IN SITU CALLS OF THE MARINE PERCIFORM *GLAUCOSOMA HEBRAICUM*

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West Australian dhufish (*Glaucosoma hebraicum*), a marine perciform, possess a swim bladder which has associated muscles that are used in sound production. Individuals have been recorded producing sounds during capture that may be associated with disturbance from their normal behaviour. To determine whether individuals produce sound during natural behaviour, a passive sea-noise logger was deployed on the seafloor for one month in close proximity to low-relief artificial substrates occupied by *G. hebraicum*. During this time, both juvenile and sub-adult *G. hebraicum* were observed within metres of the logger on numerous occasions. At approximately the same time, sounds with characteristics similar to the disturbance calls of *G. hebraicum* were detected by the logger. Two types of swimbladder generated calls were recorded, one of widely-spaced pulses and the other of pulses in quick succession The maximum received levels and sound exposure levels of the recorded calls were 132 dB re 1 μPa and 121 dB re 1 μPa^2.s, respectively. Based on previously determined *G. hebraicum* source levels and time of arrival techniques (direct and surface-reflected ray paths), the vocalising fish were estimated at between 1 and 19.5 m from the hydrophone and thus within the area where they had been observed. This study has provided evidence that juvenile *G. hebraicum* produce sounds at similar source levels to those generated during human-induced disturbance. This indicates that sound is produced by individuals of this species during normal behaviour, but may or may not be associated with natural sources of disturbance.

INTRODUCTION

Sources of biological sounds in Western Australian waters are numerous, from snapping shrimp, through multiple fish species to marine megafauna, such as humpback (*Megaptera novaeangliae*) and pygmy blue whales (*Balaenoptera musculus brevicauda*) [1-8]. Recording these signals is often conducted to help monitor the temporal and spatial distribution of the source species [9-12]. Some of the greatest contributions to ambient noise come from the vocalisations of fish, particularly at frequencies of 100-1000 Hz. Previously undetected fish choruses, either from a known source at a new location or a new chorus type, are being discovered all the time [13-15] and, under certain conditions, the characteristics of these types of choruses can provide a complementary source of data for monitoring and management [e.g. 16, 17].

The West Australian dhufish (*Glaucosoma hebraicum*) is an important marine perciform in Western Australian fisheries [18] and has been the subject of numerous studies to understand its biology [e.g. 19, 20, 21]. The species has been shown to produce disturbance calls comprising a mean of all maximum root mean square (rms) source levels (SL) within calls and sound exposure level (SEL) of 126 dB re 1 μPa at 1 m and 117 dB re 1 μPa^{2}s at 1 m, respectively [22]. Determining the behaviours associated with sounds produced by *G. hebraicum* would increase our understanding of their biology (e.g. are sounds associated with reproduction) and the possibility of employing passive acoustic techniques for detection of their presence in an area. If the species only produces disturbance calls, the application to monitoring presence and the number of callers is significantly reduced.

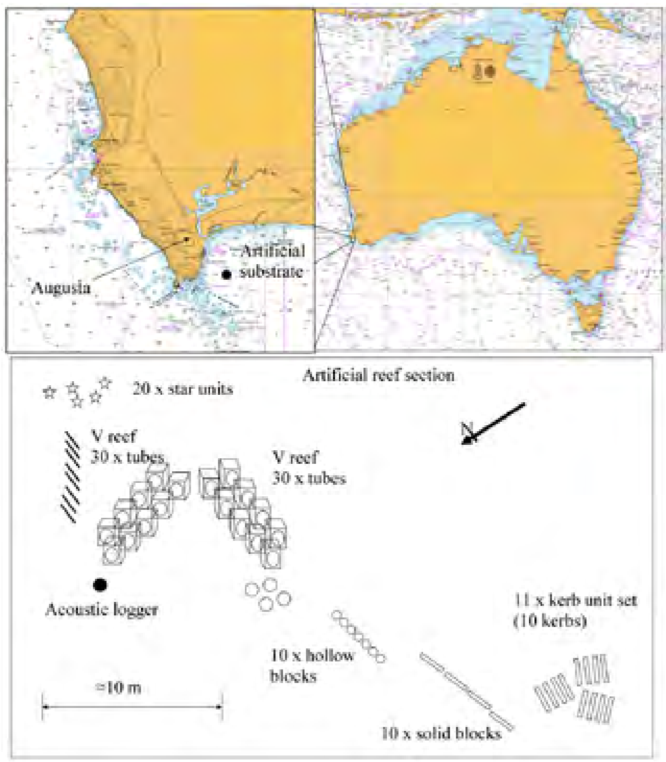

Figure 1. Map of southwest Australia indicating location of lease and line drawing of the spatial organisation of artificial substrates located in the area. Location of logger marked by the black circle.

