



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

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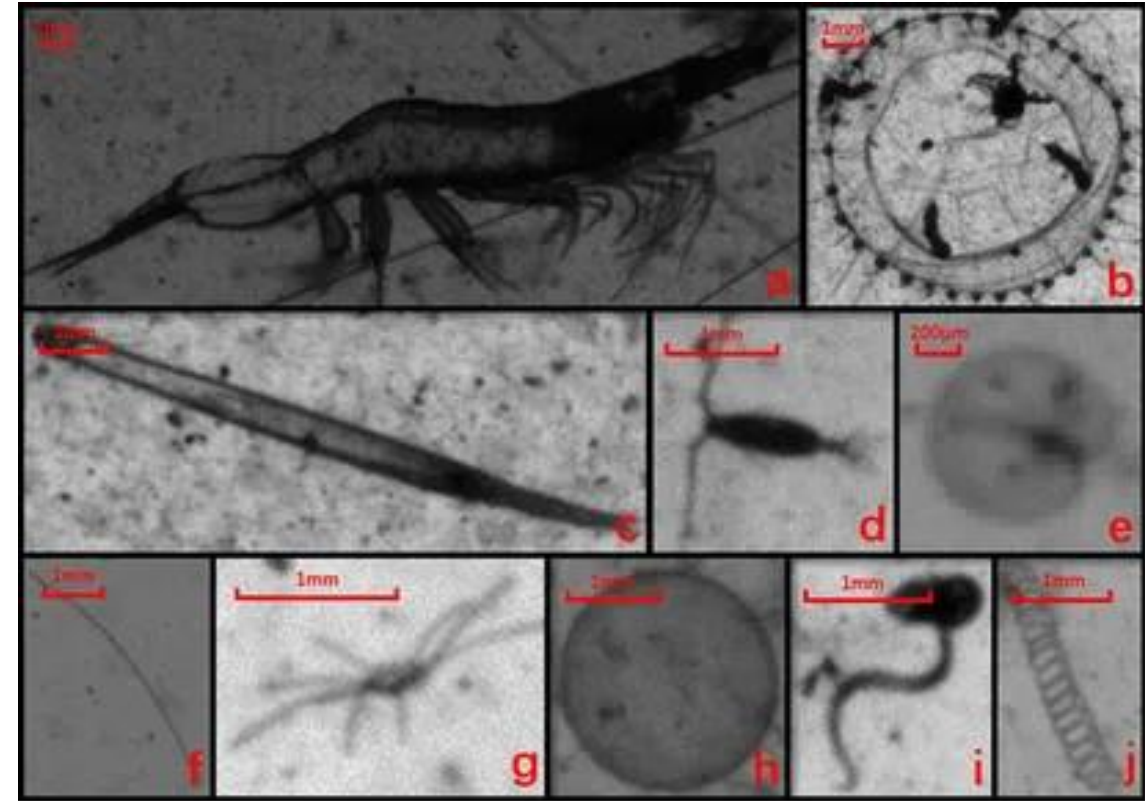
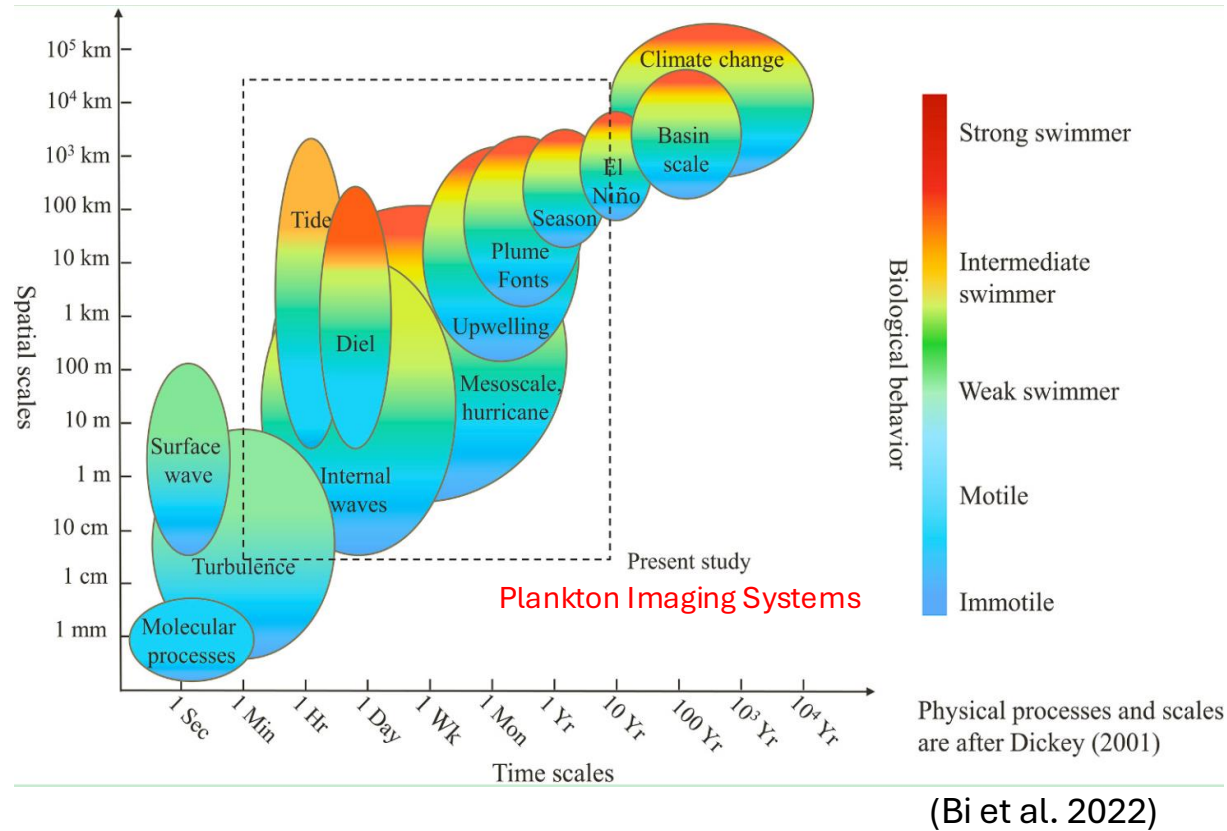


Introduction

- 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



Shadow images of zooplankton

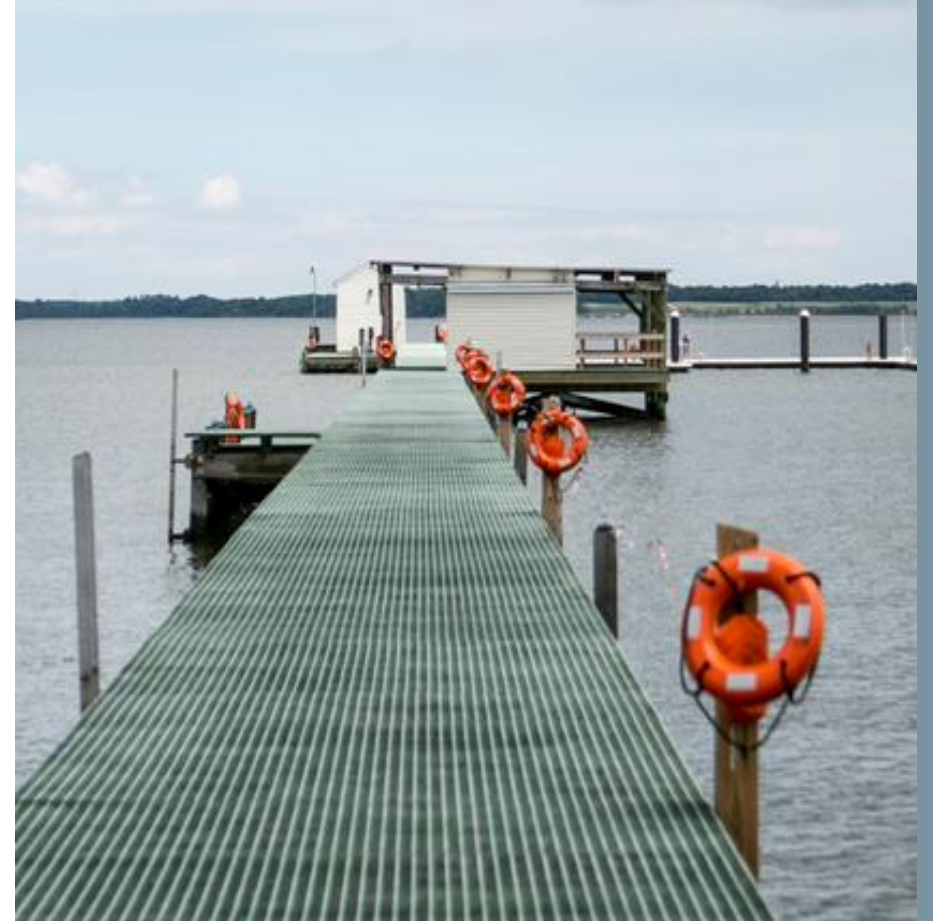
(Zhang et al. 2023)

