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

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11/11/2025

Introduction

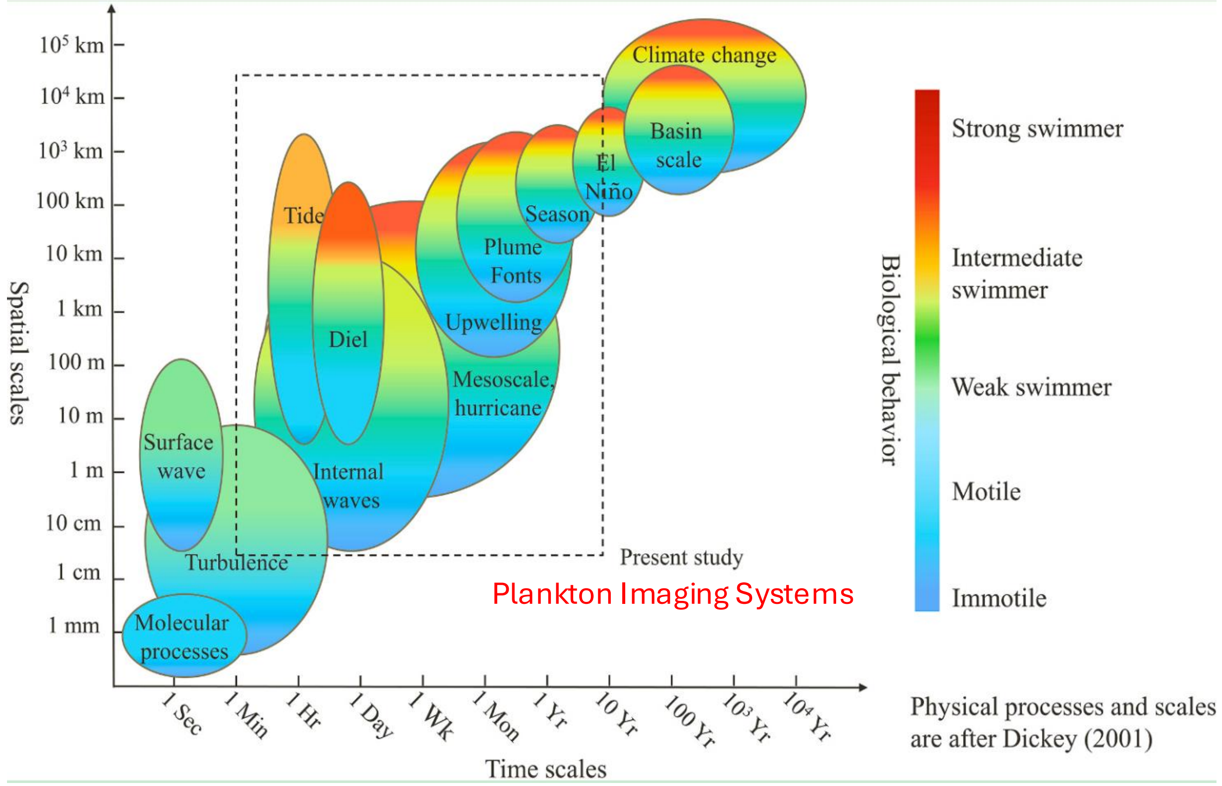
- Estuaries are important habitats for numerous diadromous species, yet susceptible to climate change.
  - Patuxent River Estuary is a representative shallow water estuary (~ 2.5 m).

- Copepods are key links in aquatic food webs, serving as an abundant food source for fish larvae and directly influencing fish recruitment.

