



Climate-induced seasonal shift in copepod density in a shallow water estuary

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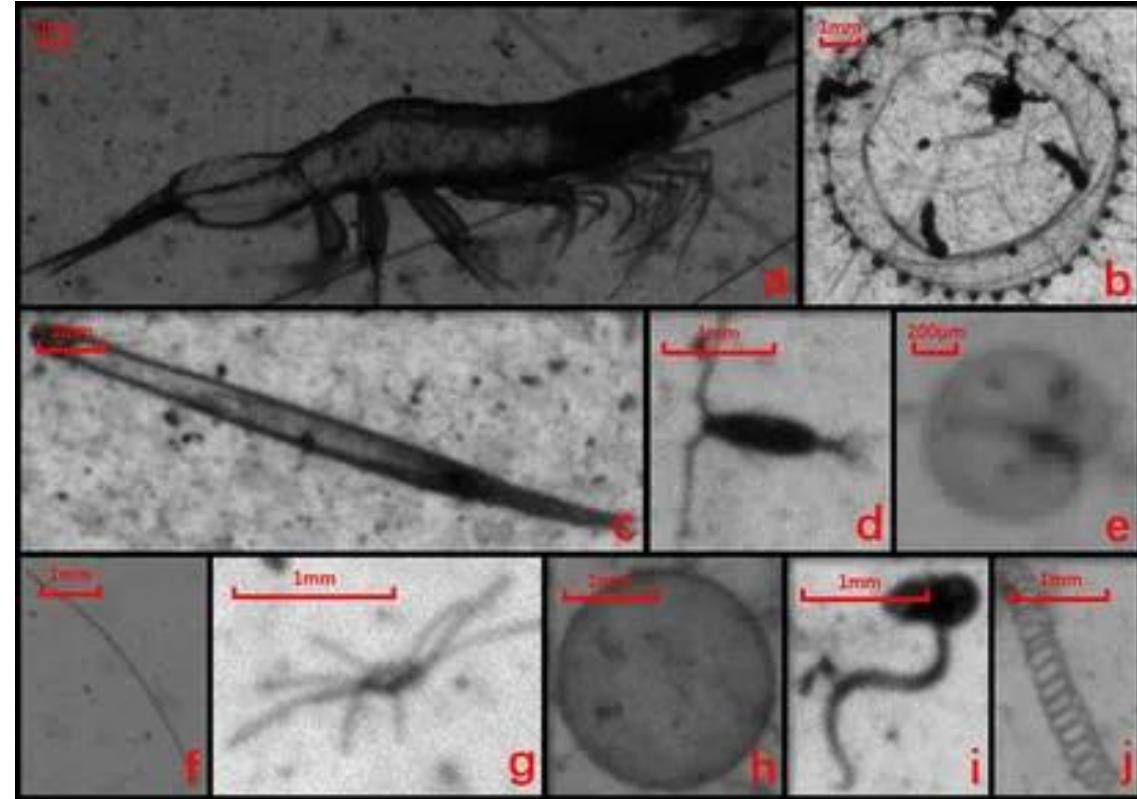
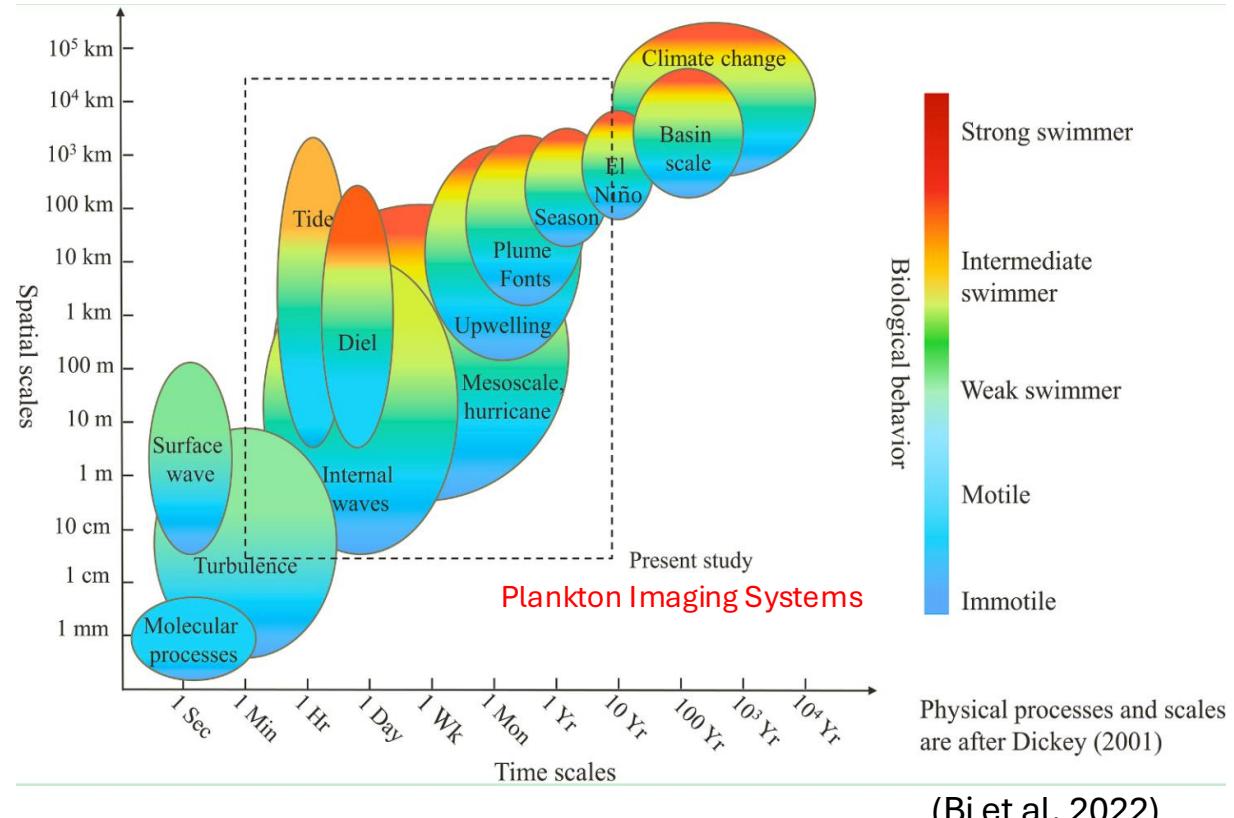


Introduction

- Estuaries are **important habitats** for numerous diadromous species, yet **susceptible to climate change**.
 - Patuxent River Estuary is a representative shallow water estuary (~ 2.5 m).
- Copepods are key links in aquatic food webs, serving as **an abundant food source** for fish larvae and directly influencing fish recruitment.
- **Freshwater discharge** has been identified as a primary determinant of copepod phenology (Kimmel and Roman 2004).
 - The quantification of discharge effects remains challenging, particularly for brief, episodic events.



Introduction



More **high-frequency data** is required to elucidate copepod dynamics under the accelerating climate change and anthropogenic stressors

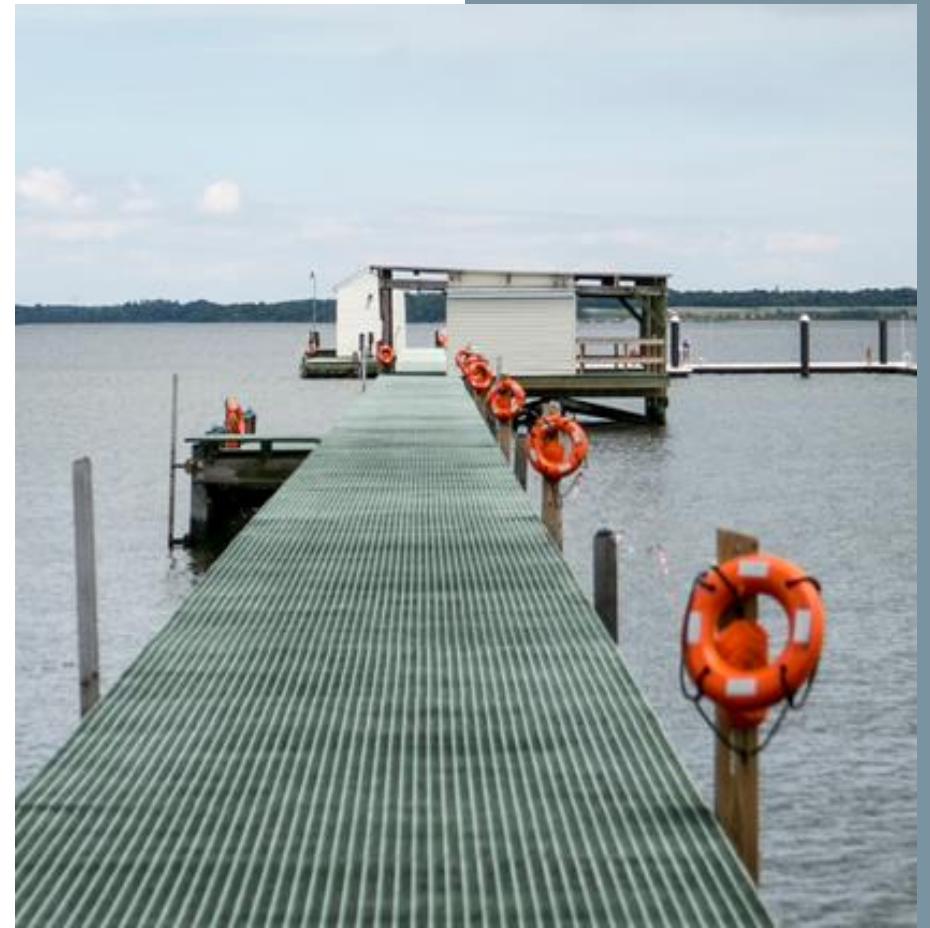
Shadow images of zooplankton

(Zhang et al. 2023)

