Preliminary Results on Seasonal and Diel Periodicities of a Resident *Cynoscion nebulosus* Spawning Aggregation in Tampa Bay, Florida

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ABSTRACT

Diel and seasonal periodicities of a resident Tampa Bay spotted seatrout (*Cynoscion nebulosus)* spawning aggregation were determined using passive acoustics during the 2004 spawning season. This was possible because spotted seatrout males make courtship sounds or calls associated with spawning. Data were collected by two long-term acoustic recording systems (LARS) between February and early October 2004. The LARS recorded ten continuous seconds of sound every ten minutes. Sounds were categorized based on the estimated number of fish calling: 0, 1-2 males, 3-5 males, small aggregation, and large aggregation. Sounds from large aggregations were first recorded in mid-March and were detected daily from mid-May to mid-September (except during July, when the LARS was not functioning). Spotted seatrout typically begin spawning in mid to late March or early April in Tampa Bay, but the LARS data indicated that large aggregation sound did not occur daily until the month of May. Daily large-aggregation sounds ceased in mid-September, which is when previous studies have reported that the spawning season ends. Duration of aggregation sounds during the prime spawning season varied daily and seasonally, with peaks in sound coinciding with new and full lunar phases. Longer durations of aggregation sounds were recorded daily during the second half of the prime spawning season (August-September) than during the first half (May - June).

KEY WORDS: Passive acoustics, spawning aggregations, spotted seatrout

Establecimiento del Desove Estacional y la Periodicidad Diaria de una Agregación Residente de *Cynoscion nebulosus* en la Bahia de Tampa, Florida Usando Técnicas de Acústica Pasiva

El desove diario y la periodicidad estacional de una agregación residente de spotted seatrout *Cynoscion nebulosus* en la Bahia de Tampa fue determinada para la estación de desove del año 2004. Un sistema acústico de grabación a largo plazo (LARS) fue desplegado en el paso de Bunces en noviembre de 2003 y permaneció en el área por un año, grabando diez segundos continuos de sonido cada diez minutos. Los machos de spotted seatrout produjeron sonidos asociados con el cortejo reproductivo durante el desove, la presencia de sonidos de múltiple machos en el LARS indicó " un sonido al nivel de agregación" que indicaba una actividad de desove. El dispositivo de LARS registró los sonidos de cortejo de spotted seatrout comenzando a finales de abril y que continuo hasta finales de septiembre del 2004. El spotted seatrout comienza típicamente a desovar entre mediados y finales de Marzo en la Bahia de Tampa sin embargo los datos registrados por el LARS indicaron un retrazo en le comienzo de la estación de desove del 2004, mientras que el final de la temporada de desove coincidió con la información conocida previamente acerca del las fechas de la temporada de desove. Sonidos de cortejo al nivel de agregación fueron detectados cada tarde durante los cinco meses de la temporada de desove. Los sonidos de agregación comenzaron típicamente antes o durante la puesta del sol y continuaron por cuatro a nueve horas. No se detectó ningunos sonidos de cortejo durante el día. La duración diaria del sonido de la agregación varió por algunas semanas ambas al principio y fin de la estación de desove mientras que los meses de mayor desove la duración fue más constante.

PALABRAS CLAVES: Acústica pasiva, agregaciones de desove, spotted seatrout, Bahia de Tampa, estacionalidad y periodicidad diaria

INTRODUCTION

Spotted seatrout are multiple-batch spawners that form spawning aggregations during their protracted spring through summer spawning season (Brown-Peterson *et al*. 1988, Gilmore 2003). In Tampa Bay, the spotted seatrout spawning season extends from mid-March or early April through mid-September or October with peaks in May or June and August or September (Lowerre-Barbieri 2004, McMichael and Peters 1989). At dusk during the spotted seatrout spawning season (Holt *et al*. 1985), mature males produce courtship sounds by vibrating specialized sonic muscles against their swim bladders (Fish and Mowbray 1970, Tavolga 1969). When spotted seatrout aggregation sounds were recorded at the same time ichthyoplankton in the area were collected, a positive correlation was noted between aggregation sounds and gamete release (Mok and Gilmore 1983, Saucier and Baltz 1992, Saucier and Baltz 1993). However, further work is necessary to determine the level of sound that is consistently associated with spawning activity.

