Does Vessel Noise Affect Oyster Toadfish Calling Rates?

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Abstract

The question we address in this study is whether oyster toadfish respond to vessel disturbances by calling less when vessels with lower frequency spectra are present in a sound recording and afterwards. Long-term data recorders were deployed at the Neuse (high vessel noise site) and Pamlico Rivers (low vessel noise site). There were many fewer toadfish detections at the high vessel-noise site than the low-noise station. Calling rates were lower in the high-boat traffic area, suggesting that toadfish cannot call over loud vessel noise, reducing the overall calling rate and may have to call more often when vessels are not present.

1. Introduction

The midshipman and toadfish (Batrachoididae) family is one of the more vocal groups of fishes, being found in all the world's oceans. Sound production and reception is very important to toadfish during their mating period. Male *Opsanus tau* (Oyster toadfish) produce sounds during courtship and nest guarding (Gray and Winn 1961, Fine 1978, Amorim and Vasconcelos 2008, Rice and Bass 2009). Sound production occurs more often at night than during the day (Thorson and Fine 2002). Metabolic costs of sound production are important (Amorim et al. 2002), as the *Opsanus tau* muscle is among the fastest vertebrate muscles ever measured (Skoglund 1961, Rome and Lindstedt 1998) and muscle fatigue during long periods of courtship and calling have been documented (Mitchell et al. 2008). In addition, *Tursiops truncatus* (bottlenose dolphin) predation on *Opsanus tau* guarding eggs during the mating period is significant and dolphin may use the mating sounds to locate the toadfish (Barros and Randall 1998, Gannon et al. 2005, Dunshea et al. 2013) . Finally, it has been shown that shipping noise interferes with a related toadfish species *Halobatrachus didactylus* (Lusitanian toadfish) hearing (Vasconcelos et al. 2007), with up to a 30 dB loss in sensitivity at certain low frequencies, suggesting that females may be unable to hear males in some situations (masking from ship noise). Thus, an important question is how does vessel noise impact the calling rates of *Opsanus tau* males? Do they reduce calling rates in noisy environments, move to locations with less noise to make mating calls, or increase calling rates or sound pressure levels to continue to be heard by females?

In this paper, we investigate these questions by comparing the calling rates of male *Opsanus tau* (Oyster toadfish) in two locations, one near a noisy boat channel (Neuse River Junction site, near the Intra Coastal Waterway) and one in a remote location (Pamlico Middle Sound site), in Pamlico Sound, North Carolina, USA. We hypothesized that fish would call more often in quiet periods between vessel passes, and the calling rates would be higher in the noisy environment, as the males call more often to be heard over the noise.

2 Methods

2.1 Passive Acoustic Recorder deployments

We used mobile estuarine observatories based on a stainless steel tripod frame (called instrumented tripods or ITPods). The ITPods are rapidly deployable, mobile estuarine observing stations for short- and long-term studies in NC estuaries with have passive acoustic data loggers that record variation in fish sound pressure levels while also measuring physical parameters (temperature, salinity, dissolved oxygen, water and air weather conditions). With these data, we can measure the short- and long-term variation in sound levels that indicate toadfish spawning and study how sound production correlates with environmental conditions (vessel noise, physical measures that are correlated with spawning). The components of these ITPods include a passive acoustic digital recorder (Long-term Acoustic Recording System or LARS – Loggerhead Industries, Inc.) that records low and mid-frequency sounds (< 10 kHz) on a digital file (the LARS records 10 s of ambient sounds to a WAV file on a 2 GB compact flash card from a single HTI model 96-min hydrophone at 15-min intervals) along with temperature, salinity, oxygen, and turbidity levels using a Hydrolab Surveyor water quality meter. A Nortek Aquadopp Acoustic Doppler Profiler (ADP) was used for measuring water depth, tidal variations, currents and waves, a Nortek Vector for seabed elevation changes, and an OBS for near bed turbidity measurements. An ITPod was deployed beginning in April until November 2006 at the mouth of the Neuse River (NRJ site), near the Intra Coastal waterway. Another ITPod was deployed in April 2008 – November at the PMS site (middle Pamlico Sound). We deployed and recovered ITPods every 45 d. On each of these recovery and redeployment days, data were downloaded, instruments were cleaned and calibrated and batteries were replaced. Data used for this work focused on recordings made at the start of the *Opsanus tau* mating season (June and July).