Other than the confirmation of sound production by *G. hebraicum* during capture, vocalisation of this species under natural circumstances, *i.e.* in the wild, has not been recorded. The aim of this study was to determine whether individuals of this species produce sound in the natural environment and thus without behavioural bias. This was conducted via the collection of long-term recordings from a location where *G. hebraicum* have been regularly observed at close range (< 20 m) [22]. As the logger was deployed 17 days before recordings commenced, this gave fish the opportunity to become habituated to its presence, thus any recorded vocalisations would be less likely to be associated with disturbance.

METHODS

In 18 m deep waters off Augusta, Western Australia, Ocean Grown Abalone Pty Ltd deployed numerous types of low-relief artificial substrates in 2011 to investigate which type provides preferred habitat for marine ranching greenlip abalone *Haliotis laevigata* [23]. Subsequently, juveniles of various species of fish also recruited to the habitats, including *G. hebraicum* [24, Figure 1]. An autonomous sea-noise logger, developed by the Centre for Marine Science and Technology and the Defence Science and Technology Organisation, was deployed to the seabed next to one of the artificial substrates where *G. hebraicum* were consistently observed, between 17th November, 2012 and 12th January, 2013. This logger was connected to an omni-directional, HTI 90-U hydrophone (HighTech Inc., MS, USA) and recorded for 700 of every 900 s for the entire deployment, sampling at 6 ksps. The system was calibrated with a white noise generator at -90 dB re 1 V^2/Hz and data analysed using the Characterisation Of Recorded Underwater Sound (CHORUS) Matlab toolbox, written at the Centre for Marine Science and Technology (CMST). Spectrograms were produced with a 1024-point Hanning window at a frequency resolution of 1 Hz.

In calls where reflected paths could be identified, techniques using the difference in time of arrival between direct- and surface-reflected paths of a biological signal were used here to estimate source ranges of *G. hebraicum* [25, 26]. As *G. hebraicum* is a demersal species, often reported around the base of rocky lumps [20], an assumption of their position near the seafloor was made to simplify the range estimate calculations.

The combination of estimated range and known received levels (RLs) provides the possibility of estimating SL using methods similar to Parsons *et al*. [27]. As the fish were assumed, but not confirmed to be near the seafloor at the time of vocalisation, the calculated SL is taken as a coarse estimate to add weight of evidence to determine source species. The effective plane receive beam pattern of the bottom positioned hydrophone should also be considered. In this case, the sand substrate and likely calcarenite beneath it in the area, combined with the estimated water column position of the callers would most likely increase the RLs by between 1 and 4 dB re 1 μPa [28].

Figure 2. Still shots from video of a sea-noise logger deployed near artificial substrates off Augusta in December 2012 and January 2013, showing a single juvenile *Glaucosoma hebraicum* next to the sea-noise logger (left) and multiple juveniles next to artificial substrate approximately 7 m from the logger (right). Photos taken by S. Longbottom

Table 1. Acoustic characteristics of calls recorded in an area where multiple *G. hebraicum* occurred. Mean values are presented with standard deviation, maximum and minimum values in parentheses.

Call Type (n)	Number of pulses	Pulse repetition frequency (Hz)	Duration (s)	Spectral peak frequency (Hz)	Bandwidth (Hz; 3dB down)
All multiple pulse calls (68)	13.5 (9.7, 36, 2)	9.2 (5.6, 25.9, 2.4)	1.41 (0.73, 4.1, 0.4)	231 (21, 268, 114)	89 (59, 155, 71)
Pulses in quick succession (36)	13.0 (5.9, 36, 10)	13.2 (4.7, 25.9, 4.0)	1.8 (0.71, 4.1, 1.02)	159 (66, 251, 114)	171 (57, 122, 71)
Separated pulses (32)	4.4 (1.9, 9, 2)	4.66 (1.7, 10.2, 2.4)	0.99 (0.48, 2.6, 0.42)	178 (58, 268, 145)	110 (61, 155, 101)
Single pulse calls (7)	1	n/a	0.04 (0.02, 0.6, 0.02)	149 (46, 251, 99)	107 (66, 185, 89)

