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Sperm whale vocalisations around São Miguel Island (Azores)

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Introduction

Sperm whales (*Physeter macrocephalus*) are common around the Azores archipelago (Steiner *et al.*, 2012). Their foraging and social activity can be studied by analysing acoustic emissions (Drouot *et al.*, 2004; Teloni *et al.*, 2005; Gannier *et al.*, 2012). We studied sperm whale distribution and acoustic behaviour off São Miguel Island (Azores) during the summer of 2013 and 2014.

Table 1 : Data summary. Data points with date, estimated school size, juvenile presence and recording durations.

Data unit	Date	Sighting hour	Group size	Calves or juveniles	Recording duration
2013-1	21/07/2013	**12h36**	6 - 10	C	16.98
2013-2	25/07/2013	**16h48**	5 - 10	N	18.10
2013-3	28/07/2013	**14h54**	6 - 15	J	29.75
2013-4	12/08/2013	**16h50**	4 - 7	?	56.75
2013-5	20/08/2013	**14h40**	5 - 10	C	33.50
2014-1	06/07/2014	**10h46**	5 - 10	J	9.65
2014-2	06/07/2014	**14h19**	5 - 20	N	20.52
2014-3	23/07/2014	**12h59**	10 - 18	C	16.25
2014-4	23/07/2014	**13h30**	10 - 18	C	72.60
2014-5	23/07/2014	**15h06**	1 - 10	?	19.02
2014-6	23/07/2014	**15h47**	2 - 3	J	24.07
2014-7	01/08/2014	**10h21**	4 - 10	J	4.98
2014-8	01/08/2014	**11h45**	8 - 12	C	23.00
2014-9	01/08/2014	**13h51**	3 - 8	N	44.50
2014-10	03/08/2014	**18h10**	2 - 4	N	48.88
2014-11	12/08/2014	**13h48**	5 - 15	?	8.02
2014-12	13/08/2014	**10h39**	1 - 2	N	44.50

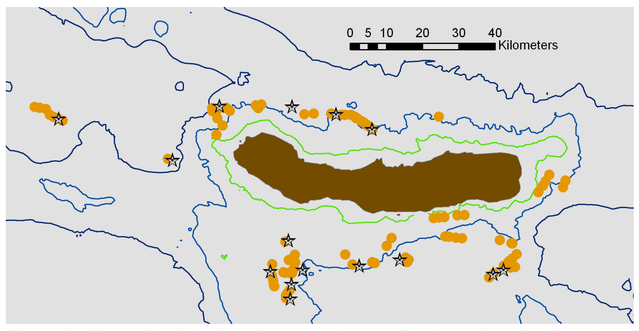

Figure 1: Map with sightings (stars) and recording locations (yellow dots). The light blue line is the 1,000m bathymetric. 2013 and 2014 sightings used for the study, and all locations where sperm whale vocalisations were recorded with a good signal level (>= 4 on a 5-level scale).

Methodology

Field methods

Sperm whale vocalisations were recorded with a wide-band towed hydrophone during surveys around São Miguel Island in 2013 and 2014 (Fig. 1). Sperm whale was not the focal species, but recordings were obtained opportunistically during the course of systematic distribution surveys, depending on available time. Whenever a sperm whale individual or group was detected, data on school structure and activity was logged. School size was estimated from visual and acoustic cues. In general, acoustic data was already being recorded well before sighting occurred. All field data were entered in real-time on a Cetacean Acoustic Monitoring System (SMAC, Fusaro & Gannier, 2010).

Acoustic analysis

Based on signal-to-noise ratio, we selected 43 recordings with a duration comprised between 3 and 26 minutes. In addition to normal clicks, these recordings included various vocalisation types, known to be associated with predation (creaks), communication (codas, clangs, squeals) or whose function is still discussed (chirrups and other pulse trains). Every recording was analysed by at least two different operators, using Cool-Edit software, and each vocalisation was logged and classified. Then, all recordings belonging to a sequence and associated with a given sighting were pooled to form a data unit (named 2013-1, 2013-2, ..., Tab.1).