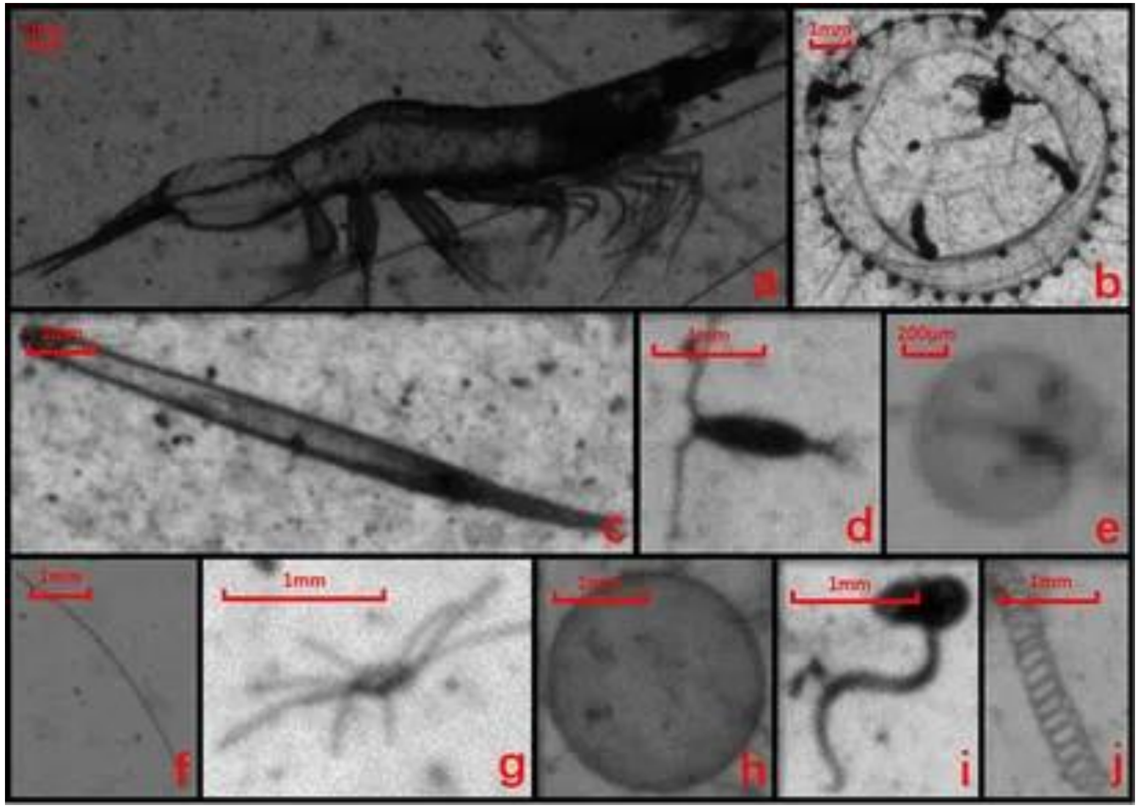
- Freshwater discharge has been identified as a primary determinant of copepod phenology (Kimmel and Roman 2004).
  - The quantification of discharge effects remains challenging, particularly for brief, episodic events.

I am yummy food to fish!

Introduction



(Bi et al. 2022)