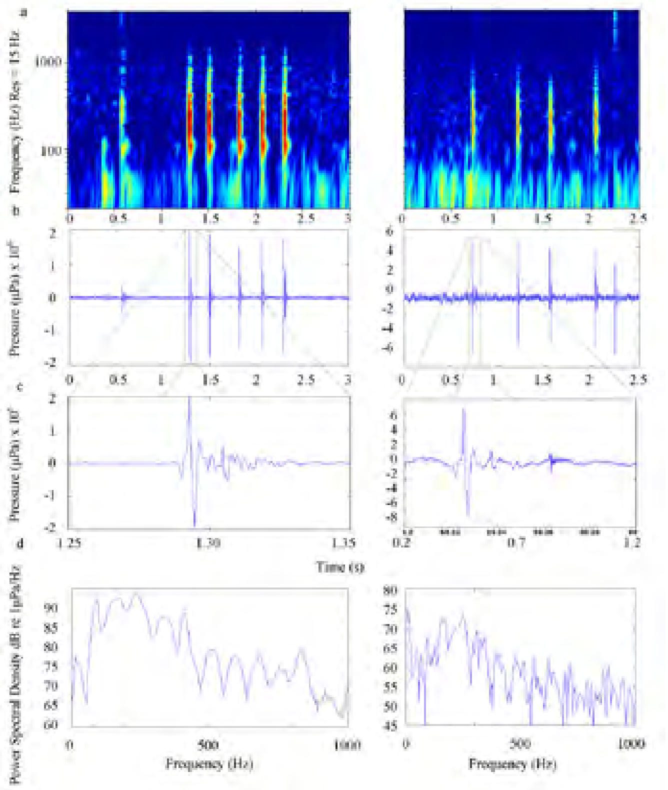

Figure 3. Spectrogram (a) and waveform (b) of two sets of likely *Glaucosoma hebraicum* calls recorded. Expanded waveforms of individual pulses (c) and power spectral density of the overall calls (d) are also shown.

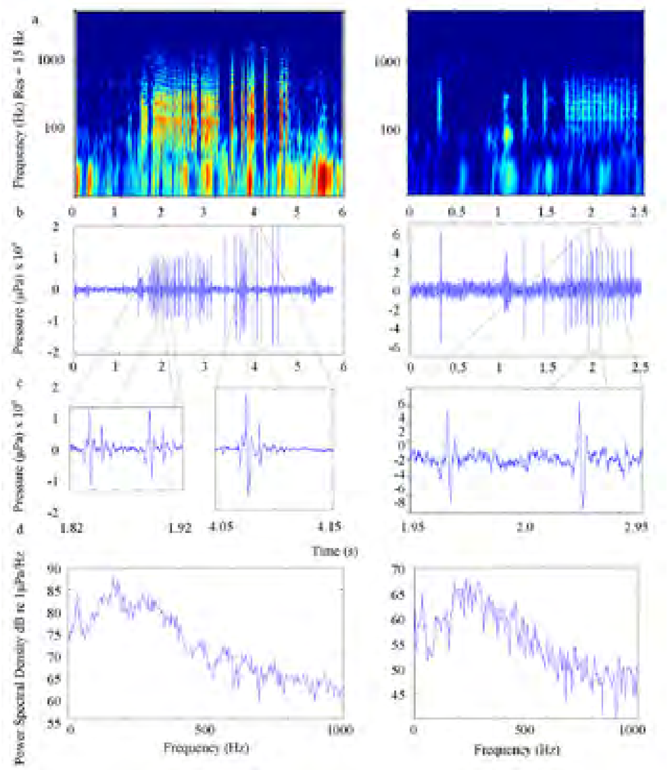

Figure 4. Spectrogram (a) and waveform (b) of two multiple pulse *Glaucosoma hebraicum* calls recorded. Expanded waveforms of individual pulses (c) and power spectral density of the overall calls (d) are also shown.

RESULTS

Ongoing monitoring of the study site by Department of Fisheries WA (DoFWA) and Curtin Aquatic Research Laboratory (CARL) researchers has noted that the study site consistently supports many juvenile and, on occasion, *G. hebraicum* greater than the species length at which 50 % of individuals reach sexual maturity (50-246 individual *G. hebraicum* across nine surveys, Lewis, unpublished data). The site was examined multiple times during the day while the logger was deployed by CARL scientists. Three length cohorts of *G. hebraicum*, estimated by eye at a mean of approximately 100, 200 and 300 mm (total length), predominantly of the former two size cohorts, were often seen within 10 m of the noise logger (Figure 2). Other species predominantly observed were snapper (*Pagrus auratus*), weeping toadfish (*Torquigener pleurogramma*), Western king wrasse (*Coris auricularis*) and a single juvenile Rankin's cod (*Epinephelus multinotatus*) that was also noted on the 15th January, 2013.

