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Settings of demersal longlines reveal acoustic cues that can inform toothed whales where and when to depredate

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Abstract: Fishing boats produce acoustic cues while hauling longlines. These acoustic signals are known to be used by odontocetes to detect the fishing activity and to depredate. However, very little is known about potential interactions before hauling. This article describes the acoustic signature of the setting activity. Using passive acoustic recorders attached to the buoys of longlines, this work demonstrates an increase in the ambient sound of $\sim$6 dB re 1 μPa^2 Hz^{-1} within 2–7 kHz during the setting activity. This could also be used as an acoustic cue by depredating species, suggesting that predators can detect longlines as soon as they are set.

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1. Introduction

Anthropogenic underwater noise results from increasing human activities, such as resource exploration and exploitation, military activity, pile driving for construction, and marine traffic (Williams *et al.*, 2015). Underwater noise can create stress, resulting in modifications of natural behaviours and/or inducing physiological responses (Southall *et al.*, 2019). However, specific anthropogenic sounds may conversely attract marine mammals. This is the case for some fishing activities which produce acoustic cues that inform marine mammals about the ongoing fishing activity, and the easily available fish resource (Carretta and Barlow, 2011; Mul *et al.*, 2020; Thode *et al.*, 2015). Competition between fishermen and predators may result in depredation behaviour, i.e., predators removing fish from fishing gear (Hamer *et al.*, 2012). This has been mainly reported for longlines, since this fishing gear is composed of a main line with baited hooks, making fish easily accessible for depredating animals (Hamer *et al.*, 2012). Depredation behaviour has substantial socio-economic consequences (Peterson *et al.*, 2014) as well as conservation issues either for the depredating species and for the fish resources (Hanselman *et al.*, 2018). New measures and ideas are required to mitigate these interactions. However, appropriate countermeasures are difficult to obtain since depredation behaviours are highly variable. They notably depends on the species involved and on the type of longlines that are used.

Depredation from pelagic longlines, i.e., deployed within the water column close to the surface, has been described to occur through the whole fishing process (Rabearisoa *et al.*, 2012; Thode *et al.*, 2016). Conversely, depredation by toothed whales on demersal longlines, i.e., set on the seafloor, was thought to occur at specific moments of the fishing process. Indeed, demersal longline fishing can be decomposed into three main phases. During the first phase, called "setting," longlines are deployed at sea. Then for the second phase, called "soaking," longlines are left on the seafloor and fish are caught. The last phase, named "hauling," occurs when the lines are recovered. Note that a given longline may be soaking for days. During that period, the fishing vessel may leave the area and perform other activities.

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Toothed whale depredation on demersal longlines is traditionally believed to happen during hauling (Mathias *et al.*, 2012; Söffker *et al.*, 2015). Indeed, toothed whales need to perform shallow dives to access the fish caught on longlines being hauled (Mathias *et al.*, 2012), while interacting with soaking longlines would require deeper dives, and thus more effort. Also, previous studies revealed that fishing vessels produce specific acoustic cues while recovering longlines, i.e., when switching on winch, changing speed, or increasing maneuvers (Richard, 2018; Thode *et al.*, 2015; Thode *et al.*, 2007). These cues are believed to attract marine mammals during the hauling phase (Carretta and Barlow, 2011; Mul *et al.*, 2020; Richard, 2018; Thode *et al.*, 2015). However, recent studies revealed that sperm whales and killer whales can also depredate from demersal longlines during soaking (Cieslak *et al.*, 2021; Janc *et al.*, 2018; Richard *et al.*, 2019; Richard *et al.*, 2020). This raises the question of how these animals find the longlines on the seafloor within the vastness of the sea.

In this paper, we hypothesize that similar to the hauling activity, line setting produces acoustic cues that attract marine mammals. To explore this question, the acoustic signature of the setting of demersal longlines is experimentally measured. To do so, passive acoustic recorders were deployed on demersal longline gears from fishing vessels operating around the French sub-Antarctic islands (Southern Indian Ocean).