Passive acoustic monitoring of soniferous fish spawning aggregations is an effective and noninvasive methodology used to determine spawning patterns. Permanent as well as mobile hydrophones assist in locating and monitoring fish species that make sounds associated with reproduction. Mobile hydrophones have been used in passive acoustic studies in coastal North Carolina, South Carolina, Louisiana, and the Florida east coast to locate spotted seatrout spawning sites (Mok and Gilmore 1983, Saucier and Baltz 1992, Saucier and Baltz 1993, Luczkovich *et al*. 1999). Permanent recording devices may also be used to monitor soniferous aggregations continuously for prolonged periods of time, providing detailed information on how a particular spawning site is being used. The objectives of this study were to use permanent recording devices to establish the seasonal and diel periodicities of a known spotted seatrout spawning aggregation.

METHODS

Long-term acoustic recording systems (LARS) were deployed at Bunces Pass, Florida, a relatively deep channel (maximum depth 8.5 m) between barrier islands connecting Tampa Bay and the Gulf of Mexico. This location was chosen because it is a known spotted seatrout spawning site. Lowerre-Barbieri (2004) collected adult spotted seatrout at this site and found that they used this site almost exclusively to spawn as indicated by the very high percentage of females in spawning condition (100% in 2001, n = 55; and 96.5 % in 2002, n = 115). Two LARS were deployed at this location, one at the mouth of the pass (Figure 1, site 1) and the other 502 m to the southeast in the center of the pass (Figure 1, site 2). Preliminary sound-propagation testing at Bunces Pass indicated the LARS is capable of detecting individual spotted seatrout calls within an estimated range of 200 m, although further analyses are needed to verify this estimate. The site 1 LARS was deployed February 1, 2004, and remained until October 8, 2004, in order to cover all possible dates of the spotted seatrout spawning season. The site 2 LARS was deployed for only 42 days (March 11, 2004 - April 22, 2004) because its primary purpose was to collect data for another research project and that project only needed the site 2 LARS for a limited time period. As the two LARS sites were close to one another, aggregation sounds that occurred in Bunces Pass were recorded by both systems. Data were not collected during April 1 - May 5, June 29 - August 1, and August 14 - 15 by the LARS at site 1 because of equipment failure. Recording problems also prevented the site 2 LARS from collecting data from March 11-April 15. Acoustic data were sampled at a frequency of 3333 Hz at site 1 and of 4410 Hz at site 2 for 10 continuous seconds every 10 minutes and recorded to onboard Compact Flash memory. The LARS at both sites were contained in underwater housings and connected to external hydrophones (HTI-96 min sensitivity: -164 dBV re 1 µPa; High-Tech, Inc.). Each LARS was anchored 0.5 m off the bottom and floated vertically in the water column. Data were downloaded to a PC, and all sounds were analyzed both by ear and spectrographically in Cool-Edit.

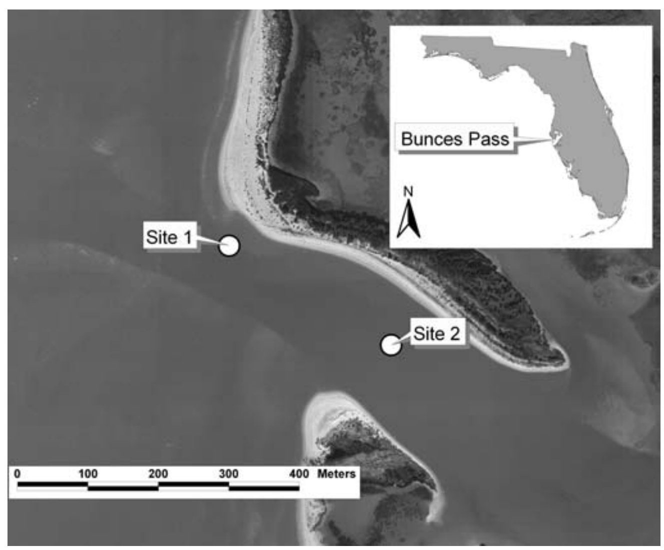

Figure 1. Bunces Pass, Florida, location of the two long-term acoustic recording systems (LARS).