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

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

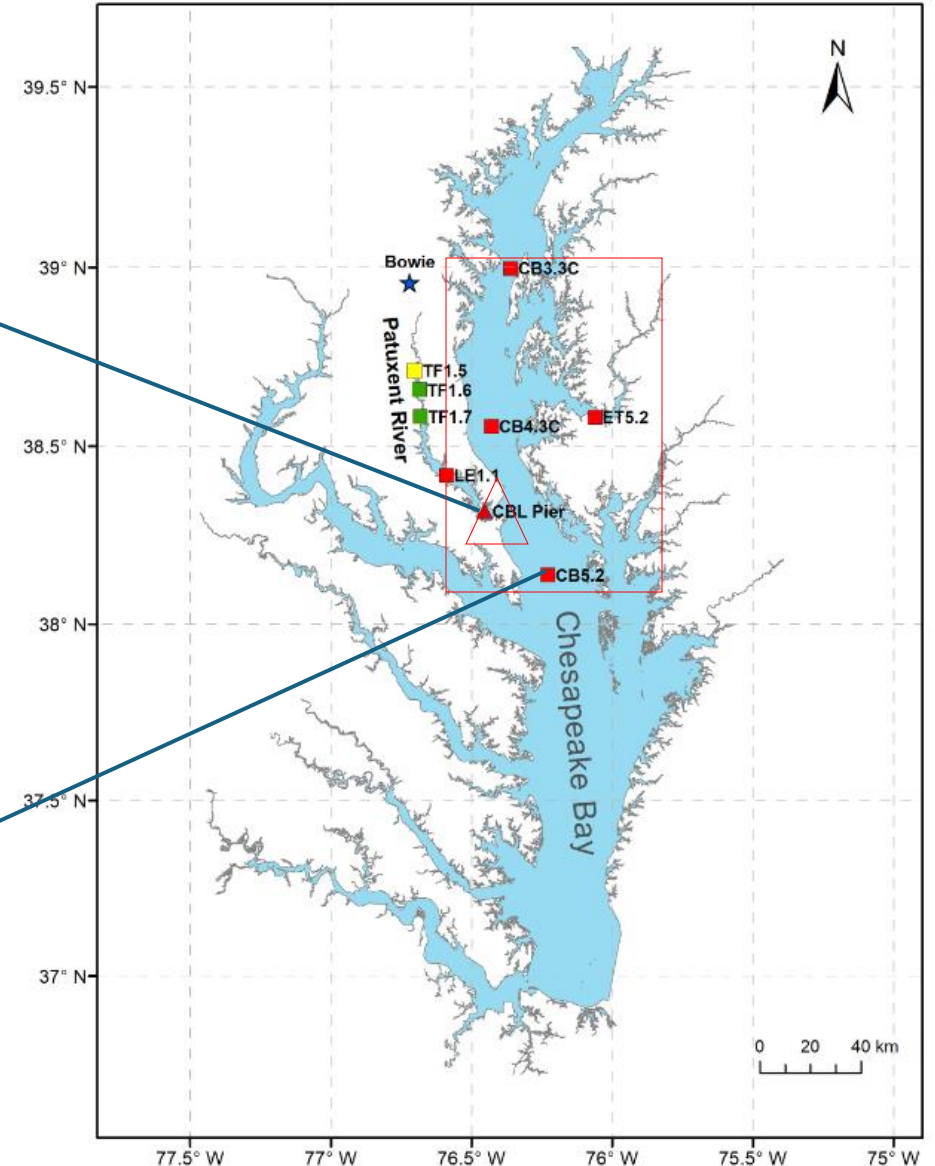
Patuxent River mouth:

- Chesapeake Biological Lab pier (triangle)



Upper Chesapeake Bay:

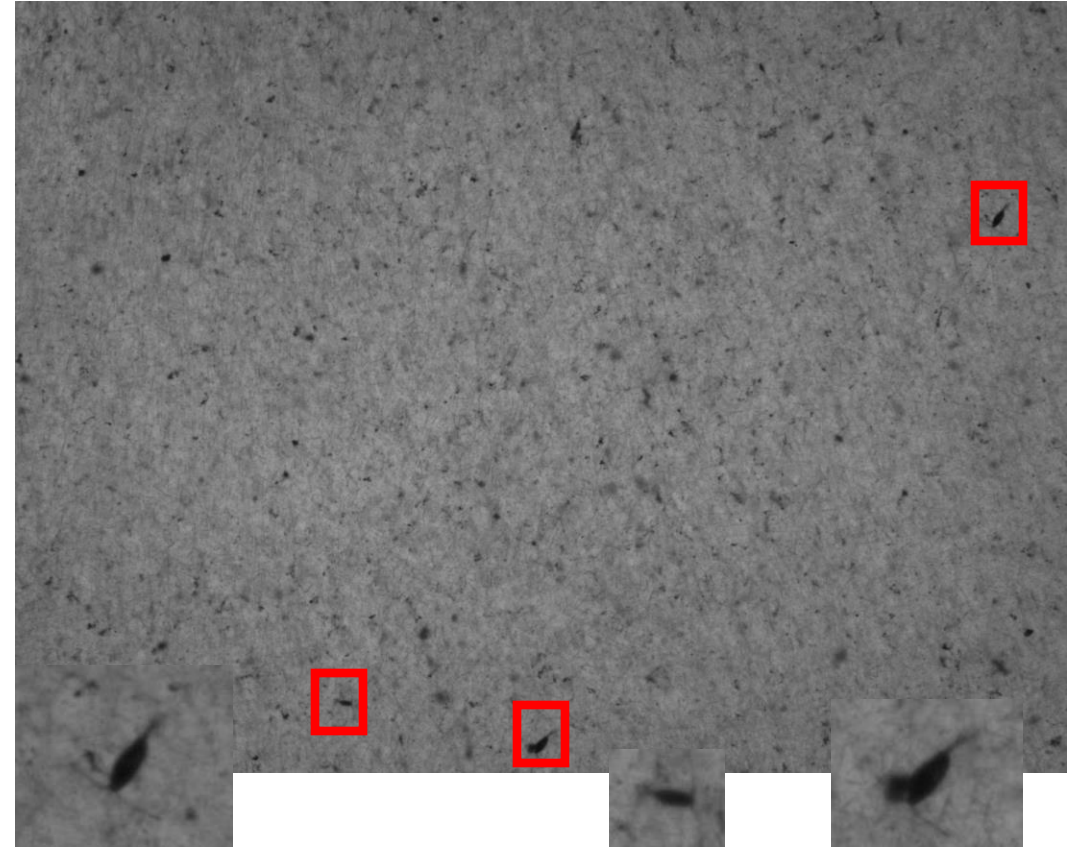
- Five **mesohaline** stations in the upper bay (CB3.3C, CB4.3C, LE1.1, ET5.2, CB5.2)
- Four stations (TF1.5, TF1.6, TF1.7, LE1.1) in Patuxent River (rectangles)



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 ✕

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
0
This data does not enter the database!
Detection Img:20231021093224703.jpeg