2. Method

2.1 Data collection

Acoustic recordings were collected from three fishing vessels between January and March 2017 and between January and March 2018. Vessels are targeting the Patagonian toothfish using demersal longlines within the economic exclusive zones of Crozet (46°25′S, 51°59′E) and Kerguelen (49°20′S, 70°20′E). Recordings were obtained with a Soundtrap ST300 HF (Ocean Instruments, New Zealand) and an EA-SDA14 autonomous recorder (RTSys, France). Recorders were programmed to record continuously during the whole longline deployments (from a minimum of 6 h up to a week) with sampling rates varying from 38 to 144 kHz. As illustrated in Fig. 1, recorders were clamped at a depth of 100 m on the downline connecting the buoy to the anchor (ballast) of a longline.

Soaking recorders were used to assess the potential acoustic cues associated with surrounding longlines being set. In other words, a recorder was never used to assess the setting sounds of the longline it is attached to.

2.2 Fishing data

Information on fishing vessel activity during recorders' deployments were available through the PECHEKER database (Martin and Pruvost, 2007). This database was used to identify specific times during which a longline was set around a deployed hydrophone (within a 20 km radius). However, the PECHEKER time-information are approximate (recorded on an hourly basis). As a result, the setting times obtained from the PECHEKER data could not be used to directly find setting events in the acoustic data. Rather, they were used to focus the acoustic analysis on specific (relatively short) time period.

2.3 Acoustic analysis

Long spectrograms were computed around the theoretical (PECHEKER) setting time. These spectrograms were manually analyzed to determine potential variation of the soundscape associated with the setting activity. It was notably found that setting activities drastically increase the ambient sound. This is illustrated by two examples in Fig. 2. Figure 2(a) shows a spectrogram of the ambient sound at the beginning of the setting phase, while Fig. 2(b) shows a spectrogram of the ambient sound at the end of setting.

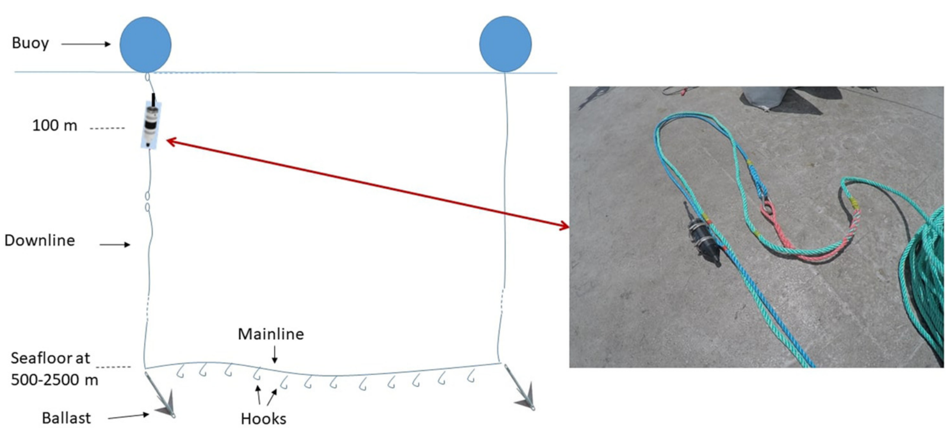

Fig. 1. Diagram of a soaking longline and of the acoustic system.

