Does Vessel Noise Change the Calling Rate and Intensity of Soniferous Fishes?

Joseph J. Luczkovich, Cecilia S. Krahforst, and Mark W. Sprague

1 Introduction

Fishes of the family Sciaenidae (drums and croakers) are well-known for their abilities to produce sounds using both sonic muscles and the swim bladder (Luczkovich et al. 2008a,b; Rountree et al. 2006; Sprague and Luczkovich 2004). Calls of sciaenid fishes like *Micropogonias undulatus* (Atlantic croaker) can be heard with hydrophones throughout the day, producing sounds when disturbed, during aggression, and during spawning (male advertisement calls). In this study, we examined if the noise associated with coastal vessels (ferry boats and tugboats) that operated daily during the early morning through early evening had any effect on the seasonal and daily calling rate of *Micropogonias undulatus*.

2 Methods

Fishes were recorded in situ using passive recorders (long-term acoustic recording system [LARS], Loggerhead Instruments, Inc., Sarasota, FL). The recordings were time-stamped 10-s wave files (<10 kHz) recorded to a compact flash disk at 15-min intervals from March through December 2008 at a site (Potash Corporation of Saskatchewan site; 35°23.207' N latitude and 76°44.673' W) in the Pamlico River near Aurora, NC. The fishes were exposed on a regular basis to vessel noises from a North Carolina State Department of Transportation ferryboat making sixteen 0.5-h trips each day, beginning at 0530 and ending at 2015 EDT. In addition, large tugboats pushing barges from the phosphate mine pass by the site intermittently. Passive recordings were analyzed using MATLAB

J.J. Luczkovich (✉)
Department of Biology, East Carolina University, Greenville, NC 27858, USA

Institute for Coastal Science and Policy, East Carolina University, Greenville, NC 27858, USA
e-mail: luczkovichj@ecu.edu

C.S. Krahforst
Department of Biology, East Carolina University, Greenville, NC 27858, USA

Coastal Resources Management Doctoral Program, East Carolina University, Greenville, NC 27858, USA

M.W. Sprague
Department of Physics, East Carolina University, Greenville, NC 27858, USA

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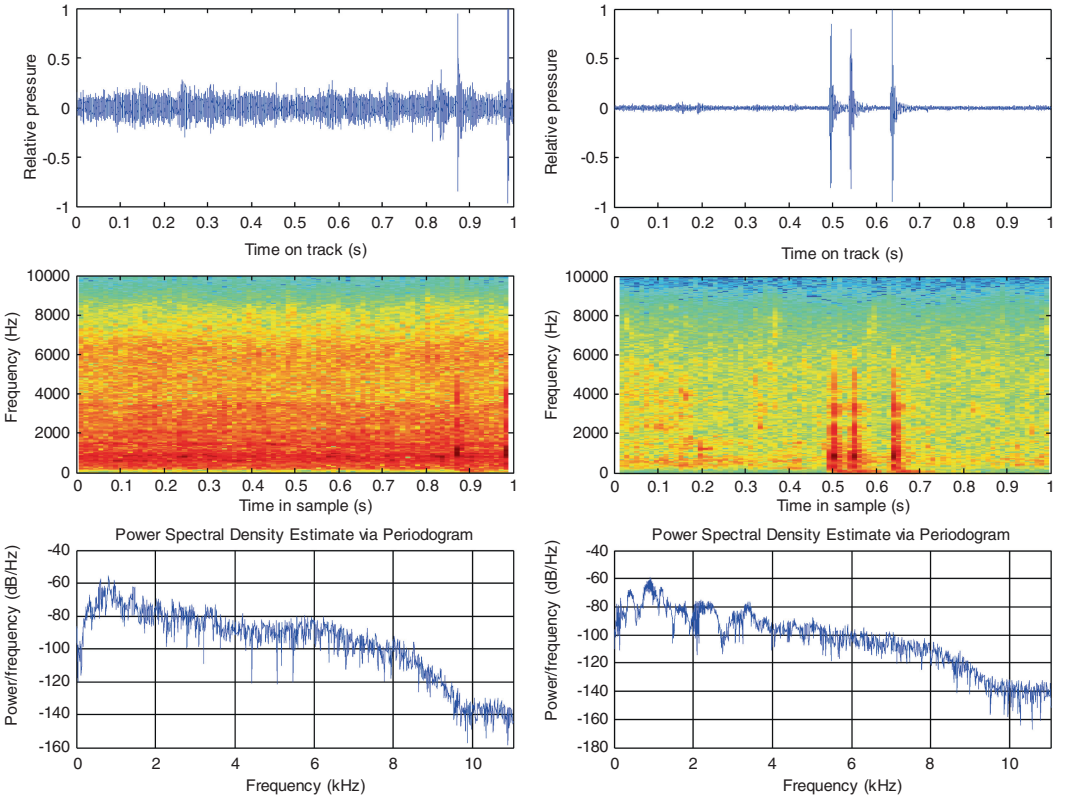

