Journal of Fish Biology (2016)
doi:10.1111/jfb.12926, available online at wileyonlinelibrary.com

BRIEF COMMUNICATION

Sound production by the Shi drum *Umbrina cirrosa* and comparison with the brown meagre *Sciaena umbra*: a passive acoustic monitoring perspective

M. Picciulin*, †, M. Bolgan‡§, A. B. Corò||, G. Calcagno* and S. Malavasi||

**Department of Life Science, University of Trieste, via Giorgieri 7, 34127 Trieste, Italy, ‡Marine and Freshwater Research Centre, Department of Natural Sciences, Galway-Mayo Institute of Technology, Dublin Road, Galway, Ireland and ||CEMAS – Center for Estuarine and Coastal Marine Sciences, Department of Environmental Sciences, Informatics and Statistics, University Ca' Foscari Venice, Campus scientifico, Via Torino 155, 30170 Venezia Mestre, Venice, Italy*

(Received 7 September 2015, Accepted 25 January 2016)

Sounds produced by the Shi drum *Umbrina cirrosa* were short trains of pulses with an average pulse period of 180 ms, pulse duration of *c.* 40 ms and an average peak frequency of 400 Hz; average values of acoustical properties differed from those recorded from the brown meagre *Sciaena umbra* in previous studies. The present study provides a preliminary tool for discriminating between these two species while conducting passive acoustic monitoring. The potential effects of ontogeny on sound production in both species are discussed and recommendations are made for further research.

Key words: acoustic characterization; Sciaenidae; spawning sounds.

Many fishes of the family Sciaenidae are known to make sounds (Ramcharitar *et al.*, 2006). The presence of sciaenid species of commercial interest has been investigated through passive acoustic monitoring (PAM), especially along the northern American coast (Rountree *et al.*, 2006; Fine & Thorson, 2008; Luczkovich *et al.*, 2008; Mann *et al.*, 2008; Aalbers & Sepulveda, 2012). In the Mediterranean Sea, there are five different species of sciaenids. Vocal communication in two of these species has been examined in some detail: the meagre *Argyrosomus regius* (Asso 1801) (Lagardère & Mariani, 2006) and the brown meagre *Sciaena umbra* L. 1758 (Picciulin *et al.*, 2013*a*). Sound production in the Shi drum *Umbrina cirrosa* (L. 1758) was first briefly mentioned by A. Francescon & B. Barbaro (unpubl. data) and a description of 11 sounds emitted by six large *U. cirrosa* was provided by Lagardère & Parmentier

§Author to whom correspondence should be addressed. Tel.: +353 894230616; email: marta.bolgan@gmail.com
†Present address: Via Alviano 18, Gorizia, Italy.

(2014). A detailed description of the vocal repertoire of *U. cirrosa* is still largely lacking. Examination using PAM of presence and distribution of commercially important fishes, including sciaenids, is not yet common practice in the Mediterranean Sea, probably because of a lack of information on the sounds made by the different fish species inhabiting this area.

Recently, PAM proved to be successful in detecting the presence of *S. umbra* within natural and artificial rocky habitats during the reproductive season (Picciulin *et al.*, 2013*b*). A similar approach could be used to map the presence and the distribution of *U. cirrosa* in the field, once the sound features characterizing the calls of this species are known. *Umbrina cirrosa* is a multiple-batch group synchronous spawner, *i.e.* it engages in several spawning bouts within the spawning period, which lasts from June to August (Barbaro *et al.*, 1996). *Sciaena umbra* reproduces from May to August (Grau *et al.*, 2009). *Umbrina cirrosa* and *S. umbra* overlap in their distribution, inhabiting similar coastal waters with sandy and rocky bottoms. Both *S. umbra* and *U. cirrosa* have high commercial value, and are captured by small-scale artisanal fisheries (Arneri *et al.,* 1998). *Umbrina cirrosa* is considered to be a threatened Mediterranean species and it is currently classified as vulnerable by the IUCN. More recently, *U. cirrosa* has been highlighted as a candidate species for aquaculture (Mylonas *et al.*, 2004).

