Using Passive Acoustics to Monitor Spawning of Fishes in the Drum Family (Sciaenidae)

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Introduction

Drum fish (Family Sciaenidae) are known for their sound production during mating, from which the family derives its name (Fish and Mowbray 1970). Members of the drum family are dominant species in the large and valuable commercial and recreational fisheries in North Carolina and the Southeastern USA. Recently, concerns have been raised about the decline in the population and spawning stock of some sciaenids, especially the red drum, *Sciaenops ocellatus* (Ross et al. 1995). One management option that has been suggested is to create spawning reserves, but spawning areas must be surveyed first in order to protect them. Sciaenid fishes held in captivity produce species-specific sounds associated with spawning behavior (Guest & Laswell 1978; Connaughton and Taylor 1996, Sprague et al. 2000) and recently spawned eggs and sounds co-occur in field samples (Mok and Gilmore 1983, Luczkovich et al. 1999). Spectral analysis of these sounds allows us to identify each sciaenid species based on their sound production, even when they co-occur in the same area (see Sprague et al 2000, Sprague and Luczkovich 2002). Because sounds are produced by male fishes in the Sciaenidae in communication during courtship and spawning, we are able to use these sounds as an indicator of spawning areas. Here we report on how we used passive acoustic survey techniques for mapping spawning areas of red drum, weakfish (*Cynoscion regalis*), spotted seatrout (*C. nebulosus*) and silver perch (*Bairdiella chrysoura*) in Pamlico Sound, NC.

Methods

Sounds of sciaenid fishes were recorded in two ways: 1) a hydrophone and recording system deployed from a small boat that was able to move from station to station; and 2) a hydrophone array system on a remotely operated vehicle (ROV) with low-light video capabilities. From May through September during 1997 and 1998, we used an InterOcean (902) Calibrated Acoustic Listening System [consisting of a gain-adjustable pre-amp, a hydrophone, and an overall sound pressure level meter] and a Sony (TCD-D8) Digital Audio Tape recorder to record from a small boat at fixed stations in Pamlico Sound for up to 5 min per station after sunset on monthly intervals. The hydrophone was suspended over the side of the boat at a depth of 1 m. In order to confirm that the sites where we recorded sounds were spawning areas, we conducted ichthyoplankton surveys at the hydrophone stations immediately after each sound recording ended. A 28-cm diameter bongo net with 500 μm mesh was towed at the surface for 5 min to capture the buoyant eggs. In May of 2001, we used a Phantom S2 ROV with low-light video and a calibrated

International Transducer Corporation (ITC-4066) hydrophone array to record the sound production of a silver perch in situ. The hydrophone array was mounted on the ROV on a 1.5 m long boom. The pre-amplified signal from the hydrophone array was sent up the 900-foot ROV umbilical cord to an audio and video recorder on board the boat. Although we used a four-hydrophone array, which was originally intended to help localize fish sounds, only one hydrophone (hydrophone number 4 located on the far right side of the boom as viewed from the point of view of the video camera) was selected for recording in this study. All sound recordings were resampled at 24 kHz from the original tapes using a National Instruments A/D board. We used 1024-point Fast-Fourier-Transforms (FFTs) to obtain spectrograms and estimates of overall sound pressure levels. To generate the spectrograms, we used Virtual Instruments written for use with LabView data acquisition software and Mathematica for creating plots. Statistical analysis was done using Systat 10 (Sprague et al. 2000).