Fig. 1 Oscillograms (top panels), spectrographs (middle panels), and average power spectra (bottom panels) of a ferry with a single *Micropogonias undulatus* (Atlantic croaker) call (left panels) and three *M. undulatus* calls with no ferry sounds (right panels)

spectral analysis to estimate ferry and vessel noise (1,000-8,000 Hz) and fish sound (200-1,000 Hz) frequencies. We created automated sound event detectors in XBAT (Extensible Bioacoustics Tools, see http://www.xbat.org; Fig. 1), which was used to count fish calls and vessel noises and estimate minimum, maximum, and mean frequencies of vessel noises. Variation in salinity (10–23 practical salinity units [psu]), temperature (5-30°C), dissolved oxygen (1-13 mg/l), and turbidity (1-3,000 nephlometric turbidity units [NTU]) were measured daily at both sites with automated water quality meters (see Krahforst et al., Chpater 38). We compared the number of fish calls detected in 60 s (six 10-s recordings) each hour that ferries or other vessels (phosphate mine tugboats and barges) passed by the recording station to the number of calls detected in each hour without ferries present. We analyzed these data using ANOVA (SYSTAT, $\log_{10}$-transformed number of *M. undulatus* detections) with factors month (March, April, July, August, September, October, November, and December) and vessel noise (ferry or no ferry operating during recording). Finally, a plot of the vessel noise midfrequencies (halfway between the minimum and maximum frequencies reported by the XBAT detector), which shifted temporally due to varying vessel traffic, was compared with a plot of a calling index for *M. undulatus* during the month of October. The calling index was computed by dividing the calling rate for each observation by the maximum calling rate recorded times 100.

3 Results

The vessel sounds were broadband, ranging from 200 to 8,000 Hz (Fig. 1, left panels), and variable, especially at the lower frequencies that often overlapped the *M. undulatus* Atlantic croaker calls (300-1,000 Hz; Fig. 1, right panels). We recorded 5,926 *M. undulatus* calls at this station, made during 906 hourly measurements from March through December 2008. Sounds were made by *M. undulatus* both day and night regardless of the presence of the ferry (Fig. 2). However, fish sounds were less common (the calling index declined) when large vessels with low midfrequencies passed by the recorder on 13-15 October 2008 (Fig. 2, left). These vessel noise frequencies were close to the *M. undulatus* calling frequency range, perhaps causing the fish calling index to decline (Fig. 2, right). The rate of fish sound production varied significantly with month (ANOVA, $F_{7,892}$ = 22.4359, $P < 0.0001$), with the greatest number of *M. undulatus* calls occurring in a 3-mo period in the fall (August, September, and October; Fig. 3). There was no overall significant difference in the number of calls detected when a ferry was either present or absent in the recording area (ANOVA, $F_{1,892} = 0.0478$, $P = 0.8269$).

