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Changes in whistle structure of resident bottlenose dolphins in relation to underwater noise and boat traffic

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ABSTRACT

The habitat of the resident bottlenose dolphins (*Tursiops truncatus*) of the Cres-Lošinj archipelago overlaps with routes of intense boat traffic. Within these waters, Sea Ambient Noise (SAN) was sampled across ten acoustic stations between 2007 and 2009. Data on boat presence was concurrently collected and when dolphins were sighted group behaviour was also recorded.

Acoustic recordings were analysed for 1/3 octave bands. Samples containing dolphin whistles were analysed and compared with boat presence and SAN levels. Results indicate that dolphins whistle at higher frequencies in conditions of elevated low frequency noise. Conversely, they reduce maximum, delta and start frequencies and frequency modulations when noise levels increase significantly across higher frequencies. The study shows that high levels of SAN causes significant changes in the acoustic structure of dolphin whistles. Additionally, changes in whistle parameters, in the presence of boats, appear to be related to the behavioural state of the dolphin group.

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1. Introduction

Boat traffic is an issue of major ecological concern to dolphin species inhabiting coastal waters, as boats represent a source of behavioural and acoustic disturbances (Pirotta et al., 2015; Rako et al., 2013). The effects of boats on coastal populations of dolphins have been studied frequently in terms of behavioural disturbance. Generally, presence of boats has been found to cause behavioural changes, such as vertical and horizontal avoidance, that involves an increase in dive duration and changes of direction and speed of their travel (Constantine et al., 2004; Lusseau, 2006; Miller et al., 2008). Conversly, dolphin reaction towards acoustic disturbance related to boat engine noise (propeller cavitation, propulsion and other machinery noise) has been examined to a much lesser degree (Buckstaff, 2004; Jensen et al., 2009; Pirotta et al., 2015). The energy produced by recreational boats dominates the range of frequencies between 100 Hz and 10 kHz (Hildebrand, 2009; Picciulin et al., 2010; Rako et al., 2013). These may overlap with frequencies of dolphin vocalization calls (May-Collado and Quiñones-Lebrón, 2014; Morisaka et al., 2005; Pirotta et al., 2015), particularly with whistles, a narrowband tonal sound that dolphins emit during many of their social interactions, with most of the energy concentrated below 20 kHz (Richardson et al., 1995). Previous studies have suggested that in noisy environments, dominated by recreational boating noise, variations in whistle parameters allow dolphins to facilitate the transmission of their signals and avoid masking. These variations include whistle frequency modulations, increased emission rate and changes of call duration (Ansmann et al., 2007; Luís et al., 2014; May-Collado and Wartzok, 2008; Morisaka et al., 2005). Moreover, recent studies have demonstrated that significant changes in the structure of dolphin vocalizations in the vicinity of boats may be dependent also on the behaviour of dolphins. This was particularly evident with regard to in dolphin foraging activities (López, 2011; Hawkins and Gartside, 2010; May-Collado and Quiñones-Lebrón, 2014).

In the Cres–Lošinj archipelago (northeast Adriatic Sea, Croatia), leisure boating noise has been identified as the major contributor to the overall sea ambient noise (SAN; Rako et al., 2013). These waters have been designated a Site of Conservation Interest (SCI) of the NATURA 2000 network due to their importance as a habitat for the resident bottlenose dolphin (*Tursiops truncatus*) population. This relatively shallow, coastal area is considered to be used by resident dolphins as their feeding and nursing ground (Bearzi et al., 1999). The population has been monitored consistently for more than two decades (Bearzi et al., 1997; Fortuna, 2006; Pleslić et al., 2015). Nautical traffic that peaks over the summer months (July and August) has been shown to cause significant changes in the soundscape of this marine habitat, which in turn has affected dolphin distribution and habitat use (Rako et al., 2013).

The aim of this study is to assess the relationship between vessel noise and acoustic behaviour of the resident bottlenose dolphins in the Cres–Lošinj archipelago. We focus on whistle frequency modulations and frequency shifts as a vocal response to elevated SAN and the presence of vessels. Sound is an important sense for these animals in their communication, navigation and foraging (Au, 1993; Tyack, 2008, Deecke et al., 2005). Understanding shifts in dolphin vocal behaviour would provide a basis for spatial management of main disturbance

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factors and help develop conservation measures within this NATURA 2000 site.

2. Materials and methods

In the period of 2007–2009, monitoring of SAN and its dominant anthropogenic sources was undertaken in an area of approximately 525 km^2, extended over the eastern side of Cres and Lošinj islands (Northern Adriatic Sea, Croatia). Systematic monthly sampling of SAN was made at ten predefined acoustic locations (Fig. 1) with depths ranging from 40 to 90 m, in sea state <2 (Beaufort scale). In total, 418 SAN recordings were made from a rigid inflatable boat (with the engine off), at approximately 5 m depth, using a RESON TC 4032 hydrophone (sensitivity −170 dB re 1 V/Pa) connected to a Pioneer DC-88 DAT recorder calibrated with a signal of 100 mV RMS @ 2 kHz (sampling rate 44.1 kHz, 16-bit).

