How Tidal Flow Influences Eastern Oyster Larval Dispersal and Spat Settlement in the Mullica River

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Introduction

- The Mullica River (MR) is one of the few estuaries in New Jersey with natural populations of the eastern oyster, *Crassostrea virginica*. Oyster market value and the interest in its added ecosystem and ecological benefits emphasizes the need to monitor early life history through larval sampling and spat collection.
- Bivalve larvae are passively transported with the current during the planktonic stage before settling and metamorphosing into spat. It is generally unknown what occurs when they are planktonic because bivalve larvae are difficult to sample. By collecting plankton along the MR, we can begin to assess larval flux within this transect and make predictions on where oyster larvae are concentrated.
- Since 2012, the Stockton University Marine Field Station has monitored oyster spat settlement during the spawning season along this same transect in the MR bimonthly using shell bags. We are now comparing spatfall to plankton abundance and utilizing polarized microscopy with automated imaging software to detect bivalve larvae and identify unique birefringence patterns.
- By comparing the spat settlement to larval abundance positioned along this transect, we can gain a better understanding of how these subpopulations within the MR are connected. Furthermore, we are applying velocity data to shed light on the tidal dynamics. Comparing larval flux from up-estuary stations to down-estuary stations will help identify potential source and sink areas based on the timing and abundance of larvae and spat. This translates to a holistic view on eastern oyster ecology that can predict larval transport and aid in projects that restore sites based on larval settlement success.

Field Methods

Study Site

- The MR feeds into the Great Bay, located below Barnegat Bay, and stretches across Ocean and Atlantic county (Fig. 1).

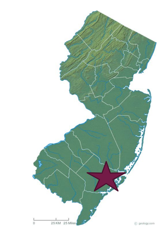
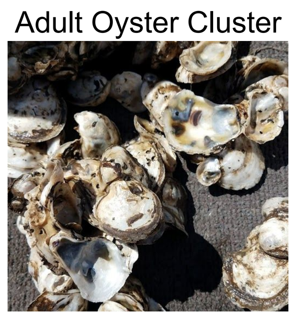


Figure 1. Spatfall and larval monitoring stations in the Mullica River. Swan Point (station 1) and Fitney Bit (station 4) were analyzed in this study. Arrows indicate along channel axis (theta) up-estuary.

Adult Oyster Cluster



Spat on Oyster Shell

Plankton Net

Adult Oyster Surveys

- Adult oysters were surveyed in April 2018 by dredging at both stations.
- Live individuals were measured and counted.

Spat Settlement

- Spatfall was observed using bags (370mm x 300mm / 25mm mesh size) suspended 0.5m off-bottom and containing 20 cleaned oyster shells deployed along 4 stations (Fig. 1).
- Bags were replaced every 2 weeks from late June-October.
- Settled oyster spat were counted after each recovery.

Larval Collection

- Oblique water column samples were collected at 4 stations every 2 weeks from July-August 2017 (Fig. 1).
- 100L samples were pumped from a submersible diaphragm pump into a plankton net of 53 micron mesh and preserved in buffered formalin.
- YSI data was collected for temperature (°C), salinity, dissolved oxygen (%), and turbidity.

Lab Methods[1]

Sample Collection

- Samples were filtered with a 333 micron screen and rinsed with bleach into a 15mL centrifuge tube to open valves and dissolve tissue.
- After 20 minutes, bleached samples were rinsed with DI water over a 53 micron screen.Samples were allowed to settle and supernatant pipetted off to 2mL.
- Remaining concentrated sample was resuspended in the 2mL for imaging.

Slide Preparation

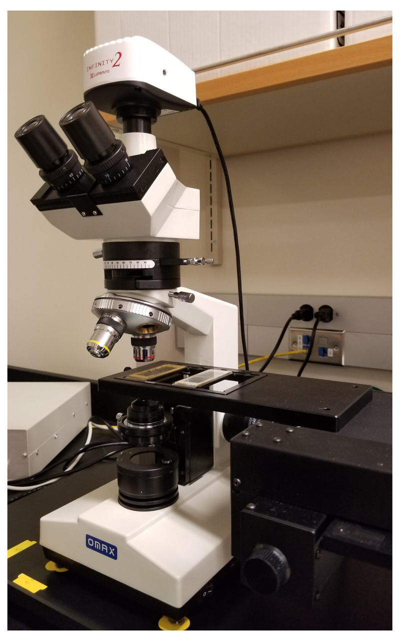
- Two separate 1mL aliquots of the sample were pipetted onto a Sedgewick-Rafter 1mL counting cell to be used on imaging scope.