4 Discussion

The number of detections with and without ferry noise suggested that vessel noise has a limited effect on *M. undulatus* sound production. Instead, the variation in seasonal changes of acoustic sound production may be related to seasonal behavior and migration patterns, water quality parameters, and photoperiod. Spawning time for *M. undulatus* occurs from August through December, when the sound production, which is typically associated with spawning, increases. Sound production by *M. undulatus* persists despite the significant amount ferry noise present at the site. When large vessels pass by, the calling rate appears to fall. It is likely that these large vessels may prevent sound

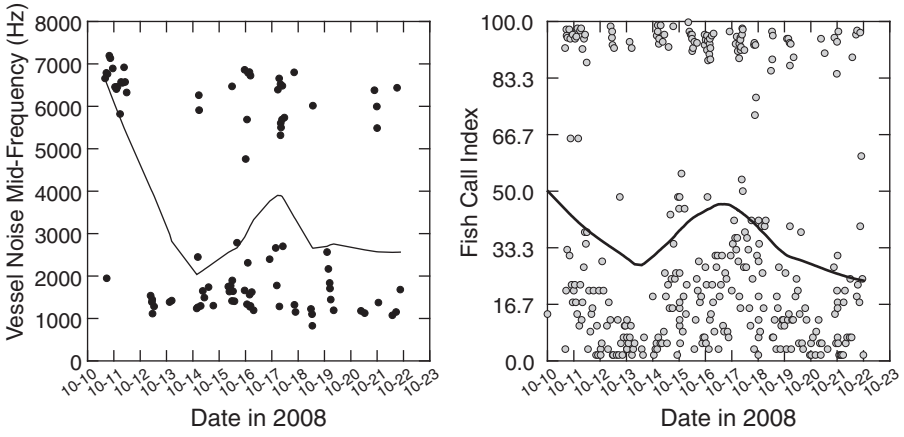

Fig. 2 Vessel and fish sounds detected by the passive acoustic recorder during two weeks in October 2008 at the Potash Corporation of Saskatchewan (PCS) site in the Pamlico River Estuary in North Carolina. Left: Temporal change in midfrequencies (minimum + maximum frequencies/2) associated with each vessel noise detected (points). Solid line is locally weighted (LOWESS) fit to the data. Right: Calling index (number of calls/60 s, scaled as a percentage of the maximal number of calls) of *Micropogonias undulatus*

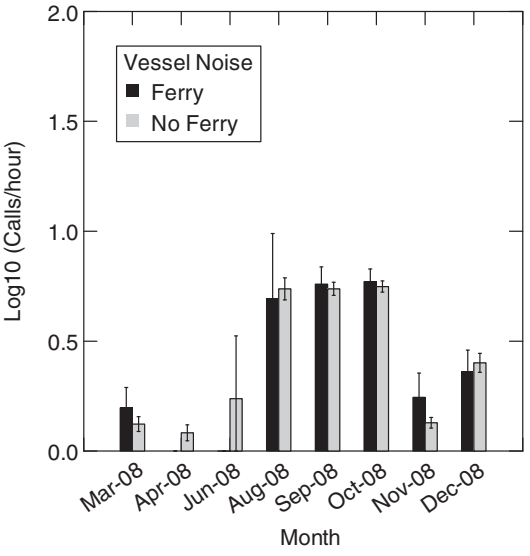

Fig. 3 Calling rate (number of calls/hour, $\log_{10}$ transformed) variation of *Micropogonias undulatus* at the PCS site near a ferry route in the Pamlico River Estuary in North Carolina by month with and without the presence of ferry noise

communication in this species at this location due to masking of the calls as well as a change in calling rate. Some vessel sounds (the phosphate tugboat and barge) overlapped the frequency of fish calls; when this occurred, calling rate declined. These low-frequency sounds would also prevent another fish nearby from hearing the sounds. The impact of noise on the ability of these fishes to attract a mate and successfully spawn needs to be investigated.

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