Objectives

Using high-frequency image data to:

- (1) investigate seasonal patterns of **copepod densities and body sizes**
- (2) explore the effects of **freshwater discharge** in shaping copepod phenology
- (3) compare copepod seasonal patterns in recent years with **historical records** from three decades ago



Methods

➤ Study area

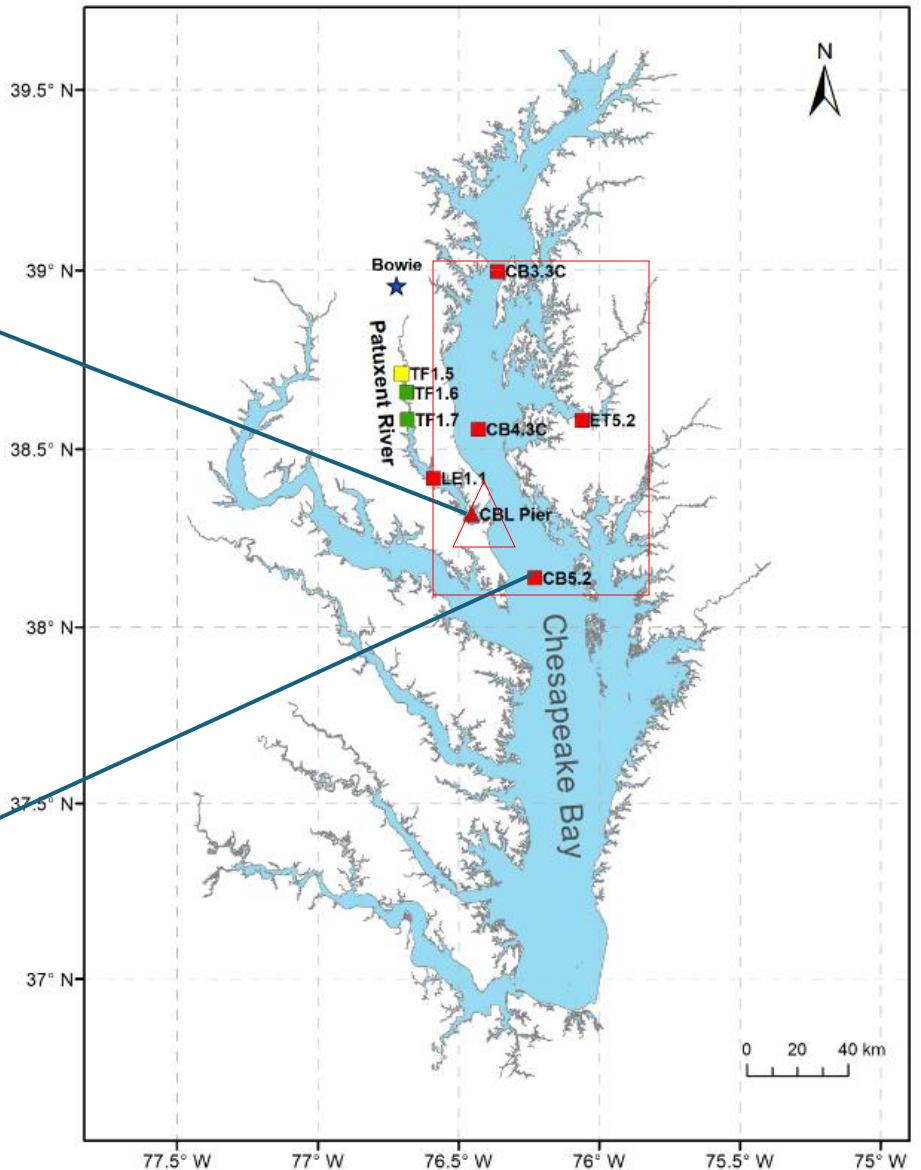
Patuxent River mouth:

- Chesapeake Biological Lab pier (triangle)



Upper Chesapeake Bay:

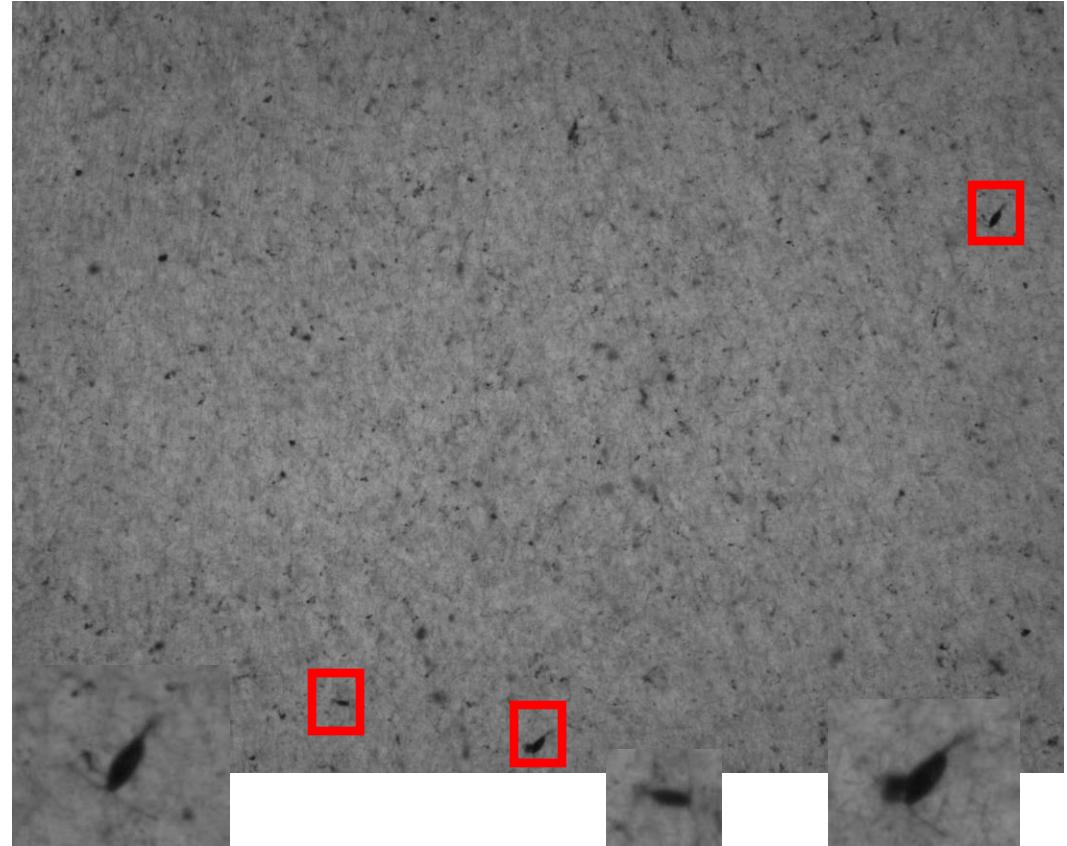
- Five **mesohaline** stations in the upper bay (CB3.3C, CB4.3C, LE1.1, ET5.2, CB5.2)
- Four stations (TF1.5, TF1.6, TF1.7, LE1.1) in Patuxent River (rectangles)



Methods

➤ *Image data between 2023-2024*

- *In-situ* zooplankton images were collected from Feb 2023 to Feb 2024 at CBL pier, using **PlanktonScope**, a shadowgraph imaging system
- 640 nm strobe illumination & 2 μ s exposure
- Pixel resolution is 20 μ m
- 1/20 Hz (1 frame per 20 seconds)
- \sim 236 mL / frame



Example frame from PlanktonScope

OutputMessage X

Detecting Img:20231021093104704.jpeg

0

This data does not enter the database!

Detecting Img:20231021093124704.jpeg

{"Copepoda": "1"}

This data does not enter the database!

Detecting Img:20231021093144703.jpeg

0

This data does not enter the database!

Detecting Img:20231021093204704.jpeg

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This data does not enter the database!