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

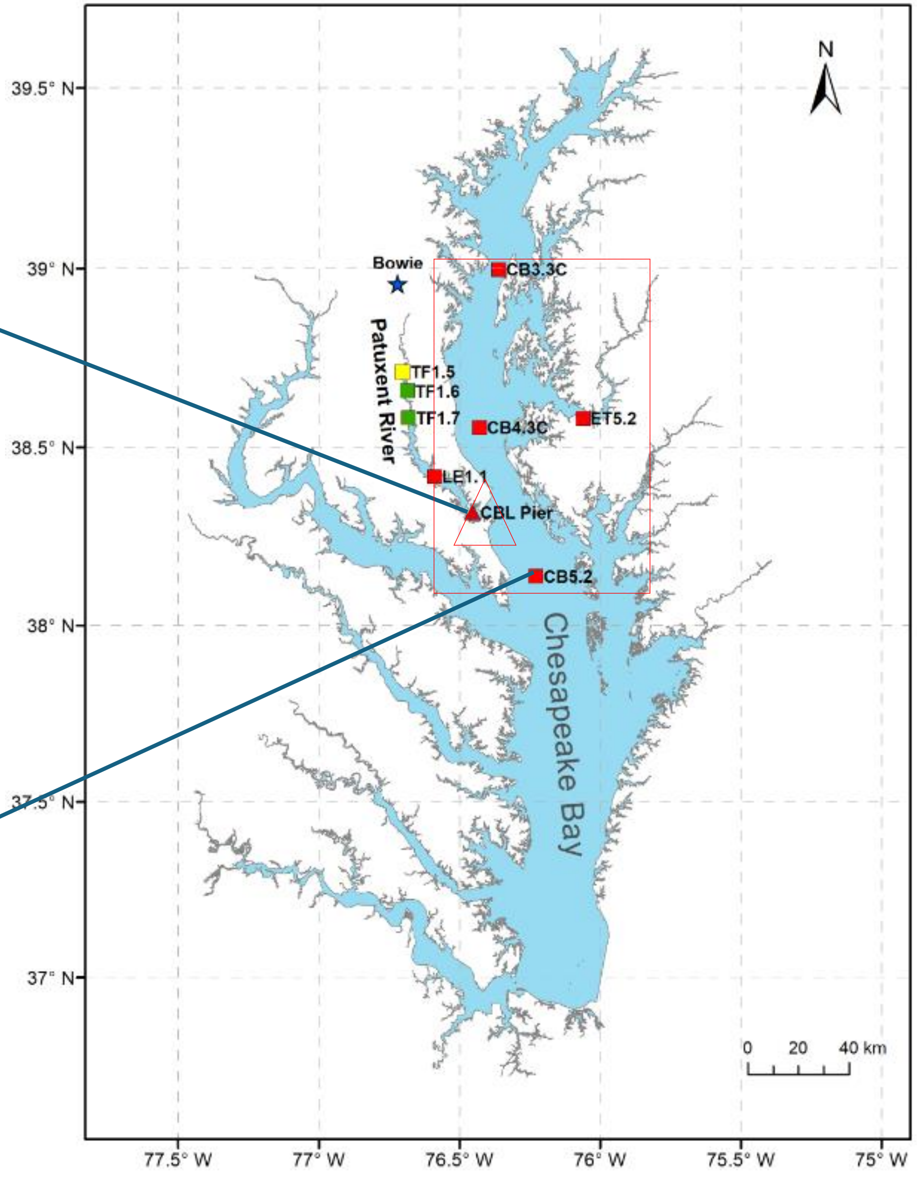
➢ *Study area*

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*

