What’s All that Racket! Estuarine Soundscapes in South Carolina

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- Acoustic communication & soundscape ecology
- Environmental monitoring of estuaries
- Diversity and abundance of invertebrates & fish
- Bottlenose dolphin population monitoring

https://www.facebook.com/MarineNeuroLabAtUSCB/
USCB Marine Sensory and Neurobiology Lab

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1. The Soundscape of the May River Estuary

2. Soundscape Phenology and Biodiversity

3. Fish Courtship Sounds Correlate with Juvenile Fish Appearance

4. Estuarine Soundscape Observatory Network of the Southeast (ESONS)
Why Is Long-term Monitoring So Important?

**Shifting Baseline Syndrome**

“Each person evaluates the condition of the environment based on its state when they first experienced it, so changes to the environment are evaluated from this initial baseline. Thus, each generation accepts the environment in its degraded form as if it were normal, overlooking the changes the environment has undergone before their lifetime”. Ian McHarg & Daniel Pauly

University of Victoria, “Stories of Our Era”
Soundscape Ecology? A Useful Tool in Monitoring Marine Ecosystems

Many Aquatic Organisms Produce Sound. They can eavesdrop on animal behavior at multiple levels of biological complexity. Useful in estuaries where visibility is limited. Technology allows high temporal resolution.

- Natural Rhythms?
- Natural Disturbances?
- Noise Pollution?
- Nutrients?
- Chemical Pollution?
- Invasive Species?
- Habitat Alteration?
- Ocean Acidification?
- Warming Climate?
- Whaling?
- Overfishing?
Monitoring the Soundscape of the May River Estuary

2012 → short-term acoustic recordings at 27 stations.

2013 & 2014 → DSG-Oceans at 6 stations (2 minutes every 20 minutes); HOBO temperature & depth loggers; March to December.

2015 to present → DSG-Oceans at 3 stations; year round; 2 minutes every 1 hour.
Snapping Shrimp Snaps

- Big claw → air bubble → collapse → snap
- Snaps are vertical and broadband
- Territory, communication, and foraging?

Frequency (kHz)

10

5

1

Time (s)

30

Frequency bandwidth (1 kHz to 200 kHz)

Alpheus and Synalpheus sp.
Temporal Rhythms of Snapping Shrimp Acoustic Behavior

Station 9M: Snap rate (# snaps / 2 min)
Spring - Silver Perch Evening Chorus

- Male sonic muscle beats → swim bladder → calling
- Low frequency pulses: 300 to 2000 Hz
- Courtship and spawning behavior
Summer – Spotted Seatrout Nightly Chorus Dominates the May River

- ‘Grunts’, ‘drums’, & ‘staccatos’ ~ peak 100 to 700 Hz
- Courtship and spawning behavior

Cynoscion nebulosus
Fall – Late Afternoon Chorus of Red Drum at the Mouth of the May River

- Low frequency pulses: 100 to 600 Hz
- Courtship and spawning behavior

**Sciaenops ocellatus**

Long-term acoustic monitoring of fish calling provides baseline estimates of reproductive timelines in the May River estuary, southeastern USA

Agnieszka Monczak¹, Andrea Berry², Chris Kehrer³, Eric W. Montie¹•**
Patterns of Fish Courtship Sounds

Station 37M (mouth of May River)

- Calling intensity score: 0=no calls; 1=one call; 2=multiple calls; 3=chorus.
- Sum calling intensity score per evening.
- Spawning timelines = exact start & end dates for calling and chorusing.
- Reproductive / spawning potential = number of hours chorusing per year.
Bottlenose Dolphin Sounds - Mouth of the May River

Sound patterns of snapping shrimp, fish, and dolphins in an estuarine soundscape of the southeastern USA

Agnieszka Monczak1,2,*, Claire Mueller1, Michaela E. Miller2, Yiming Ji3, Stephen A. Borgiani3, Eric W. Montie1,4,***
Seasonal Increases of Dolphin Vocalizations
Detected at the Mouth of the May River

Water temperature (red line) and hours of daylight (brown dotted line).
Marian et al. 2020 resubmitted to *Marine Mammal Science*
We integrate traditional visual surveys with our passive acoustics monitoring.
By listening, we can understand key behaviors in organisms that occupy different trophic levels at a high temporal resolution.

