UNDERWATER BOW-RADIATED NOISE CHARACTERISTICS OF THREE TYPES OF FERRIES: IMPLICATIONS FOR VESSEL-WHALE COLLISIONS IN THE CANARY ISLANDS, SPAIN

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INTRODUCTION

Lethal collisions of ships with whales are increasing worldwide. Often whales do not appear to avoid approaching ships, but the reasons for this are unclear. In the Canary Islands, a large fleet of commercial ferries operates on a year-round basis (Ritter 2010). At the same time, a high number of stranded cetacean carcasses showed injuries typically attributed to ship strikes (Carrillo & Ritter 2010). Very regularly, these ships also cross Special Areas of Conservation under the EU habitat directive, i.e. marine protected areas (Elejabeitia & Urquiola 2009; Ritter 2010). On the other hand, underwater acoustics of the ferries and in particular underwater bow-radiated noise characteristics are largely unknown until today.

METHODS

Recordings of underwater sound characteristics of three types of ferries (regular ferry, fast ferry and high speed ferry) were made during September 2012 off the island of La Gomera at a depth of 15 m using a pre-amplified (± 20dB) and calibrated C55 hydrophone with a built-in anti-aliasing filter operating with a sample rate of 192,000/s at 24 bit. Information on ferry speed and distance were gained with an AIS100 automatic identification system receiver.

Ferry passages were sampled every 10 seconds as soon as the vessel was within 4.0 km of the recording vessel and during normal ferry travel speed.

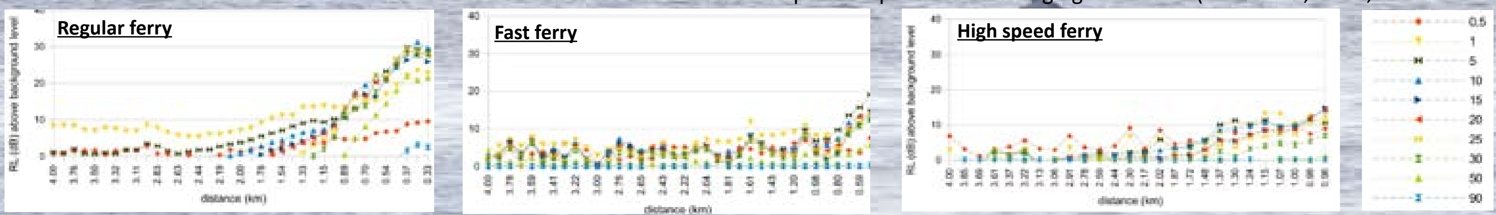

Figure 1: RL (in dB) measurements above background level for selected frequency bands (0.5-90 kHz) during approaches from a 4 km distance to CPA for the (a) fast ferry, (b) regular ferry and (c) high-speed ferry

Recordings were analysed using Raven Pro 1.4 software. Spectral analysis (512 FFT, 50% overlap) of received noise levels (RLs) for frequency bands at 0.5, 1, 5, 10, 15, 20, 25, 30, 50 and 90 kHz were made from 5 sec slices taken from each 10 sec sample. To calculate RLs of ferry noise above background noise (=critical ratio exceedance; CRE), RL of ambient noise was subtracted from the corresponding RL of frequency bands attributed to ferry noise.

RESULTS

Nearest CPAs were 0.33 km for the fast ferry, 0.41 km for the regular ferry and 0.96 km for the high-speed ferry (see Table 1).

Table 1 also summarizes distances at CRE, peak frequencies at CRE and remaining time from CRE to potential collision for CRs 10-30 dB, as well as absolute RL values of peak frequencies at CREs. Peak frequencies at CRE (CR=10 dB) differed between the propeller-driven ferries (1 kHz) and the jet-driven high-speed ferry (5kHz). By applying a CR of 10 dB, the fast ferry was detectable at a distance of 1.67 km which results in a remaining time of 2.53 min to a potential collision from the distance at CRE. The regular ferry could be detected at a distance of 1.61 km (remaining time: 3.50 min) and the high-speed ferry at a distance of 1.37 km (remaining time: 1.30 min). When applying a CR of 15 dB, remaining time decreased to 1.26 min for the fast ferry and 1.28 min for the regular ferry. This CR (and all others above it) was not exceeded by the high-speed ferry until it reached CPA. All CREs with CRs of 15-30 dB for the fast and regular ferries occurred below the CPA of the high-speed ferry. At a CR of 30 dB the fast ferry has a remaining time of 0.53 min whereas both the regular and high-speed ferries did not exceed this CR (see Table 1).

