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LONG-TERM TEMPORAL PATTERNS OF BOTTLENOSE DOLPHIN (*TURSIOPS TRUNCATUS*) ECHOLOCATION ACTIVITY IN THE SICILY STRAIT

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ABSTRACT

Understanding temporal variations in the occurrence of cetacean species is critical for the design and application of successful conservation and management measures. In this study we used passive acoustic monitoring to investigate bottlenose dolphins (*Tursiops truncatus*) acoustic presence through the detection of their echolocation clicks. We deployed a single sensor on an elastic beacon fixed to the seabed at 3 miles from the coast, in the shallow waters of the Sicily Strait (Italy). Data were collected continuously for 8 months, from January to August 2016. About 3800 hours of recording were processed with an automatic detection algorithm. We calculated click detection rates (CDRs) as number of clicks on recording time. In order to identify and describe temporal patterns in the echolocation activity, we analysed the CDRs in relation to temporal variables (season, time and diel phase), by using General Additive Models. The results are discussed in the light of previous information about this bottlenose dolphin resident population. Further studies will be essential to estimate the density of the population that uses this coastal area.

Keywords: *bottlenose dolphin, echolocation, tursiops truncatus, temporal patterns*

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1. INTRODUCTION

Environmental factors such as diel and seasonal cycles, as well as anthropogenic activities, can have an impact on animal distribution and behavior [1-4]. As natural rhythmicity can cause variations in prey distribution, several predators, in turn, align their behavior and physiology to prey occurrence along the year or the day [5, 6]. Furthermore, due to physical and acoustic disturbance, top predators' spatio-temporal distribution in ecosystems with a high anthropogenic impact may be altered, and this could have an effect on the trophic chain [7]. Understanding these variations is important for assessing anthropogenic impacts, and ultimately implementing effective management strategies. Bottlenose dolphins (*Tursiops truncatus*) are marine top predators which integrate information from the whole food web and they are a keystone species, serving as an indicator of the maritime ecosystems' health. They can indeed reflect the species' response to natural and anthropogenic stressors [8]. Long-term monitoring of local dolphin populations, and the identification of baseline acoustic patterns, can allow for the detection of environmental stressors or anthropogenic disturbance [6, 9, 10]. This can be achieved by applying passive acoustics, a cost-effective method to provide spatio-temporal estimations on animal distribution, as well as abundance and the possible impact of human activities on species occurrence and behavior [11]. In the present study, we monitored a shallow water area of the Sicily Strait from January until August 2016, to understand echolocation patterns of the local bottlenose dolphin population. Due to the Strait characteristics of a very productive region, extremely affected by human activities [12], the area represents a good model to study both the spatio-temporal patterns of dolphins and the potential anthropogenic impacts.

2. MATERIALS AND METHODS

The acoustic monitoring station was installed in the North–Western coast of the Sicily Strait, 3 miles far from the coastal seaside of Capo Granitola (South-Western of Sicily). The acoustic system was positioned on an elastic beacon (MOBI R.S.E.). This was anchored to the seafloor, which was 45 m deep, with a weight of concrete and maintained vertical by a deep-water buoyancy float. The hydrophone was at 16 m below the surface. The acoustic data acquisition system consisted of a hydrophone (Reson TC 4014, Denmark, linear frequency range: 30Hz to 100 kHz ±2 dB and 25Hz to 250 kHz ± 3 dB), and a digital acquisition card (USGH 416HB, Avisoft Bioacoustics, Berlin, Germany, set at 40 dB gain) managed by Avisoft Recorder USGH software (Avisoft Bioacoustics). Data were sampled at 50 kHz (16 bits), and saved in 5 min recordings (without time gap between consecutive files). The acquisition could be monitored from a remote workstation on land through a GPRS connection. The device provided continuous fine-scale temporal recordings along the year. Data used for this study were collected from 1 January 2016 to 31 August 2016. However, due to forced stops for technical maintenance, data were not collected: on 3rd, 9th and 10th January; from 3rd to 15th March; from 22nd March to 5th April; from 10th to 24th May, and from 23rd July to 19th August. The detection used to estimate the number of echolocation clicks consisted of a Teager-Kaiser energy operator [13] implemented in a MATLAB code described by [14-17]. The acoustic data were high-pass filtered at 10 kHz. A subset of 10% of the files were visually inspected by an operator, and all clicks were counted to evaluate if the final detection process was reliable. Click Detection Rates (CDRs) per recording were calculated as the number of clicks/minutes recorded. To evaluate the effects of hour, season, and diel phase on the CDRs and estimate any patterns, General Additive Models (GAMs) were performed in R (mgcv package, version 1.8–28, [18]) with Gaussian distribution and identity link function. A cubic regression splines for the explanatory variables were used. Click detection rate was chosen as the response variable and tested as a function of the predictors "hours" (discrete variable ranging from 0 to 23), "phases" (discrete variable ranging from 0 to 3, representing in this order: night, day, dawn and dusk) or "months" (discrete variable ranging from 1 to 8).

3. RESULTS

45355 files were collected from January 1, 2016 to August 31, 2016, corresponding to 226'775 minutes of recording (on 168 days). 722'519 clicks were counted, with a mean detection rate (number of vocalizations/minute) of 3.19 (Sd = 3.55). Data were not normally distributed (Kolmogorov-Smirnov test $p < 0.001$), and had unequal group sizes and variances (Levene test $p < 0.001$).

Kruskal-Wallis tests identified significant differences between the detection rates through months, phases and hours ($p < 0.001$), but clicks were still detected almost every day.