2.1 Analysis of sound recordings

We used Raven 1.4 with a band-limited energy detector trained for *Opsanus tau* mating calls (boatwhistle or "boop" sound). Band-limited energy detectors compute a background noise level and look for sound energy variations in a defined frequency band that exceeds the noise threshold by a given signal-to-noise parameter. These detectors are good when looking for characteristic calls of a species with a known duration in a frequency band. The toadfish boatwhistle is such a call and our detectors used the temporal and spectral parameters shown in Table 1. The band-limited energy detector and these parameters are explained in the Raven user manual (Charif et al. 2010). Two different detectors in Raven were used, varying only by the minimum occupancy, or the minimum percent of the time during a sample window in which the sound level exceeded the signal to noise threshold and met the other criteria. Both detectors were tested for accuracy by running them against a test set of data from NRJ in June 2006 and PMS in June 2008, with an analyst listening to the recordings and scoring accuracy. The prototype band-limited energy detector for toadfish boops (Detector 0, with 10% minimum occupancy) had a true positive rate (true positives detected/total) was 90.9% and the false positive rate (false positive detected/total) was 6.9 % for 1 s intervals from 250 10-s recordings in the test run on May 2006 NRJ data. However, this prototype band-limited energy detector was influenced by background noises from vessels and many false positives occurred when *Cynoscion nebulosus* spotted seatrout were actively calling in June and July. Thus, two different slightly detectors (identical in all parameters, except Detector 1 used a 50% occupancy criterion, Detector 2 used a 70% criterion) were run on each set of data to minimize the false positives from biological and anthropogenic background noises. Representative sounds were listened to and spectrograms were examined to display fish sounds and vessel noise.

3. Results

Opsanus tau Oyster toadfish boatwhistles were heard and detected at both sites, both at the Neuse River (Noisy site) and the Pamlico Sound (Quiet site). In addition, *Cynoscion nebulosus*, spotted seatrout and *Bairdiella* *chrysoura*, silver perch (both in the family Sciaenidae) were also heard on both sets of recordings. Many vessels were heard at the Neuse River site, but few or none at the Pamlico Sound site (Figure 1). Overall sound levels of fish choruses and vessels were higher at the Neuse River site. The calling rate, as judged by the number of *Opsanus tau* toadfish boatwhistle detections in a 37.5 h period, was lower in the quiet site Pamlico Middle Sound (Table 2). Using Detector 1, with 50% occupancy parameter, 600 detections were made in 300 10-s recordings, an average of 2 boatwhistles per 10-s recording, or 12 per minute. In contrast, using this same detector, only 381 boatwhistles were detected in the Neuse River Junction recordings, an average of 1.27 boatwhistles per 10-s recording, or 7.6 per minute. Using Detector 2, with 70% occupancy parameter, 350 detections were made in 300 10-s recordings, an average of 1.2 boatwhistles per 10-s recording, or 7 per minute. In contrast, using this same detector, only 185 boatwhistles were detected in the 300 Neuse River Junction recordings, an average of 0.61 boatwhistles per 10-s recording, or 3.7 per minute. This lower rate could be due to disturbance from vessel noise, which overlaps in frequencies that the fishes make. Vessel noise often dominated the sound spectra form 0 – 10 kHz in a single 10-s recording, during which no boatwhistles were detected or heard on the recording. Vessel noise is apparently masking the sounds of nearby males calling, and this results in a cessation of calling when a vessel passes, as clearly seen in Figure 2.

4. Discussion

The rate of calling by male *Opsanus tau* was lower in the noisy site (Neuse River Junction) near the Intracoastal Waterway relative to the quiet site (Pamlico Middle Sound). *Opsanus tau* males may be influenced by vessel noise in a negative way, shutting down until the vessel passes. However, *Opsanus tau* continue to call when a vessel has passed by and may briefly attempt to make up for the lost time by raising calling rates. However, with enough noise-induced disturbance, the overall calling rates are lower, with an unknown impact on mating success o f tehse fish. Calling rates are less than the maximum that has been observed for this species of toadfish, as described by (Winn 1972) and (Fish 1972), which is as high as 80 boatwhistles in a 5 min period (or 16 boatwhistles per minute). It is also possible that there were more toadfish in general at the quiet site, contributing to the higher calling rates. The detectors we used produced some false positives, especially when *Cynoscion nebulosus* (spotted seatrout) were calling at night, so the rates reported here may actually be lower. Competition with the *Cynoscion nebulosus* sounds may cause disturbance as well, as the *Opsanus tau* toadfish must be heard by a female over that call in the background. We did not attempt to enumerate the toadfish present at each location, and were not able to tell individual fishes apart in the recordings. In summary, this observational study is in need of experimental verification using controlled vessel sound levels, and known number of *Opsanus tau* individuals present, with calling rates measured before and after vessel noise exposure. Such experiments are underway at the current time.