The present study provides a detailed description of the structure and variability of the sounds produced by *U. cirrosa,* recorded under semi-natural conditions. Furthermore, the acoustical properties of *U. cirrosa* sounds are compared with those of *S. umbra* sounds, previously recorded in the field (Picciulin *et al.*, 2013*a*). The main aim was to identify those acoustical features that could be used to discriminate between these two species during PAM in the wild.

The study took place in the Veneto Agriculture Bonello Trial Fishing Centre (Porto Tolle, Rovigo, Italy) in a large aquaculture tank (outdoor pond of 1·5 m depth and 0·2 ha in area, supplied with seawater). Water temperature ranged from 18 to 22° C. The acoustic activity of 30 mature *U. cirrosa* individuals, raised in captivity, was recorded. The *U. cirrosa* were *c.* 3 years old, which corresponds to the age of sexual maturity (Basaran *et al.*, 2009). Both females and males were present in the tank but the sex ratio was unknown. The *U. cirrosa* were exposed to a natural photoperiod (45° N). No hormonal treatments were carried out. Preliminary visual observations indicated that the *U. cirrosa* shoaled for most of the day, usually in close proximity to the tank bottom. For this reason, the autonomous sonobuoy used to register *U. cirrosa* vocal activity was placed in the tank at 0·6 m depth, where it was stabilized by 5 kg weights. The distance of the individual *U. cirrosa* making sounds from the hydrophone was not known. The sonobuoy was provided with a preamplified Reson TC 4013 hydrophone (sensitivity 170 dB re 1 V mPa^{-1}, frequency range 1 Hz–170 kHz; www.teledyne-reson.com) and a Gemini iKey Plus Recording Device (http://geminisound.com/), which created six 10 min samples every hour (WAV file format, sampling rate 44·1 kHz, 16 bit), together with a calibration signal recorded at the beginning of each sample. Recordings were carried out on 14 May 2011 from 1230 until 2000 hours, providing a total of 450 min of continuous recordings. These were subsequently analysed minute by minute using Cool Edit Pro 2.0 software (www.adobe.com/it/products/audition.html).

A total of 1160 individual calls with a good signal to noise ratio (S:N) were selected for detailed analysis. Temporal features were measured from the waveform (showing instantaneous sound pressure against time), while frequency parameters were obtained from power spectra. Each call was made up of a series of repeated pulses and the following sound variables were measured: pulse duration (PD, ms); pulse period (peak to peak time interval between consecutive pulses in a call; PP, ms); number of pulses (NP) per call; sound duration (measured from the first peak of the first pulse to the last peak of the last pulse of the same call; DUR, ms); interval between calls (measured from the peak of the last pulse of one call and the peak of the first pulse of the following recorded call, ms); peak frequency (Hz) of single pulses (PFP) and of the whole call (PFS). Frequency spectra were obtained using a Hanning window, fast Fourier transformation (FFT) size 1024.

Sciaena umbra calls used for comparison with those of *U. cirrosa* were recorded in 2009 at the Natural Marine Reserve of Miramare (Trieste, Italy) (where *S. umbra* is the only sciaenid species present) by using the same sonobuoy deployed at 6–8 m depth; details on methodological aspects are given by Picciulin *et al.* (2013*a*).

Umbrina cirrosa calls consisted mainly of a series of two pulses (74% out of 1160 sounds; range: 1–11 pulses) with most of the energy below 2 kHz and a mean peak frequency of 440 Hz (Fig. 1). Individual calls lasted *c.* 240 ms, single pulse duration was on average *c.* 40 ms and pulse period was *c.* 180 ms. The number of pulses per call showed a positive correlation with call duration (Spearman rank correlation, $n = 1042$, $r = 0{\cdot}655$, $P < 0{\cdot}001$) and a negative correlation with pulse period (Spearman rank correlation, $n = 1042$, $r = 0{\cdot}636$, $P < 0{\cdot}001$) and sound peak frequency (Spearman rank correlation, $n = 1042$, $r = 0{\cdot}062$, $P < 0{\cdot}05$). The peak frequency was significantly correlated with the pulse period (Spearman rank correlation, $n = 1042$, $r = 0{\cdot}182$, $P < 0{\cdot}001$).