Results

We detected the spawning aggregations of silver perch, weakfish, spotted seatrout, and red drum in Pamlico Sound during both 1997 and 1998. Male silver perch were detected on both the eastern and western side of Pamlico Sound, but were loudest at the inlet stations during May and June of both years (Figure 1a). The male weakfish were detected making their characteristic “purring” sounds only at stations on the eastern side of Pamlico Sound, near Ocracoke and Hatteras Inlets in May through August of both years, but the peak calling was in May and June (Figure 1b). Spotted seatrout were found producing their grunts at stations on both sides of the sound from June through September, but were more regularly recorded near the Bay River on the western side of Pamlico Sound in July of both years (Figure 1c). Red drum were heard both at the inlets and on the western side of the sound in August through September both years, but they were loudest in September near the mouth of the Bay River in the western side of the sound (Figure 1d). The overall picture is one of a seasonally shifting use of specific areas near river mouths and inlets by the four species, with distinct peak spawning times for each species. To demonstrate that these sounds are associated with spawning activity, we collected sciaenid type eggs in the areas where we had recorded fish sounds. The overall sound pressure level (in dB re 1 μPa) at each station was directly correlated with the $\log_{10}$ transformed sciaenid type egg density (Figure 2, $r = 0.61$). This suggests that the sounds (produced by male fish) and the recently spawned sciaenid eggs (produced by female fish) are associated in space and time, an indication that the sounds are associated with spawning.

The low-light capabilities of the video camera of the Phantom S2 ROV allowed us to see fish as they made their sounds. Thus, we were able to measure of the sound production by silver perch when they were a known distance from the hydrophone. In this way, we were able to determine the sound source level for an individual fish in situ, which is a necessary first step for modeling sound production and propagation. In May 2001, we had the opportunity to capture a single silver perch on video while it passed in front of the ROV and the hydrophone, producing some of the loudest sounds that we had recorded during our surveys. The ROV was deployed in Wallace Channel, near

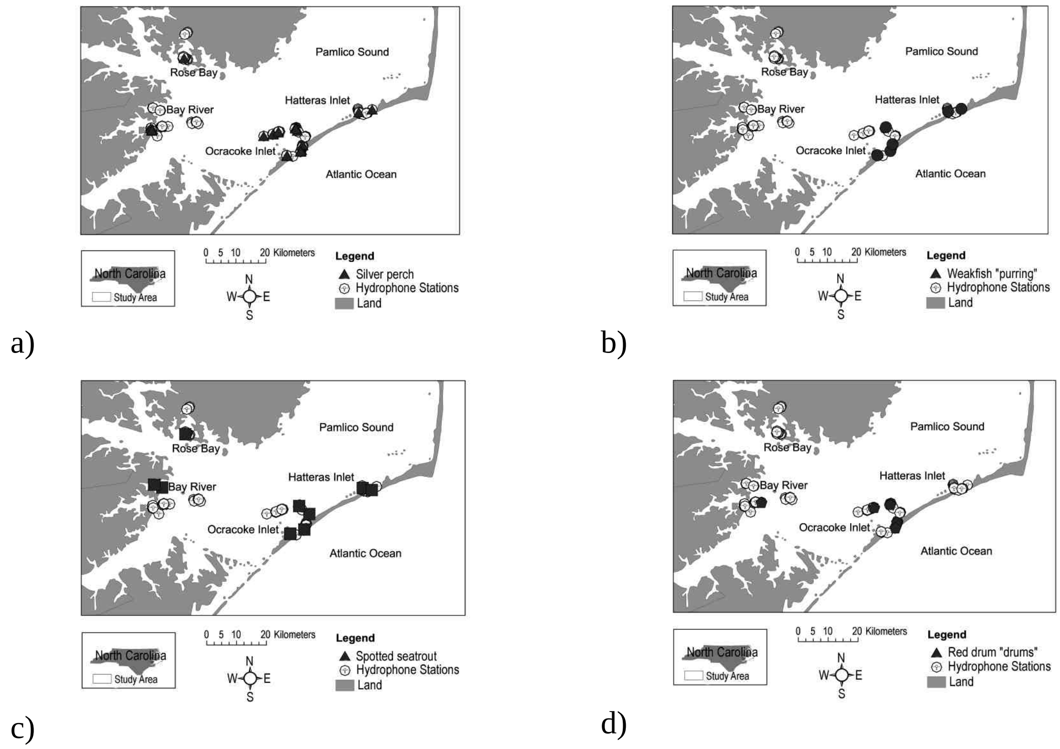

Figure 1 Maps of Pamlico Sound sciaenid species' spawning areas and times as determined by hydrophone surveys: a) silver perch (triangles), peaking in May and June; b) weakfish (circles) peaking in May and June; c) spotted seatrout (squares) peaking in July; and red drum (pentagons) peaking in September.

