VOCALIZATIONS OF FREE-RANGING SHORT-FINNED PILOT WHALES (*GLOBICEPHALA MACRORHYNCHUS*) OFF TENERIFE: SIGNAL REPERTOIRE AND CHARACTERISTICS

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INTRODUCTION The vocal repertoire of free-ranging short-finned pilot whales (*Globicephala macrorhynchus*) has been reported in part by several authors from other populations (Schevill, 1964; Evans, 1967; Caldwell and Caldwell, 1969; Fish and Turl, 1976; Taruski, 1976; Rendell *et al.*, 1999). Scheer *et al.* (1998) describes stereotyped calls among social groups off Tenerife. Each observed group showed a group-specific call repertoire with no call sharing between groups. All these studies are focused on whistle, call or whistle-like vocalization descriptions. Only Fish and Turl (1976) and Evans (1973) report frequency and energy measures for broadband clicks of free-ranging short-finned pilot whales. With regard to frequency and duration measures for all vocalization types as well as in detail repetition rates per time unit for click and grunt vocalizations, further sound categories used by this species remain unnotified. In this work we will describe physical characteristics for all sound categories being recorded for the Tenerife population and give spectrographic examples.

Citation:
Scheer, M., Hofmann, B. And Behr, I.P. 2003. Vocalizations of free-ranging short-finned pilot whales (Globicephala macrorhynchus) off Tenerife: signal repertoire and characteristics. Poster presented at the annual conference of the European Cetacean Society, Las Palmas de Gran Canaria, Spain, 10-13 March, 2003.

Material and methods Observations and recordings were made during September and Oktober 1996 off the southwest coast of Tenerife (between 27°58‘36‘‘ to 28°01‘56‘‘ N and 16°42’21‘‘ to 16°50‘50‘‘ W), a region where at least a part of the population of short-finned pilot whales is resident and can be found year-round. Research platform was the *Caldéron* being normally used to patrol the southwest coast to enforce legislative rules during whale watching activities. This research was especially authorized by the Canary government. During 55 h 7 min within observation contact a total of 12 h 58 min of audio recordings were obtained. Alltogether 1 h 12 min of the recordings were used for analysis. 1315 vocalizations were counted. The flat frequency response of the recording system was 200 Hz to 24 kHz using a pre-amplified (+/- 30 dB) Sea Mike SM – 1000 hydrophone (Deepsea Power and Light, San Diego, California) and a Sony TCD3 digital audio tape recorder. For spectrographic analysis we used Avisoft Sonagraph™ software (by Raimund Specht, Berlin, Germany; Pro Version 2.5). Sound sequences were digitised at 48 kHz (16 bit), spectrograms (512 pt FFT, 75% overlap, Hamming window) had a time resolution of 2.67 ms and a frequency resolution of 121 Hz. For visual inspection of the spectrograms we used the same time and frequency resolution for all sounds to ensure fixed parameters for comparisons. For calls physical parameters in this study were derived from the band with the most energy. For call comparisons and classification we used the overall spectrographic contour (time vs. frequency). Stereotyped calls were matched subjectively by comparing spectrograms. To compare calls in this study more in detail and to adjust parameters for comparisons with previous studies from other authors we measured duration (D), initial frequency (IF), end frequency (EF), minimum frequency (MiF) and maximum frequency (MaF) (the limit was the upper range of the recording system) for each call.

Results 87% or 1144 of the total 1315 recorded vocalizations were calls. Of these, 199 calls were spectrographically analysed. Calls subjectively appeared tonal to the human ear, however these sounds have different spectrographic appearances and are supposed to be generated using different sound production mechanisms. A huge proportion had sideband structures and are presumed to be pulsed sounds (Watkins, 1967) (Fig. 1 a, b). Others had harmonics thus being tonal (Fig. 1 c, d). Some calls showed a tonal and a pulsed part. Calls can rise and fall as well as being levelled or multiply modulated in their contour. Generally calls (n = 199) had a mean MaF of 10.97 (± 4.02) kHz and a mean MiF of 2.53 (± 1.54) kHz. Mean IF was 3.6 (± 2.26) kHz and mean EF 8.12 (± 4.7) kHz. The general frequency range for sidebands with most energy was 280 Hz – 23.44 kHz. For some calls harmonics or energetically less pronounced sidebands had frequencies >24 kHz. Mean D of calls was 0.9 (0.32) s (range 0.09 – 4.55 s). Out of 199 spectrographically analysed calls, 177 (89%) were heard more than once and up to 15 times during recording sessions and are termed stereotyped calls (Fig. 1 a, d). 22 calls (11%) were only heard once and are termed variable calls (Fig. 1 b, c). A spectrographic overview of stereotyped and variable calls can be found in Scheer (1999).