In contrast to Lagardère & Parmentier (2014), who reported two types of call from *U. cirrosa* sounds, lasting respectively 60–90 and 140–160 ms, the present study showed a continuous range of variability in sound duration, ranging from *c.* 150 to 1400 ms. This variability reflected differences in the number of pulses making up each call: while Lagardère & Parmentier (2014) described calls made of 1–3 pulses, a maximum of 11 pulses per call was observed in the present study.

In terms of spectral properties, a much higher mean peak frequency (*c.* 400 Hz) was observed in comparison to that reported by Lagardère & Parmentier (2014), where the peak frequency range was 150–250 Hz. The mean peak frequency of call in the present study, however, showed a great range of variation, from *c.* 100 up to 500 Hz. Three factors could explain these discrepancies: the call sample size (1160 *v.* 11), and differences in the age and size of *U. cirrosa*. In the present study, the investigation involved a single *U. cirrosa* cohort (of 3 year old individuals) while Lagardère & Parmentier (2014) were reporting results from *U. cirrosa* that had reached the upper size and age limit for this species (six large individuals, 2·5–6 kg). Connaughton *et al.* (2002) have shown that larger fishes tend to produce sounds that are lower in frequency than those from smaller fishes. Individual *U. cirrosa* can grow in length by *c.* 10 cm in 10 months (Ayala *et al.*, 2015), and assuming a negative frequency and body size relationship, there is potential for a large variability in peak frequency within the species.

Interspecific comparisons highlighted a significant difference between *U. cirrosa* and *S. umbra* vocalizations in all measured acoustic features (Table I). *Umbrina cirrosa* calls were made up, on average, of a smaller number of pulses, and showed shorter pulse duration, pulse period and sound duration than *S. umbra* calls. Furthermore, the peak frequency characterizing both pulses and calls was found to be higher in *U. cirrosa* than in *S. umbra*, with most pulses of *U. cirrosa* showing a peak frequency

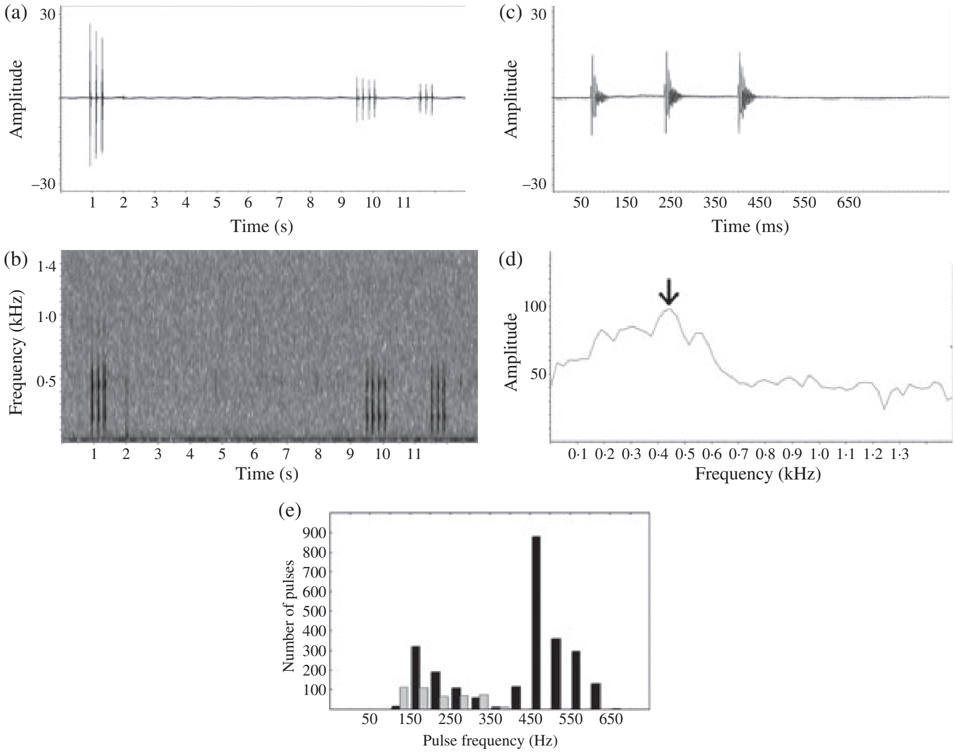

FIG. 1. (a) Oscillogram and(b) sonogram of three sounds made by the *Umbrina cirrosa* (Sciaenidae) recorded in semi-natural conditions and (c) structure of three pulses from a *U. cirrosa* sound [Hamming window, fast Fourier transformation (FFT) size = 125]. (d) Power spectrum for one of the three pulses (Hamming window, FFT size = 1024), where the peak frequency is indicated by the black arrow and corresponds to 452 Hz. (e) Frequency distribution histogram of *U. cirrosa* (■) and *Sciaena umbra* (□) (Sciaenidae) sound pulse frequency.

