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Mapping widespread and increasing underwater noise pollution from acoustic deterrent devices

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ABSTRACT

Acoustic deterrent devices (ADDs) are used in attempts to mitigate pinniped depredation on aquaculture sites through the emission of loud and pervasive noise. This study quantified spatio-temporal changes in underwater ADD noise detections along western Scotland over 11 years. Acoustic point data ('listening events') collected during cetacean line-transect surveys were used to map ADD presence between 2006 and 2016. A total of 19,601 listening events occurred along the Scottish west coast, and ADD presence was recorded during 1371 listening events. Results indicated a steady increase in ADD detections from 2006 (0.05%) to 2016 (6.8%), with the highest number of detections in 2013 (12.6%), as well as substantial geographic expansion. This study demonstrates that ADDs are a significant and chronic source of underwater noise on the Scottish west coast with potential adverse impacts on target (pinniped) and non-target (e.g. cetaceans) species, which requires further study and improved monitoring and regulatory strategies.

1. Introduction

Over the past 30 years marine finfish aquaculture has expanded dramatically across the globe, and is projected to provide two thirds of global food fish by 2030 (FAO, 2017). This expansion has, however, resulted in increasing conflict with marine top predators such as cetaceans and birds, but particularly pinnipeds (Northridge et al., 2013; Quick et al., 2004). To reduce such interactions, various predator control methods have been tried, including targeted shooting of problem individuals, culling programmes to reduce populations, and different forms of non-lethal deterrence like physical barriers and animal relocation programmes (Quick et al., 2004). Of the non-lethal methods used, the emission of loud acoustic signals from Acoustic Deterrent Devices (ADDs, also known as Acoustic Harassment Devices [AHDs]) is often considered a comparatively benign solution to the problem of depredation at aquaculture facilities (Nash et al., 2000). However, their (long-term) effectiveness in preventing pinniped depredation has not been shown conclusively and remains a topic of considerable debate (reviewed by Götz and Janik, 2013).

Most commercially available ADDs are designed to produce intense and aversive sounds within the hearing range of the target species (pinniped underwater hearing range 50 Hz to 86 kHz; National Marine Fisheries Service, 2016), aiming to deter them from approaching and damaging the pens or the fish themselves (Coram et al., 2014; Götz and Janik, 2013; Jacobs and Terhune, 2002; Quick et al., 2004). ADDs are deployed underwater, attached to aquaculture cages and can be set to run continuously (Northridge et al., 2013). A variety of ADD types exist which differ substantially in their acoustic characteristics (e.g. frequency range, amplitude, and duty cycle). The majority of these devices produce sounds in the range of 2 to 40 kHz, with source levels ≥185 dB re 1 μPa @ 1 m (RMS; Gordon and Northridge, 2003; Lepper et al., 2014; Reeves et al., 2001).

Given their frequency ranges and source levels, ADDs have the potential to cause physical and behavioural effects on both target and non-target species, including cetaceans. Physically, ADD noise may result in temporary or permanent reductions in hearing sensitivity (Temporary Threshold Shift [TTS] or Permanent Threshold Shift [PTS]) of marine mammals which use sound as their primary sense (Götz and Janik, 2013). ADD use can also lead to behavioural responses, and potential exclusion from key habitats used for foraging, resting and/or