Imaging a Slide

- Prepared slides were placed onto the automated stage and microscope was programmed to take images of the entire slide for a total of 644 images per slide.

Extracting Larval Images

- Larvae were removed manually using ROI (region-of-interest) extraction methods for each frame in MATLAB



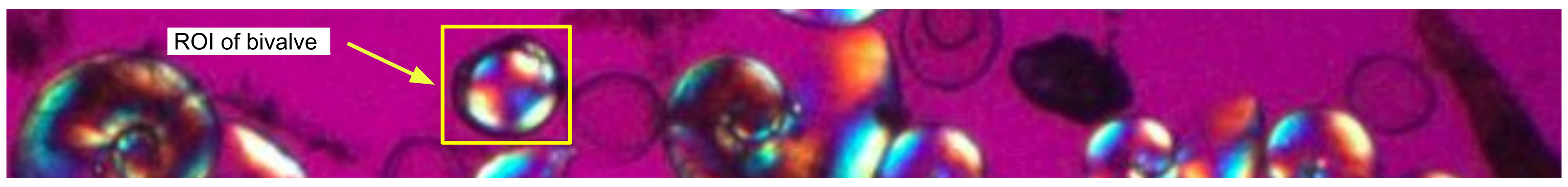


Figure 2. Steps for preparing larvae samples and taking images of bivalve larvae through the automated polarized light microscope.

Larval-Excursion Distance

- Tilt current meters and bottom pressure sensors were deployed at stations 1 and 4 in July-August 2017.
- Current velocities were rotated to along channel direction (α=250°T at Station 1; α=340°T at Station 4)

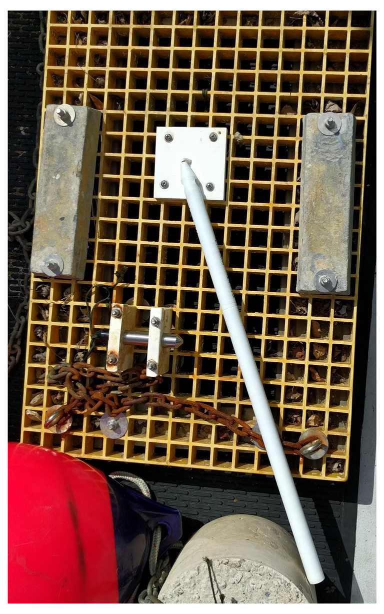
$$u_{along} = u_{east}\cos(\alpha) + u_{north}\sin(\alpha)$$

- Excursion distances were approximated in 1 minute time intervals (dt) from along channel velocity. Excursion distances were summed from the time of sampling to the prior slack tide.

$$Larval - Excursion = \sum_{t=t_{slack}}^{t_{sample}} u_{along}(t) * dt$$

- Larval-Excursion represents the approximate distance that sampled water traveled relative to the prior high or low tide. Positive excursion distances were up-estuary transport. Negative excursion distances were down-estuary transport.

Tilt Current Meter



Results

- **To quantify eastern oyster larval abundance, ROIs must be classified by species using birefringence patterns, however, high concentrations of eastern oyster were observed at Fitney Bit while undergoing ROI extraction methods. Noted is the general trend of more larvae up-estuary to down-estuary. Potential set at Fitney Bit was similar and proportional to the abundance of bivalve larvae (Fig. 3).**
- **Swan Point shows a steady-state in low larval abundance and an August increase in spat settlement, but no clear settlement pulse (Fig. 3).**