5. Acknowledgements

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Figure Legends

Figure 1. Composite spectrograms of sounds from A) noisy Neuse River Junction site starting on 30 June 2006; and B) from quiet Pamlico Mouth Site 27 June 2008. Composite spectrograms of recordings taken at a duty cycle of 10-s recorded sound every 15 min for the period shown (57.6 h or 2.4 d). Fish choruses are red and yellow regions under 1 kHz, with peaks extending to 8 kHz; bright vertical bands at Neuse River site are vessels passing, which dominate the 10-s sound recordings and are often broad-band 0-9.5 kHz. *Opsanus tau* boatwhistles occurred both day and night, but the *Cynoscion nebulosus* spotted seatrout and *Bairdiella chrysoura* silver perch Sciaenidae choruses, which are visible as the two dark regions in the figure, were loudest after sundown, occurring nightly through the month of June and July.

Figure 2. Spectrogram composite from eighteen 10-s recordings taken at 15-min intervals showing detections of *Opsanus tau* oyster toadfish using the band-limited energy detector at the Neuse River Junction (noisy) site. Blue boxes indicate a toadfish was detected at that time. Dark band is a large vessel that passed by the recorder at 1:20. Time axis is in m:s, with the divisions in the spectrogram indicating the 10-s recording segments.

Table Legends

Table 1. Parameters used in the Band Energy Threshold Detectors used in Raven.

Table 2. Detections of *Opsanus tau* oyster toadfish using the band-limited energy Detector 1 and 2 at the Neuse River Junction (noisy) site and Pamlico Middle Sound (quiet) site.

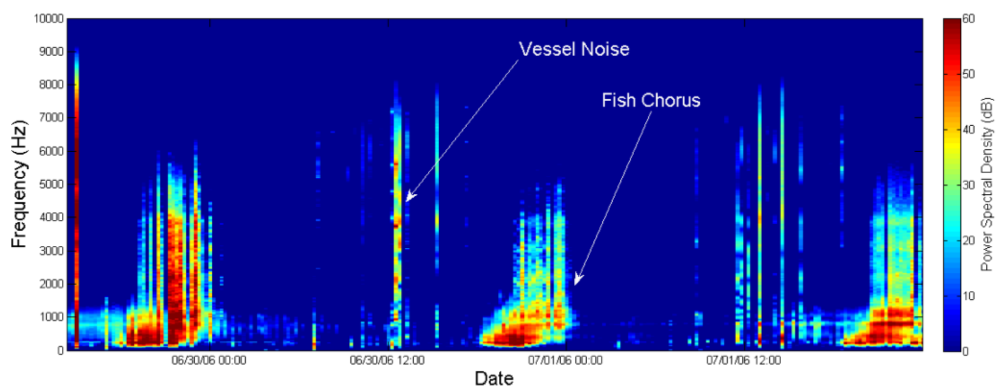
Table 1.

Band Energy Threshold Detector Parameter(unit)	Detector 1	Detector 2
Minimum Frequency (Hz)	15	15
Maximum Frequency (Hz)	250	250
Minimum Duration (s)	0.09288	0.09288
Maximum Duration (s)	0.89977	0.89977
Minimum Separation (s)	0.09288	0.09288
Minimum Occupancy (%)	50	70
Signal to Noise Threshold (dB)	10	10
Noise Estimate Block Size (s)	3.00118	3.00118
Noise Estimate Hop Size (s)	0.99846	0.99846
Noise Estimate Percentile (%)	50	50

Table 2.