Individual spotted seatrout calls have been classified as being one of four major sound types:

i) A dual-pulse call,
ii) A long grunt call,
iii) A multiple-pulse call, and
iv) A stacatto call (Mok and Gilmore 1983, Gilmore, 2003).

The calls of spotted seatrout can be distinguished from the calls of other soniferous fish based on pulse duration and intensity of sound by frequency range (Figure 2). In this study, calls of spotted seatrout were identified and the number of fish calling were estimated as being in one of four categories:

i) 1 - 2 individuals,
ii) 3 - 5 individuals,
iii) Small aggregation with individuals still distinguishable, or
iv) Large aggregation.

For the remainder of this paper, "aggregation sounds" refers to the sounds made by a large aggregation, the fourth category above. Sounds of large aggregations were used to determine spawning activity because it has the most individuals contributing to courtship activity, making it the most conservative classification for assessing spawning. Consistent daily aggregation sounds of three hours or more were used to define the prime spawning season.

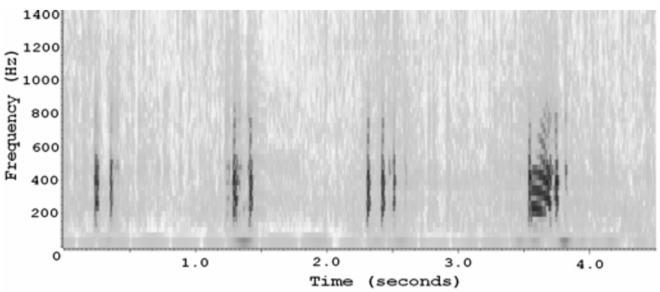

Figure 2. Spectrograph of an individual spotted seatrout call composed of three sets of multiple pulses followed by a long grunt. Darker shading corresponds to higher decibel levels.

RESULTS

Start of Season

Spotted seatrout courtship sounds were first detected in March. Aggregation sounds were first detected on March 19th (Figure 3). Aggregation sounds continued over the following two evenings but then were not heard for the remainder of March. On March 21st and 22nd, only sporadic individual calls and a few small-aggregation sounds were detected, and no spotted seatrout calls were heard from March 23rd until March 26th. On March 27th and until the end of the month, sporadic individual calls and a few small aggregations were recorded. Data were not available between April 1st and April 15th because of equipment failure. Although only individual calls were detected on April 16th, on the evenings of April 17th -19th, aggregation sounds were recorded. On May 6th, when the LARS was again recording, aggregation sounds were inconsistent with aggregation sounds being detected May 6th -10th, no detections from May 11th - 14th, and then detections again on May 15th. However, small-aggregation sounds were detected throughout this period (May 11th - 14th). After this date, aggregation sounds were detected daily on all dates that the LARS was functioning until the end of the spawning season (Figure 3). Continuous daily aggregation sounds with durations exceeding three hours were not detected until May 20th.

End of Season

The conclusion of the prime spawning season at Bunces Pass occurred four months after its start on May 20th. Every evening between August 16th and September 19th aggregation sounds were present, averaging 7.2 hours per evening (Figure 3). However, the duration of aggregation sounds began to decline by September 13th, and on September 20th, no aggregation sounds were detected. During the period from September 20th to September 26th, aggregation sounds were recorded only on the 24th. Aggregation sounds returned on September 27th and continued through October 5th, but sounds were of short duration. Aggregation sounds slowed to a few individual calls by October 6th and had completely ceased by October 8th (Figure 3). Based on this information, because the diel periodicity and duration of aggregation sounds became irregular after September 19th, mid-September was marked as the end of the 2004 prime spawning season.