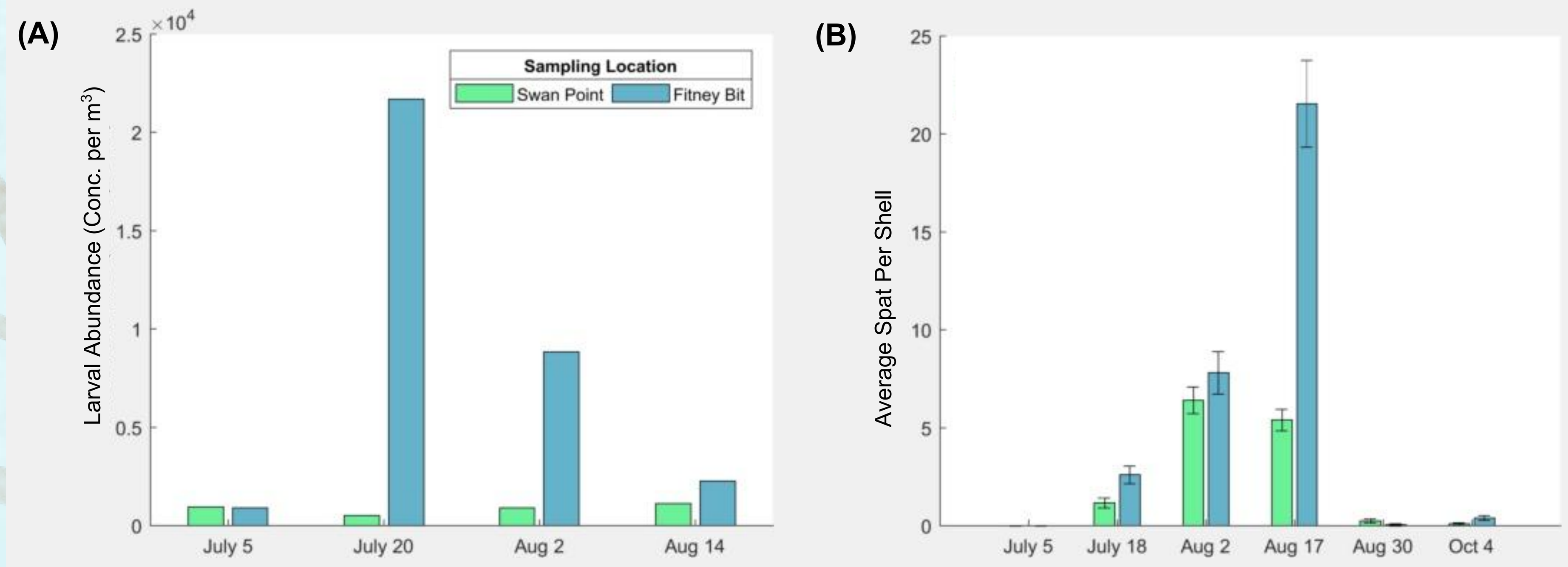


Figure 3. (A) Bivalve larval abundance, according to the amount of all ROIs extracted from imaged slides, at Swan Point (Station 1) and Fitney Bit (Station 4) and (B) the average amount of spat at both stations per bag of 20 shells during the 2017 summer sampling period from July to August 2017.

- **Swan Point tidal flux is asymmetrical, strongly flood dominated, and transport is mostly up-estuary (Fig. 4A). To determine whether Swan Point is a source population for larvae in the MR, the current variation from bank to bank must be better understood.**