Acoustic recordings were analysed in terms of instantaneous Sound Pressure Level (SPL) (L_{SP}, L-weighted, 63 Hz–20 kHz, root mean square fast) and equivalent continuous (L_{eq}) SPL calculated for each 5 minute acoustic recording for the 1/3 octave band frequencies. Median SAN SPL levels were calculated based on the overall 418 SAN samples, for the 4 frequency bands: 63 Hz, 125 Hz, 63 Hz–2 kHz and 2–20 kHz. Acoustic recordings were then classified for each band with rank values 1 or 0 depending on whether a sample's SPL level is below (1) or above (0) band median noise level.

Those acoustic recordings containing dolphin whistles were analysed considering the following standard whistle parameters (May-Collado and Wartzok, 2008; May-Collado and Quiñones-Lebrón, 2014): whistle duration, maximum and minimum whistle frequencies, delta frequencies (Max–Min), start and end frequencies, number of inflexion points (IP) and the number of harmonics.

A total of 592 bottlenose dolphin whistles, with good signal-to-noise ratios, were manually identified from 48 acoustic recordings and analysed using Raven 1.5 (Cornell Laboratory of Ornithology, New York) software with resolutions of 512 FFT and Hamming window. Of these, 475 analysed whistles occurred in 37 acoustic recordings made during the period October–May (Non-Tourist Season — NTS). The remaining 117 whistles were identified in 11 acoustic recordings made

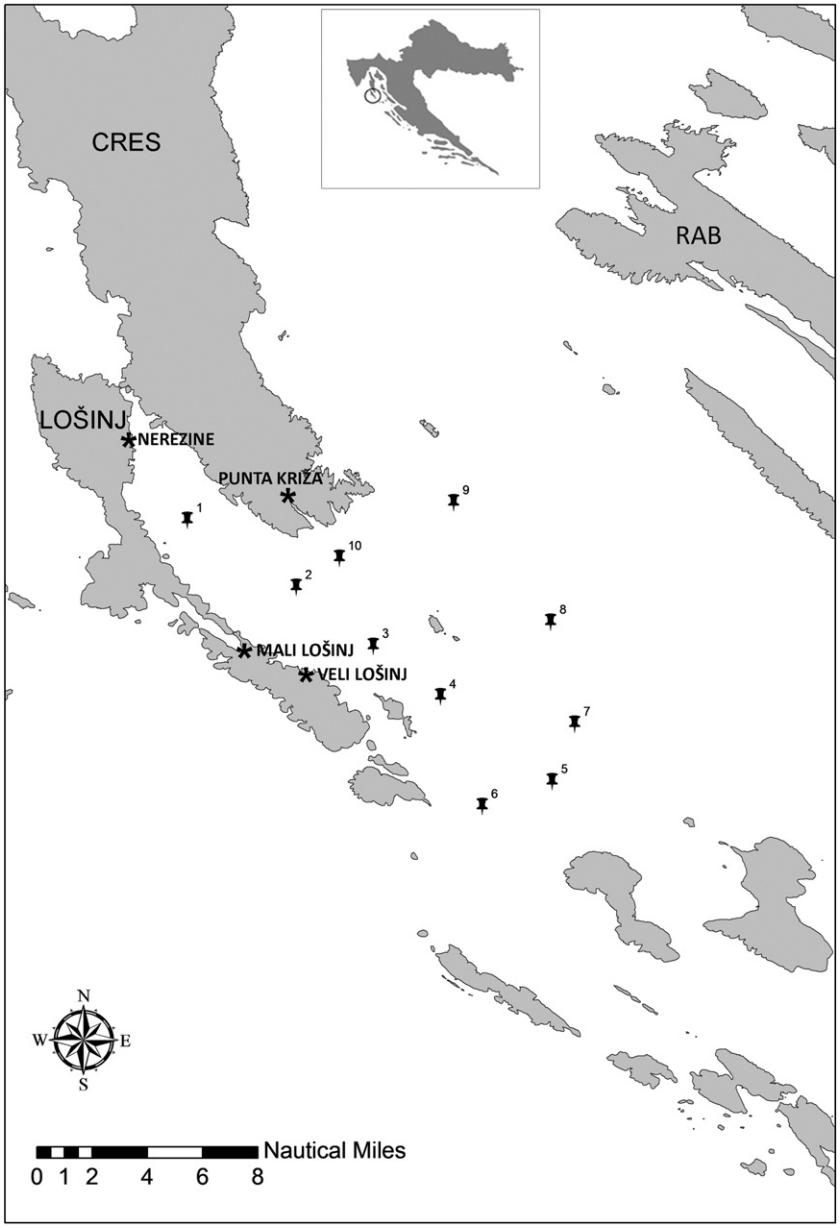

Fig. 1. Study area. Locations of ten acoustic stations are indicated with pins.

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