DetectionImg:20231021093224703.jpg

Train

Detect

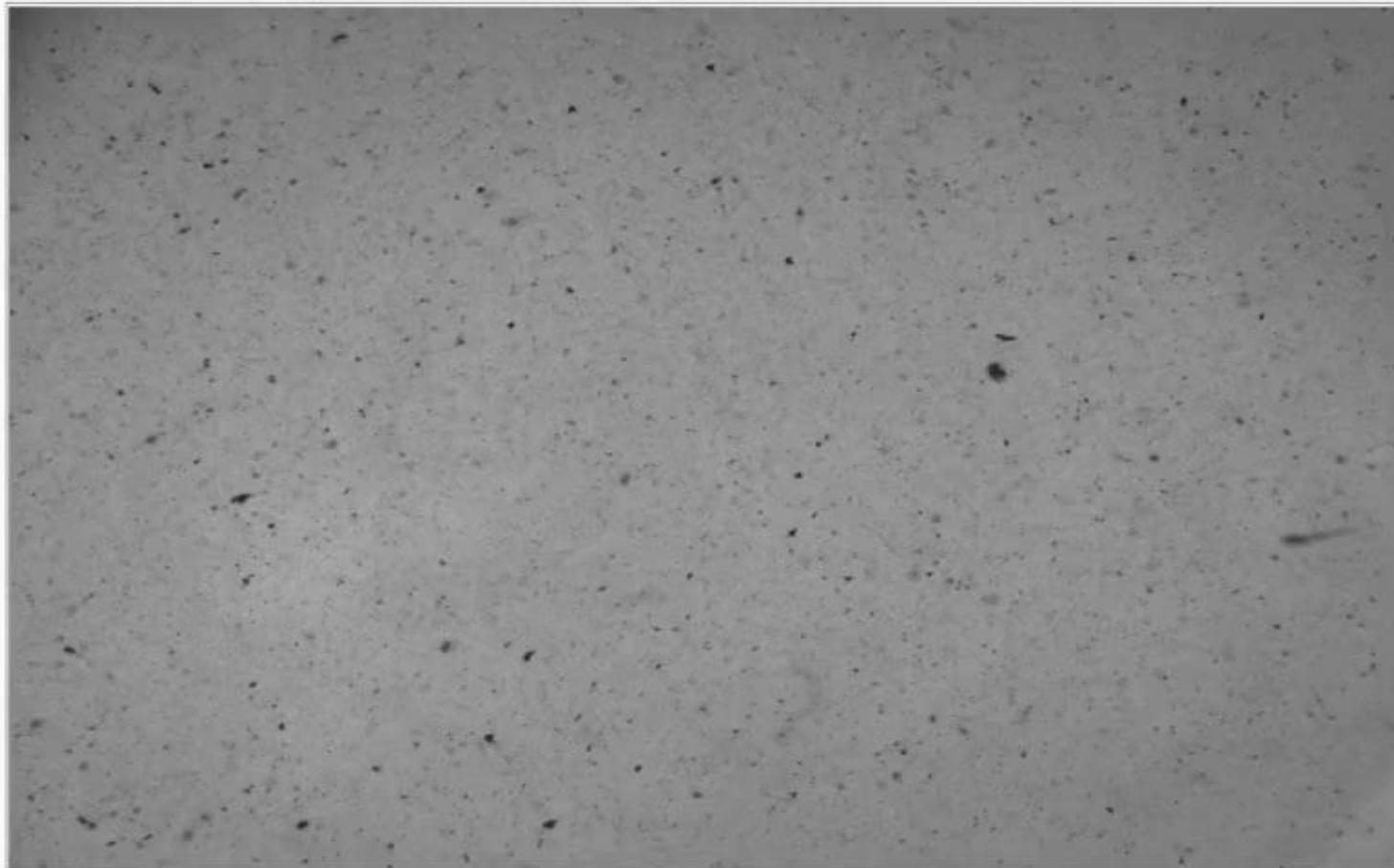
Parameter

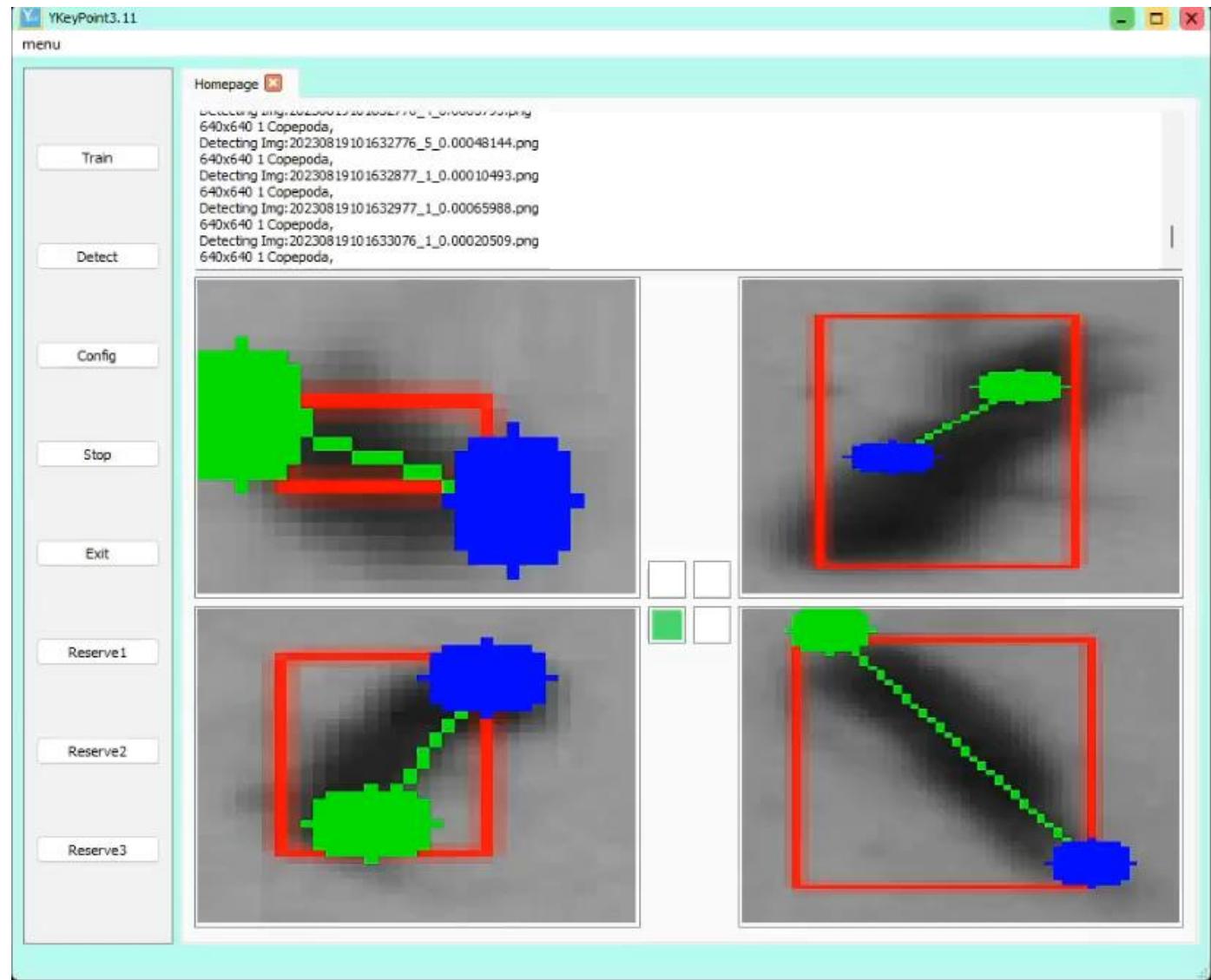
Curve

Stop

Exit

Reserve2





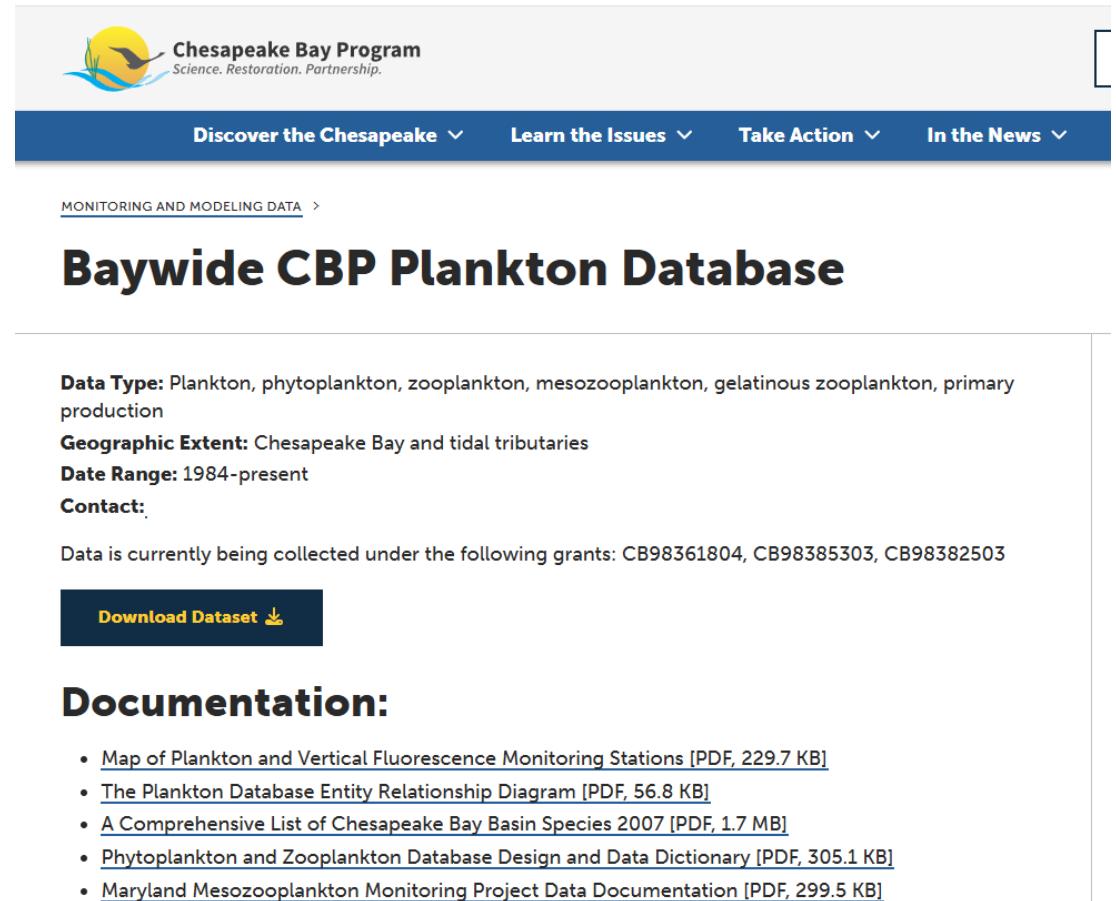
	True value (ImageJ)	Measured value (Key point)	Difference
91	A 15.70211	B 16.17	G 0.029798
92	28.12548	28.71	0.020782
93	33.75	34	0.007407
94	22.94754	23.3	0.015359
95	28.18499	28.85	0.023594
96	32.60383	31.77	0.025575
97	22.1109	22.89	0.035236
98	33.38345	33.75	0.01098
99	23.4375	23.27	0.007147
100	23.44265	23.54	0.004153
101			0.023422

Mean error : 2.34%

Methods

➤ *Bongo net data between 1984-2002*

- Historical copepod data of 5 stations between 1984–2002 were downloaded from the **Chesapeake Bay Program Plankton Database**
- Monthly basis through the water column using paired bongo nets
- 50 copepod species or groups were selected and subsequently summed



The screenshot shows the Chesapeake Bay Program website with a navigation bar at the top. The navigation bar includes links for "Discover the Chesapeake", "Learn the Issues", "Take Action", and "In the News". Below the navigation bar, a section titled "MONITORING AND MODELING DATA" is shown, with a sub-section titled "Baywide CBP Plankton Database". This section includes details about the data type (Plankton, phytoplankton, zooplankton, mesozooplankton, gelatinous zooplankton, primary production), geographic extent (Chesapeake Bay and tidal tributaries), date range (1984-present), and contact information. It also mentions grants CB98361804, CB98385303, and CB98382503. A "Download Dataset" button is present. Below this, a "Documentation" section lists several links to related documents.