Train

Detect

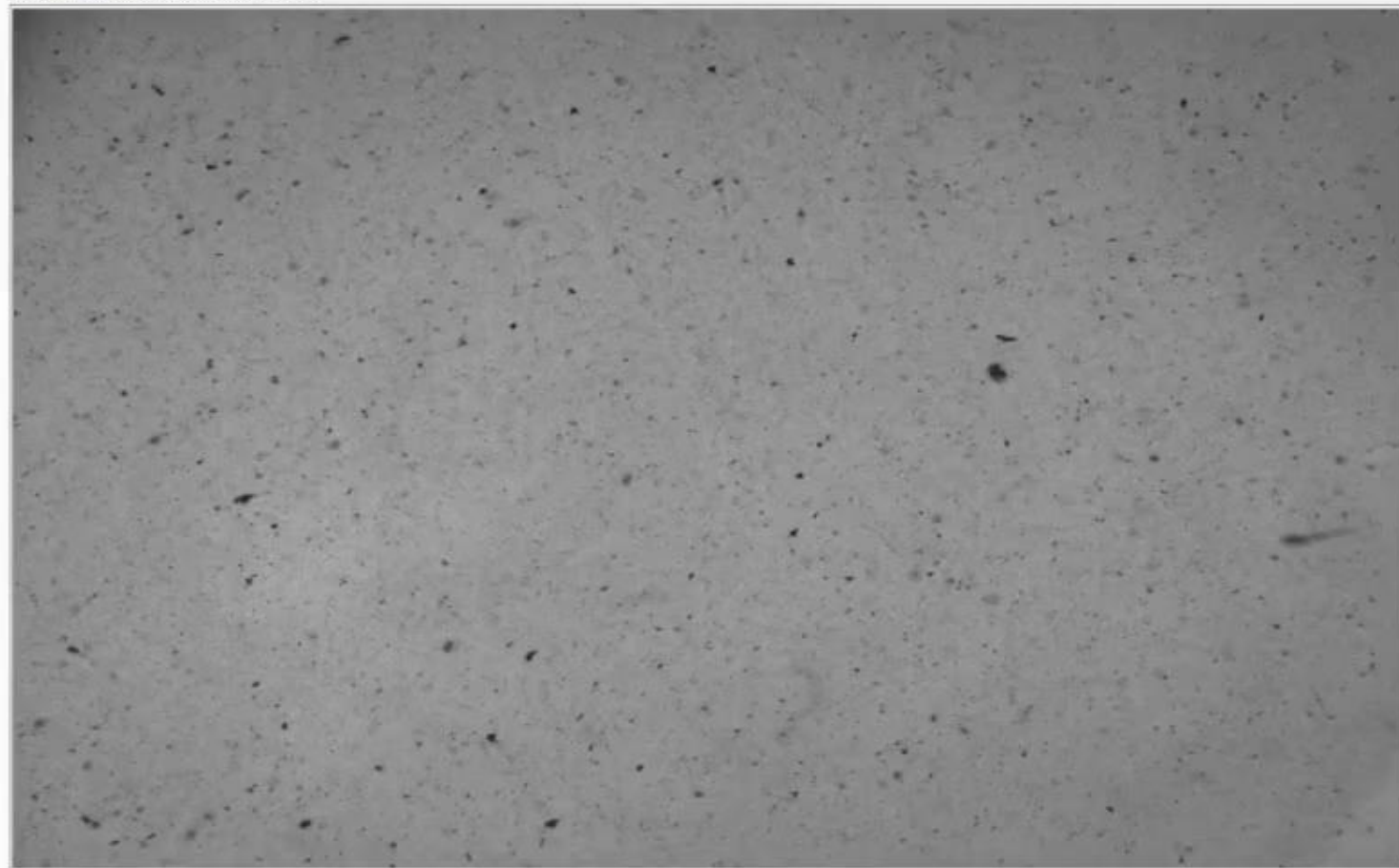
Parameter

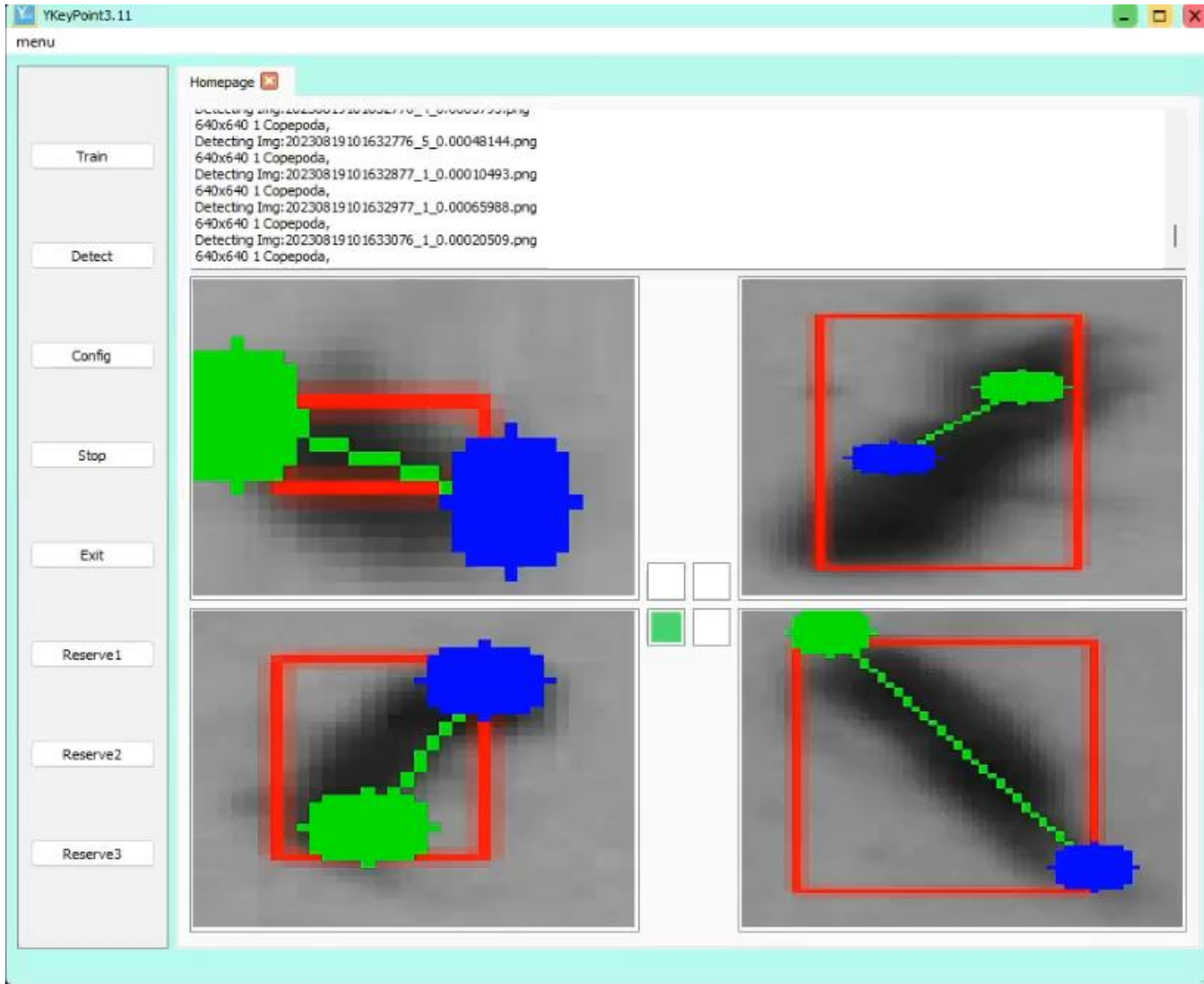
Curve

Stop

Exit

Reserve2





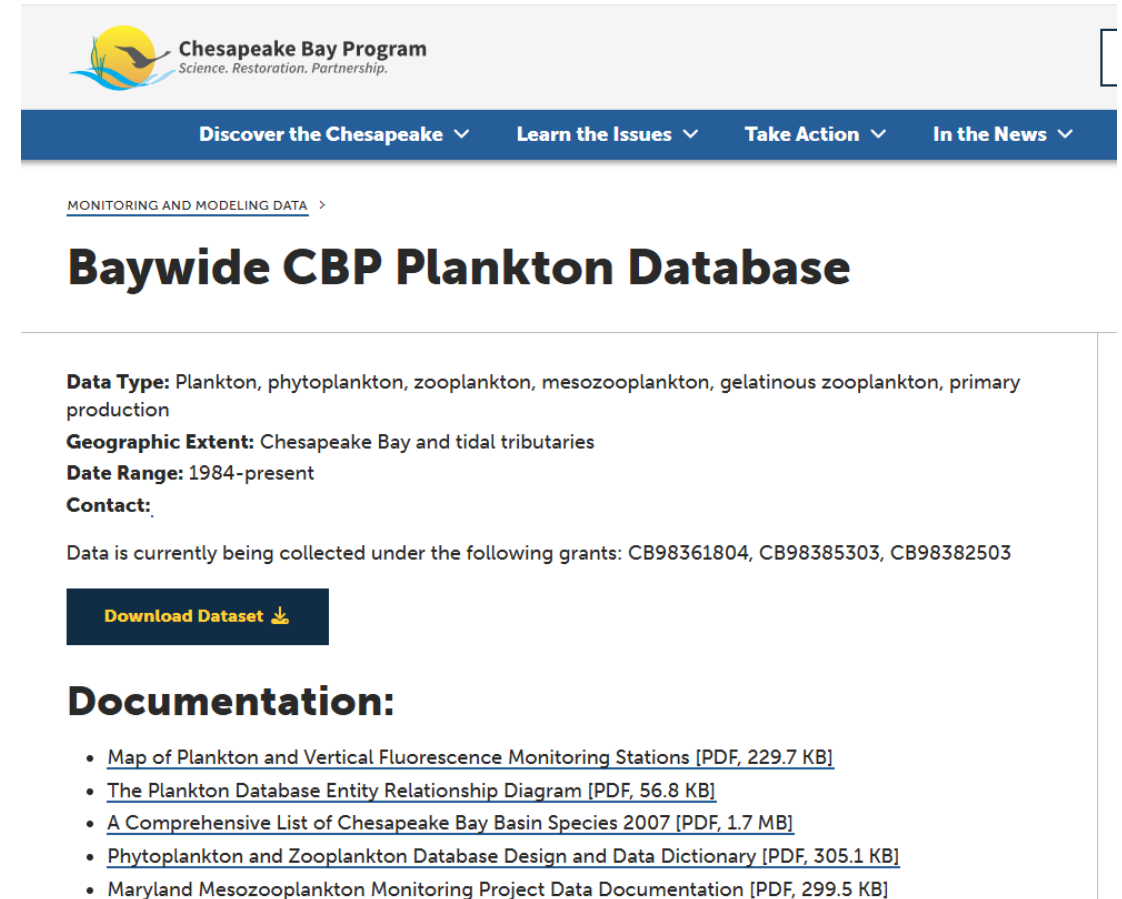
	True value (ImageJ)	Measured value (Key point)	Difference
	A	B	G
91	15.70211	16.17	0.029798
92	28.12548	28.71	0.020782
93	33.75	34	0.007407
94	22.94754	23.3	0.015359
95	28.18499	28.85	0.023594
96	32.60383	31.77	0.025575
97	22.1109	22.89	0.035236
98	33.38345	33.75	0.01098
99	23.4375	23.27	0.007147
100	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 website for the Chesapeake Bay Program Plankton Database. The header features the Chesapeake Bay Program logo and navigation links: "Discover the Chesapeake", "Learn the Issues", "Take Action", and "In the News". Below the header, a breadcrumb trail reads "MONITORING AND MODELING DATA >". The main title is "Baywide CBP Plankton Database". Underneath, key details are listed: "Data Type: Plankton, phytoplankton, zooplankton, mesozooplankton, gelatinous zooplankton, primary production", "Geographic Extent: Chesapeake Bay and tidal tributaries", "Date Range: 1984-present", and "Contact:". A note states "Data is currently being collected under the following grants: CB98361804, CB98385303, CB98382503". A "Download Dataset" button with a download icon is present. The "Documentation:" section lists five links to PDF documents: "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]", and "Maryland Mesozooplankton Monitoring Project Data Documentation [PDF, 299.5 KB]".