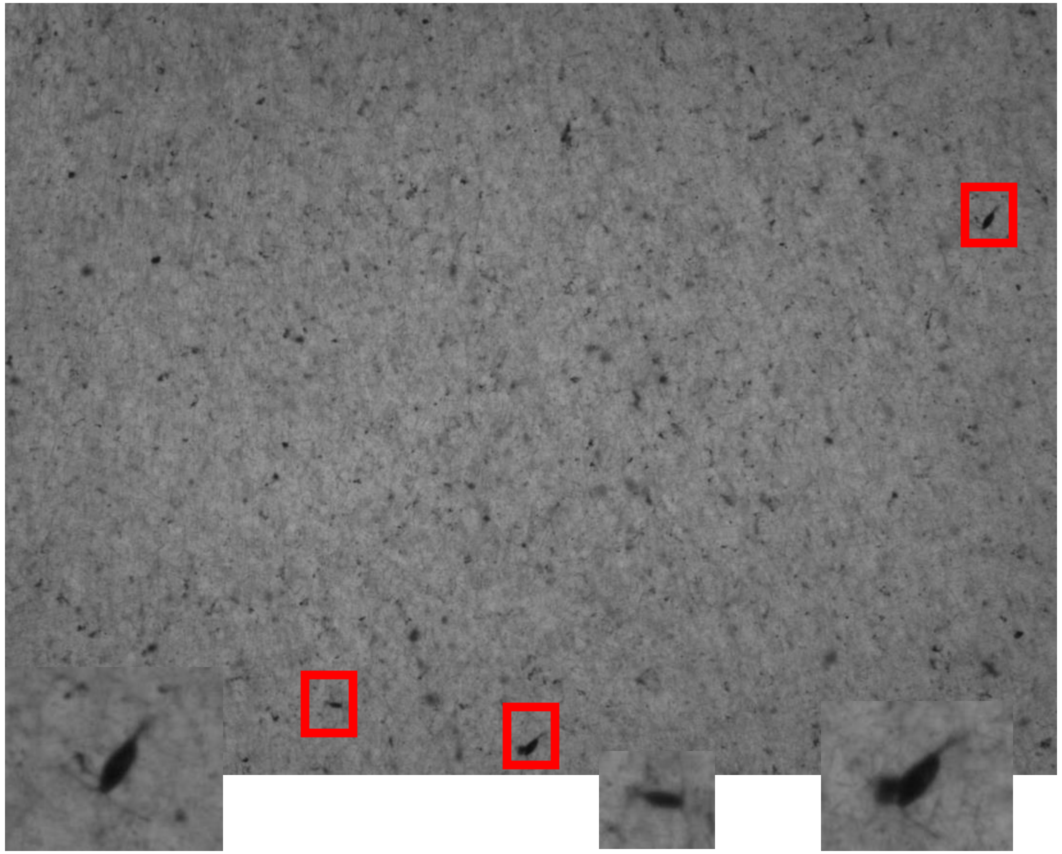
- *In-situ* zooplankton images were collected from Feb 2023 to Feb 2024 at CBL pier, using PlanktonScope, a shadowgraph imaging system

