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RESPONSE

The startle reflex in acoustic deterrence: an approach with universal applicability?

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Interactions between predators and human livestock cause a range of management and conservation challenges (Treves & Karanth, 2003). Acoustic deterrent systems have been used for decades, but the sounds employed by these devices often only show initial effectiveness (Götz & Janik, 2010, 2013). Few deterrence methods have emerged from scientific research, which is one of the reasons why little data are available on the efficiency of most commercial systems. Airmar filed a patent (Jeffers, 1997) stating that their system causes auditory pain while other devices claim to cause irritation or discomfort. However, it is important to understand the exact biological mechanism by which an avoidance response is induced. Almost all systems produce signals at very high source levels and duty cycles (Götz & Janik, 2013). Depending on the assumed exposure scenario, animals could potentially suffer hearing damage as a result of repeated exposure (Götz & Janik, 2013). Once an animal has experienced auditory damage, its pain tolerance will be greater, eventually no pain will be experienced and the deterrence system will be ineffective. Furthermore, high source level and high duty cycle devices often cause adverse effects, such as habitat exclusion, in non-target species (Götz & Janik, 2013). The method we designed (Götz & Janik, 2011) can be tuned towards the taxon in question and reduces the risk of long-term auditory damage by decreasing noise pollution. In a 1-year test, we could show that a startle-based system protected a farm efficiently without affecting marine mammal distribution in the area (Götz & Janik, 2016).

In their commentary on this study, Trites and Spitz (2016) raise several important issues. They point to a long history of frustrated expectations with deterrent systems where initial results were promising but the wider applicability limited. Furthermore, Trites and Spitz (2016) state that field experiments are often difficult to reproduce, the number and motivation of predating individuals can vary and our test sites may not have had high predation pressure (Trites & Spitz, 2016). What is it then that might still set a reflex-based deterrence method apart from previous approaches? The startle response is mediated by a simple oligosynaptic reflex which can be triggered by different modalities and is conserved among many mammalian taxa (Yeomans *et al.*, 2002). The reflex arc itself is simple; however, the startle pathway is influenced by efferent projections from brain centres related to emotional processing (Koch, 1999). Neurophysiological studies only quantify the response itself but show little interest in the follow-up behaviour associated with the reflex. A study on grey seals *Halichoerus grypus* demonstrated that individuals that could be startled underwent a sensitization process in a simulated foraging task, thereby increasing the responsiveness to the stimulus over time (Götz & Janik, 2011). A consecutive experiment in the same study demonstrated that this behaviour is linked to the startle reflex, rather than the defence reflex (Turpin, Schaefer & Boucsein, 1999) which points towards the existence of a hitherto unknown afferent projection from the startle pathway to the brain centres involved in the mediation of follow-up behaviour (Götz & Janik, 2011). Hence, the method we tested in this study is based on a solid scientific background that goes beyond trial and error approaches often used in this field.

We agree with Trites and Spitz (2016) that one should not expect a panacea solution. Biological systems are dynamic, and to expect such a solution would be naïve. Our previous research clearly indicated limitations of the startle approach, such as the presence of some undeterred seals (Götz & Janik, 2015). Any acoustic deterrence method will run into difficulties when faced with a population of animals that show large variability in their auditory sensitivity, most likely as the result of exposure to anthropogenic noise or age. Lower auditory sensitivity results in decreased startle behaviour which reduces deterrence ranges. As a result, predation reduction is unlikely to be 100% effective. However, given that conventional acoustic deterrents can cause hearing damage in seals (Götz & Janik, 2013), the problem may in part be 'home-made' and could potentially be addressed on the regulatory level.

Furthermore, it is important to look at the predation phenomenon more widely. Trites and Spitz (2016) state that surfacing rates of seals at our test sites were low and predation may well have been caused by a single animal. Northridge, Coram and Gordon (2013) conducted a photo-identification study of seals around fish farms in Scotland which also included our main test site. They specifically mentioned our test site as an example for seals being 'transient 'with 'new' seals being identified throughout the year (Northridge *et al.*, 2013). Overall, they identified 12 different individuals in 16 sessions at our long-term test site with limited re-sightings across sessions. Thus, we think it is likely that predation was caused by a range of different individuals which stayed around the farm site for a limited time. However, even if predation was caused by just one seal, our tests were conducted in one of the prime fish farm areas in Scotland where seals often cause losses that are commercially relevant. Contrary to what Trites and Spitz (2016) suggest, we did provide absolute numbers (see fig 2 in Götz & Janik, 2016). Together with the associated statistical models, these data showed a clear effect of the acoustic deterrence sounds. Our deterrence method decreased predation with the desirable side effects of dramatically lower noise levels than those from commercially available Acoustic Deterrent Devices (ADDs) and not affecting seal hearing or porpoise abundance (Götz & Janik, 2015). On the latter point, Trites and Spitz (2016) are a little unclear. While they acknowledge our previous study in a high-density porpoise area (Götz & Janik, 2015), they also call for further tests at such sites. We are less convinced that further tests of that aspect are needed since our 2015 study has demonstrated the lack of an effect on porpoises in an area where ADDs cannot be legally used because of high porpoise abundance. However, further tests on other odontocete species might be useful.

The biggest question, and partly the motivation for our test, is whether animals will habituate to our signals in the long term. Trites and Spitz (2016) believe that all technology-based deterrence methods are likely to fail in the long term. We agree that static solutions are not always long-term ones. Each study has to monitor its application closely and report on its functionality. For example, underwater transducers and amplifiers can show fatigue. Our method relies on the signals having a short onset time and minimum amplitude making it crucial to monitor system performance. If over time, the equipment is unable to provide this, our method will become ineffective. To address the issue of long-term effectiveness, it is crucial to be able to monitor every system and identify any malfunction or failure. In many previous studies, it was unclear whether malfunction or habituation was responsible for the changes in animal reactions.

With the approach we chose using a signal that unlike any other (Götz & Janik, 2010) led to sensitisation in the avoidance response rather than habituation over repeated exposures (Götz & Janik, 2011), we found long-term effectiveness over a year (Götz & Janik, 2016). Given the theoretical framework and previous data on sensitisation to startle stimuli (Götz & Janik, 2011), we think this approach is more promising than previous ones. Further long-term tests at additional sites will help to fully explore all parameters that may influence the reliability of startle sounds in acoustic deterrence.

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