Chesapeake Bay Program
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MONITORING AND MODELING DATA >

Baywide CBP Plankton Database

Data Type: Plankton, phytoplankton, zooplankton, mesozooplankton, gelatinous zooplankton, primary production
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[Download Dataset](#) 📄

Documentation:

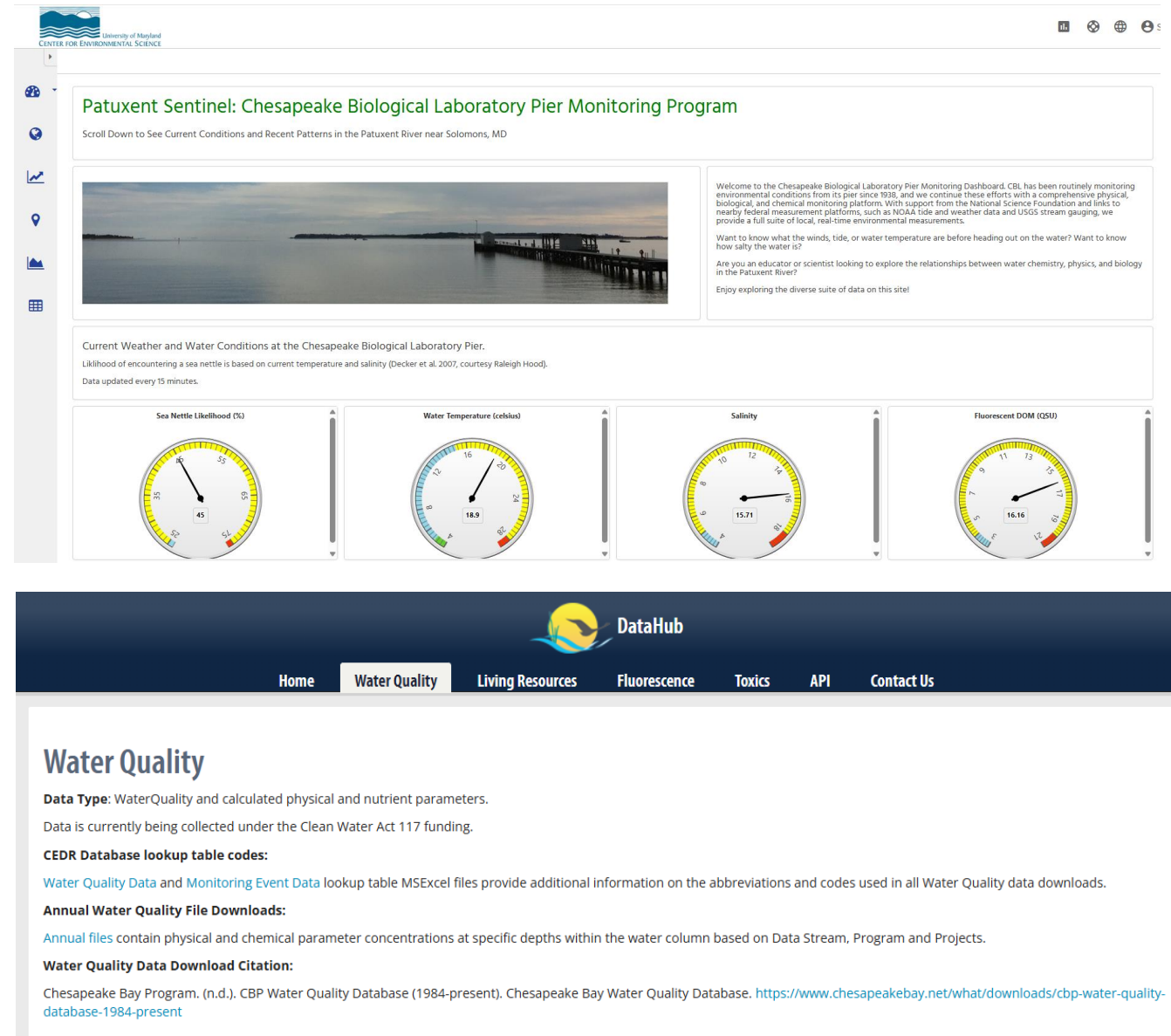
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Methods

