraging (Martin, 2012), and to investigate some of the key general problems which birds face in human modified environments. This includes understanding the sensory and cognitive bases of fatal interactions between flying birds and large human artefacts that are conspicuous to humans, such as wind turbines, power lines and oil platforms, and which can cause high levels of bird mortality (Martin et al., 2012; Martin and Shaw, 2010; Shaw et al., 2010).

A sensory ecology approach has been discussed with the aim of reducing the bycatch of sea turtles in longline and gillnet fisheries (Swimmer and Brill, 2006; Southwood et al., 2008) and some solutions stemming from this work have recently been tested (Wang et al., 2013, 2010).

As a framework for investigating collisions or net entanglement, sensory ecology employs the premise that such problems are not simply explained as the result of animals "making mistakes", i.e. a hazard is detected but there is a cognitive failure to interpret the danger of the hazard. A sensory ecology framework, when applied to net entanglement, assumes that under many circumstances bycatch prone species can and do detect nets, but there are limits to their ability to detect them and it is when those limits are breached that animals may get caught. To describe these as "mistakes" is simply to admit that from a human perspective we do not know what is going on. Sensory ecology tries to understand the limits of sensory performance and employ this to reduce the situations when these limits are met. This is an approach pioneered by research into why motorists make "mistakes" and have accidents e.g. Clarke et al. (1995). The results of such work are widely seen today in that roads are heavily signed with standardised signals; lines, chevrons, lights, cats eyes, etc. For many circumstances the information that these signals provide is redundant and unnecessary for safe driving. However, when visibility is reduced, for example, due to lower light levels, rain, and fog, the perceptual limit of driving may be reached. Under these circumstance these gross signals become crucial for accident avoidance.

A similar approach is employed here to the reduction of net entanglement leading to bycatch. However, since bycatch species have a different suite of sensory abilities and extract different kinds of information from the world compared with humans, it is not possible to make simple assumptions based upon human experience and data and apply these to bycatch species and situations. What follows is an attempt to understand those limits and how they apply in the particular circumstances of underwater environments. This information is then used to propose signals which will have applicability in reducing bycatch across a wide range of species and situations.