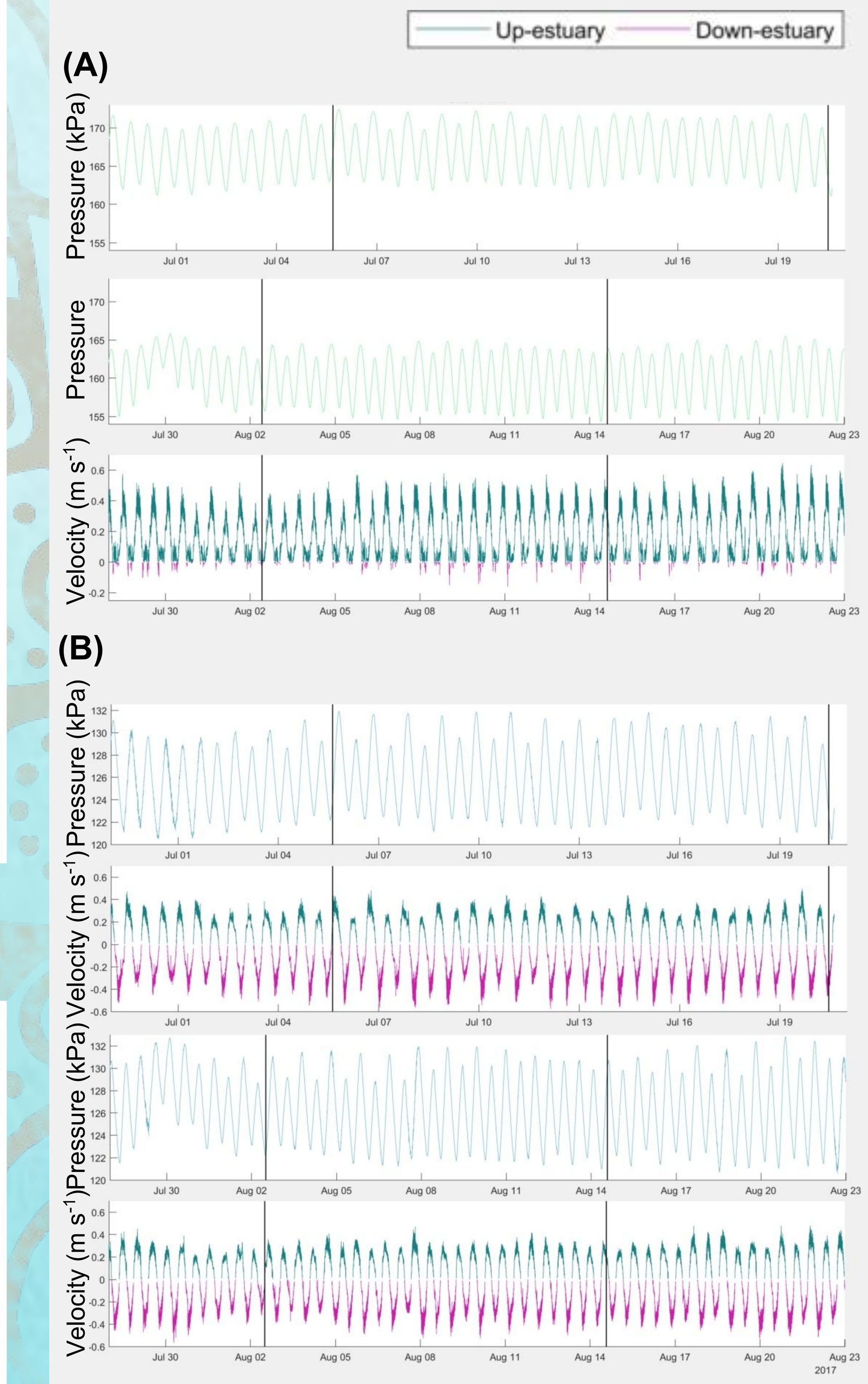


Figure 4. Pressure and along channel velocity from (A) Swan Point (Station 1) and (B) Fitney Bit (Station 4) was used to analyze slack tide before sampling time (vertical lines). These along channel velocities were used to calculate larval-excursion distances (Table 1).