➤ Environmental data

- Salinity
- Water temperature

CBL Pier Monitoring Dashboard & CBP Water Quality DataHub



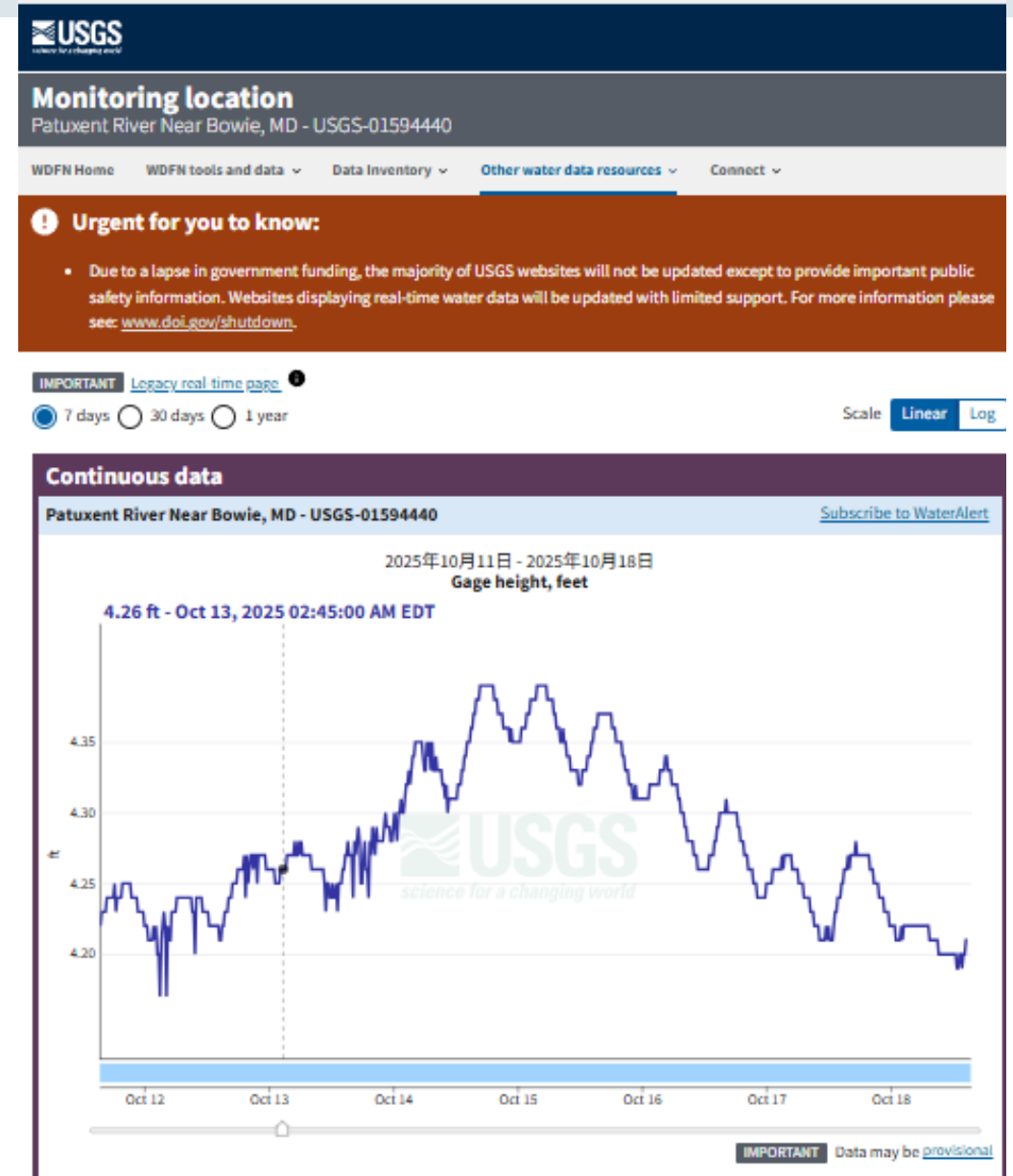
Methods

➤ Environmental data

- Salinity
- Water temperature
- Freshwater discharge rates

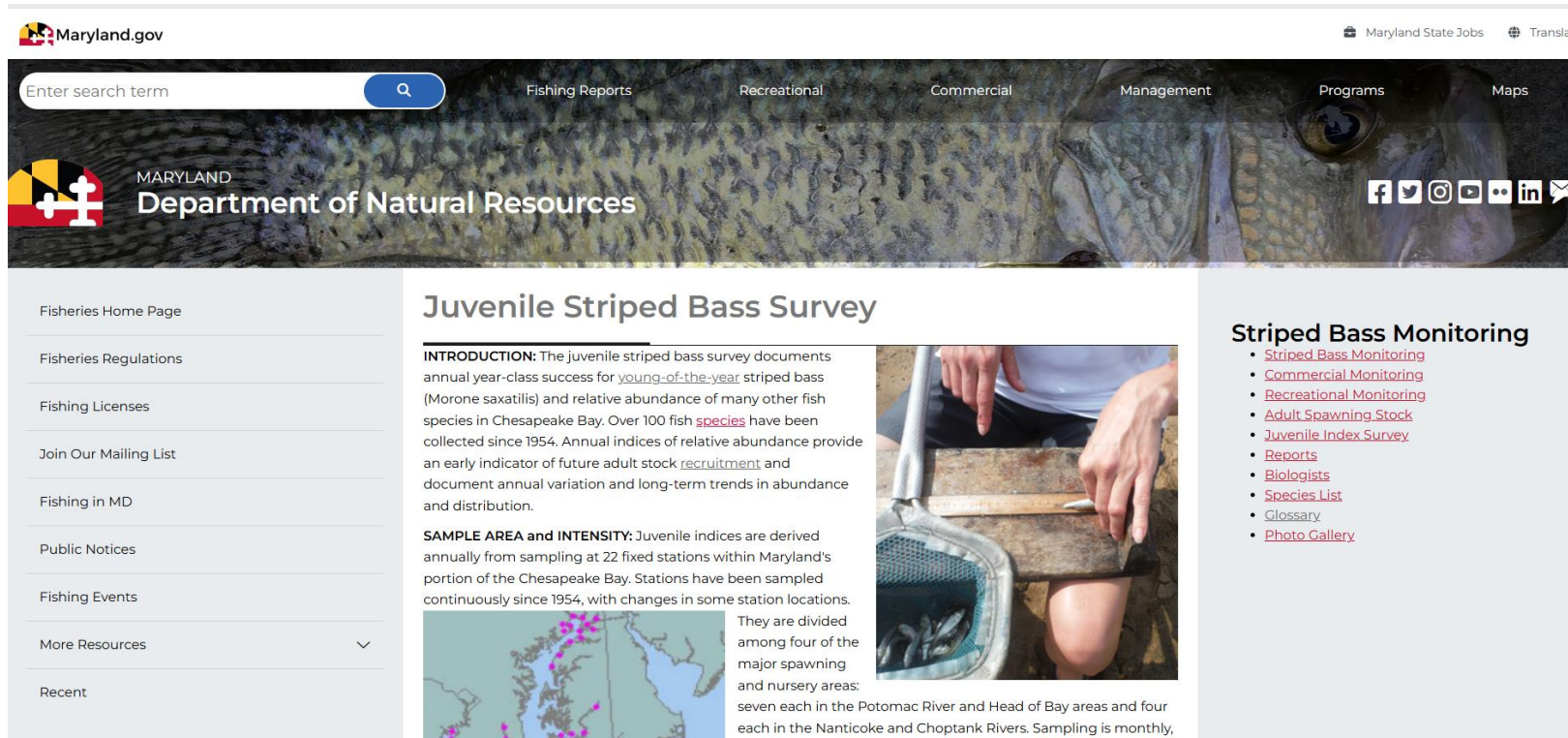
Distributed Lag Non-linear Model (DLNM) was applied to study the effect of freshwater discharge

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



Methods

➤ *Striped bass recruitment data*



The screenshot shows the Maryland Department of Natural Resources website. The header includes the Maryland.gov logo, a search bar, and navigation links for Fishing Reports, Recreational, Commercial, Management, Programs, and Maps. The main banner features the Maryland Department of Natural Resources logo and social media icons. The left sidebar contains links to Fisheries Home Page, Regulations, Licenses, Mailing List, Fishing in MD, Public Notices, Fishing Events, More Resources, and Recent. The main content area is titled "Juvenile Striped Bass Survey" and includes an introduction, sample area and intensity information, and a photo of a person holding a fish. A right sidebar lists "Striped Bass Monitoring" resources.

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.

