FIRST ACOUSTIC RECORDINGS OF KILLER WHALES (ORCINUS ORCA) ENCOUNTERED IN THE CANARY ARCHIPELAGO

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Introduction

Killer whales (*Orcinus orca*, figure 1) are the most widespread species of marine mammals worldwide. Different ecotypes have been identified, and most of them exhibit variations in diet, social structure and behavioural patterns. These cetaceans have a complex acoustic behavior, producing vocalisations such as clicks, whistles and pulsed calls. Understanding this acoustic behavior, through Passive Acoustic Monitoring (PAM), is crucial for evaluating killer whale abundance, habitat use, and monitoring population dynamics. This would further improve our limited knowledge and allow us to better understand the spatial and temporal distribution of killer whales in the waters of the Canary Archipelago. This study represents the first characterization of the acoustic behavior of killer whales in the Canary Archipelago. Our aims were to conduct a quantitative analysis of pulsed calls, and a qualitative analysis of whistles, by comparing them to those described in previous studies in the Pacific Ocean (Western Jhonson Strait ,Vancouver Island; Easter Australian waters; San Juan Island, Southern British Coulmbia) and in the Atlantic Ocean (Norway and Iceland).

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Figure 1. Killer whales (*Orcinus orca*) are the most widely distributed species of marine mammals. Although the Canarian archipelago is an important cetacean biodiversity hotspot globally, their presence in this area remains a rare sight.

Materials and methods

Data collection took place during a 2009 survey in the eastern waters of Lanzarote, conducted by the Society for the Study of Cetaceans in the Canary Archipelago (SECAC) (figure 2). Approximately 9 hours of recording were collected, from which 242 vocalizations, which included whistles, pulsed calls and click trains, were identified. Of these, 56 whistles and 17 burst pulses of best quality were selected and analyzed (figures 3-4) with the Raven Pro 1.6.5 software. Whistles were classified using five different types of contour (figure 5), and seven parameters were measured, on which descriptive statistics were performed (table 1). Similarly, pulsed calls were assessed and analyzed using six parameters (table 2). A comparative analysis was done using Rstudio 2023.12.1+402, and a two-sided T test was performed to compare the values obtained for the whistles with those reported in other studies (table 3).

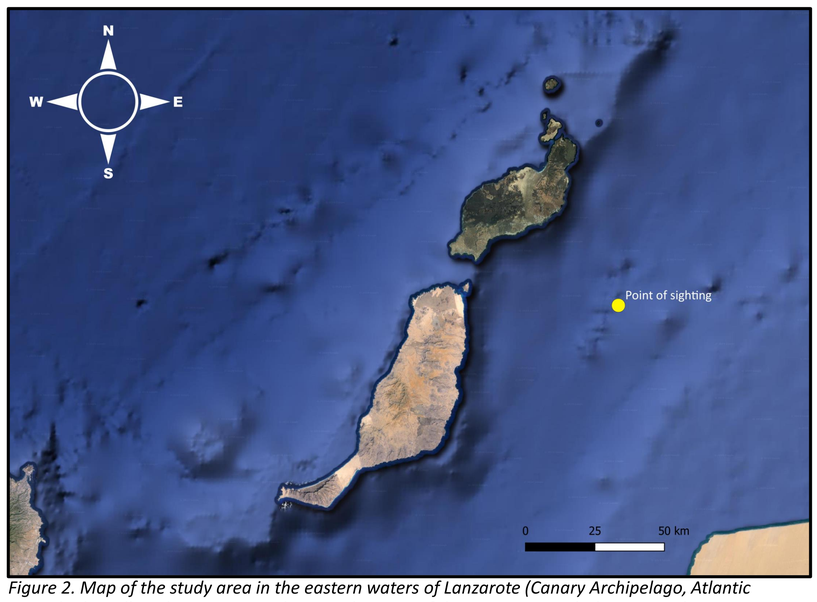

Figure 2. Map of the study area in the eastern waters of Lanzarote (Canary Archipelago, Atlantic Ocean). The yellow dot represents the exact location of the encounter with the orca pod.