- 640 nm strobe illumination & 2 µs exposure

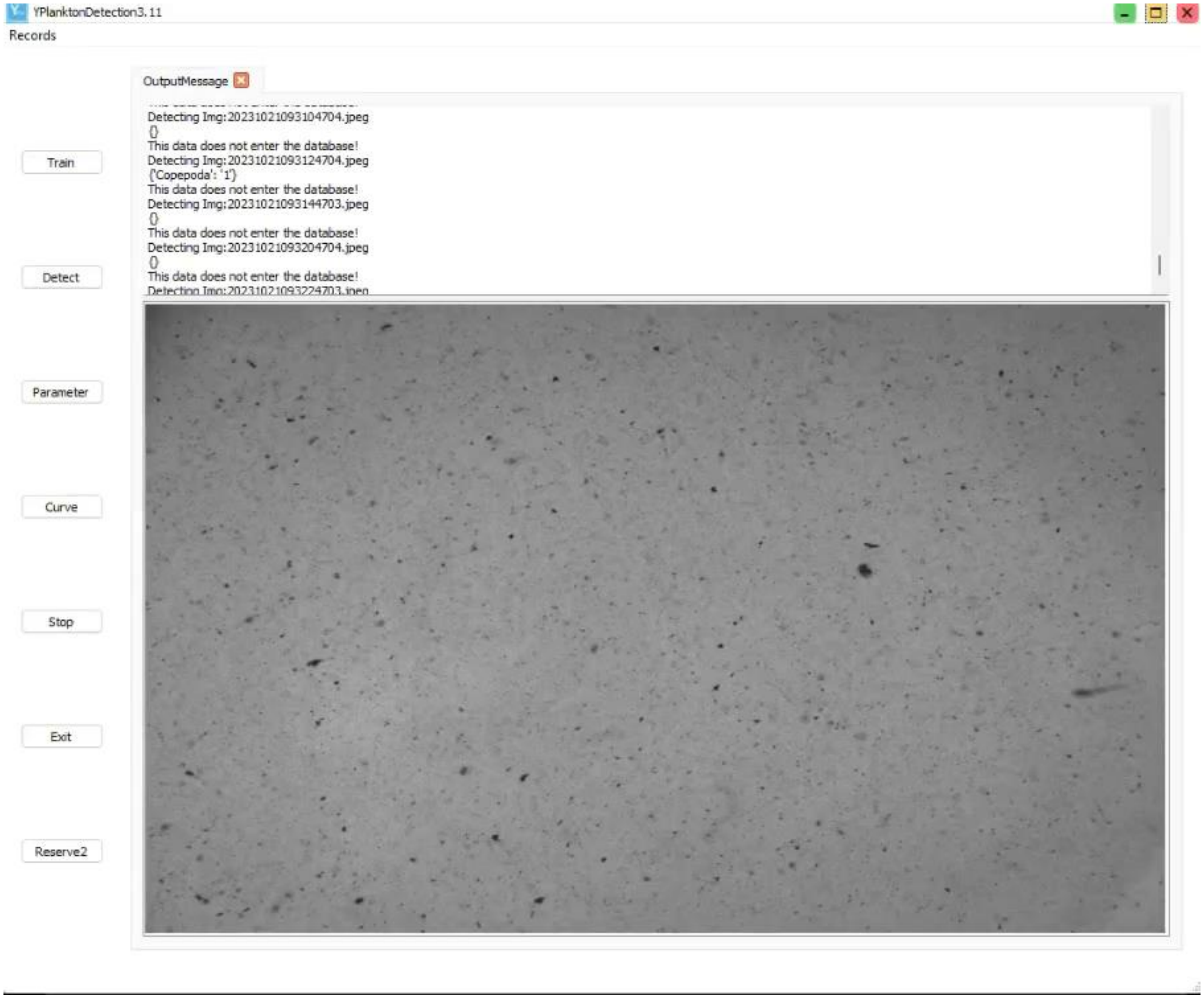
- Pixel resolution is 20 µm

- 1/20 Hz (1 frame per 20 seconds)