Data analysis

After a preliminary analysis, we grouped elementary sound categories into three broader classes: (1) creaks, (2) codas, squeals and clangs, (3) chirrups and other fast pulse trains. Vocalisation rates were calculated for each sound type and sound class and then averaged per time period.

Results

During our surveys we observed sperm whale schools or clusters, with average school size of 5 to 11 individuals, excepted for data units 2014-10 (2 to 4 animals with estimated sizes of about 10 m) and 2014-12 (one or 2 individuals, estimated size over 12 m). Calves or juveniles were present in 61% of the sightings groups.

Annual variations

A total of 17 data units was obtained: five data in 2013 and 12 in 2014. Acoustic activity was much lower in 2013 (0.73 vocalisations/min) than in 2014 (5.32 voc./min) – see Fig.2. Creak emission rates were much lower in 2013 compared to 2014 (0.08 creak/min against 0.24 creak/min). Coda emission rate was higher in 2014 (0.76 /min) than in 2013 (0.36 /min). In 2014, chirrups/train pulses emission rate was much higher (3.16 /min) than in 2013 (0.25 /min) (Tab.2). Hence, in both years, chirrup emission rate varied along with coda emission rate, as well as with other social sounds (Fig.2).

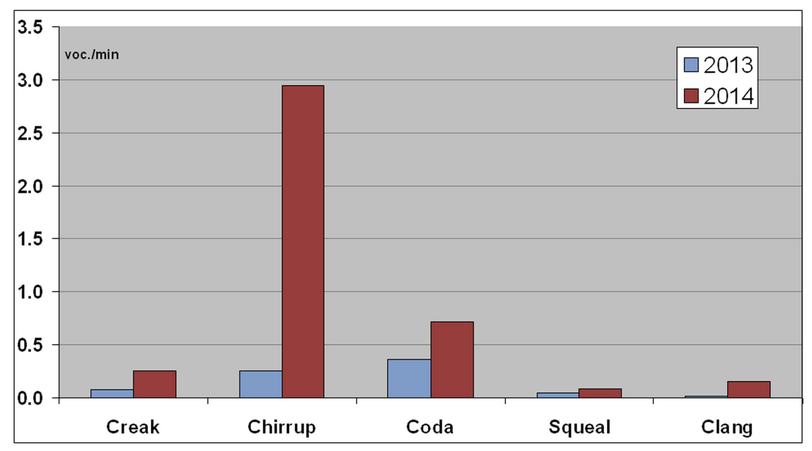

Figure 2: Vocalisation rates in 2013 and 2014

Monthly variations

Monthly analysis was only possible in 2014, when six data points were collected both in July and in August (Fig.3). Coda and chirrup emission rates were higher in July than in August (codas: 1.24 /min against 0.19 /min – chirrups: 5.79 /min against 0.09 /min). Foraging-associated vocalisations showed a strong and inverse monthly variation, with 0.03 creak/min in July against 0.48 creak/min in August.

Creaks, chirrups/fast pulse trains, codas, other social vocalisations

For all three data sub-sets (2013, July 2014, August 2014) a higher creak emission rate corresponded to lower coda and chirrup emission rates. We also observed that codas and squeals were closely linked, in particular (but not only) for data unit 2014-4, while clang emission rate was apparently not linked to codas and squeals, an driven up by a single data unit (2014-10).

Summary

Sperm whale vocal emission rates were highly diverse and variable around São Miguel Island. Chirrups/fast pulse trains, codas and squeals emission rates appeared to vary in the same way, with highest values in July 2014 and lowest in August 2014. There was no homogeneity for foraging vocalisations during the three reference periods (0.08 creak/min in 2013, 0.03 creak/min in July 2014, 0.48 creak/min in August 2014). Hence, foraging vocalisation rate and social + chirrup vocalisation rates were observed to vary in opposite ways.