ranging from 400 to 600 Hz (Fig. 1). Considering that the acoustic behaviour of both Sciaenidae species was recorded in similar water temperatures (18–22° C for *U. cirrosa* *v.* 15–20° C for *S. umbra*), a significant influence of temperature on the comparison can be excluded. The lack of information regarding body size and behavioural and motivational state of *U. cirrosa* individuals requires caution in interpreting the present comparison. The temporal patterns of fish sounds can vary greatly in different behavioural contexts or in relation to motivational state (Amorim, 2006). For example, captive *S. umbra* individuals tend to produce shorter sounds with fewer pulses than wild *S. umbra* individuals (M. Picciulin, pers. obs.). Thus, the shorter calls produced by *U. cirrosa*, the lower number of pulses and the differences in the temporal patterns are likely to be influenced by the behavioural context or by the motivational state of the individuals.

In conclusion, these differences in calls made by two sympatric Sciaenidae species provide a preliminary tool for discriminating between *U. cirrosa* and *S. umbra* whilst conducting PAM in those parts of the Mediterranean Sea where both species co-exist. To refine the ability to separate calls of the two species, further studies are

TABLE I. Statistical comparisons of the acoustic features of sounds produced by *Umbrina cirrosa* and *Sciaena umbra*. Mean ± S.D. of the number of pulses (NP) per sound units, pulse duration (PD, ms), pulse period (PP, ms), sound duration (DUR, ms), peak frequency (Hz) of single pulses (PFP) and of the whole sounds (PFS) and interval between sounds [DIS, ms; calculated by using Hanning window, fast Fourier transformation (FFT) size 1024] are shown. All the variables are significantly different (Mann–Whitney *U*-test, $P < 0.001$)

	Umbrina cirrosa				*Sciaena umbra*				
	n	Minimum	Maximum	Mean ± S.D.	*n*	Minimum	Maximum	Mean ± S.D.	*U*-test
NP	2476	1	11	2·4 ± 1·1	455	1	12	5·1 ± 2·3	166394·5
PD	1317	33	235	186·5 ± 16·8	345	59·1	503·4	136·0 ± 40·6	118 641
PP	2479	14	87	38 ± 10·3	455	7	64	24 ± 8·3	27 361
DUR	1042	147	1389	236 ± 120	106	16	1116	458·7 ± 215·1	121 026
PFP	2480	134·7	656·2	427·7 ± 136·8	455	104	559	212·3 ± 78·1	86 169
PFS	1160	134·7	656·2	441·0 ± 135	105	117	559	249·6 ± 87·7	11 402
DIS	907	95	95 163	4035·3 ± 5758·1	109	28	8951	1287 ± 1752·4	18 250

n, sample size.

needed to relate the acoustical properties of calls to body size and age, by comparing ontogenetic changes of the sounds for both species. Further comparisons are also needed to rule out the possibility that differences in the structure of the sounds arise from differences in recording conditions or the behavioural context of the sounds.

The authors are grateful to A. Codarin for the technical support to this research and to A. Hawkins and A. L. Lusher for valuable comments on the present manuscript and the revision of the English. The authors are grateful to E. Parmentier and a second anonymous referee for their suggestions which contributed to the improvement of the present paper.

References

Aalbers, S. A. & Sepulveda, C. A. (2012). The utility of a long-term acoustic recording system for detecting white seabass *Atractoscion nobilis* spawning sounds. *Journal of Fish Biology* **81,** 1859–1870.

Amorim, M. C. P. (2006). Diversity of sound production in fish. In *Communication in Fishes*, Vol. I (Ladich, F., Collin, S. P., Moller, P. & Kapoor, B. G., eds), pp. 71–104. Enfield, NH: Science Publishers.