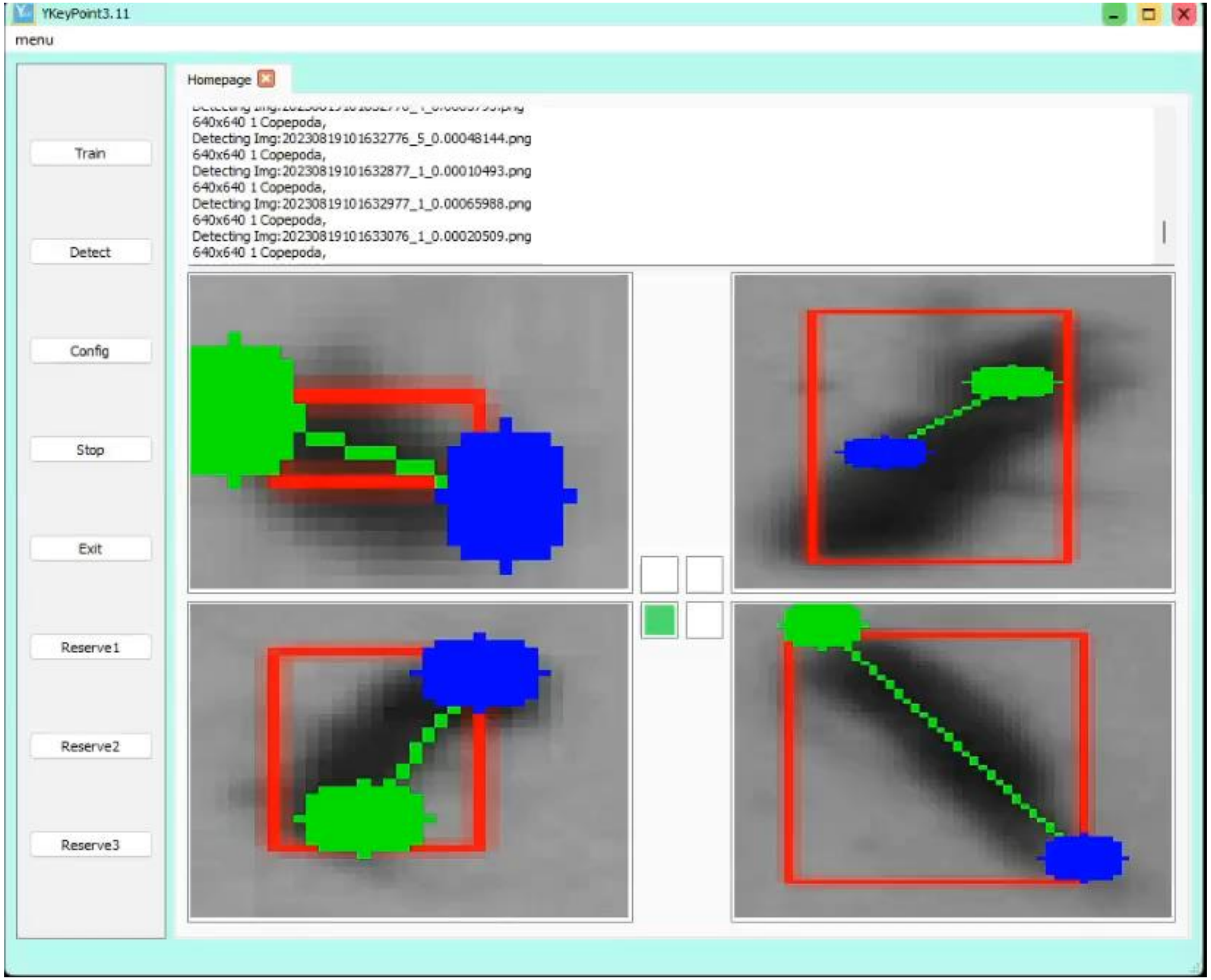
- ~ 236 mL / frame



Example frame from PlanktonScope


YPlanktonDetection3.11
Records
OutputMessage
Detecting Img:20231021093104704.jpeg
{}
This data does not enter the database!
Detecting Img:20231021093124704.jpeg
{'Copepoda': '1'}
This data does not enter the database!
Detecting Img:20231021093144703.jpeg
{}
This data does not enter the database!
Detecting Img:20231021093204704.jpeg
{}
This data does not enter the database!
Train
Detect
Parameter
Curve
Stop
Exit
Reserve2