**“Healthy Estuary”**

**“Healthy Soundscape”**

<table>
<thead>
<tr>
<th>Signal</th>
<th>Key Behavior</th>
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<tbody>
<tr>
<td>Echolocation</td>
<td>Foraging</td>
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<tr>
<td>Whistles</td>
<td>Communication</td>
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<tr>
<td>Burst pulses</td>
<td>Mating</td>
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<tr>
<td>Calls &amp; choruses</td>
<td>Spawning</td>
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<tr>
<td></td>
<td>Silver perch</td>
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<tr>
<td></td>
<td>Black drum</td>
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<td></td>
<td>Oyster toadfish</td>
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<td></td>
<td>Spotted seatrout</td>
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<tr>
<td></td>
<td>Red drum</td>
</tr>
<tr>
<td>Snaps</td>
<td>Foraging</td>
</tr>
<tr>
<td></td>
<td>snipping shrimp</td>
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</tbody>
</table>
Noise Pollution

Boat noise in an estuarine soundscape – A potential risk on the acoustic communication and reproduction of soniferous fish in the May River, South Carolina

Somers Smott\textsuperscript{a, b}, Agnieszka Monczak\textsuperscript{b}, Michaela E. Miller\textsuperscript{b}, Eric W. Montie\textsuperscript{b, c, l}

![Graph showing noise levels over time and frequency]
1. The Soundscape of the May River Estuary

2. Soundscape Phenology and Biodiversity

3. Fish Courtship Sounds Correlate with Juvenile Fish Appearance

4. Estuarine Soundscape Observatory Network of the Southeast (ESONS)
Specific Objectives

1. Determine temporal patterns of high, low, and broadband frequency sound pressure levels (SPLs) over a six year time span (2013 to 2018) in the May River estuary.
2. Determine how certain environmental factors influence SPLs.
4. Determine temporal patterns of species richness and abundance and examine how these indices correlate with the soundscape.
Seining Program Design

• Seining 2016 – 2020 (4 yrs)
• Seined 6 to 12 tidal pools, creeks, or shoreline habitats monthly on low tide
• Selected randomly from pool of 50 sites near listening stations from headwaters to mouth
• Monthly water temperature, salinity, dissolved oxygen, pH
• Species abundance / m² & lengths
440 Seines!
5/11/2016 – 1/8/2020

Bighead searobin

Southern flounder

Planehead filefish
Objective 1: Measuring Sound Levels - Bandwidths that Represent Snapping Shrimp and Fish Courtship Behavior

Frequency (kHz)

- Broadband: 0.1 to 40 kHz
- Low frequency: 50 to 1200 Hz
- High frequency: 7 to 40 kHz
Time Series of High Frequency SPLs from 2013 to 2018

- 7 to 40 kHz rms SPLs = snapping shrimp snaps
- SPLs increased & decreased with the seasonal temperature changes
- 2018 coldest winter, lowest SPL
- Phenology: green dots = 1st posterior probability change ≥ 0.5 detected during spring
Time Series of Low Frequency SPLs from 2013 to 2018

- 50 to 1200 Hz rms SPLs = fish courtship
- SPLs increased spring/summer evenings
- SPLs fluctuate with the seasonal temperature changes
- 2018 coldest winter, lowest SPL
- Phenology: green dots = 1st posterior probability change ≥ 0.5 detected during spring
Objective 3: Soundscape Phenology

- Phenology of acoustic activity of snapping shrimp (high frequency SPL) and fish (low frequency SPL) by detecting the date of the first abrupt change in SPL.
- In years with higher mean spring water temperatures, the first peak in (A) high, (B) low, and (C) broadband SPL occurred earlier as compared to years with lower mean spring water temperatures.
- Negative correlations occurred between mean spring water temperature and the timing of the first peak in probability of change for (D) high, (E) low, and (F) broadband SPLs.
Biodiversity - 7 Invertebrate Species

Grass shrimp (Palaemonetes vulgaris)

Big claw snapping shrimp (Alpheus heterochaelis)

Brown shrimp (Farfantepenaeus aztecus)

Mantis shrimp (Squilla mantis)

Blue crab (Callinectes sapidus)