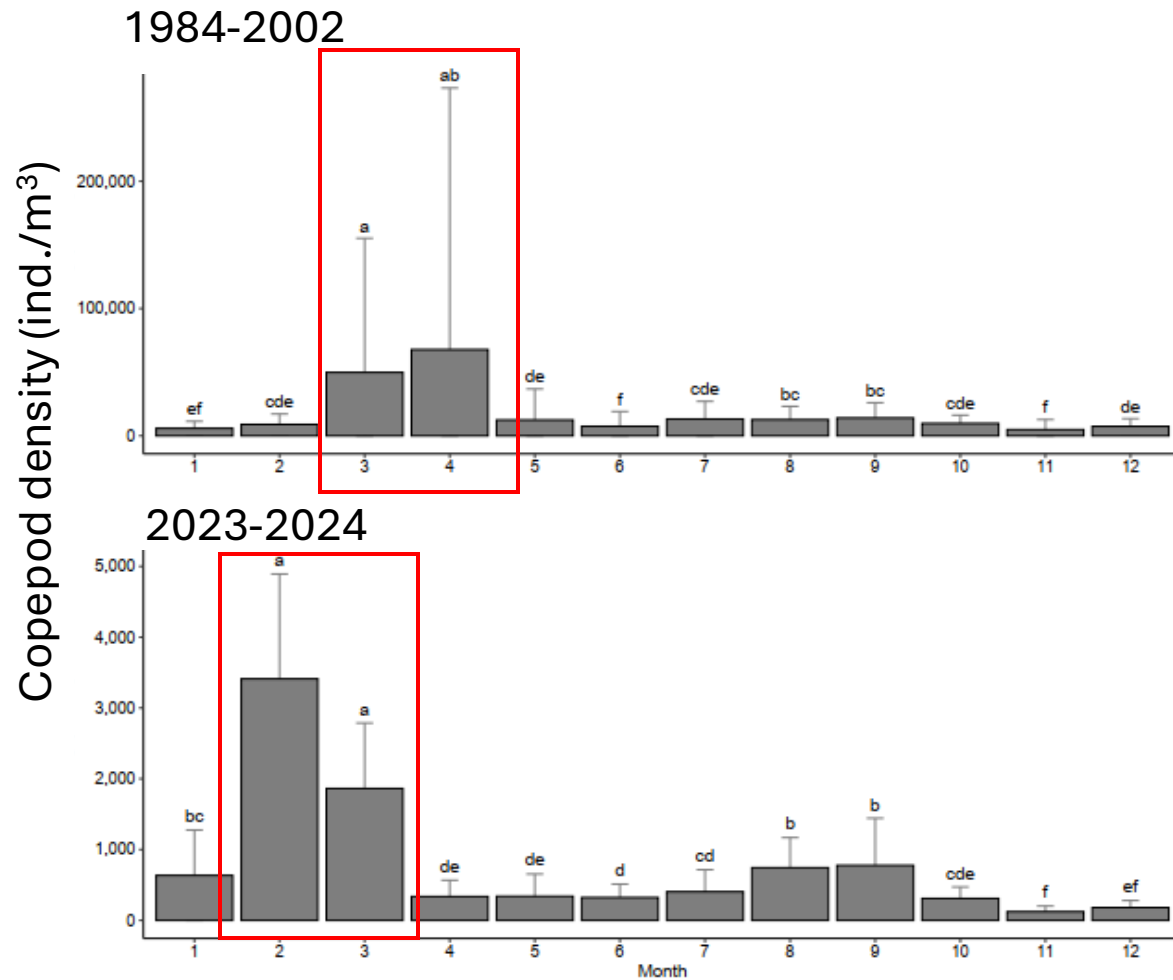
Striped Bass Monitoring

- [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

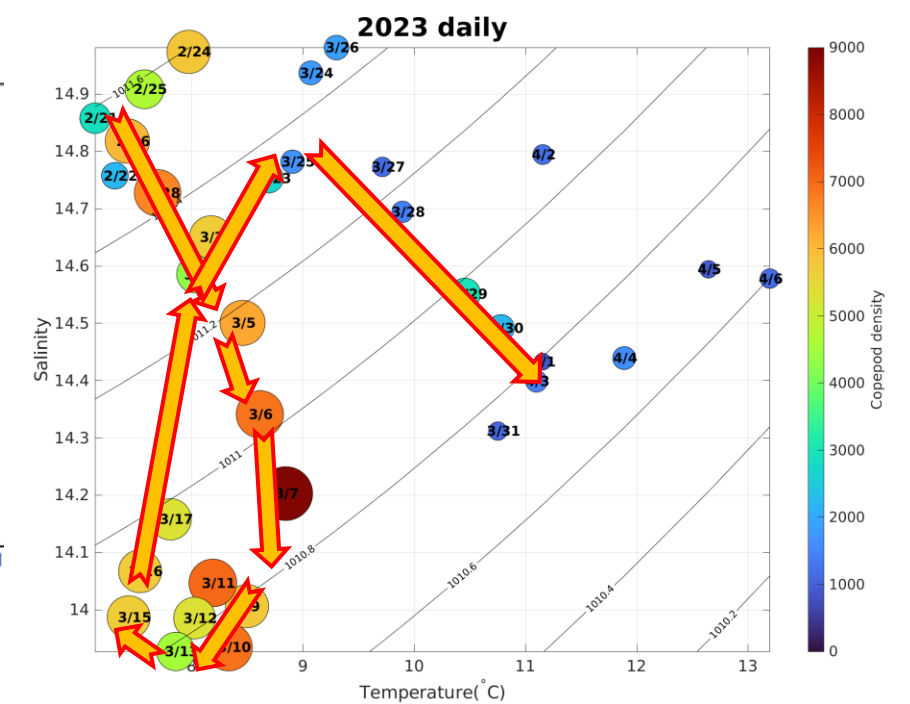
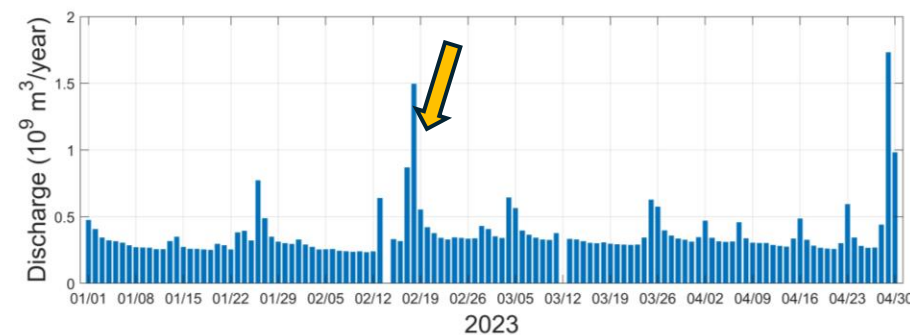
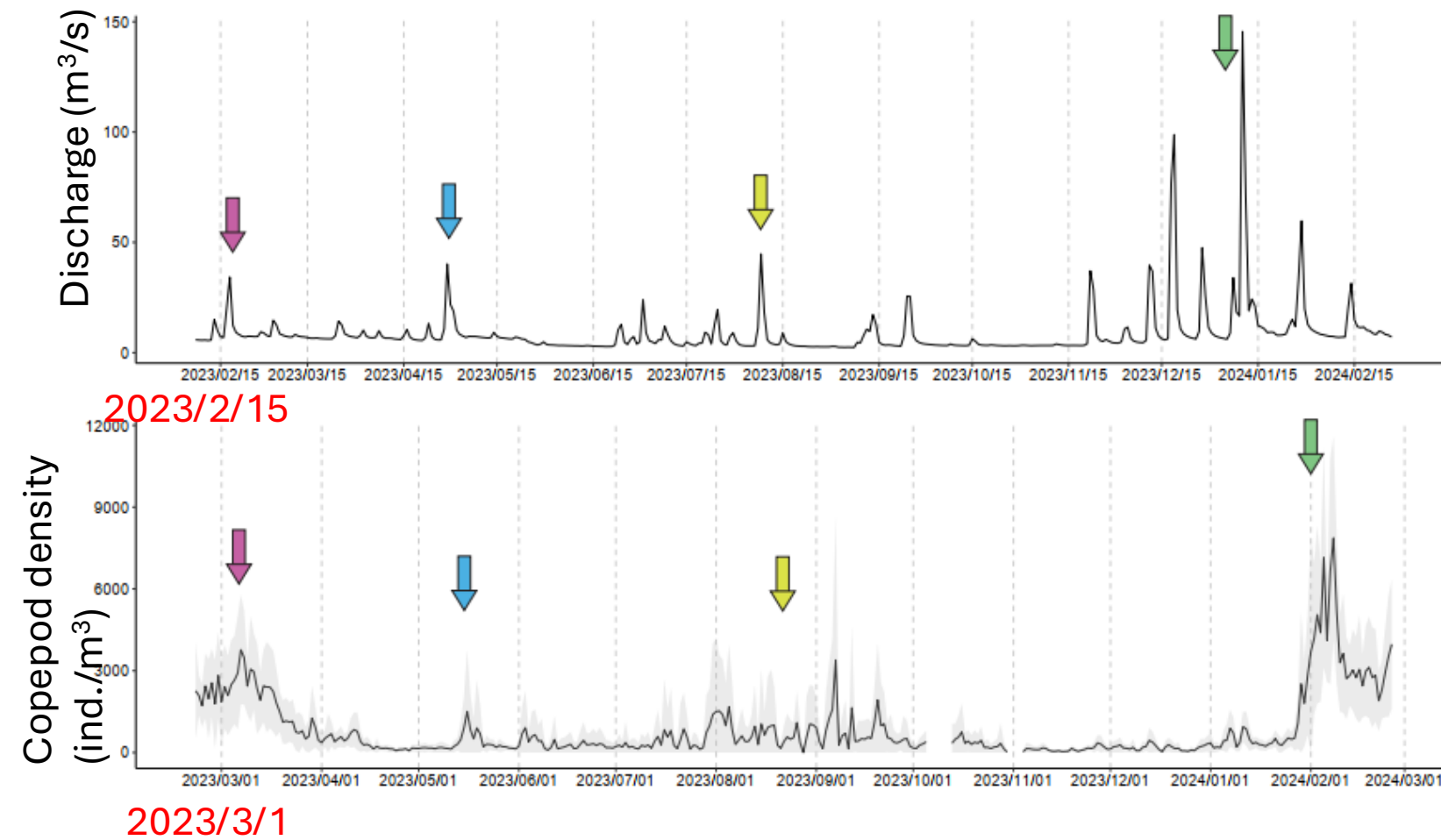
Results