Diel Periodicity and Duration

Daily start and stop times and duration of aggregation sounds were recorded between May 20th and September 19th. The aggregation was present continually between these two dates, although data are not available from June 28th - August 1st and August 14th - 15th. For the 86 days sampled, the duration of aggregation sounds per evening ranged from 3.0 to 12.3 hours (Figure 3) and averaged 5.9 hours. Daily durations were longer in August and September than in May and June. Between May 20th and September 19th, the earliest that aggregation sounds were detected was at 16:00 EST, four hours before sunset on August 16th. On most evenings (72%), aggregation sounds began from three hours before sunset up to sunset. During the remaining quarter of days, aggregation sounds began after sunset, with the latest start time (21:04 EST) being 1.5 hours after sunset (19:28 EST) on June 13th.

Although daily duration of aggregation sounds was highly variable, peaks in duration coincided with both full and new moon lunar phases (Figure 3). Examining the 86 days of data collected from May 20th to September 19th, there was about a one- to two-hour increase in the duration of aggregation sounds within 1 - 3 days following both the full and new moon phases except on one cycle in mid-September. The new moon on September 14th coincided with a reduction in the duration of aggregation sounds from 7.3 hours on September 12th, to 4.3 hours on September 13th, to 3.3 hours on September 14th (Figure 3). Because this downward trend in duration occurred just prior to the conclusion of the spawning season, it is difficult to attribute the duration reduction exclusively to lunar influence.

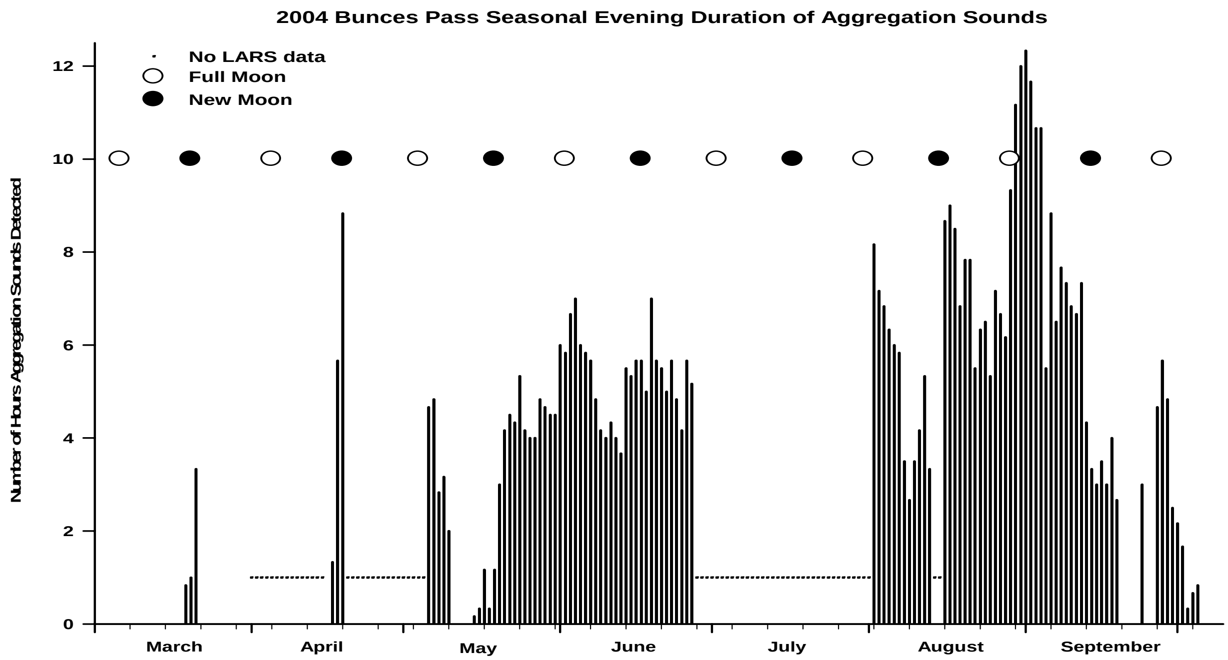

Figure 3. Daily duration of large spotted seatrout aggregation calls and lunar phase from March 1-October 8, 2004 at Bunces Pass. Horizontal dotted lines indicate periods during which data were not collected because of equipment failures.

