NOISE EFFECTS ON THE CALL AMPLITUDE OF SOUTHERN RESIDENT KILLER WHALES (*ORCINUS ORCA*)

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INTRODUCTION

Southern resident killer whales (SRKWs) are an endangered population found in the inland waters surrounding Washington State, US, and British Columbia, Canada. Their summer range is particularly congested with a number of anthropogenic underwater noise sources including commercial ships, ferries, and whale-watching boats. Given that killer whales rely on sound for biosonar, communication, and passive listening, noise-vessel interactions were identified by regulatory agencies as one of several factors potentially related to their population decline.

Masking by anthropogenic sources can be predicted by knowing how exposure overlaps with biologically important sounds relative to the sensitivity of the whales. Killer whales can probably overcome some masking through strategies such as communicative compensation. For example, animals might call louder, longer, or more often to vocally compensate for increased background levels. Such responses have been identified as a critical research need for understanding noise impacts on free-ranging marine mammals (NRC 2003). Furthermore, knowing exposure limits beyond which vocal compensation might not be able to overcome masking effects can indicate the degree to which anthropogenic factors would impede the use of social and filial vocal signals. In this study, amplitude compensation was investigated in SRKW social calls from recordings made in Haro Strait off San Juan Island, WA, US. (48°33.5' N, 123°10.4' W).

METHODS

Recordings (0.1-10 kHz) were made from a fixed array of four hydrophones (one ITC-6050C and three ITC-4066) as previously reported by Veirs (2005). After recordings were obtained, the array was calibrated to determine hydrophone locations, hydrophone sensitivities (with amplification), and sound-spreading functions.

An algorithm was used to trigger call recordings at a 22.05-kHz sampling rate. When a recording was triggered, 1,500 ms of data including 400 ms prior to the call were stored as a file. The smallest running average and the largest running average were defined as background level (BL) and maximum signal level, respectively. Both were averaged in voltage over a 250-ms window. Maximum received levels were calculated after background level was subtracted from maximum signal level. Calls were localized using "matched field processing" in which the difference between observed and predicted time of arrival differences between hydrophones were minimized. Call source levels (SLs) were calculated using cylindrical spreading loss based on calibration observations. Call SLs and associated BLs were averaged (in square voltage) over the four channels and then converted to dB_{rms} re 1 µPa.

Localized calls included in the analysis were those that were recorded in a range between 20 and 400 m of any hydrophone, had adequate cross-power spectra quality ($Q > 6$), and consisted of a single call that was confidently assigned a call type of the SRKW community (Ford 1987).

RESULTS

Background levels ranged from 95.3 to 119.5 dB and call SLs from 128.3 to 161.9 dB re 1 µPa. The relationship between BL and call SL was best described as linear. Whales increased their call amplitude by approximately 0.5 dB for every 1-dB increase in background levels ($P < 0.0001$; $R^2 = 0.29$; $n = 86$). Further analysis by call type was limited by sample size. There was no significant relationship between call SL and computed range or between BL and computed range.

DISCUSSION

SRKWs increased their vocal output when ambient noise levels increased. Such adjustment helps maintain an adequate signal-to-noise ratio relative to listening whales. Other factors that likely influence call amplitude include differences between individuals, call types, behavioural context such as spacing among whales, and call directionality. Results suggest that environmental noise influenced the vocal behaviour of SRKWs, but the costs of such behavioural changes are unknown. For example, modifying acoustic signal parameters might have costs associated with energetic output and/or communicative functionality. Furthermore, the use of passive listening to detect sounds that are not under the control of the whales (e.g., prey sounds) might be more vulnerable to masking effects.

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NOISE LEVELS AND MASKING POTENTIAL OF SMALL WHALE-WATCHING AND RESEARCH VESSELS AROUND TWO DELPHINID SPECIES

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INTRODUCTION

During the last few decades, whale watching has expanded into a billion-dollar industry covering more than 87 countries worldwide. Concern has arisen that this nearly exponential growth may have negative consequences for marine mammals. Various studies have documented short-term effects of cetacean tourism. Recent studies that provide evidence for long-term detrimental effects of whale watching has led the International Whaling Commission to acknowledge that there might be direct fitness reductions associated with this industry (International Whaling Commission 2006). It is likely that at least