➤ Copepod Density

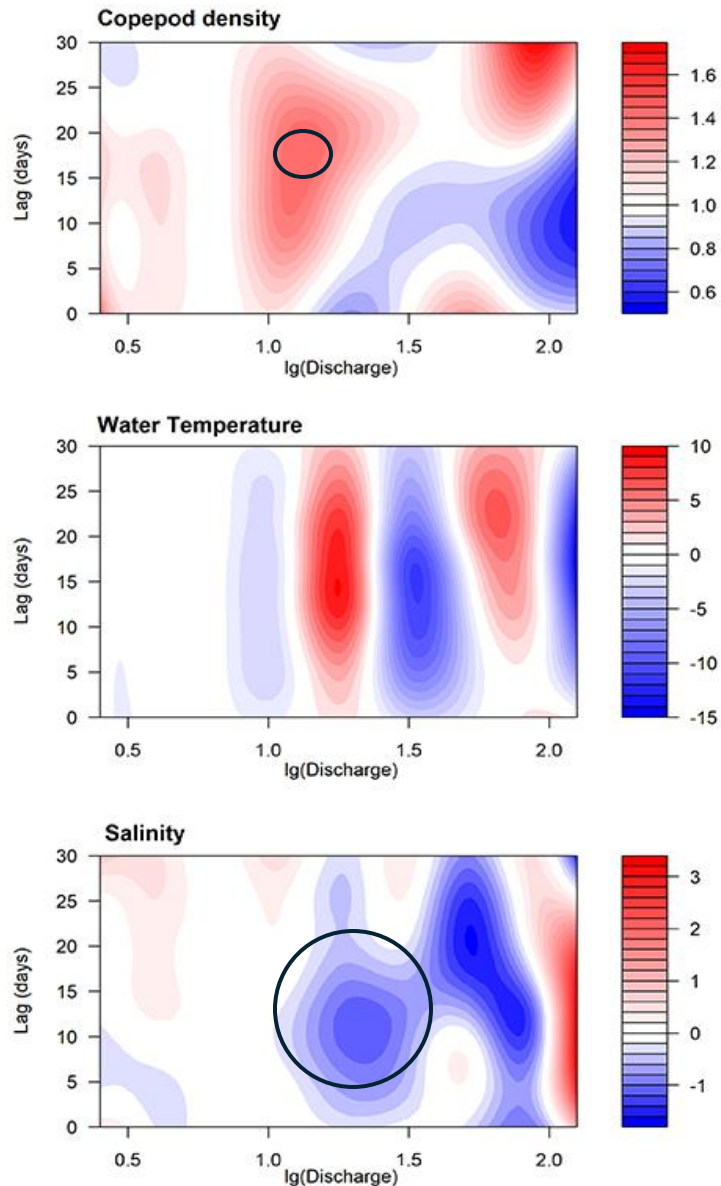


- Copepod density peaked in **spring** (Mar.-Apr.) in 1984-2002
- Copepod density peaked in **late winter and early spring** (Feb.-Mar.) in 2023-2024
- The spring peaking time **was 1-2 months earlier** than 30 years ago

Results



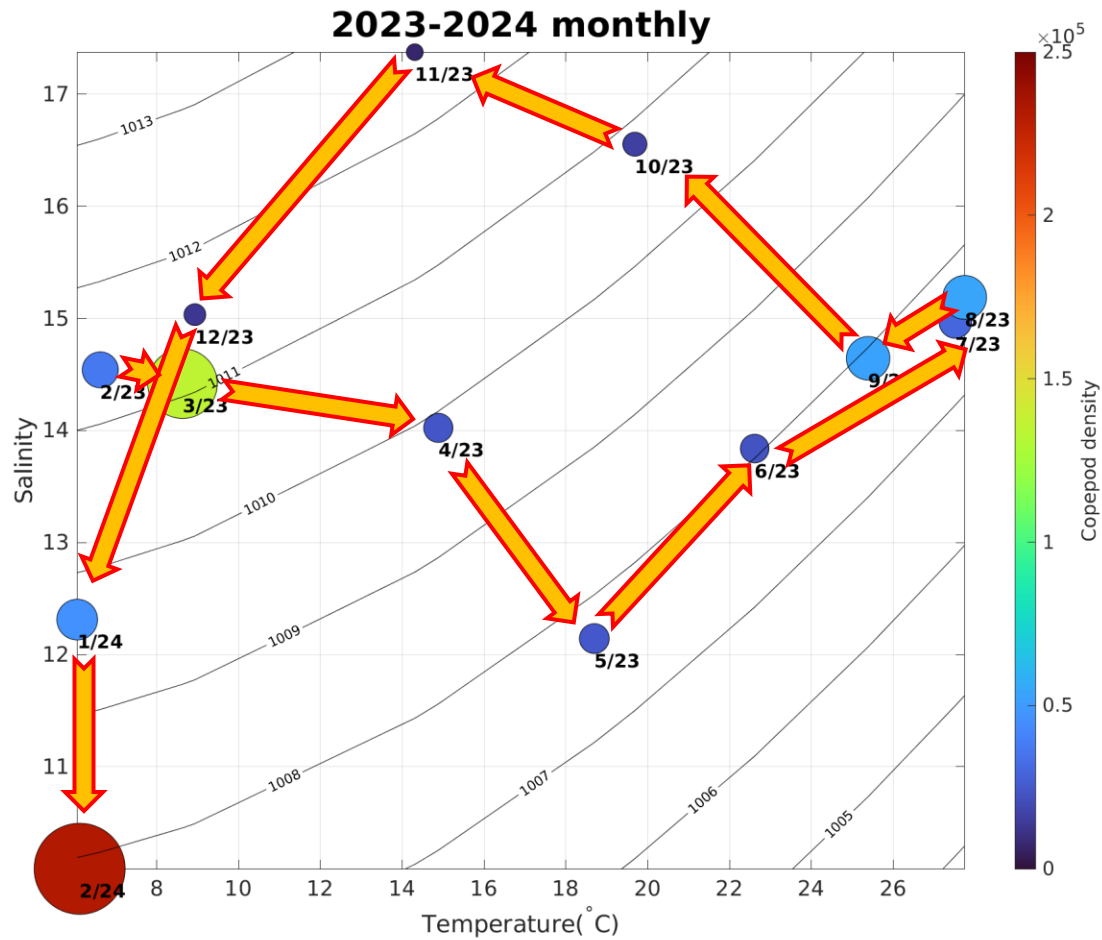
Results



Distributed Lag Non-linear Model (DLNM) results:

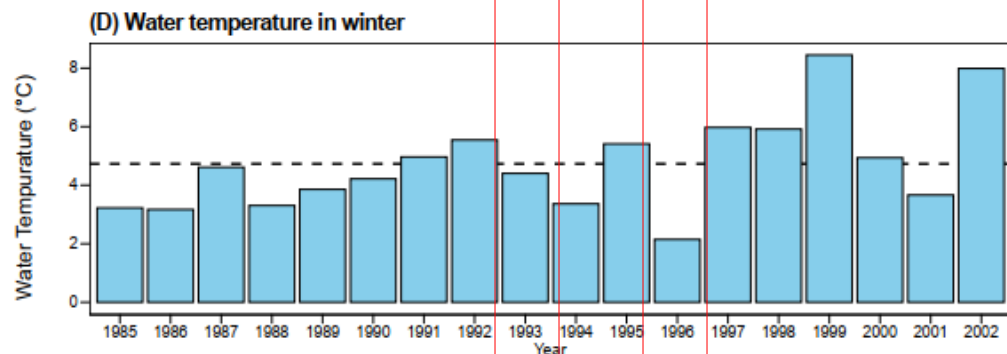
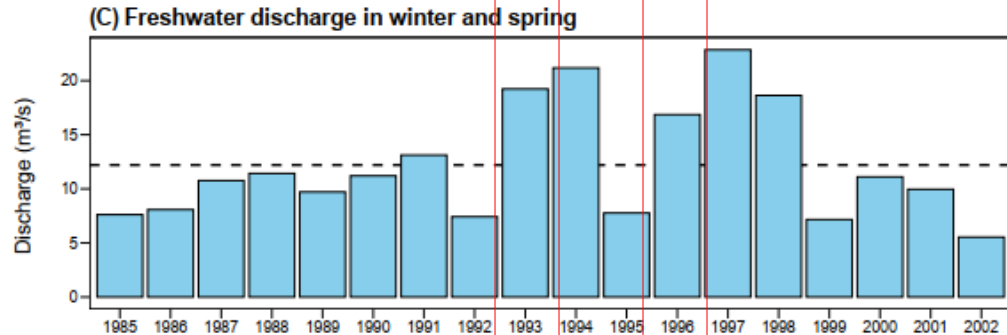
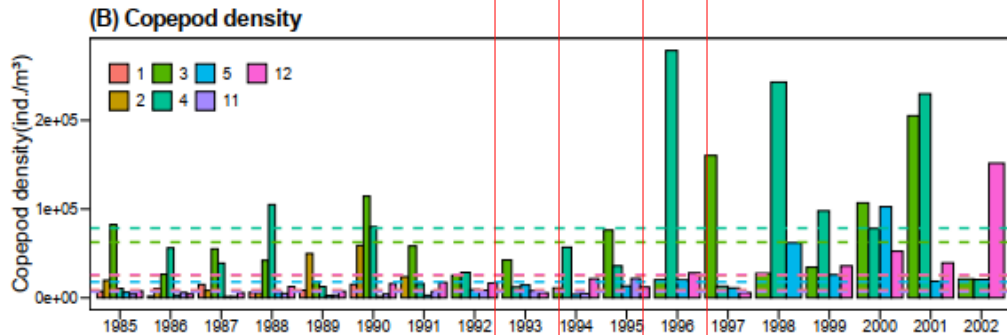
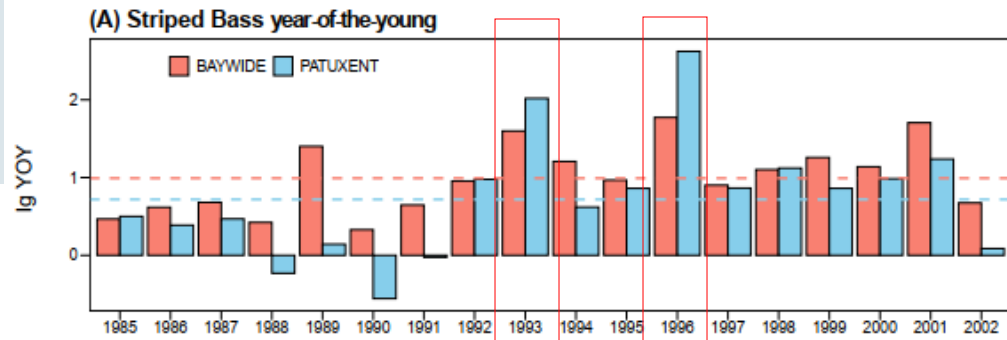
- Moderate freshwater discharge had a **positive effect** on copepod density with the strongest effect estimated **at 27.5 m³/s and a 17-day lag**
- No obvious effect on water temperature; other factors influence T more, likely seasonality
- **Negative effect** on salinity