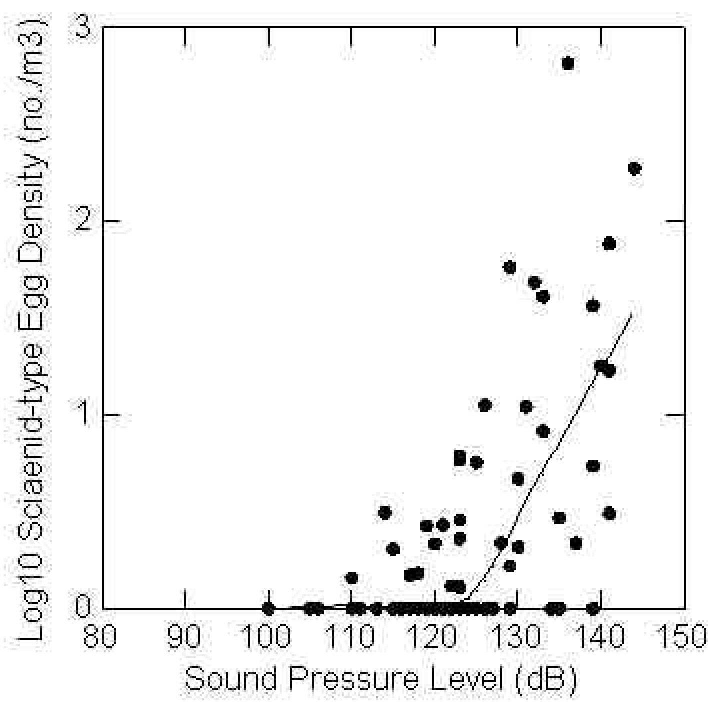

Figure 2 Log 10 transformed sciaenid-type egg production plotted versus sound pressure level (db re 1 μPa). Line fitted with a locally weighted regression (LOWESS).

Ocracoke Inlet, at a depth of 28 feet, in an area where we had previously recorded loud vocalizations of both silver perch and weakfish. Poor water clarity and strong currents at this site limited the camera's ability to see and the mobility of the ROV, which was deployed with a down-weight rig to hold near to the bottom during the tidal current shifts. On May 5, 2001 at 21:18:05, we recorded a calling male silver perch and measured the sound pressure level at hydrophone #4 when the fish was swimming through (from left to right) the viewing field of the low-light video (Figure 3). At this point, the sound pressure level was 126 dB re 1 μPa. At 21:18:15, after the fish swam across the video field of view, and closer to hydrophone # 4, which was on the boom to the right, the sound pressure level was measured at 129 dB re 1 μPa. Thus, the overall sound pressure level increased as the fish (sound source) got closer to the hydrophone.