A seasonal trend was highlighted for click detection rate during months, with the lowest recorded during winter. Two peaks were detected, one in April and another August (Fig. 1). Tamhane post hoc test for pairwise comparisons revealed significant differences within all months pairs ($p < 0.001$) except for January *vs.* February ($p = 0.979$), and May *vs.* June ($p = 0.959$).

Over the diel phases and the 24 hours, click detection rates followed a circadian rhythm, increasing during night time compared to light hours (Fig. 1). Tamhane post hoc test for pairwise comparisons revealed significant differences within all phases pairs ($p < 0.001$). The best fit Generalized Additive Model ($R^2 = 0.238$, $p < 0.001$) highlighted that 24 % of variance is explained by the interaction between the variables month, phase and hour.

4. DISCUSSION

The results of the current study suggest that dolphins are consistently present in this coastal area of the Sicily Strait across all months. A seasonality in dolphins' acoustic activity was detected, with an echolocation peak during summer. Furthermore, an increase in the click detection rates during dark hours and dusk was recorded, as well as a more detailed difference in echolocation activity between hours.

These findings are consistent with a recent study carried out in the same geographical area [17]. They found seasonal variations with peaks in August and November probably linked to increased feeding availability and adaptation to the fishing activities. However, the differences in click detection rates between months, might also depend on behavioural changes or variations in the abundance of individuals.

The same study also reports a marked diel pattern in the acoustic behaviour, with peaks of echolocation activities during nighttime. During these hours, the concentration of prey might attract dolphins to feed along the coastal area. This acoustic pattern is in agreement with other studies on bottlenose dolphins in the same area [19], as well as studies on related species in different areas [2, 15].

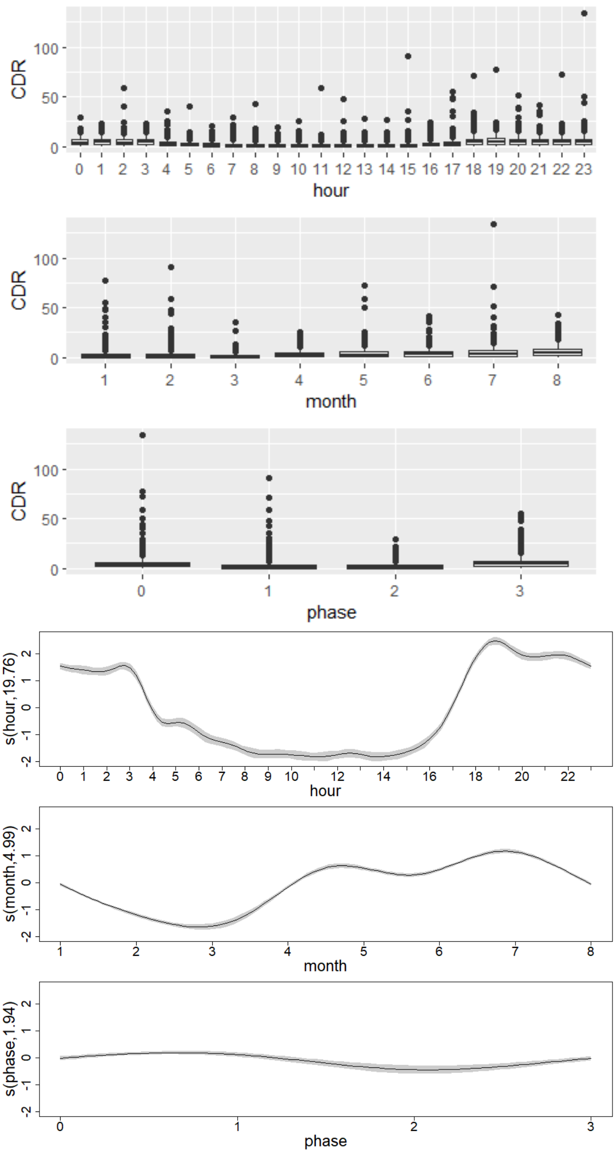

Figure 1. Box plots of the click rate by hour, month and phase (0 = night, 1 = day, 2 = dawn, 3 = dusk), and smoothing splines of the Generalized Additive Model. Solid black lines represent the effect of the predictor and the shaded areas the 95% confidence interval. On the y-axis, the scale of the linear predictor of the model is represented.

Furthermore, [17] suggested that differences in echolocation activities between hours can be due to changes in local boat traffic, especially fishing vessels, with which dolphins indeed coexist and interact. Fishing activities could alter dolphins' typical seasonal and diurnal cycles, causing local movements and changing natural patterns. Even if, here we do not collect vessel data, the amount of deviance explained by the GAM suggests the presence of other variables influencing dolphins' acoustic activity.

Many studies have been carried out on this particular bottlenose dolphin population [*e.g.* 14, 17, 19, 20], however, only two of them were based on long-term data collections [17, 20]. Based on [20] results, this population consists of about 140 individuals, and spatially ranges not only in the coastal, but also, in the offshore waters. This latter information, is particularly relevant in the light of the numerous offshore renewable energy construction projects in the Sicily Strait. Having a thorough knowledge of the dynamics of this population is necessary for conservation reasons, since offshore energy production could potentially impact on their distribution and behaviour.

Long-term acoustic studies are a good support to monitor these dynamics, since they are relatively cheap and easy to perform. Acoustic data can be very informative, especially if combined with other population data.

To conclude, this is the first study, to our knowledge, in which echolocation patterns of bottlenose dolphins were compared between years. We suggest that long-term studies on the acoustic behavior should be carried out in order to better understand the temporal patterns of dolphins' echolocation. This would allow, in turn, to compare these patterns between years and detect possible changes. This information, if matched with data on anthropogenic activities, can be valuable for impact assessments and for the implementation of conservation actions. Finally, long-term acoustic data collection can be also exploited for abundance and density studies.

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