Chesapeake Bay Program
Science. Restoration. Partnership.

Discover the Chesapeake ▾ Learn the Issues ▾ Take Action ▾ In the News ▾

MONITORING AND MODELING DATA >

Baywide CBP Plankton Database

Data Type: Plankton, phytoplankton, zooplankton, mesozooplankton, gelatinous zooplankton, primary production

Geographic Extent: Chesapeake Bay and tidal tributaries

Date Range: 1984-present

Contact:

Data is currently being collected under the following grants: CB98361804, CB98385303, CB98382503

Download Dataset ↴

Documentation:

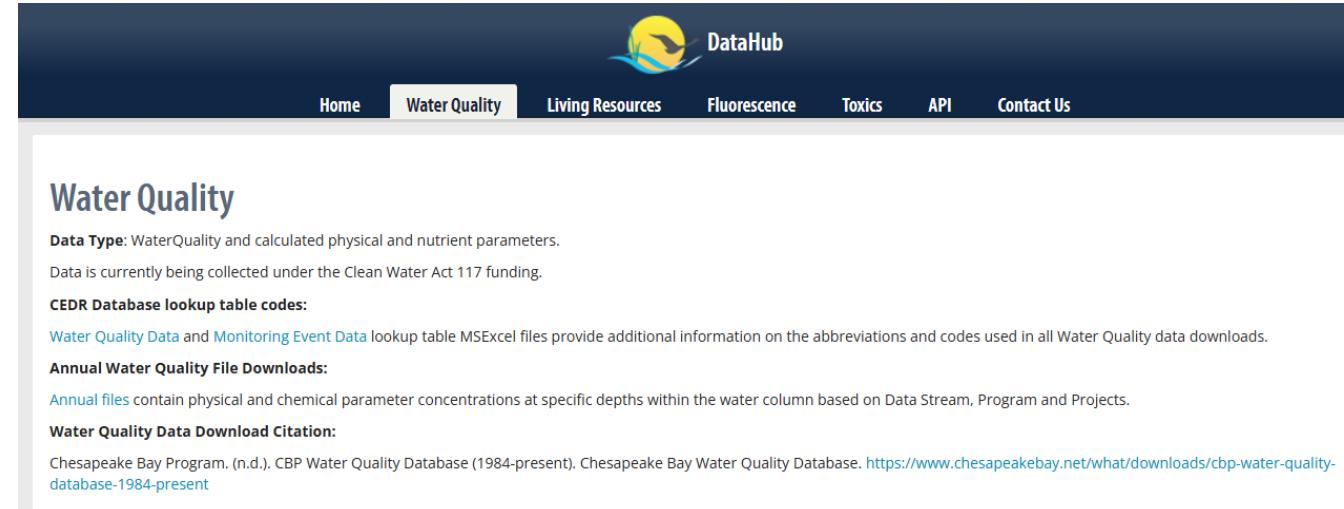
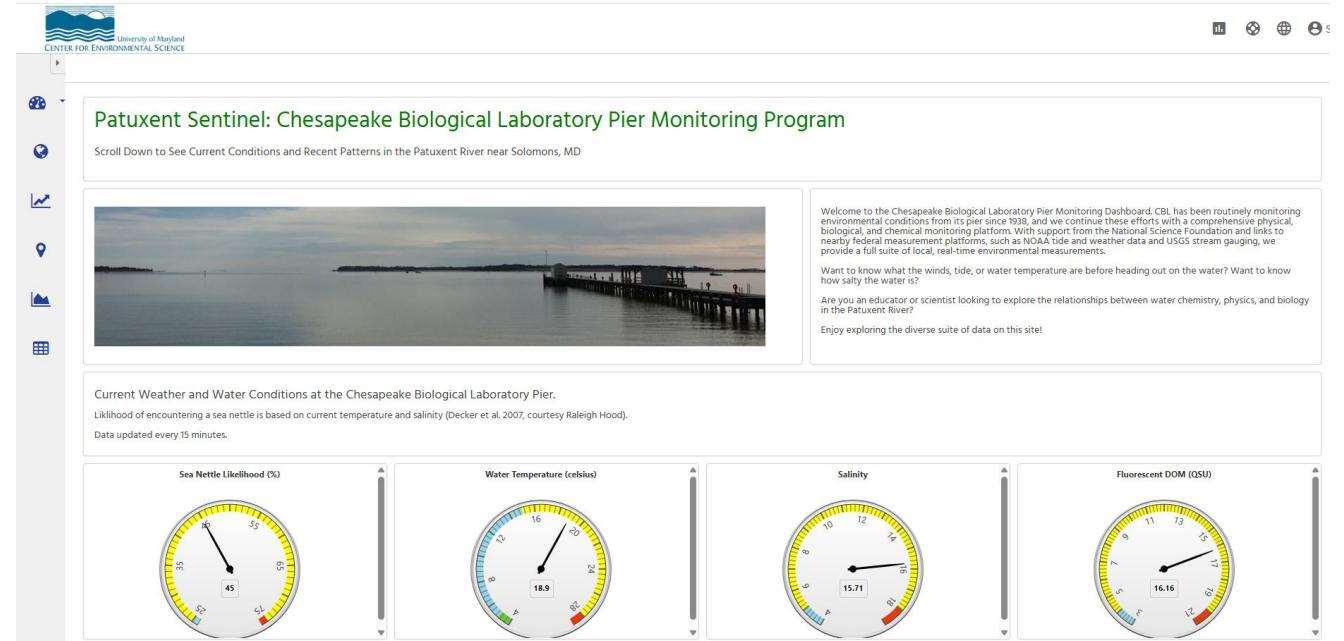
- [Map of Plankton and Vertical Fluorescence Monitoring Stations \[PDF, 229.7 KB\]](#)
- [The Plankton Database Entity Relationship Diagram \[PDF, 56.8 KB\]](#)
- [A Comprehensive List of Chesapeake Bay Basin Species 2007 \[PDF, 1.7 MB\]](#)
- [Phytoplankton and Zooplankton Database Design and Data Dictionary \[PDF, 305.1 KB\]](#)
- [Maryland Mesozooplankton Monitoring Project Data Documentation \[PDF, 299.5 KB\]](#)