Spider crab (Libinia emarginata)

Brief squid (Lolliguncula brevis)
58 Fish Species, 31 Families

Atlantic silverside (*Menidia menidia*)

Atlantic needlefish (*Strongylura marina*)

Atlantic spadefish (*Chaetodipterus faber*)

Pigfish (*Orthopristis chrysoptera*)

Bighead searobin (*Prionotus tribulus*)

Atlantic cutlass fish (*Trichiurus lepturus*)

Black cheek tonguefish (*Symphurus plagiusa*)

Great barracuda (*Sphyraena barracuda*)
Objective 4: Soundscapes, Biodiversity, and Abundance

- Lower species diversity and abundance during winter, and higher species diversity and abundance during spring and summer.

- This temporal pattern of species diversity and abundance followed the warming and cooling patterns of the estuary as well as the oscillating pattern of the biological soundscape.
Conclusions

- We showed that the transition between winter and spring is a dynamic time-period with an increase in biological sound during the spring, which mirrors the increase in (phytoplankton), (zooplankton), invertebrates, and fish abundance that drive changes in primary, secondary, and tertiary productivity within estuaries.

- In years with warmer spring temperatures, this seasonal transition occurred earlier than in years with cooler spring temperatures.

- This means that temperature plays an important factor in initiating certain behaviors (e.g. spawning), and earlier occurrences of these behaviors reflect an organismal response to climate variability.
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Specific Objectives

1. Examine the patterns of fish calling in the May River Estuary over a six-year time span from 2013 to 2018.

2. Determine how environmental factors influence fish acoustic activity.

3. Investigate the correlation between fish calling and young-of-the-year (YOY) appearance and abundance from 2016 to 2018.

4. Examine the phenology of fish calling and YOY appearance.
Year-to-year Patterns of Fish Calling at the Mouth of the May River Estuary

37M

Daylight hours

Sum of calling intensity

Temperature (°C)

Date (m/d/y)

Black drum Silver perch Spotted seatrout Red drum
Year-to-year Patterns of Fish Calling in the May River

**Black drum**

**Silver perch**

**Spotted seatrout**

**Red drum**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sum of calling intensity</th>
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<tbody>
<tr>
<td>9M</td>
<td></td>
</tr>
<tr>
<td>14M</td>
<td></td>
</tr>
<tr>
<td>37M</td>
<td></td>
</tr>
</tbody>
</table>

- **A:** Number of calling hours
- **B:** Sum of calling intensity over daylight hours
- **C:** Date and temperature of calling events

[Graph showing seasonal calling patterns of different fish species over the years 2013 to 2018]
From 2016 to 2019, we monitored the abundance of fish using haul seines.
Correlation between Fish Calling and Young-of-the-Year (YOY) Appearance

Silver perch

Spotted seatrout

Red drum
Correlation between Fish Calling and Young-of-the-Year Abundance

Silver perch

Spotted seatrout

Red drum
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Estuarine Soundscape Observatory Network in the Southeast (ESONS)

We monitor the sounds of four estuaries in South Carolina using long-term passive acoustic recorders.

- Snapping shrimp
- Silver perch
- Spotted seatrout
- Red drum
- Bottlenose dolphins
- American alligators
ESONS Overlaps in Space with Fishery Independent Surveys Performed by SCDNR

Four Estuaries
1. May River Estuary
2. Chechessee Creek / Colleton River in Port Royal Sound
3. Charleston Harbor
4. North Inlet-Winyah Bay NERRS

SCDNR Surveys
1. Estuarine Trawl Survey
2. Electrofishing
3. Trammel Net
4. Longline
Future Goals: Correlate Soundscape Endpoints with Biodiversity and Abundance from SCDNR Surveys
Climate Variability ~ Courtship Calls ~ Reproduction ~ Year Class Strength?

- **Silver perch** (spring spawner)
- **Spotted seatrout** (summer spawner)
- **Red drum** (fall spawner)

**Acoustic Data**
- Total number of hours chorusing / year

**Seining**
- YOY abundance / year

**SCDNR Electrofishing**
- Abundance / year

**SCDNR Trammel net**
- Abundance / year

**Reproductive Potential**
- Near-term reproductive success

**Medium-term year class strength**

**Long-term year class strength**
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