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Echolocation and burst clicks from franciscana dolphins (*Pontoporia blainvillei*) on the coast of Uruguay

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Passive acoustic monitoring (PAM) is being used increasingly to study, survey, and census cetaceans, many of which are easier to hear than to see (Zimmer 2011). Due to its small size, color, and rare aerial displays it is difficult to study the franciscana dolphin (*Pontoporia blainvillei*, Gervais and d'Orbigny 1844) in the wild. In fact, most of our information on this species has been collected from individuals caught in fishing nets (*e.g.*, Ott *et al.* 2002, Cappozzo *et al.* 2007). Therefore, PAM should be ideal for surveying and studying this elusive species.

The franciscana is endemic to the southwestern Atlantic Ocean (Itaúnas, Brazil, $18^{\circ}25'S$, $30^{\circ}42'W$; Península Valdés, Argentina, $42^{\circ}35'S$, $64^{\circ}48'W$) (Crespo *et al.* 1998, Siciliano *et al.* 2002) and is classified as Vulnerable (A3d) by the International Union for Conservation of Nature (IUCN, Reeves *et al.* 2008). Little is known about franciscana echolocation sounds. Busnel *et al.* (1974) obtained the first clicks in the wild with limited equipment, and Von Fersen *et al.* (1997) recorded clicks from a captive individual. Recently, Melcon *et al.* (2012, 2016) recorded clicks in the wild, and Tellechea and Norbis (2014) recorded clicks from a pair of 2-wk-old dolphins in captivity.

We were informed by an artisanal and recreational fisherman that in Santa Lucia del Este (Rio de la Plata estuary, 34°47′S 55°31′W), franciscana dolphins are commonly caught and die in artisanal fishing nets (JST, unpublished data) (Fig. 1). The aim of this study was to record sounds in the wild using passive acoustic monitoring technology and characterizes franciscana dolphin clicks trains.

Data were collected over five nonconsecutive days in March and April 2016 (16– 17, 20–21, 23–24, 25–26 March and 30 April–1 May). Recordings were obtained using two PAM buoys placed 1,200 m apart at the site (Fig. 1). The buoys were placed 200 m from shore at a depth of 2 m and were set to record between 1000 and 1200 the next day. We picked days with Beaufort sea state 2 because the sea state can

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Figure 1. Map of Uruguay and the Rio de la Plata estuary showing the position of the PAM buoys from which acoustic recordings of franciscana dolphins (*P. blainvillei*) were obtained.

change rapidly in this area and it would be difficult to recover the buoys if bad weather occurred. The presence of the franciscanas near the buoys area was confirmed throughout observation with binoculars.

The PAM buoy contained a calibrated omnidirectional hydrophone (built in the laboratory, -40 dB: re 1 μ Pa, and linear from 20 Hz to 100 kHz), connected to amplifier with antialiasing filter and a TASCAM HD-P2 digital recorder (20 Hz and 96 kHz, sample rate = 192 kHz). A voltage regulator was built to keep the system working for 26 h. The response of the system is limited at high frequencies, and it may not have recorded the highest frequencies in the clicks.

Recordings were analyzed using *Audacity* free software, version 1.2.3 (Mazzoni 2006) (free license) and *Ishmael* open-access bioacoustics analysis software (Mellinger 2001). All sound files were manually verified for echolocation sounds, and only clear clicks were selected for further analysis. Power spectra used a 1,024-point Fast Fourier Transform (FFT) with a Hann window. Peak frequency, interclick interval, rms click duration and 3 dB bandwidth (defined as the bandwidth at 3 dB points below the maximum intensity) were measured manually following Au (1993). Data are presented as the mean, standard deviation, maximum, and minimum values for each click train.

The sounds recorded during 20–21 March (buoy one = 6 min; buoy two = eight minutes) and 23–24 March (buoy one = 3 min; buoy two = 7 min) were emitted in the afternoon, night, and early morning. On day one, sounds were registered from 1923 to 1939 on buoy one and from 2046 to 2120 on buoy two. On day two (23–24) sounds were registered from 0053 to 0104 on buoy 1 and 0437 to 0458 on buoy 2 (local time).