Results



Discharge-driven water mass controls:

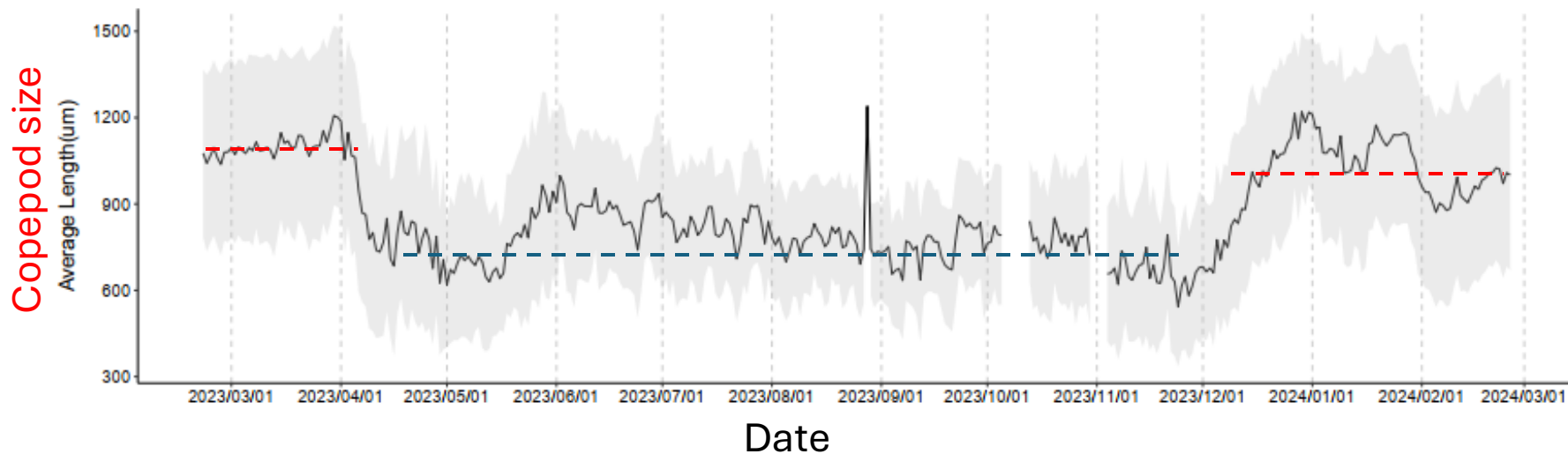
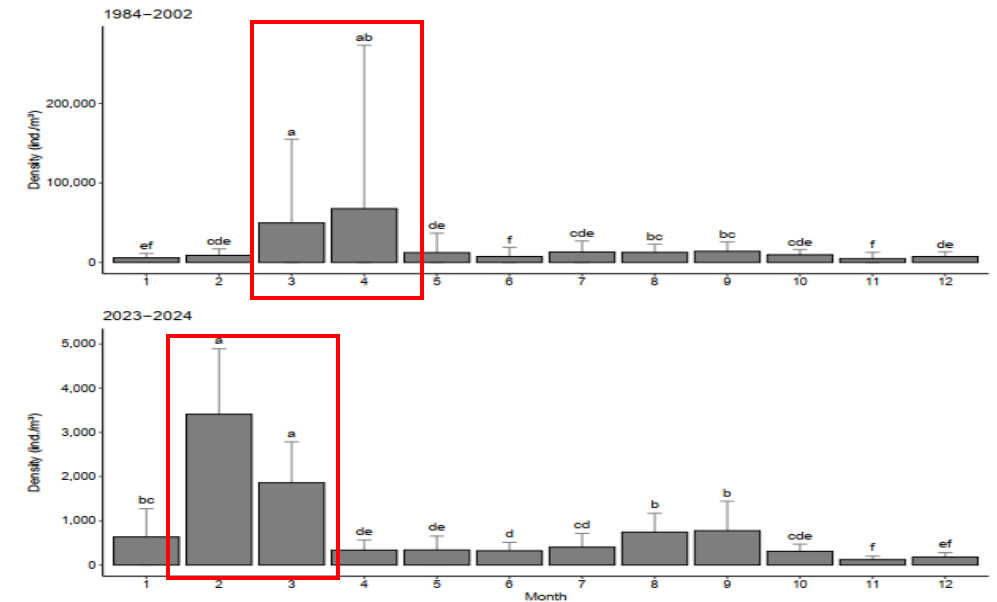
- Copepod density was elevated during winter and early spring (December to March), a period characterized by **cold** and relatively **fresh** water masses
- Copepod density declined in late spring to early autumn (April to September) with a **warm** water mass.



- 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

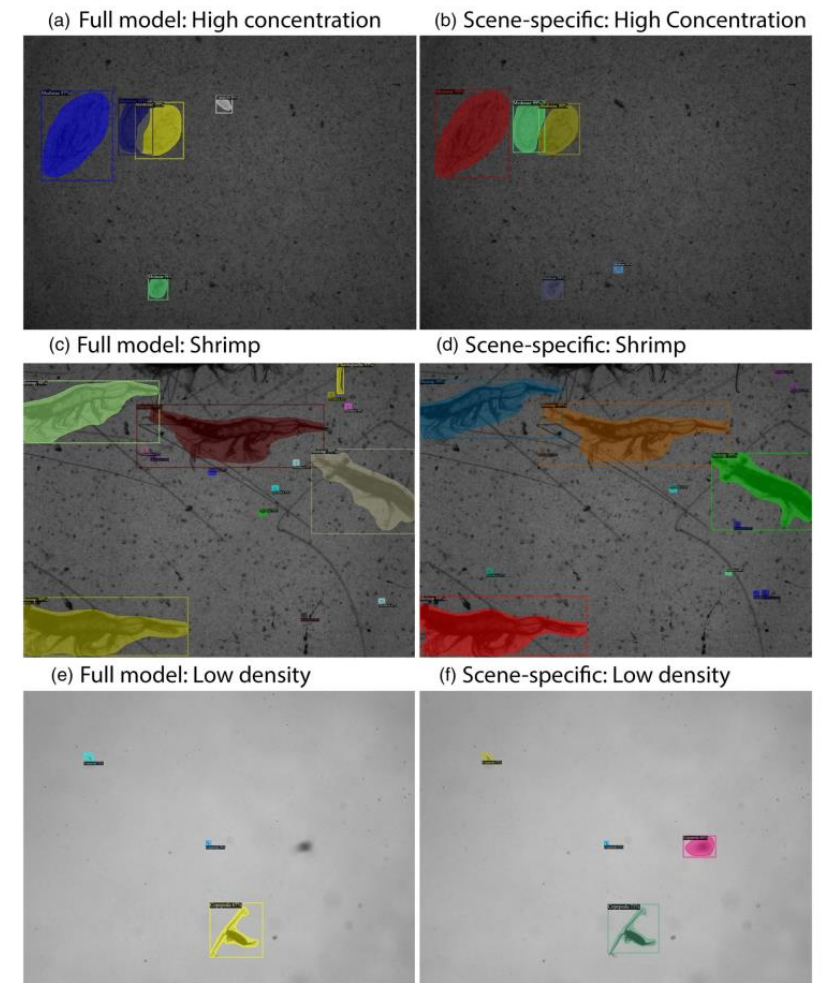


Fig. 5. Examples of processed underwater plankton images from three different scene categories using the full model and scene-specific models.

(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?