Methods

➤ Environmental data

- Salinity
- Water temperature

CBL Pier Monitoring Dashboard & CBP Water Quality DataHub



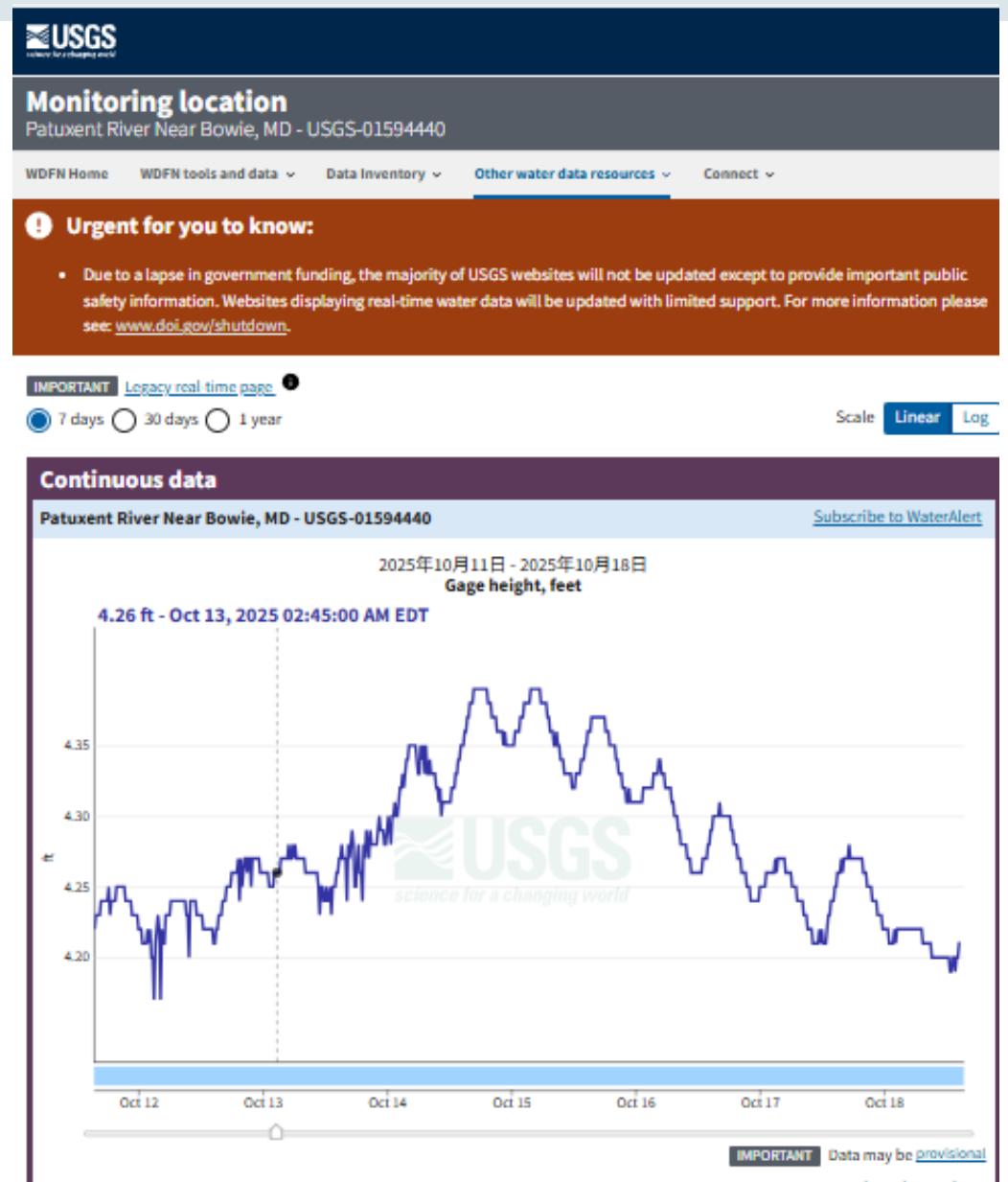
Methods

➤ Environmental data

- Salinity
- Water temperature
- Freshwater discharge rates

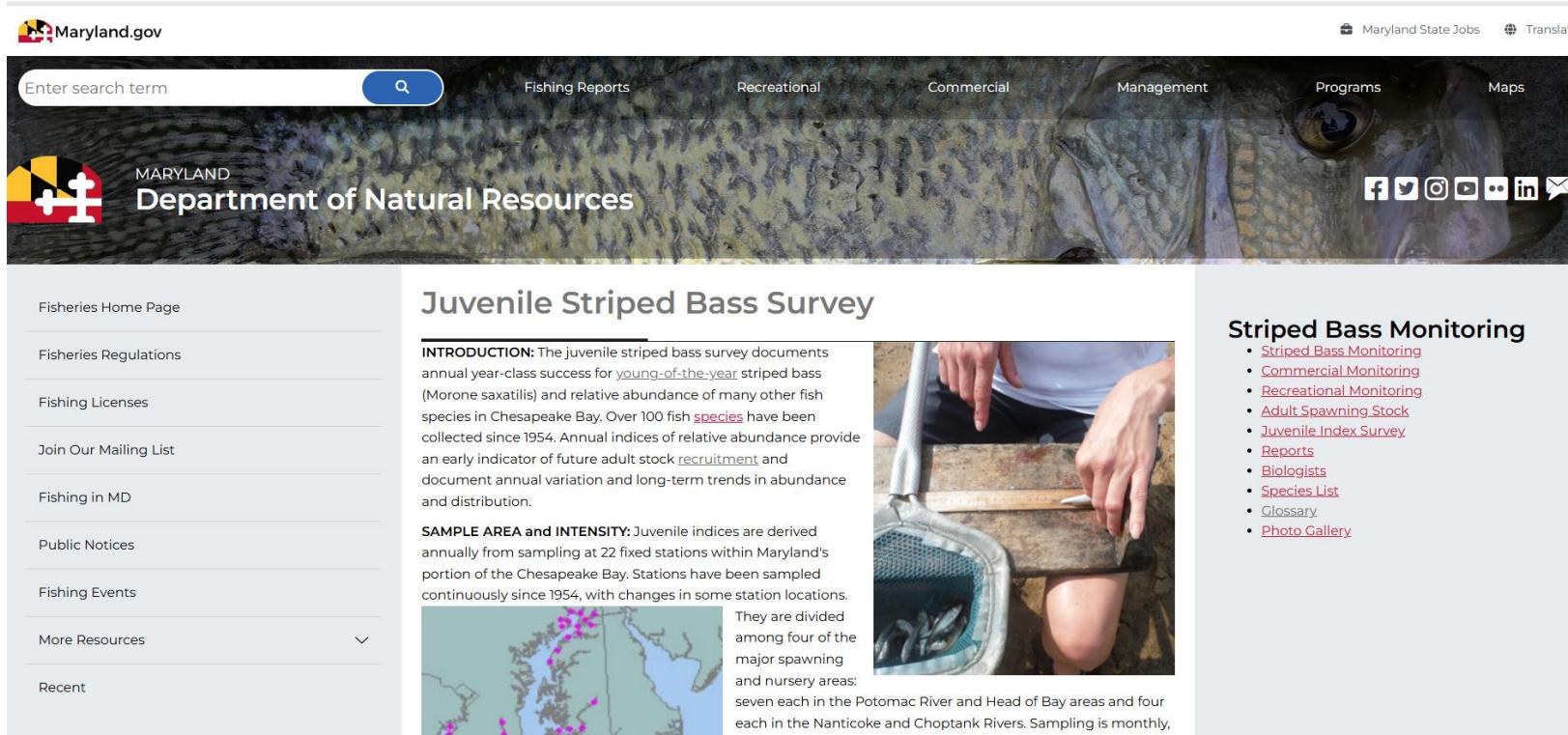
Distributed Lag Non-linear Model (DLNM) was applied to study the effect of freshwater discharge

$$\log [E(Y_t)] = \alpha + f(\lg FD_t, l) + \varepsilon_t$$



Methods

➤ *Striped bass recruitment data*



The screenshot shows the Maryland Department of Natural Resources website. The header features the Maryland.gov logo, a search bar, and links for Fishing Reports, Recreational, Commercial, Management, Programs, and Maps. The main banner image is a close-up of a striped bass. The left sidebar includes links for Fisheries Home Page, Fisheries Regulations, Fishing Licenses, Join Our Mailing List, Fishing in MD, Public Notices, Fishing Events, More Resources (with a dropdown menu for Recent), and Recent. The main content area is titled "Juvenile Striped Bass Survey". It contains two sections: "INTRODUCTION" and "SAMPLE AREA and INTENSITY". The "INTRODUCTION" section describes the survey's purpose of documenting annual year-class success for young-of-the-year striped bass and other fish species in Chesapeake Bay. The "SAMPLE AREA and INTENSITY" section details the sampling at 22 fixed stations across Maryland's portion of the bay, with continuous data collection since 1954. Below these sections is a map of Maryland showing sampling locations. To the right is a photograph of a person handling fish in a net. A sidebar titled "Striped Bass Monitoring" lists various monitoring components: Striped Bass Monitoring, Commercial Monitoring, Recreational Monitoring, Adult Spawning Stock, Juvenile Index Survey, Reports, Biologists, Species List, Glossary, and Photo Gallery.

Juvenile Striped Bass Survey

INTRODUCTION: The juvenile striped bass survey documents annual year-class success for young-of-the-year striped bass (*Morone saxatilis*) and relative abundance of many other fish species in Chesapeake Bay. Over 100 fish species have been collected since 1954. Annual indices of relative abundance provide an early indicator of future adult stock recruitment and document annual variation and long-term trends in abundance and distribution.

SAMPLE AREA and INTENSITY: Juvenile indices are derived annually from sampling at 22 fixed stations within Maryland's portion of the Chesapeake Bay. Stations have been sampled continuously since 1954, with changes in some station locations. They are divided among four of the major spawning and nursery areas: seven each in the Potomac River and Head of Bay areas and four each in the Nanticoke and Choptank Rivers. Sampling is monthly.