Grunts represent 3% of all recorded vocalizations. Though grunts subjectively sound tonal, they seem to be sounds exclusively generated by pulses at high repetition rates having broadband frequency distributions as well as several

relatively narrowband frequencies with more energy (Fig. 2 a, b). Compared with calls, sidebands for grunts are less narrow, thus they sound less clear tonal than calls. For grunts we spectrographically measured 290 – 690 pulses/s. Energetically pronounced frequency bands are less broadband for grunts (Fig. 2) than for clicks.

Clicks represent short pulses mostly having a broadband frequency composition. We observed many sequences in which short-finned pilot whales emitted click sequences with click intervals of 0.5 s with total sequence durations ranging 5 - 60 s or even longer. We observed clicks with a continous energy distribution from 200 Hz to >24 kHz and clicks with frequency bands being energetically emphasized. Generally a single pulse duration ranged 5 - 13 ms. For many sequences we observed an increase in pulse repetition rate ranging 20 - 80 pulses/s. These sequences were termed click trains. For certain click sequences pulse repetition rate increased to 280 pulses/s. Sequences with repetition rates ranging 90 to 280 pulses/s were termed fast click trains. The latter sequences generally lasted 1 - 2 s. Click trains and fast click trains were each handled as an own vocalization category, representing both 10% (7% for click trains and 3% for fast click trains) of all recorded vocalizations. Clicks with a repetition rate of less than 20 pulses/s were not handled as an own subcategory because they did not form discrete units but occurred permanently during general vocal activity, thus being excluded from total vocalization number. All click vocalization categories are variations of click sequences depending on pulse repetition rate.

Discussion Based on comparisons of spectrograms, physical characteristics and occurrence rates reported from other authors, our call vocalization category is likely to match ‚squeals' as described in Schevill (1964), ‚calls' reported by Evans (1967) and ‚whistles' from Caldwell and Caldwell (1969) and Taruski (1976). Taruski (1976) describes and compares frequencies and durations of short-finned pilot whale whistles of populations off California (frequency range 0.6 – 11.5 kHz; duration range 0.2 – 2.6 s), Peru (1.4 – 6 kHz; 0.15 – 1.5 s) and the Caribbean (1 – 17.5 kHz; 0.15 – 1.9 s), indicating geographic variations in whistle vocalizations. Compared with call parameters in our study (frequency range 0.28 – 23.44 kHz; duration range 0.09 – 4.55 s) call vocalizations among short-finned pilot whales off Tenerife represent a geographic variation, having a broader frequency and duration range. Fish and Turl (1976) report a peak in frequencies for broadband clicks of short-finned pilot whales around 25 kHz, but also having higher frequencies (at least up to 40 kHz). Evans (1973) describes frequencies of 30 - 60 kHz for click vocalizations for this species. The click frequency range from both studies remains unknown, thus not enabling a comparison with data from our study (range 0.20 - > 24 kHz).

Conclusions Short-finned pilot whales off Tenerife produce calls, grunts and click vocalizations. They generate pulsed as well as non-pulsed signals and thus show a typical odontocete sound repertoire. In comparison with call vocalizations being recorded in other locations (and from other populations), short-finned pilot whale calls off Tenerife show a geographic variation. The majority of calls were heard more than once and are termed stereotyped calls. The minority of calls were only heard once and are labeled variable calls.

Acknowledgements This field study was authorized by the Canary government. The Viceconsejería de Medio Ambiente and GESPLAN S.A. kindly provided the vessel ‚*Caldéron*' as a research platform. We want to thank Tomás de Azcárate y Bang, Erika Urquiola Pascal, Juan Luis Rodriguez Luengo and Rogelio Herrera. Manuel Louro Agraso, Juan Ramon Padilla Sanz, Carlos Goméz and Emilio Sanchez Amador were excellent skippers. Prof. Dr. Andreas Elepfandt from the Humboldt-University Berlin kindly provided recording system, analysis equipment and partial funding, Dr. Karl-Heinz Frommolt greatly assisted during sound analysis. Thanks to Projekt CONTEXT providing financial and logistic support for the field study as well Hapag Lloyd Flug for flights and equipment transports.