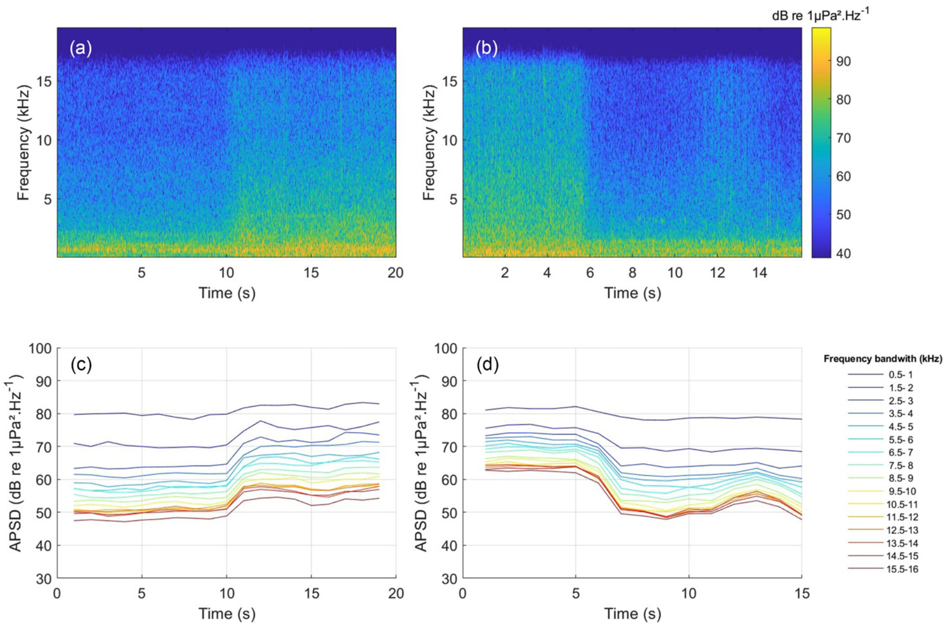

Fig. 2. Examples of two setting events recorded respectively at 1.2 km and 0.5 km from the hydrophone: spectrograms of ambient sounds recorded at the beginning (a) and at the end (b) settings, and associated APSD in different frequency bands with a 500 Hz bandwidth at the beginning (c) and end (d) of settings. Spectrogram parameters [(a) and (b)]: fs = 39 kHz, window = Hanning; FFT length = 1024; window length = 512; overlap = 0.75.

To acoustically characterize setting events, the sound pressure time series $p(t)$ was divided into small segments of length $T = 30$ ms. The ith-segment of $p(t)$ is denoted $p_i(t)$, and the corresponding power spectral density (PSD) is denoted $P_i(f)$. Each PSD was then averaged over frequency bands of bandwidth $B = 500$ Hz. The quantity

$$P_i^{f_j} = \frac{1}{B}\int_{f_j-B/2}^{f_j+B/2} P_i(f)df \tag{1}$$

denotes the PSD of segment i, averaged in a frequency band centered on f_j. Its unit is dB re 1 $\mu\text{Pa}^2\,\text{Hz}^{-1}$, and it will be referred to as averaged PSD (APSD) hereinafter. Through averaging, APSD keeps the same properties as traditional PSD. It is thus adapted to characterized broadband noise signals (Carey, 2006). On the other hand, the (frequency) average enables a synoptic vision of the ambient sound, much simpler than a full spectrogram [see Figs. 2(c) and 2(d)].

For each setting event, the APSD time series at a given frequency is further simplified into two quantities, $APSD_{set}$ and $APSD_{travel}$, that characterize the ambient sound during setting and during travel, respectively. To do so, we define $APSD_{set}$ as the 25th percentile of all $P_i^{f_j}$, with segments i restricted to a 5-s window when the boat was setting. Similarly, $APSD_{travel}$ is defined as the 25th percentile of all $P_i^{f_j}$ over a 5-s window when the boat was travelling. Using the 25th percentile (rather than the median or the mean) effectively filters loud transients shorter than T (Kinda *et al.*, 2013). The method is thus adapted to reject echolocation clicks produced by sperm whales, which last about 15 ms (Zimmer *et al.*, 2005). As a result, $APSD_{set}$ and $APSD_{travel}$ are assumed to be representative of the broadband noise of the fishing vessel.

Finally, $APSD_{diff} = APSD_{set} - APSD_{travel}$ is computed to assess the impact of the setting on the ambient sound. Note that $APSD_{set}$ and $APSD_{travel}$ were computed on time windows separated by 10 s, so that the vessel position, i.e., the source receiver range, is virtually unchanged. It is thus assumed that $APSD_{diff}$ is not driven by a change in source/receiver distance.

3. Results

Seventeen setting phases were identified from the acoustic recordings. The corresponding hydrophone to fishing vessel distances range from 0.5 to 8 km. No setting was acoustically identified when the vessel was more than 8 km away from the hydrophone.

Spectrograms and *APSD* revealed a clear shift in ambient sound during the setting phases. The setting phases were characterised by a global increase in the *APSD* for all the frequencies when compared to travel phases. This is illustrated in Fig. 2 for a given setting event, representative of the full dataset. Note that *APSD* may also increase during travel