The recordings displayed significant wave and mooring noise (artefacts created by motion of the hydrophone or tapping of the cable) throughout the deployment, often masking any concurrent sounds. However, during periods of low ambient noise, a large number of fish calls were detected. A sample of those most similar to *G. hebraicum* disturbance calls (n = 91) are described here. These calls were generalised into two categories; the first comprising calls of an individual pulse or a series of multiple pulses that were each separated in time by up to 1 s, but not less than 0.2 s (Figure 3), while the second comprised multiple pulses in quick succession (Figure 4). The latter category calls often included initial pulses separated by > 0.2 s, but were then quickly followed by a series of pulses in quick succession. In each case these calls displayed spectral peak frequencies between 100 and 300 Hz (Table 1) with further spectral peaks at higher frequencies (Figure 3). The maximum rms RLs and SELs of the recorded calls were 132 dB re 1 μPa and 121 dB re 1 μPa^2.s, respectively.

Surface reflected paths were identified in the pressure waveforms of 77 sounds. Time of arrival difference between the direct and surface reflected paths estimated the closest of these sounds at 1.2 m from the hydrophone, if positioned on the seafloor, with others at up to 19.5 m range (Figure 5). The SL of these calls, estimated from least squares linear regression of the RLs with range from the hydrophone, as per the methods in Parsons *et al.* [27], was 129 dB re 1 μPa.

DISCUSSION

This study provides significant evidence to show that *G. hebraicum* produce sound in the wild, and that these calls may be associated with behaviours other than anthropogenic disturbance. Acoustic characteristics of calls recorded (frequency, duration, estimated SL) were similar to those made during capture of adult *G. hebraicum* off Rottnest Island [22]. Moreover, video evidence and observations by researchers at times close to that of the recorded calls showed that *G. hebraicum* were present and the most likely source. There is none or little evidence that other species present (e.g. labrids, *Pagrus auratus*) can produce sound [29] or are so prevalent in surrounding locations that vocalisations of this type would be recorded more commonly [29]. Furthermore, juvenile *G. hebraicum* have been recorded at this location consistently over two years in substantial numbers [24].

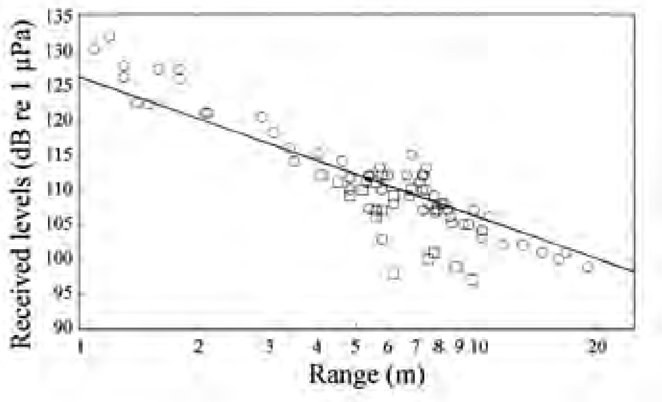

Figure 5. Relationship between mean squared (a) received levels and log estimated range for the calls of *Glaucosoma hebraicum* with closely spaced pulses (squares) and separated pulses (circles). Spherical spreading losses with range for a call of source level 126 dB re 1 μPa shown by the black line.

The estimated SLs reported here imply that the callers ranged between 1 and 19.5 m of the logger when compared to previous SL estimates [22]. Ranges determined by surface reflections techniques positioned the fish up to nearly 20 m away. However, to offer a useful and cost-effective method of gathering data on the biology/ecology of *G. hebraicum*, fish would need to be detectable at greater ranges than this. Simple models of transmission loss estimate that in low levels of ambient noise (around 80-90 dB re 1µPa) the calls could be detected at a minimum of 50-100 m from the hydrophone, but this has yet to be shown in the field [22]. If multiple *G. hebraicum* call together this detection range could be extended considerably, similar to other fish choruses [11].

The similarities between the received levels, spectral peak frequencies, waveforms and time between pulses of sounds recorded during this study suggest that both the single pulse and multiple pulse calls came from the same individual, or at least were produced using the same mechanism, and therefore, the same species. The reason for the variations in the number of pulses and time between pulses is unknown, but has been documented in other vocal species [30]. This may or may not have an associated function. The next step in understanding vocal behaviour of *G. hebraicum* is to combine the recordings with long-term visual recordings to determine what the associated functions are. These calls were produced by juvenile and sub-adult fish and therefore not related to spawning. However, as adults of this species demonstrate social hierarchies [20] and individuals produce sound in the natural environment, it is possible that *G. hebraicum* is vocal during spawning or aggregating activities. Confirmation of such behaviour would allow investigation of the presence/absence of spawning activity in particular locations using passive-acoustic techniques.

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