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Fig. 1. Spectrograms of call vocalizations of short-finned pilot whales. (a) Stereotyped pulsed call #A-2 (n = 15). (b) Variable pulsed call #B-6 (n = 1). (c) Variable tonal call #A-14 (n = 1). (d) Stereotyped tonal call #A-7 (n = 7).

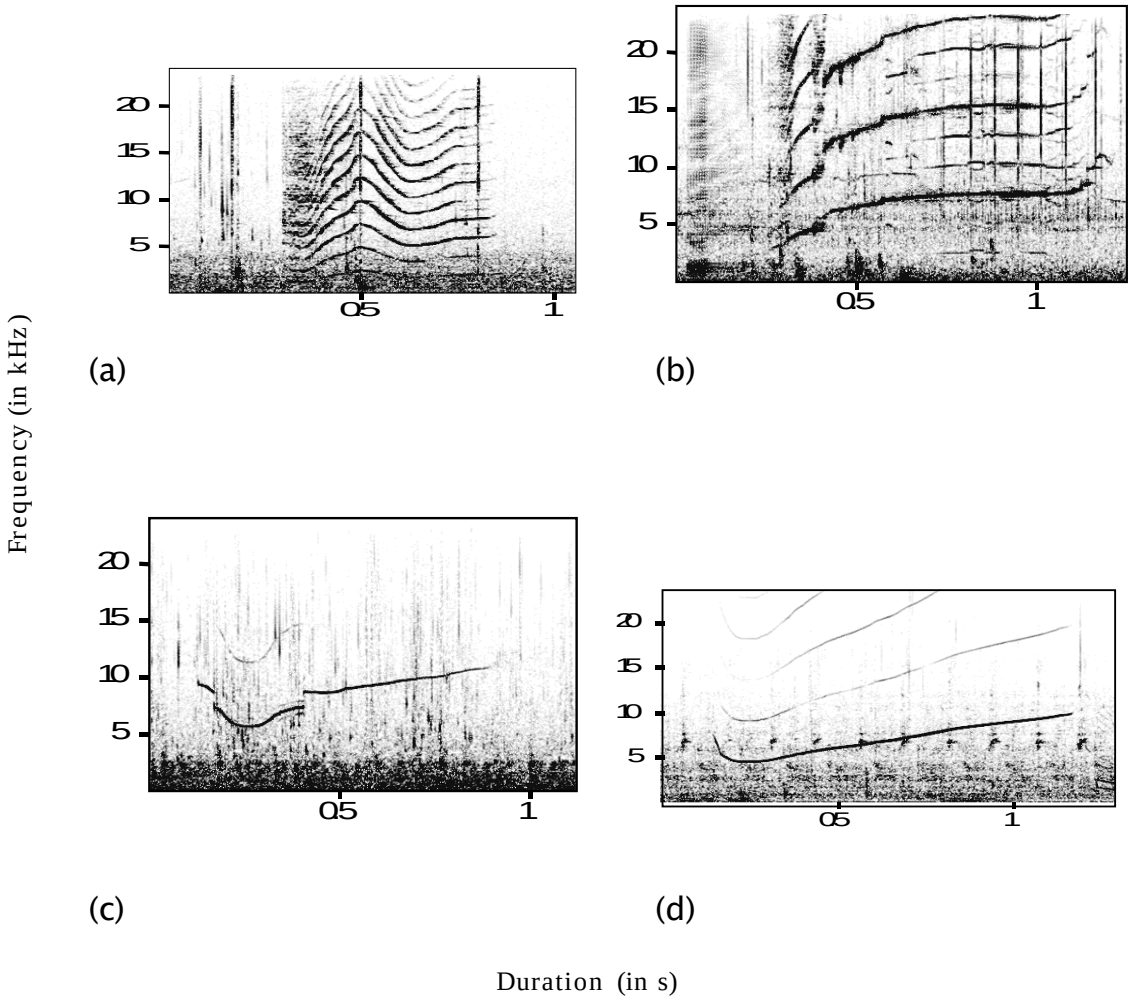

Fig. 2. Spectrograms of grunt vocalizations of short-finned pilot whales. (a) Two successive pulsed grunts (0.1–0.6 s and 0.7–0.9 s). (b) Two successive pulsed grunts (0.2–0.5 s and 0.9–1.2 s).