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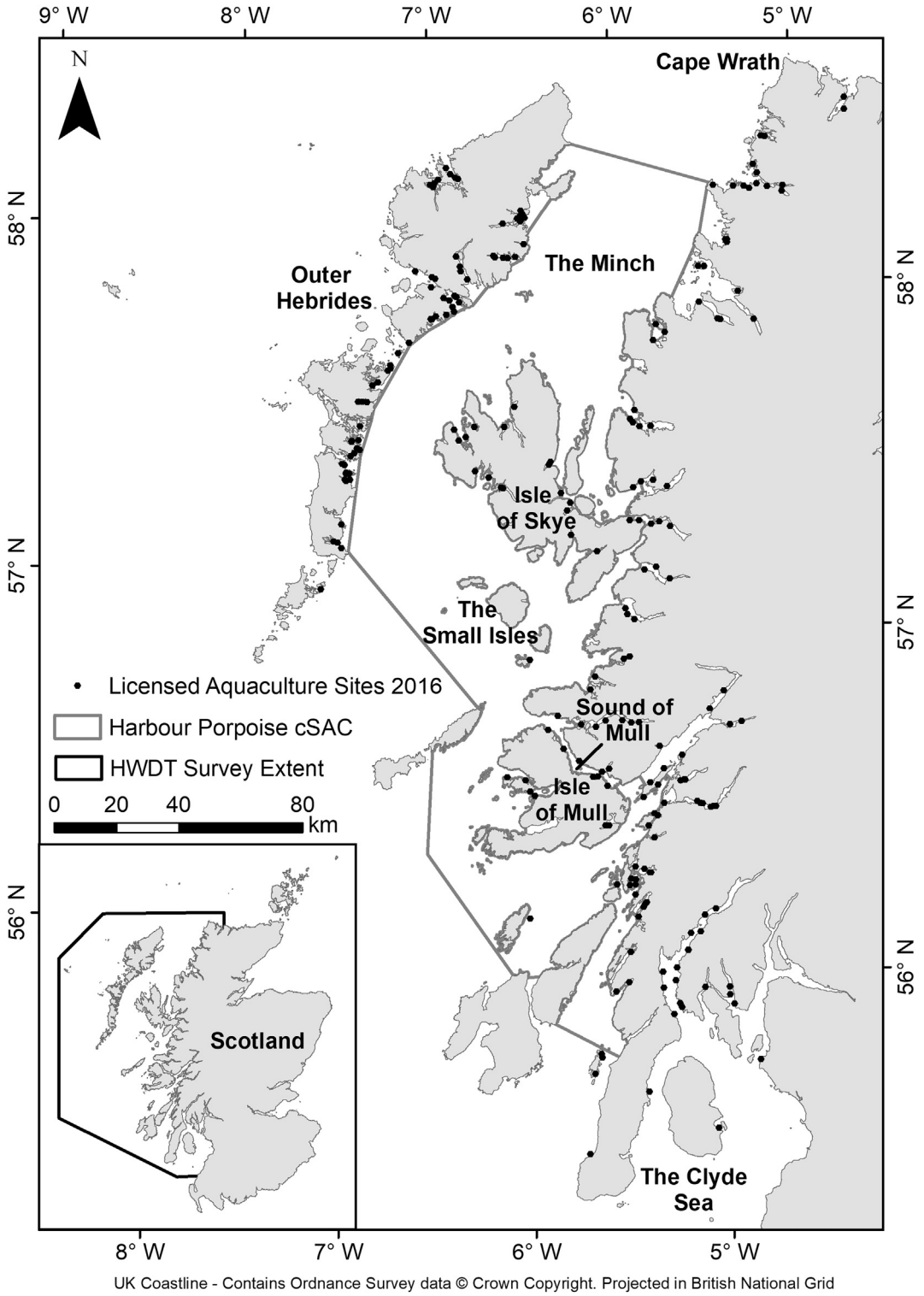

Fig. 1. Map of the west coast of Scotland, UK, illustrating overall Hebridean Whale and Dolphin Trust (HWDT) survey extent (bottom left), the locations of licensed salmon aquaculture sites (active and inactive) in 2016, and 'the Inner Hebrides and the Minches' candidate Special Area of Conservation (cSAC) for harbour porpoise (*Phocoena phocoena*).

reproducing (e.g. Brandt et al., 2013; Coram et al., 2014; Harris et al., 2014; Morton and Symonds, 2002). These issues are compounded when ADDs are used simultaneously on multiple cages within a single aquaculture site and among adjacent sites, which are often spread out to reduce cumulative negative impacts of localised eutrophication, chemical pollution, and disease outbreaks (Butler, 2002; Frid and Mercer, 1989). When used over large areas and extended time periods, ADDs may therefore represent a source of chronic underwater noise pollution which may negatively affect animals' individual fitness, potentially with long-term population consequences (King et al., 2015).

On the west coast of Scotland, cage-based finfish aquaculture (mainly involving Atlantic salmon, *Salmo salar*) is a rapidly expanding rural industry (The Scottish Government, 2015). Seal depredation has been reported by the sector (Harris et al., 2014; Northridge et al., 2013;