PlanktonScope



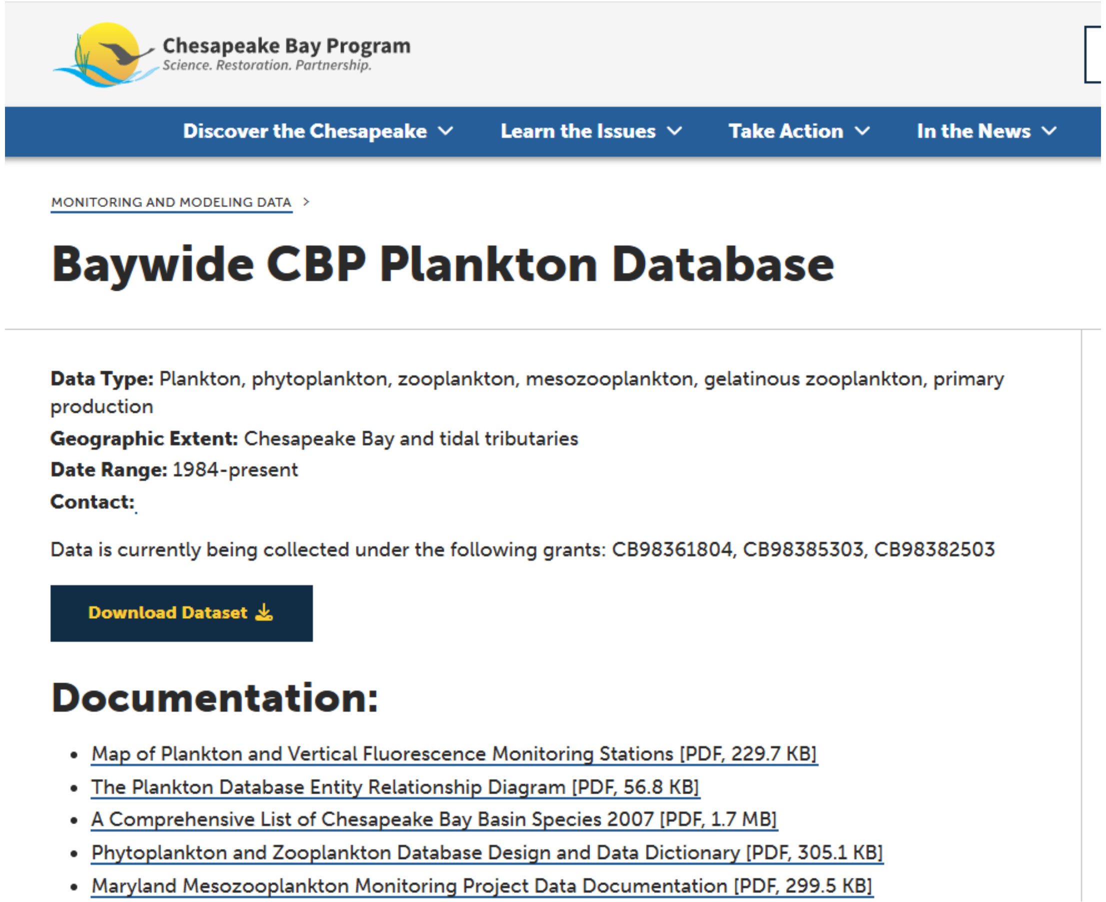
	True value (ImageJ)	Measured value (Key point)	Difference
	A	B	G
91	15.70211	16.17	0.029798
92	28.12548	28.71	0.020782
93	33.75	34	0.007407
94	22.94754	23.3	0.015359
95	28.18499	28.85	0.023594
96	32.60383	31.77	0.025575
97	22.1109	22.89	0.035236
98	33.38345	33.75	0.01098
99	23.4375	23.27	0.007147
100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