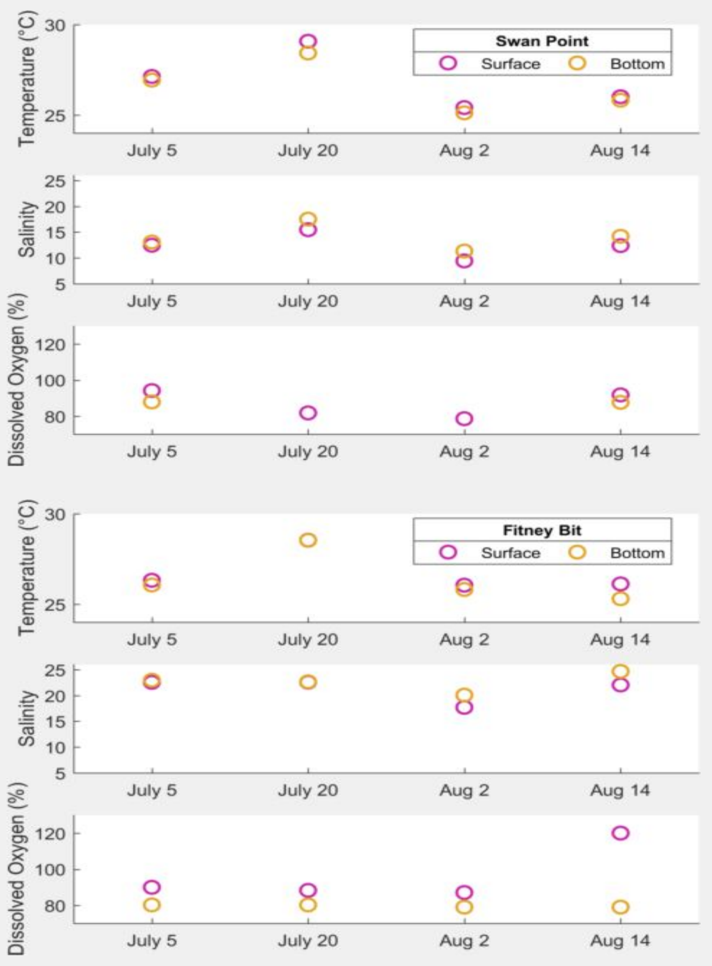


Figure 5. Temperature, salinity, and dissolved oxygen for each larval sampling event at Swan Point (Station 1) and Fitney Bit (Station 4) in 2017.

- **Highest concentrations of larvae at Fitney Bit occured on ebb tides traveling down-estuary (Table 1). We see this on July 20 and Aug 2, which also coincided to periods of higher spatfall. There are no paired flood tide larval concentrations available for this period.**

Table 1. Calculated Larval-Excursion Distances Labeled as the Direction of Transport of the Larvae/Water Parcel.

	July 5	July 20	August 2	August 14
Swan Point	Flood Tide: Distance N/A	Ebb Tide: Distance N/A	Ebb Tide: 89m Up-estuary	Flood Tide: 6030m Up-estuary
Fitney Bit	Flood Tide: 353m Up-estuary	Ebb Tide: 3002m Down-estuary	Ebb Tide: 3246m Down-estuary	Flood Tide: 3598m Up-Estuary

Discussion

Future work will add larval concentrations from the remaining two stations (Fig. 1): Chestnut Neck (Station 2) and Blood DItch (Station 3).

- Instantaneous larval collections at a station does not provide evidence that larvae would have settled in the same location.
- At Swan Point, the ebb tide on Aug 2 was traveling up-estuary and relatively localized when flood tide was approaching. This may suggest that Swan Point experiences eddy activity that interferes with larval dispersal.
- There is a grow-out lease located at Graveling Point (Fig. 1). Velocity data did not indicate that Graveling Point is a source. Assuming that larvae can cross the bank over a series of tide cycles and come in contact with the along channel tidal flux, a source of that larvae subpopulation can be within the transect when plankton samples are collected.
- With this new larval sampling method and a better map of the spatial distribution of adult (spawning) beds coupled with a further understanding of tidal dynamics, Stockton University hopes to be able to identify sources and sinks of eastern oyster larval subpopulations in the MR.

ACKNOWLEDGEMENTS:
Special thanks to the Stockton Marine Field Station staff Steve Evert, Dave Ambrose, Elizabeth Zimmerman, and Nate Robinson for field assistance and spat collections. Acknowledgements to Jaclynn Polcino for assisting with the velocity plots; and to Alexandra Blanchet and Katherine Mitchell for assisting in the processing of larval samples. Jake Goodwin and Ian Mitchell helped with microscope programming. Funding for this study was provided by a Stockton University Research and Professional Development Award to Christine M. Thompson and by the Stacy Moore Hagan Undergraduate Estuarine Science Scholarship to Jessica A. Baez.

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