Time period	Detector	Neuse River Junction (noisy)	Pamlico Middle Sound (quiet)
June 27-28 (150 10-s recordings)	1	180	309
June 28-29 (150 10-s recordings)	1	201	291
Total		381	600
June 27-28 (150 10-s recordings)	2	90	189
June 28-29 (150 10-s recordings)	2	95	161
Total		185	350

A


Vessel Noise
Fish Chorus
Frequency (Hz)
Date
06/30/06 00:00
06/30/06 12:00
07/01/06 00:00
07/01/06 12:00
Power Spectral Density (dB)

B

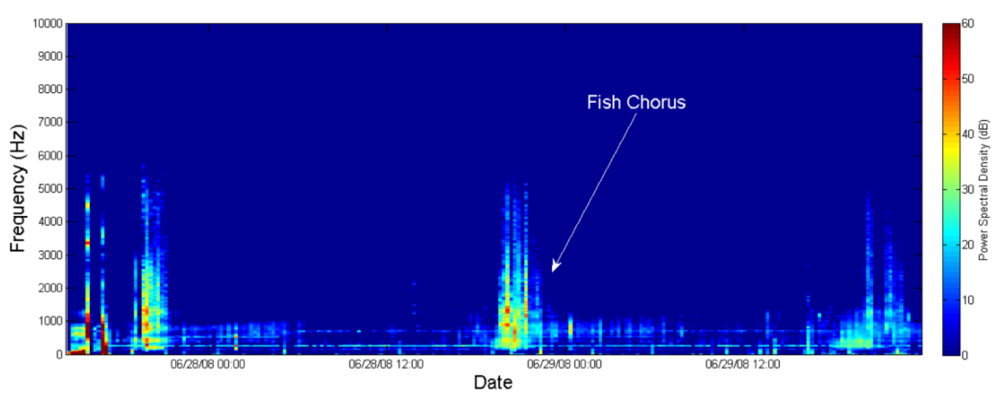
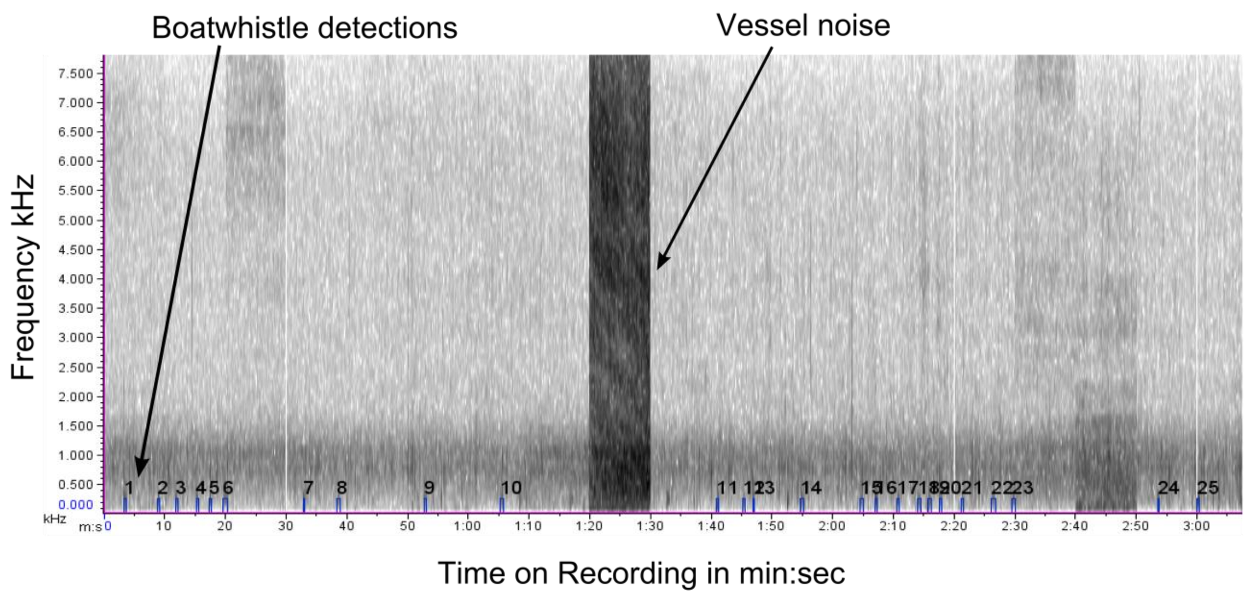

Fish Chorus
Frequency (Hz)
Date
06/28/08 00:00
06/28/08 12:00
06/29/08 00:00
06/29/08 12:00
Power Spectral Density (dB)

Figure 1

Fig



Boatwhistle detections
Vessel noise
Frequency kHz
7.500
7.000
6.500
6.000
5.500
5.000
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
0.500
0.000
kHz
m:s 0 10 20 30 40 50 1:00 1:10 1:20 1:30 1:40 1:50 2:00 2:10 2:20 2:30 2:40 2:50 3:00
Time on Recording in min:sec

Figure 2