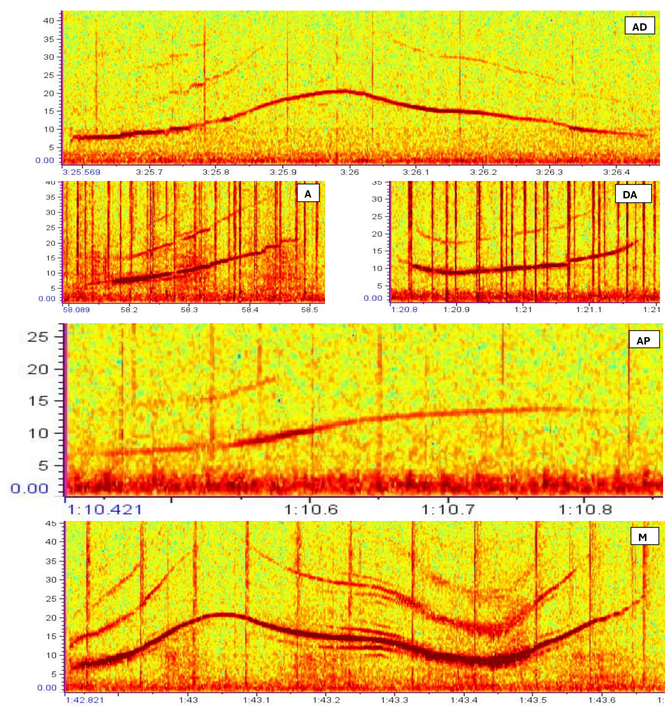

Figure 3. Spectrogram view of the categories used in the classification of *O.orca* whistles: Ascending-Descending (AD), Ascending (A), Descending-Ascending (DA), Ascending-Plateau (AP), Mixed (M). The Y-axis represents frequency (kHz) and the X-axis represents time (s).

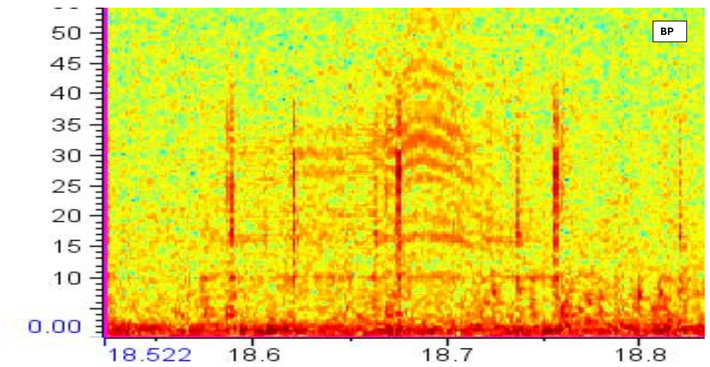

Figure 4. Spectrogram view of burst pulsed sound (BP) emitted by *O.orca*. The y-axis represents frequency (kHz) and the X-axis represents time (s).

Acoustic Parameters	Ascending	Ascending-Descending	Ascending-Plateau	Descending-Ascending	Mixed
Start Freq (kHz)	6.74±1.63; 0.24; 5.55; 8.59	6.32±0.67; 0.1; 5.4; 7.08	6.51; 0; 6.51; 6.51	12.12±4.44; 0.36; ; 5.49; 14.77	9.03±5.31; 0.58; 3.95; 23.06
End Freq (kHz)	19.87±3.69; 0.18; 15.66; 22.59	8.48±2.24; 0.26; 6.96; 12.45	14.18; 0; 14.01; 14.01	13.85±4.63; 0.33; 7.17; 17.87	15.07±6.06; 0.4; 6.54; 24.31
Low Freq (kHz)	6.74±1.62; 0.24; 5.55; 8.59	6.36±0.67; 0.1; 5.4; 7.08	6.51; 0; 6.51; 6.51	6.17±1.34; 0.22; 5.07; 8.10	6.68±1.61; 0.24; 3.9; 8.92
High Freq (kHz)	19.87±6.69; 0.33; 15.66; 22.59	19.45±3.6; 0.18; 13.71; 22.65	14.01; 0; 14.01; 14.02	16.12±1.60; 0.09; 14.54; 17.87	21.47±3.25; 0.15; 13.71; 28.67
Delta Freq (kHz)	13.13±2.69; 0.2; 10.11; 15.29	13.08±3.21; 0.24; 7.68; 15.57	7.51; 0; 7.50; 7.50	9.94±1.25; 0.12; 8.52; 11.57	14.8±3.55; 0.24; 6.23; 23.27
Delta Time (s)	0.41±0.09; 0.22; 0.35; 0.53	0.68±0.14; 0.2; 0.46; 0.86	0.37; 0; 0.37; 0.37	0.31±0.16; 0.51; 0.07; 0.44	0.77±0.35; 0.45; 0.21; 1.58
Inflection points	1±1; 1; 0; 2	1.2±1.09; 0.9; 0; 2	1; 0; 1; 1	0.5±0.57; 1.14; 0; 1	2.43±1.17; 0.48; 0; 6

Table 1. Descriptive statistics (mean, standard deviation, coefficient of variation, minimum and maximum values) of the seven acoustic parameters measured for each whistle categories (A, AD, AP, DA and M) (n=56) of *O. orca*.