DISCUSSION

Consistent spawning, as indicated by daily aggregation sounds, occurred from mid-May through mid-September. Although aggregation sounds were detected as early as mid-March, continual, nightly aggregation sounds exceeding three hours in duration did not occur until mid-May. Previous Tampa Bay studies reported a mid to late March (Lowerre-Barbieri 2004) or April (McMichael and Peters 1989) spawning start, whereas the aggregation sounds at Bunces Pass did not occur consistently until later in the spring. Because the initiation of spotted seatrout spawning has been reported to be temperature-dependent (Brown-Peterson 2003), and spring of 2004 was cool, this does appear to signal delayed spawning activity. However, due to data gaps and the lack of higher resolution information on spotted seatrout sound production and reproductive output, it is not possible to determine the exact date on which spawning activity (at any level) began. Conversely, conclusion of the prime season in mid-September was relatively straightforward and agreed with prior reports of the season's end in mid-September (Lowerre-Barbieri 2004) or October (McMichael and Peters 1989).

Duration of aggregation sounds varied both nightly and seasonally. Seasonally, the duration of aggregation sounds during the 39 days before the July break in data (May 20th -June 27th) was shorter than the duration of sounds during the 47 days sampled in the second half of the season (August 2nd -September 19th). Similar patterns of increased reproductive output later in the spawning season were observed in an adult capture study in 2002 at Bunces Pass. Collections of adult spotted seatrout yielded the highest number of females actively spawning in August and the lowest number in June (Lowerre-Barbieri 2004). Single and bimodal spawning peaks have been reported throughout the range of spotted seatrout, indicating that certain portions of the season are associated with increased reproductive output (Brown-Peterson 2003, McMichael and Peters 1989).

Diel periodicity of spotted seatrout spawning activity, based on sounds detected, was highly variable. Previous studies have reported a fairly short and consistent window of activity centered around dusk (Brown-Peterson *et al.* 1988 Mok and Gilmore 1983, Holt *et al.* 1985, Saucier and Baltz 1993). It has been hypothesized that the lower light of dusk helps synchronize spawning-ready fish as well as makes eggs less visible, thus decreasing egg predation (Holt *et al*. 1985, Gilmore 2003). However, no work has been done to determine what cues fish to spawn at this time. Also, the variability in the time that aggregation sounds began from as early as four hours prior to sunset (16:00 EST) to 1.5 hours after sunset (21:04 EST) suggests that spawning activity is not cued solely by light level.

A number of factors may affect both the time that aggregation sounds start and their duration. Spawning activity of spotted seatrout and other aggregate spawners has been reported to be correlated with lunar phase (Kupschus 2004, Gilmore 2003, McMichael and Peters 1989, Sadovy *et. al* 1994). Peaks in Bunces Pass aggregation sounds corresponded with new and full lunar phases. Increased spotted seatrout spawning activity during the full moon phase is the most frequently reported lunar association, corresponding with increases in both larval abundance (McMichael and Peters 1989) and aggregation sounds (Gilmore 2003). In a pass that is a spawning site for spotted seatrout, advantageous egg and larval transport would be expected to be associated with both current direction and speed and might influence the reproductive output on any given night. Because both of these parameters are influenced by lunar activity, this association requires further analysis. Another factor potentially contributing to the diel fluctuation in aggregation sounds is movement of the aggregation around the LARS sites. Data from multiple LARS will be necessary to evaluate how potential shifting of the aggregation's center might affect the recorded level of courtship sounds.

Passive acoustics is emerging as a powerful research tool to conduct detailed research on spawning aggregations of soniferous fishes. Although further research is necessary to better understand the relationship between aggregation sounds and reproductive output, passive acoustics gives us the ability to monitor spawning activity over a relatively long time and with greater resolution than has been possible with more traditional methods. This has important implications in terms of determining essential spawning habitat and evaluating the diel and seasonal periodicities of spawning activity at any given spawning site.

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