Forty-two of 50 click trains were clear and analyzed. Twenty-six had high frequencies (trains <2 s), 11 low frequencies (trains <3 s), and there were five burst-click trains (trains <2 s). Clicks were separated into high and low frequency types based on accepted classification criteria (Evans 1967, Au and Hastings 2008). Table 1 summarizes parameters of the burst and clicks trains emitted (n = 283 burst clicks, 860 high-frequency clicks and 363 low-frequency clicks).

High-frequency click trains had a mean duration of 1.0 ± 0.6 s (mean \pm SD). Click duration was 0.21 ± 0.23 ms and interclick interval was 35 ± 2.24 ms. Click trains had a peak frequency of 86 ± 1.87 kHz (Table 1).

Low-frequency click trains had a mean duration of 0.5 ± 0.35 s. Click duration was 0.20 ± 0.12 ms, interclick interval was 20.0 ± 2.0 ms. Click trains had a peak frequency of 14 ± 2.73 kHz (Fig. 2, Table 1). Therefore, clicks of similar durations can vary in frequency.

Burst click trains had a mean duration of 90 ± 0.40 s. The clicks had duration of 15 ± 1.71 ms, interclick interval was 10 ± 1.02 ms, and peak frequency was 41 ± 4.69 kHz (Fig. 3). The mean 3 dB bandwidth for high-frequency clicks was 3 kHz, for low-frequency clicks was 5 kHz, and for burst clicks was 9 kHz. Due to overlap, click train likely came from more than one animal.

Although it is unlikely all clicks were on-axis (Au 1993), frequencies in this study were similar to those from two neonates in captivity (Tellechea and Norbis 2014). Busnel *et al.* (1974), recording in the wild, found clicks with a range of 14–23 kHz and interclick intervals between 19 and 228 ms. However, our data differ in

Click parameters	п	Mean	SD	Maximum	Minimum
High frequency clicks					
Number of trains	26				
Number of clicks per train		38	3.55	49	22
Interclick interval (ms)		35	2.24	40	17
Click duration (ms)		0.21	0.23	0.23	0.20
Frequency (kHz)		86	1.86	93	82
Low frequency clicks					
Number of trains	11				
Number of clicks per train		33	6.21	41	18
Interclick interval (ms)		34	1.97	35	22
Click duration (ms)		0.20	0.12	0.21	0.19
Frequency (kHz)		14	2.73	19	8
Burst parameters					
Click train	5				
Number of clicks per train		52	5.66	58	39
Interclick interval (ms)		10	1.02	12	9
Click duration (ms)		15	1.71	17	10
Frequency (kHz)		41	4.69	63	32

Table 1. Characteristics (mean, standard deviation and range) of click sounds emitted by the wild franciscana dolphins in the Rio de la Plata estuary, Uruguay.



Figure 2. An example of franciscana dolphin low-frequency click train recorded by the PAM buoy off the coast of Uruguay; (A) oscillogram and spectrogram (Hanning window FFT: 1,024), (B) single expanded pulses, (C) spectrum of the expanded pulse showing the peak frequency.



Figure 3. An example of franciscana dolphin burst click train recorded by the PAM buoy off the coast of Uruguay. Representative burst click train (A) oscillogram and spectrogram (Hanning window FFT: 1,024), (B) single expanded pulses, (C) spectrum of the expanded pulse showing the peak frequency.

frequency compared with those presented by Von Fersen *et al.* (1997) and Melcon *et al.* (2012, 2016). Captive adult click trains had a mean frequency of 130 kHz and a bandwidth of 20 kHz (Von Fersen *et al.* 1997) and wild ones had a mean peak

frequency of 139 kHz and an interclick interval of 33 ± 4 ms (ranging between 14 and 43 ms). Melcon *et al.* (2016) found wild neonate clicks had a frequency ranging between 37 kHz and 160 kHz with bandwidth of 120 kHz. Low-frequency clicks in this study were similar to those described by Tellechea and Norbis (2014) and the low-frequency component registered by Melcon *et al.* (2016). Our recording sampling rate was limited and may have cut off spectral content at frequencies beyond 96 kHz. Also click-train overlap from more than one animal may have compromised some measurements of interclick interval.