Figure 1 compares absolute RLs at 1, 5 and 10 kHz between ferry types between 4 km distance and CPAs.

Date	Time of day	Ferry name	Passage (from-to)	Ferry speed	Water depth at recording location	Range at CPA [1]	Range at CRE [2]	Peak frequency at CRE	RL of peak frequency at CRE	Remaining time from CRE to potential collision
17.09.12	11:29:00	*Volcan de Taburiente*	SS-LC	21.4 kts	1,000 m	0.33 km	10 dB: 1.67 km	1 kHz	71.2 dB	2.53 min
							15 dB: 0.83 km	10 kHz	62.4 dB	1.26 min
							20 dB: 0.59 km	10 kHz	67.1 dB	0.89 min
							25 dB: 0.44 km	5 kHz	75.6 dB	0.66 min
							30 dB: 0.35 km	10 kHz	76.1 dB	0.53 min
18.09.12	11:59:00	*Benchijigua Express*	SS-LC	32.2 kts	580 m	0.96 km	10 dB: 1.37 km	5 kHz	59.1 dB	1.30 min
18.09.12	14:47:00	*Volcan de Tauce*	LC-SS	14.9 kts	650 m	0.41 km	10 dB: 1.61 km	1 kHz	72.6 dB	3.50 min
							15 dB: 0.59 km	5 kHz	64.7 dB	1.28 min
							20 dB: 0.41 km	5 kHz	69.6 dB	0.89 min

Table 1: Characteristics of ferry recordings and measurements during passages between the islands of Tenerife and La Gomera, Canary Islands (SS = San Sebastian, LC = Los Cristianos).

DISCUSSION

Unique acoustical signatures of the ferries might enable their (individual) recognition by the animals and the calculated reaction times for whales appear to be long enough for an avoidance reaction. Why then, do sperm and other whales often not avoid ferries quickly enough?

CRs for frequency bands below 20 kHz were reported to range 15-30 dB in cetaceans (Johnson 1968; Johnson et al. 1989; Thomas et al. 1990; Kastelein et al. 2009). Therefore, applying the 10 dB CR for this study is a conservative assumption, hence calculated time frames have to be seen as maximum values. When increasing CR to 20 dB, remaining reaction time is reduced for the fast ferry by 35%, and for the regular ferry by 75% (see Table 1). Extrapolating this to the high-speed ferry which also had lowest RL of the peak frequency we expect a strongly diminished detectability and a substantial reduction of the reaction time, thus increasing collision risk dramatically.

We showed that frequency bands of 1, 5 and 10 kHz were essential in detecting ferries from the distance. On the basis of what is known on hearing abilities of odontocetes today (see for example Richardson et al. 1995; Ridgway & Carder 2001; Schlundt et al. 2011) we assume that RLs of peak frequencies are above the hearing thresholds of pygmy sperm and short-finned pilot whales but below the thresholds of sperm whales. It has to be stressed that wild whales sometimes suffer from impaired hearing or even hearing loss and this could be quite frequent in free-ranging cetaceans (see André, 1997; Mann et al. 2010; Schlundt et al. 2011). Cetaceans might also be resting or sleeping, or be otherwise distracted by certain behaviours like play or socializing, and this can be specific to certain age classes or less experienced individuals. Finally, the three cetacean species representing the largest part of collision victims are all deep divers known to stay close or at the surface to restore oxygen after longer dives (Watkins et al. 1993; Tyack et al. 2006; Aguilar Soto et al. 2008; Miller et al. 2008; Wells et al. 2013). Hence, there might be physical limitations to timely react to an approaching vessel. Several of the above factors can also act together, thus elevating collisions risk even more.

We conclude that the combination of great velocity in the high-speed ferry resulting in short reaction time and the comparably low intensity of its bow-radiated noise leads to a particularly high collision risk of this ferry type.

Our results reinforce the need to reduce ship speed so as to minimize the risk for the animals, vessel crew and ferry passengers alike.

to climate change effects such as rising sea surface temperatures and their consequences for overall habitat quality and suitability. Such potential long-term changes will be subject to future investigations.

Acknowledgements

This study was supported by the Heinz Sielmann Foundation (Germany) and the foundation 30 Millions d'Amis (France). Thanks to Roland Gockel, Heinz Cadera, Ricarda Fiebig, Volker Böhlke and Samyo Hoheisel for their excellent companionship as crew members and their essential support during field work and data sampling. Thanks to Reiner Seifarth (TUI Deutschland GmbH, Germany) for logistical support. This study was authorized under research permit 01/37121 by the Ministerio de Agricultura, Alimentación y Medio Ambiente of the Canary Islands.

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