Arneri, E., Colella, S. & Giannetti, G. (1998). A method for the age determination of two Mediterranean sciaenids, *Sciaena umbra* (Linnaeus, 1758) and *Umbrina cirrosa* (Linnaeus, 1758). *Rapport Commission International Mer Mediterranee* **35,** 366–367.

Ayala, M. D., Arizcun, M., García-Alcázar, A., Santaella, M. & Abellán, E. (2015). Long-term effects of the larval photoperiod on the subsequent growth of Shi drum *Umbrina cirrosa* L. specimens and the fillet texture at commercial size. *Turkish Journal of Fisheries and Aquatic Sciences* **15,** 93–101.

Barbaro, A., Bozzato, G., Fanciulli, G., Franceson, A., Libertini, A. & Rinchard, J. (1996). Maturità gonadica in *Umbrina cirrosa* (L.), riproduzione ed allevamento in cattività. *Biologia Marina Mediterranea* **3,** 394–395.

Basaran, F., Muhtaroglu, C. G., Özden, O. & Özkizilcik, S. (2009). Spawning behaviour of Shi drum (*Umbrina cirrosa*) after hormone administration. *Journal of Fisheries Science.com* **32,** 124–133.

Connaughton, M. A., Fine, M. L. & Taylor, M. H. (2002). Weakfish sonic muscle: influence of size, temperature and season. *Journal of Experimental Biology* **205,** 2183–2188.

Fine, M. L. & Thorson, R. F. (2008). Use of passive acoustics for assessing behavioral interactions in individual toadfish. *Transactions of the American Fisheries Society* **137,** 627–637.

Grau, A., Linde, M. & Grau, A. M. (2009). Reproductive biology of the vulnerable species *Sciaena umbra* Linnaeus, 1758 (Pisces: Sciaenidae). *Scientia Marina* **73,** 67–81.

Lagardère, J. P. & Mariani, A. (2006). Spawning sounds in meagre *Argyrosomus regius* recorded in the Gironde estuary, France. *Journal of Fish Biology* **69,** 1697–1708.

Lagardère, J. P. & Parmentier, E. (2014). Les sons de contact de l'ombrine côtière – *Umbrina cirrosa* (Linné, 1758). *Bulletin de la Société de Borda* **514,** 214–217.

Luczkovich, J. J., Pullinger, R. C. & Johnson, S. E. (2008). Identifying sciaenid critical spawning habitats by the use of passive acoustics. *Transactions of the American Fisheries Society* **137,** 576–605.

Mann, D. A., Hawkins, A. D. & Jech, J. M. (2008). Active and passive acoustics to locate and study fish. In *Fish Bioacoustics* (Webb, J. F., Fay, R. N. & Popper, A. N., eds), pp. 279–309. New York, NY: Springer.

Mylonas, C. C., Kyriakou, Y., Sigelaki, I., Georgiou, G., Stephanou, D. & Divanach, P. (2004). Reproductive biology of the shi drum (*Umbrina cirrosa*) in captivity and induction of spawning using GnRHa. *Israeli Journal of Aquaculture - Bamidgeh* **56,** 75–92.

Picciulin, M., Calcagno, G., Sebastianutto, L., Bonacito, C., Codarin, A., Costantini, M. & Ferrero, E. A. (2013a). Diagnostic of nocturnal calls of *Sciaena umbra* (L., fam. Sciaenidae) in a nearshore Mediterranean marine reserve. *Bioacoustics* **22,** 109–120.

Picciulin, M., Bolgan, M., Codarin, A., Fiorin, R., Zucchetta, M. & Malavasi, S. (2013b). Passive acoustic monitoring of *Sciaena umbra* on rocky habitats in the Venetian littoral zone. *Fisheries Research* **145,** 76–81.

Ramcharitar, J., Gannon, D. P. & Popper, A. N. (2006). Bioacoustics of the family Sciaenidae (croakers and drumfishes). *Transactions of the American Fisheries Society* **135,** 1409–1431.

Rountree, R. A., Gilmore, R. G., Goudey, C. A., Hawkings, A. D., Luckzovich, J. J. & Mann, D. (2006). Listening to fish: application of passive acoustic to fisheries science. *Fisheries* **31,** 433–446.