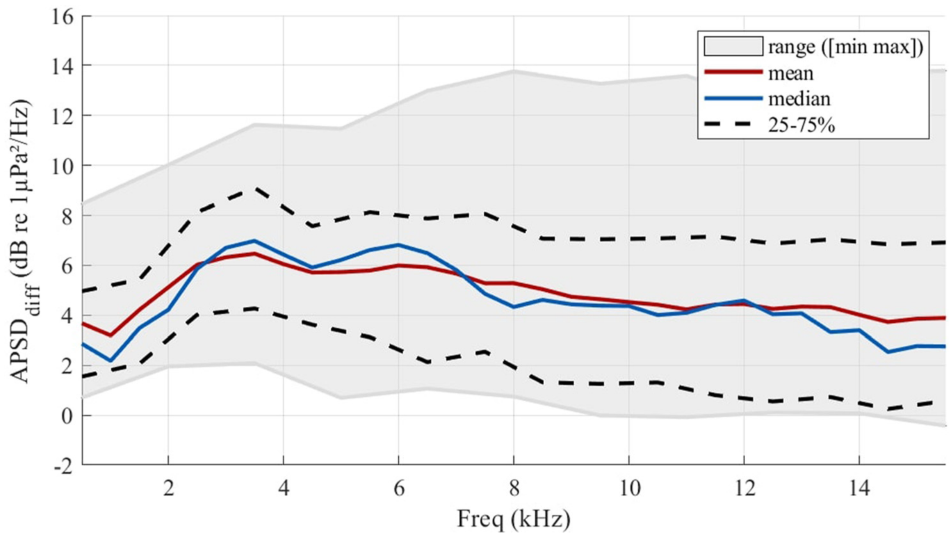

Fig. 3. Variation of $APSD_{diff}$ with frequencies: mean, median, 25th and 75th percentiles and range ([minimum maximum]).

phase [e.g., Figs. 2(b) and 2(d) for $t \sim 12$ s], but in this case the noise variability is relatively smooth, and when it occurs, characteristics of the boat changing direction (Trevorrow *et al.*, 2008).

The $APSD_{diff}$ for all the setting events ($N = 17$) are summarized in Fig. 3. The figure shows mean and median $APSD_{diff}$, as well as 25th and 75th percentiles and the range ([minimum maximum]) of the $APSD_{diff}$ measured. The mean and median $APSD_{diff}$ below 2 kHz are around 2 to 4 dB re 1 μPa^2 Hz^{-1} whereas they reach $\sim$6 dB re 1 μPa^2 Hz^{-1} between 2 and 7 kHz. Above 7 kHz, $APSD_{diff}$ tends to decrease when frequency increases. Still, a fair number of $APSD_{diff}$ exceeds 6 dB re 1 μPa^2 Hz^{-1} for frequencies above 7 kHz (see the 75th percentile in Fig. 3). Last but not least, extreme values of $APSD_{diff}$ can exceed 10 dB re 1 μPa^2 Hz^{-1} for frequencies above 2 kHz.

4. Discussion

Our results show that the setting phase produces a specific acoustic signature: a broadband noise significant enough to impact the ambient sound. Below 2 kHz, the ship noise is dominated by propeller cavitation, which occurs both during setting and travel. As a result, $APSD_{diff}$ is relatively small below 2 kHz. On the other hand, $APSD_{diff}$ drastically increases (up to 6 dB re 1 μPa^2 Hz^{-1}) between 2 and 7 kHz, and stays high up to 15 kHz (the maximum frequency that can be studied with our setup). We hypothesize that this acoustic signature is produced either by the baiting process or by the longline hitting the sea surface. Indeed, during setting, the vessel is heading forward at 6–10 kn while longlines are deployed from the stern of the vessel, a few meters above the sea surface. With the traction of the longline being pulled out, the hooks are automatically baited. Roughly three hooks per minute go through the bating machine, which produces a metallic noise on-board.

Although the exact source for the setting noise is still uncertain, our study clearly shows that the setting activity creates an increase in the ambient sound within the hearing sensitivity of sperm whales and killer whales (notably between 2 and 7 kHz) (Ridgway and Carder, 2001; Szymanski *et al.*, 1999). Further, our study suggests that, in our specific context, the acoustic signature does not propagate beyond 8 km. As a result, we believe that the acoustic signature of the cavitation propeller is still the best candidate for toothed whales to localize the fishing vessel from greater distances (Thode *et al.*, 2015; Thode *et al.*, 2007), between 30 to 40 km for the fishery under study in this article (Richard, 2018). However, once the whales have detected and approached the fishing vessel, they may know when and where longlines are set using the associated acoustic signature. This new insight of acoustic cues produced during the setting would explain how some whales are aware of longlines positions and could efficiently depredate from soaking longlines (Richard *et al.*, 2019, Richard *et al.*, 2020).

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