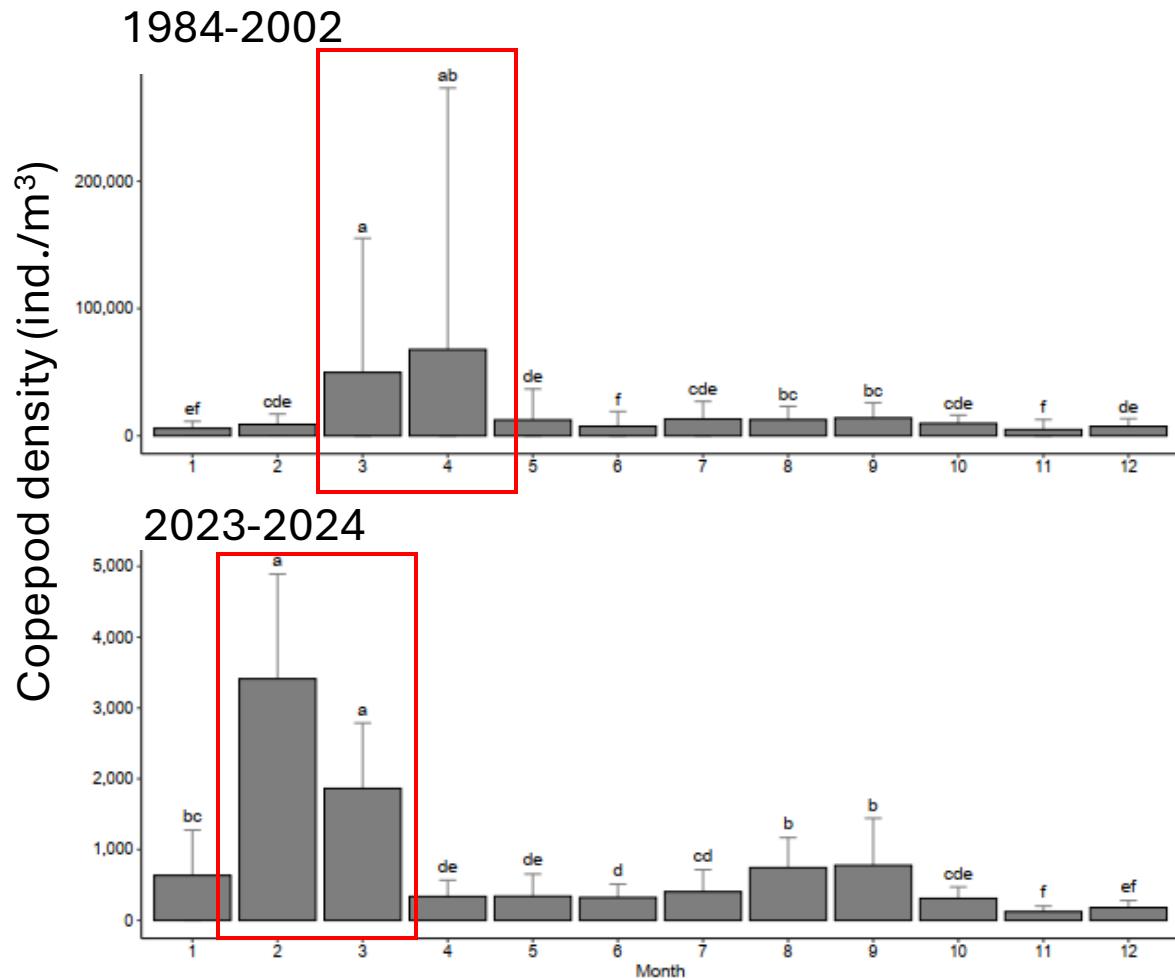
Striped Bass Monitoring

- [Striped Bass Monitoring](#)
- [Commercial Monitoring](#)
- [Recreational Monitoring](#)
- [Adult Spawning Stock](#)
- [Juvenile Index Survey](#)
- [Reports](#)
- [Biologists](#)
- [Species List](#)
- [Glossary](#)
- [Photo Gallery](#)

- Annual young-of-year (YOY) index
Fish that are less than 1 year of age

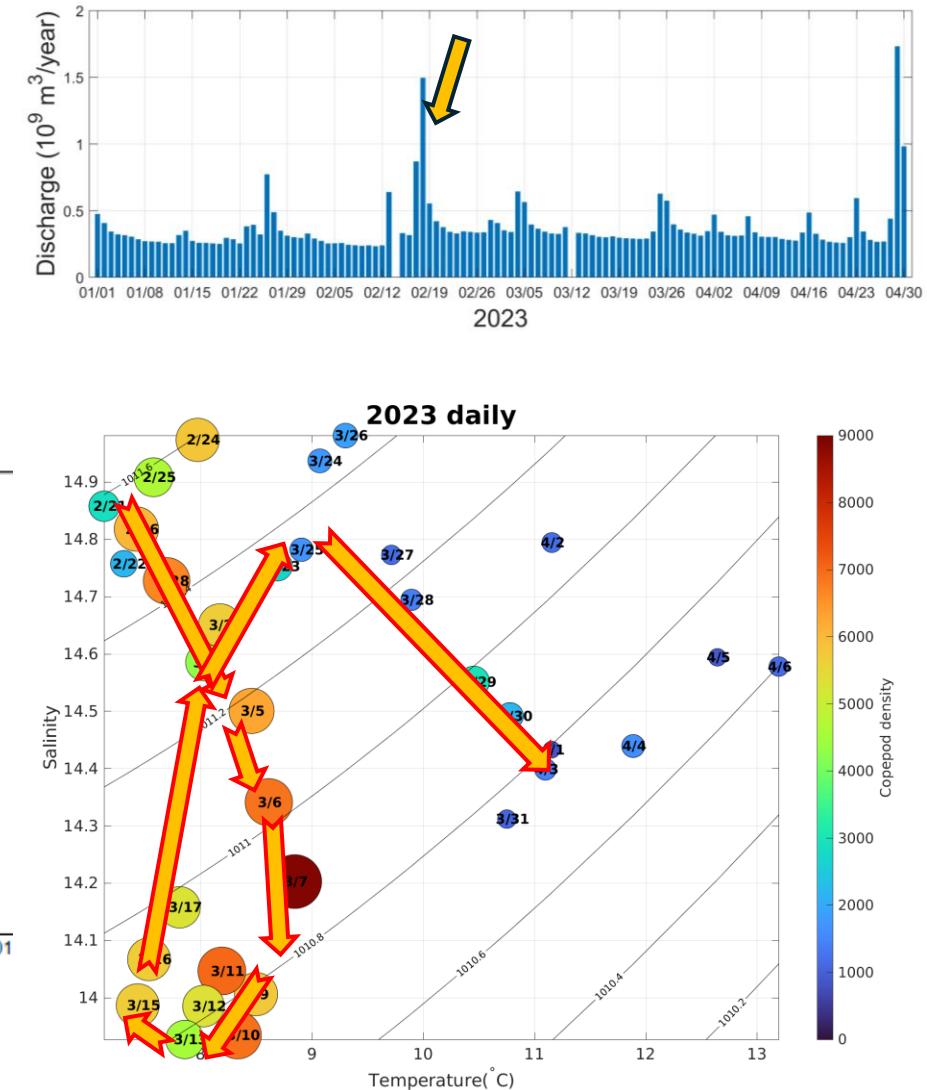
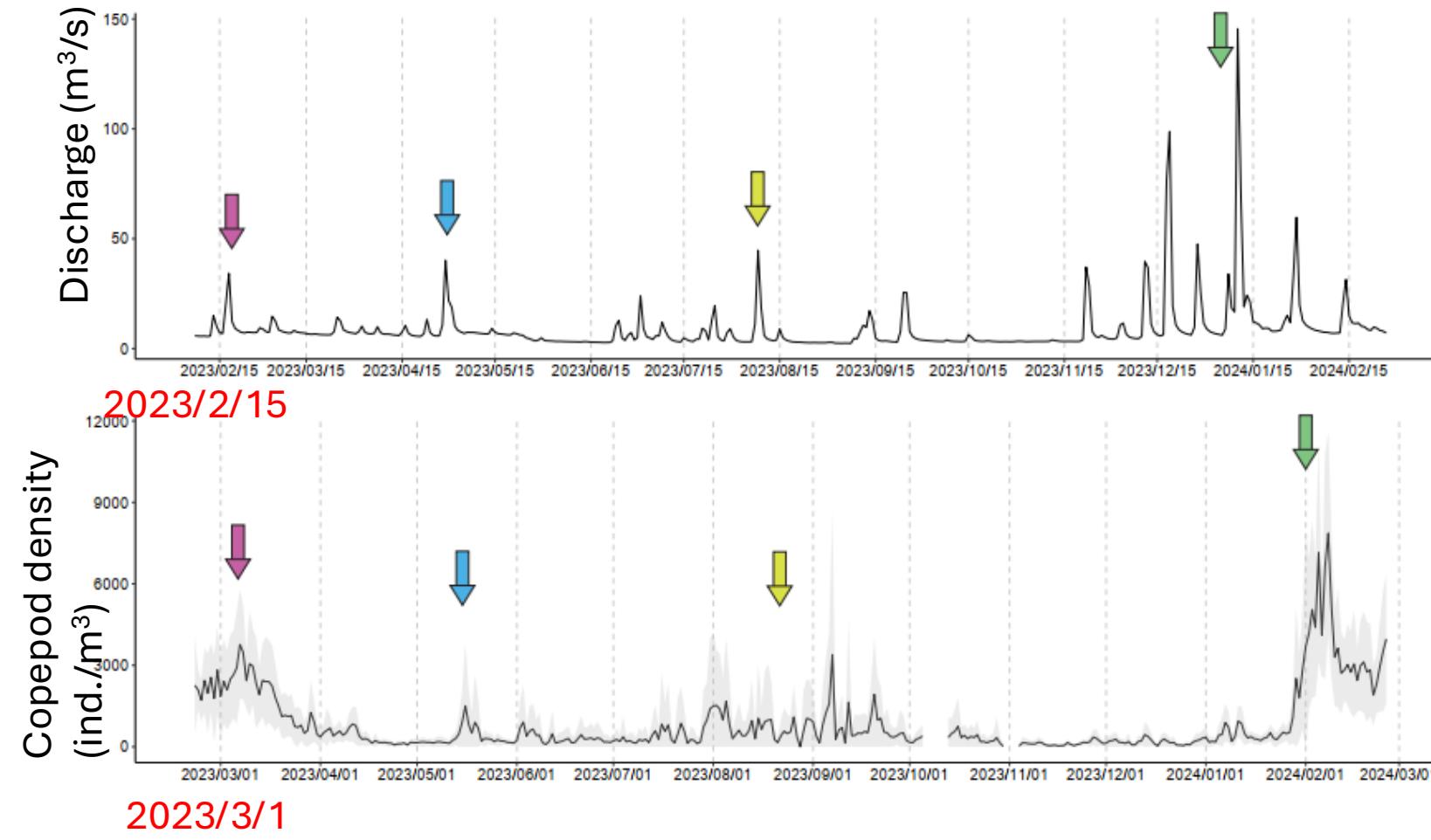
Results