Table 2 : Vocalisation rates by sound category and class. Creak, coda, chirrup/fast pulse trains, squeals, clangs: rates averaged over the study period (with SD or range)

Vocalisation type	Creak	Chirrups	Codas	Squeal	Clang
n° of 'zero'	5	2	9	14	13
max	0.90	16.25	4.28	0.99	1.72
mean	0.20	2.15	0.61	0.07	0.11
SD	0.25	4.47	1.12	0.23	0.40

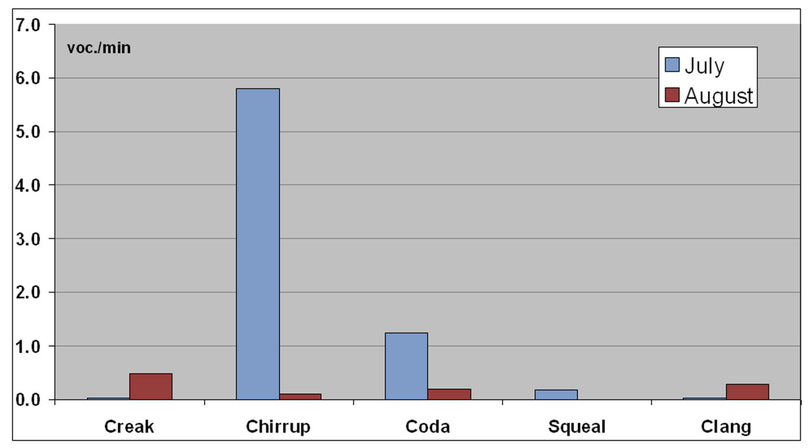

Figure 3: Vocalisation rates in 2014, July and August

Discussion

Creak rates around São Miguel Island were highly variable (range 0.03-0.48 creak/min), in contrast with those obtained in the northwestern Mediterranean, which were rather stable around 0.80 creak/min (Gannier *et al.*, 2012). This difference could be linked to the nature of preys: in the NW Mediterranean Sea and Gulf of Mexico, Miller *et al.* (2004) showed that creaks were emitted by sperm whales during particular body movements linked to prey captures. In the Azores, Clarke *et al.* (1993) indicated that sperm whales obtained 77% of their food by foraging on bio-luminescent neutrally buoyant squids. The same authors suggested that whales might capture those cephalopods without needing active echolocation. But Clarke *et al.* (1993) showed that 'Azorean' sperm whales diet also includes fast-swimming muscular squids, usually large specimens, whose capture necessitates a creak emission. Hence, our results on much variable creak rates in the Azores likely reflect temporal variation of the sperm whale diet. From visual observation, the social structure of sperm whale around São Miguel Island was variable, with nursery groups, medium-sized whales clusters, or sometimes whales larger than 12-meter. In the NW Mediterranean, mainly sub-adult and adult males were studied (Gannier *et al.*, 2012). We observed that social vocalisations, notably codas, were emitted with variable rates, some of them only in the presence of juveniles (squeals). Codas are usually emitted within social units (Weilgart & Whitehead, 1993), coda repertoires being temporally stable for a given population (Rendell & Whitehead, 2005). Our coda emission rate variability could reflect the variable social structure of encountered whales. Furthermore, if we assume that smaller whales feed on smaller squid species, as observed by Clarke *et al.* (1993), social structure variability could also explain our results on both creak rate and coda emission rate.

Conclusion

We found a high temporal variability in vocal emission rates, including creaks, codas and chirrups, and a high diversity of social vocalisation emission rates. We suggest that creak emission variability is linked to the nature of cephalopod prey species in the Azores. Variations in socially-linked sounds probably reflect local sperm whale variable social structure and activity patterns, and possibly also the influence of anthropogenic disturbance. A more detailed analysis of the present data will be carried out accounting for the specific sighting context (group structure, visual activity data, presence of whale-watching and other boats).

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