All studies show the franciscana emits a fairly wide range of click frequencies for echolocation and burst clicks. For cetaceans that do not produce whistles, the burst clicks are very important for communication (Herman and Tavolga 1980, Au and Hastings 2008), as demonstrated for the harbor porpoise, *Phocoena phocoena* (Amundin 1991, Au and Hastings 2008, Tubbert-Clausen *et al.* 2010) are another major category of sound emissions produced by all odontocetes (Au and Hasting 2008). In *T. truncatus* burst clicks have been associated with alarm and fright and in agonistic and head-to-head open-mouth encounters between individuals often accompanied by head nodding, shaking and arching (Herzing 1988, Au and Hastings 2008). Tellechea and Norbis (2014) reported them in two captive neonates franciscana dolphins. Here we report burst clicks of franciscana dolphins for the first time in the wild.

Frainer *et al.* (2015) have suggested that the development of the main biosonar structures may be one cause among others for increased bycatch mortality and the diet shift of young *Pontoporia*. Due to improved motor skills and probably more experience with echolocation, adult *Pontoporia* are less likely to be caught in nets and more successful in catching different types of prey. However, the bycatch mortality of this species includes mostly adults with developed sonar, (Fitch and Brownell 1971, Bordino *et al.* 2002, Rodriguez *et al.* 2002, Bassoi 2005, Paso-Viola *et al.* 2014).

Infrequent use of echolocation may be an adaptation to avoid detection by large predators such as killer whales (Orcinus orca) (Madsen et al. 2005, Melcon et al. 2012) or because of energy costs (Gannon et al. 2005). We suggest that the franciscana uses its sonar sparingly because it employs passive listening to find food. The prev most consumed by the franciscana along the coast of Uruguay are Cynoscion guatucupa, Micropogonias furnieri, Porichthys porosissimus, Macrodon atricauda, and Umbrina canosai (Fitch and Brownell 1971, Praderi 1984, Brownell 1989). These fish are active sound producers, generating advertisement and disturbance calls (Tellechea et al. 2010, 2011a; Tellechea and Norbis 2012b). They are likely to produce disturbance calls when tangled in a net (Tellechea et al. 2010, 2011a; Tellechea and Norbis 2012b). As long as water is not too shallow, these sounds can propagate over long distances in black drum (Pogonias cromis) (Locascio and Mann 2011) and Atlantic croaker (Micropogonias undulatus) (Gannon and Taylor 2007). Gannon (2003) estimated that croaker sounds may be audible for up to 630 m, which is further than the maximum echolocation detection range known for any dolphin (Au 1993). Given that fish sounds propagate omnidirectionally (Barimo and Fine 1998), passive listening would allow a dolphin to keep a large area under surveillance, without expending energy or advertising its presence (Gannon et al. 2005). Therefore, franciscana may be attracted to artisanal fishing nets because of the sounds produced by fish caught in nets and becoming entangled.

Click train characteristics have been associated with foraging/feeding in bottlenose dolphin (Au 1993, Nowacek 2006, Jensen *et al.* 2009, Ridgway *et al.* 2015). Compared to Melcon *et al.* (2012) who found abundant click production during feeding behavior, few click sounds were registered in this study. Fewer sounds may be

explained by foraging/feeding behavior in an area with known fishing nets. Alternatively, the animals may not have faced the PAM units. However, the same species may have different foraging behavior in different places. Gannon *et al.* (2005) found that bottlenose dolphins use passive listening extensively during the search phase of foraging in Sarasota Bay, Florida. By listening, bottlenose dolphins may obtain useful information on the identity, number, size, and location of soniferous prey. Once they discover the prey by passive means, they then use echolocation to track the prey during pursuit and capture phases (Au 1993, Gannon *et al.* 2005). Such judicious use of echolocation suggests that this ability incurs significant energetic or ecological costs. Gannon's strategy of listening and then echolocating could be used by franciscana dolphins who prey abundantly on sciaenids.

These records show that this species can swim close to shore in depths of 2 m and emit clicks and burst clicks in its natural environment. The hypotheses discussed in this paper will hopefully form the basis for experimental playback experiments using prey sounds to determine whether the franciscana is attracted to fish nets. More studies with PAM buoys will help locate franciscana hot spots to delineate specific protected areas for this endangered dolphin, where fish nets should be prohibited.

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