➤ Copepod Density

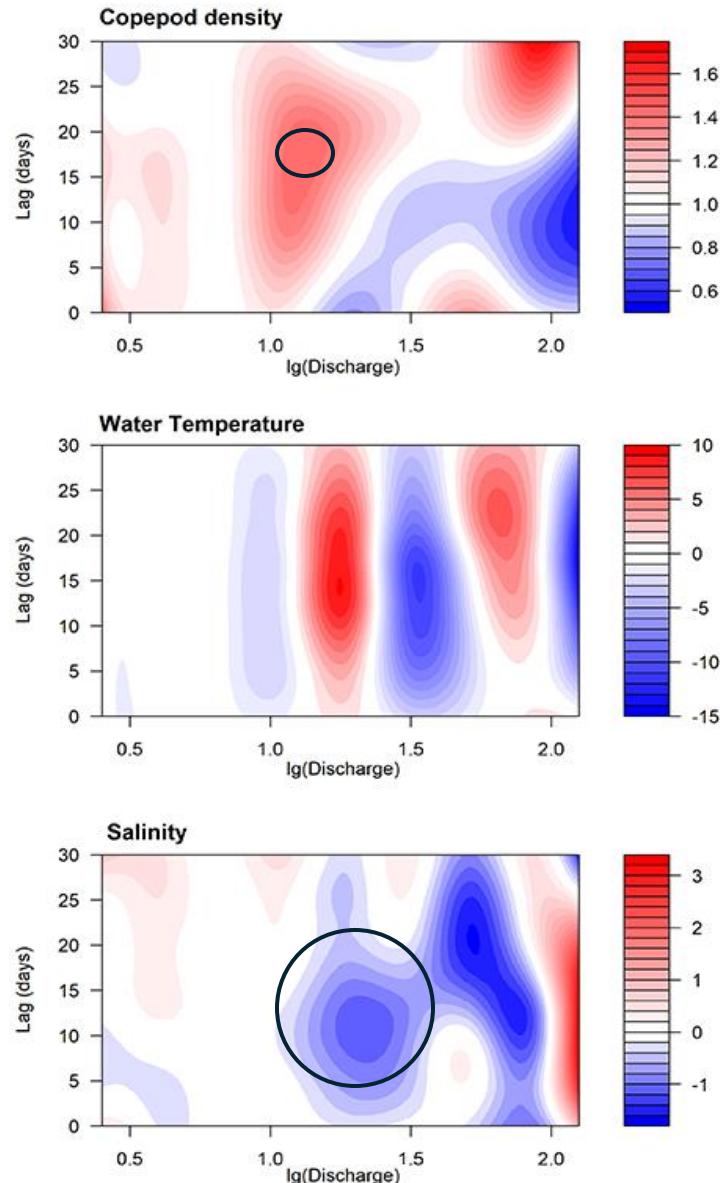


- Copepod density peaked in **spring** (Mar.-Apr.) in 1984-2002
- Copepod density peaked in **late winter and early spring** (Feb.-Mar.) in 2023-2024
- The spring peaking time **was 1-2 months earlier** than 30 years ago

Results



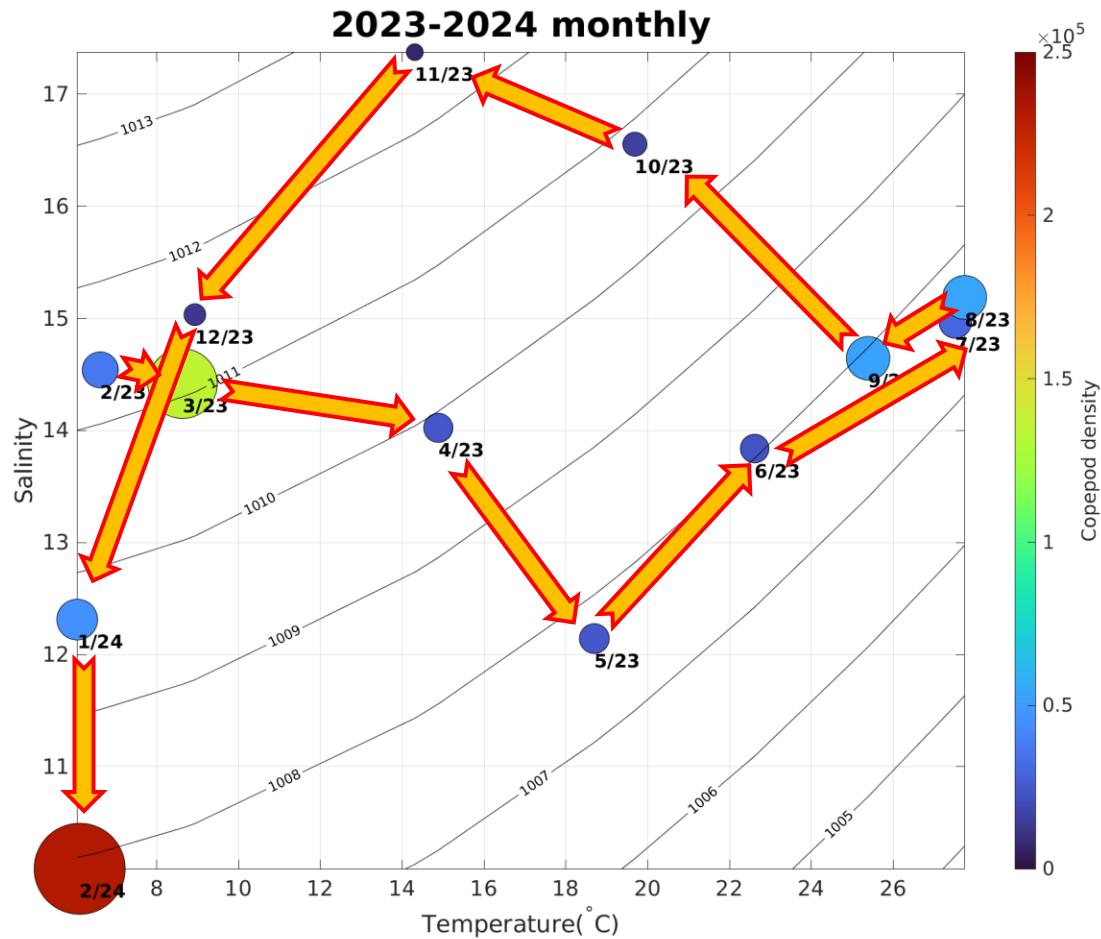
Results



Distributed Lag Non-linear Model (DLNM) results:

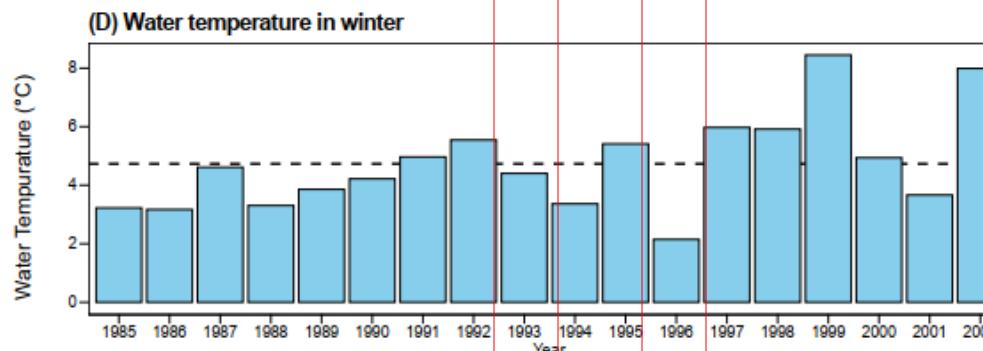
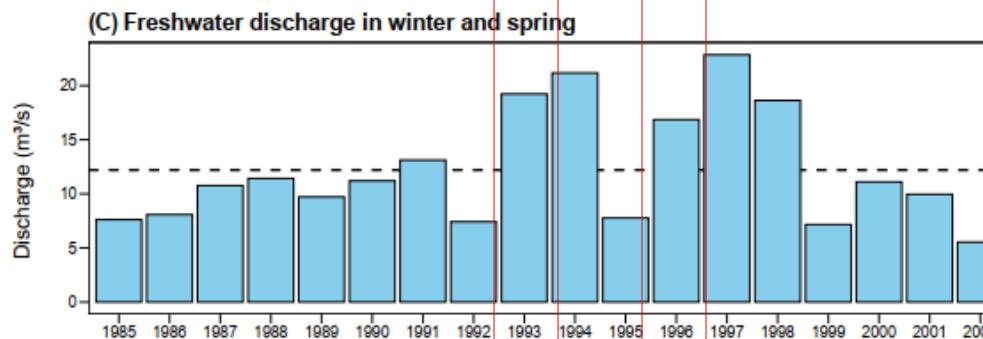
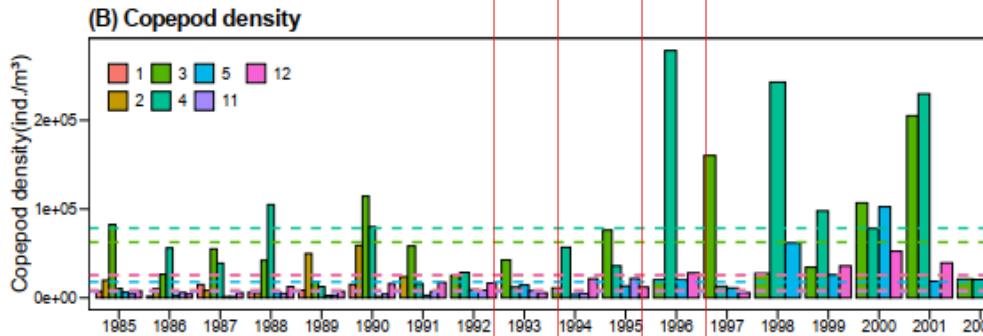
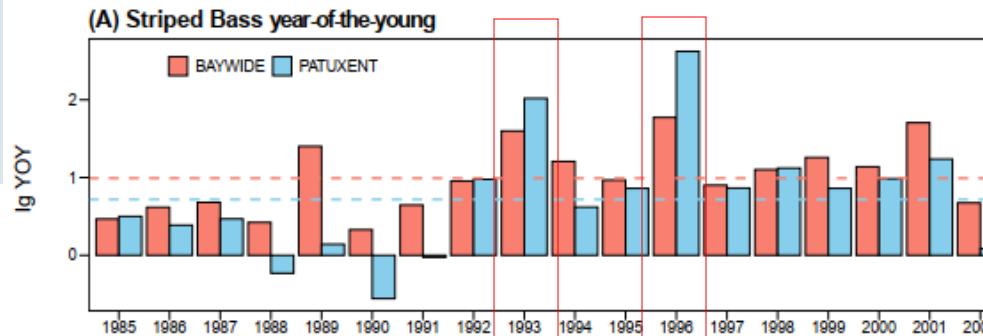
- Moderate freshwater discharge had a **positive effect** on copepod density with the strongest effect estimated at $27.5 \text{ m}^3/\text{s}$ and a **17-day lag**
- No obvious effect on water temperature; other factors influence T more, likely seasonality
- **Negative effect** on salinity