Acoustic parameters	Mean	S.D.	C.V.	Max	Min
Start Freq (kHz)	10.04	3.37	0.33	15.82	3.17
End Freq (kHz)	12.29	9.26	0.75	45.99	2.74
Low Freq (kHz)	7.38	4.57	0.62	14.43	0.62
High Freq (kHz)	40.17	20.78	0.51	90.4	17.45
Delta Freq (kHz)	33.59	17.69	0.52	75.96	16.62
Delta Time (s)	0.29	0.28	0.97	1.26	0.04

Table 2. Descriptive statistics (mean, standard deviation, coefficient of variation, minimum and maximum values) of the six acoustic parameters measured for the pulsed calls of *O. orca.*

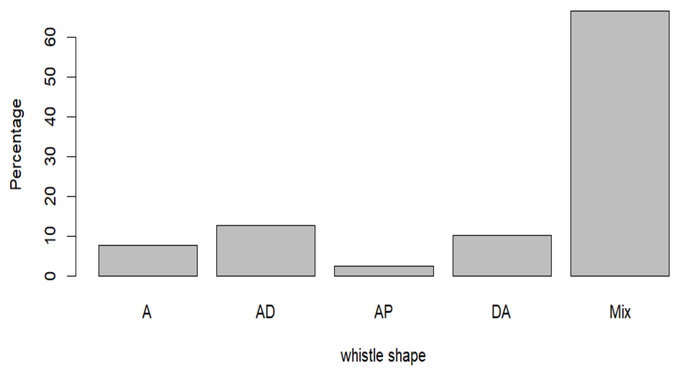

Figure 5. Barplot representing the 5 whistle shape categories identified in this study and their percantage. "n" represents the number of whistles for each category.: Ascending (n=3, 7.7%), Ascending-descending (n=5, 12.8%), Ascending-plateau (n=1, 2.6%) , Descending-ascending (n=4, 10.3%) and Mixed (n=26, 66.7%).

Acoustic parameters	*Canary archipelago (Present study)*	F. Thomsen and D.Franck (2000), western Jhonson Strait (BC)	Wellard et Al. (2015), Australia	Souhaut and Shields (2021), San Juan Island	Samarra et. Al (2015), Norway	Samarra et. Al (2015), Iceland
Start frequency (kHz)	*8.77±4.78*	\	\	\	34.7±11.0	32.6±9.1
End frequency (kHz)	*14.44±5.87*	\	\	\	37.4±9.0	38.2±8.7
Delta frequency (kHz)	*13.76±3.64*	4.5 ± 2.2	4.66±2.91	2.48±2.33	34.6±9.6	33.8±8.6
Max frequency(kHz)	*20.35±3.63*	9.9 ± 2.4	10.90±4.48	6.72±2.9	38.4±10.2	38.4±8.7
Min frequency (kHz)	*6.58±1.12*	5.5 ± 1.9	6.23±2.50	4.25±1.54	33.0±9.2	31.7±8.6
Delta time (s)	*0.66±0.33*	1.8 ± 2	1.03±1.53	2.12±2.27	0.14±014	0.14±0.13
Inflection points	*2±1.28*	5±7.8	\	\	\	\

Table 3. Comparison between the means and standard deviations detected in the whistles of the present study and those of other studies presenting similar parameters. The values obtained in the present study are represented in italics and underlined. Values with significant differences ($p<0.05$) are highlighted in bold while bars (\) indicate that there are no data available for that parameter.

Conclusions

Killer whales displayed a variable and complex acoustic behavior in this single encounter. When compared to subpopulations in the North Pacific and eastern waters of Australia, the group observed in the present study appeared to emit, on average, whistles of shorter duration at higher frequencies. These whistles showed limited modulation compared to the values reported in other studies. Comparing instead with the populations of the North Atlantic, the whistles detected in the eastern waters of Lanzarote have a longer duration and significantly lower average frequencies.

Such differences in acoustic parameters could be due to the notable geographic isolation that separates the Atlantic and Pacific Ocean populations. This isolation could be traced back to a genetic drift found between the populations of both oceans, the morphological differences between individuals and the different selective pressures to which they are subjected.

Furthermore, the killer whales of the North Atlantic belong to a well-defined ecotype, with an acoustic behavior involving the use of whistles at much higher frequencies than those detected in the eastern waters of Lanzarote. Since information on these killer whales is very limited it can be hypothesized that they are a small oceanic group; further studies will be necessary to better understand and categorize their acoustic behavior.

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