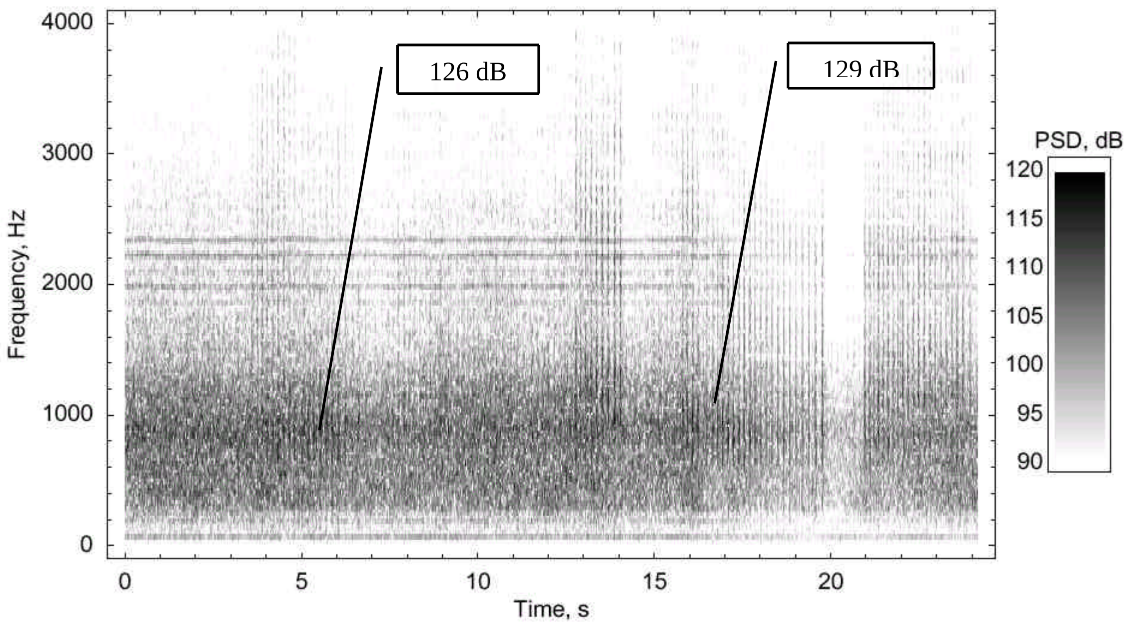

Figure 3. Spectrogram of 24-s segment of the ROV audio track from hydrophone #4, recorded 5 May 2001, beginning at 21:18:00. The sound source levels (in sound pressure in dB re 1 μPa) are shown for two times at which the silver perch first appears in the ROV video camera field of view (at 5-6 s) and just after it passed out of view of the camera, when it was the loudest (at 16-17 s)

Discussion

The passive acoustic approach we have described is limited to soniferous fishes, but almost all sciaenids fall into this category. Soniferous sciaenid fishes produced sounds during spawning in Pamlico Sound, and these general areas have been mapped. Weakfish and silver perch call commonly near Hatteras and Ocracoke inlets, peaking in May and June, whereas spotted seatrout were commonly detected calling throughout the summer in both eastern and western Pamlico Sound, peaking in July. Red drum were less commonly detected by passive acoustics than the other species of sciaenids, perhaps due to their declining spawning stocks; they were only detected at the inlets and in western Pamlico Sound in August and September, with the greatest sound production at the mouth of the Bay River in September. Sciaenid-type egg abundance was correlated to overall sound pressure level (loudness) of sciaenid drumming in field surveys, suggesting that egg production could be estimated from sound production. This passive acoustic approach to estimating spawning stock relative abundance would be useful to fishery biologists attempting to verify the variations in spawning stock sizes from year to year. No estimates of absolute fish abundance can be made at the present time; but biomass estimation may be possible in the future if active acoustics were also used.

From the ROV hydrophone measurement of sound source levels, we can now estimate the distance over which fish sounds can be detected. For an individual silver perch calling 1 m from the hydrophone at 129 dB re 1 μPa, (assuming a cylindrical spreading model, where r_{max} is the radius of the cylinder, see Luczkovich et al. 1999), we can now estimate $r_{max} = 10^{(\text{SPL source} - \text{SPL background})/10} = 79$ m. However, this cylindrical spreading model assumes that sound waves will propagate through water with constant temperature and salinity and a uniform depth, conditions that are unlikely to occur at the inlets. Consequently, we may be over-estimating the distance which we can detect sounds. It is also possible that sound may be channeled further than this due to particular bathymetric and water stratification conditions peculiar to Pamlico Sound and the inlets.

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