Results



Discharge-driven water mass controls:

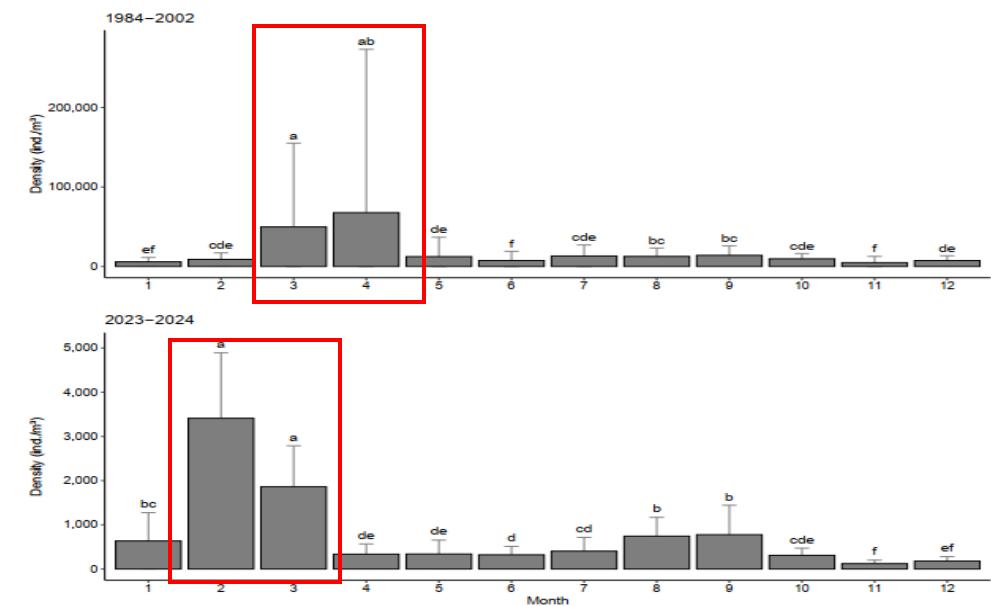
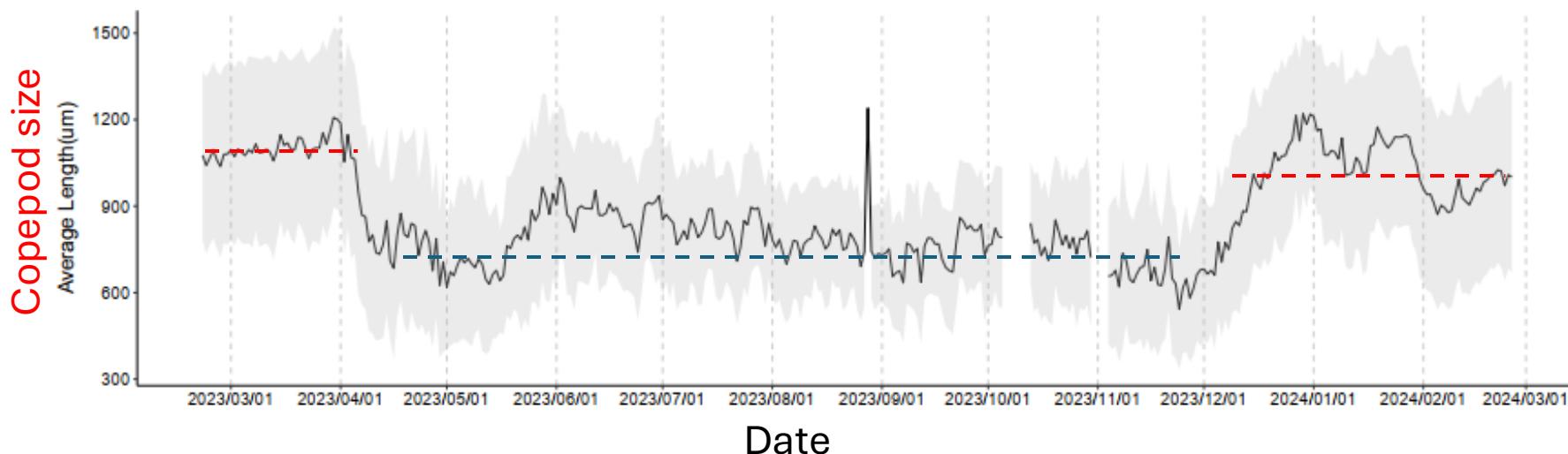
- Copepod density was elevated during winter and early spring (December to March), a period characterized by **cold** and relatively **fresh** water masses
- Copepod density declined in late spring to early autumn (April to September) with a **warm** water mass.



- Indices for young-of-the-year (YOY, per haul) striped bass were elevated during cold, wet years (e.g., 1993 and 1996).
- Low YOY during dry years with below-average discharge, even when winter temperatures were cold (e.g., 1985-1990 & 2002)
- YOY in 2023-2024 were near historical low.

Discussions

- Large copepods might contribute more to the seasonal shift of copepod phenology.
 - ◆ Large copepods are more easily influenced by climate change than small copepods.



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 - ◆ Large copepods are more easily influenced by climate change than small copepods.
- This seasonal shift of copepod phenology might cause mismatch between copepod phenology and striped bass recruitment during spring.



Discussions

- Large copepods might contribute more to the seasonal shift of copepod phenology.
 - ◆ Large copepods are more easily influenced by climate change than small copepods.
- This seasonal shift of copepod phenology might cause **mismatch** between copepod phenology and **striped bass recruitment** during spring.
- More **high-frequency data** are needed for quantifying the influence of climate change on copepod phenology.
 - ✓ **Plankton imaging systems** coupled with **AI** can provide near real-time data

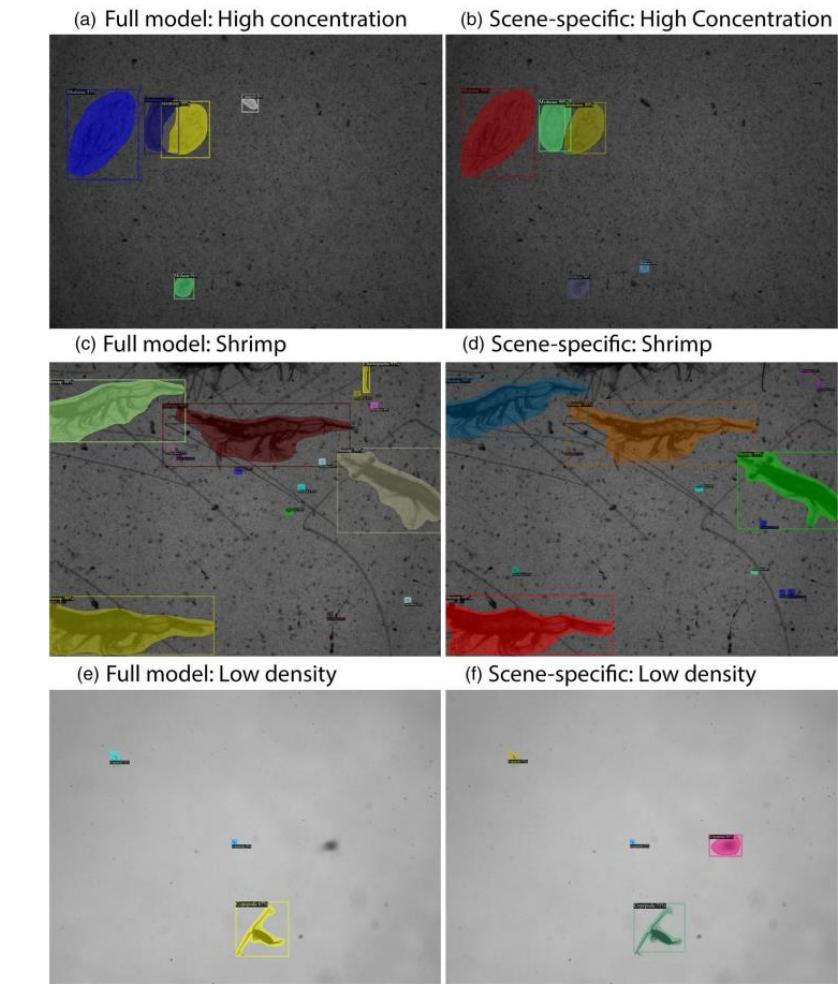


Fig. 5. Examples of processed underwater plankton images from three different scene categories using the full model and scene-specific models.

(Bi et al. 2024)

Take-home Messages

- Copepod density peaking time might change from spring to late winter and early spring, which maybe attributed to **warm and wet winter** caused by climate change.
- This seasonal shift in copepod phenology could potentially lead to a **mismatch** between copepod availability and fish larvae recruitment in Chesapeake Bay.
- **Long term monitor for high-frequency data** is needed to quantify the effect of climate change on copepod phenology.



Thank you!

Questions?