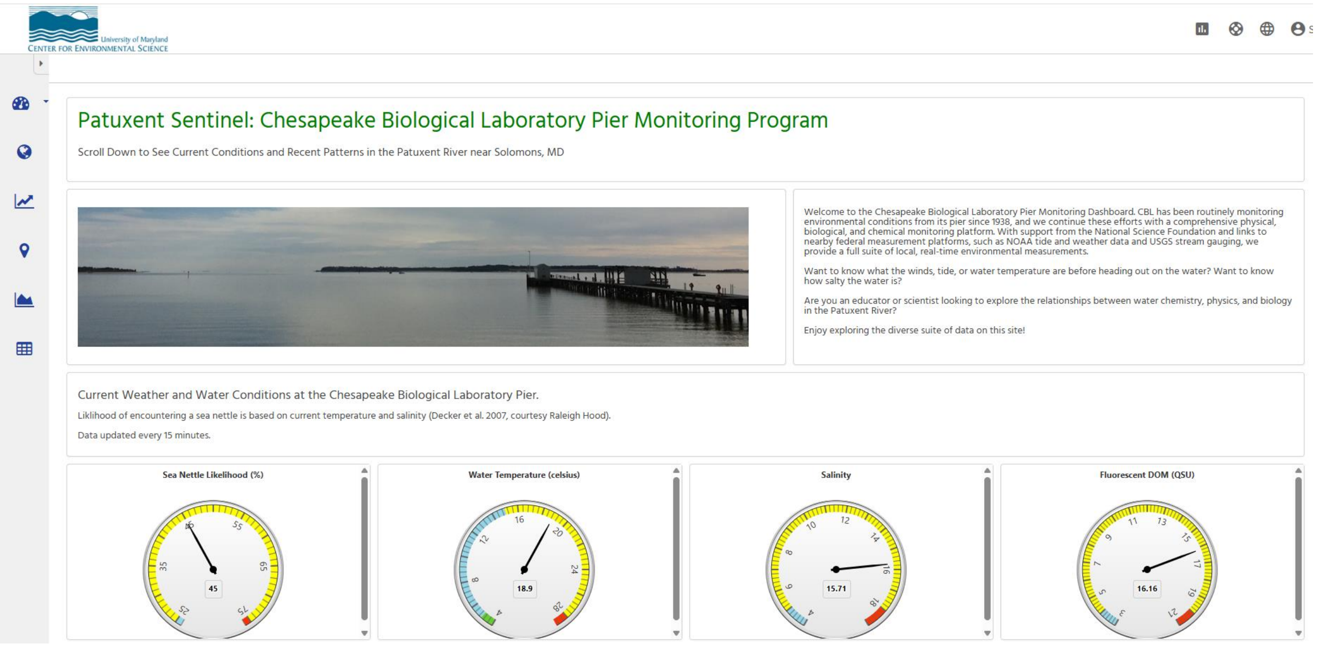


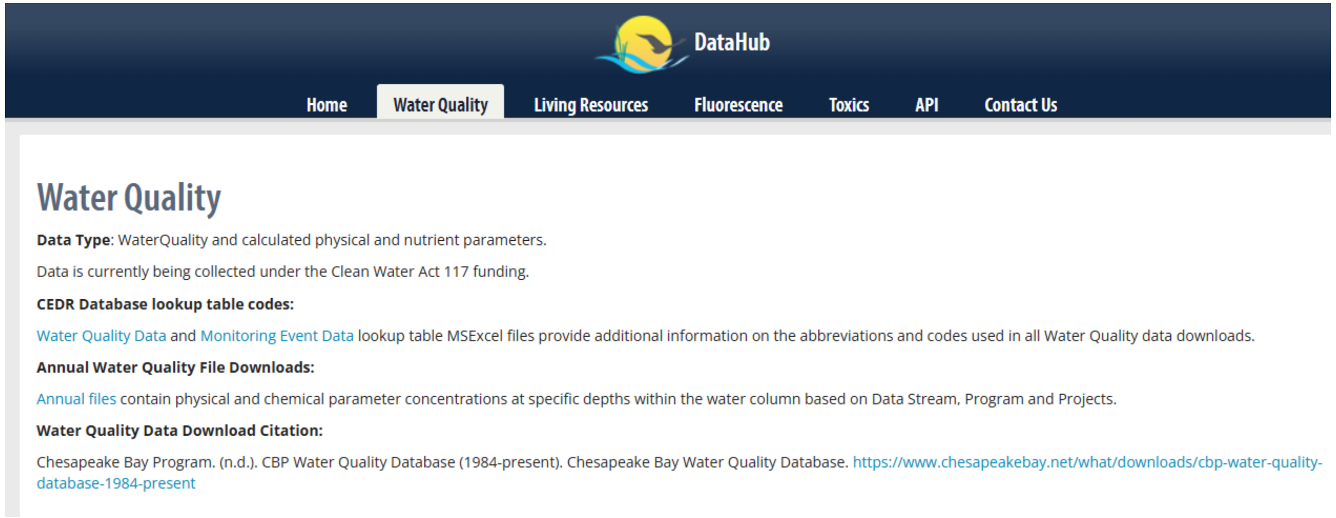
Methods

➢ *Environmental data*

- Salinity
- Water temperature

CBL Pier Monitoring Dashboard &
CBP Water Quality DataHub





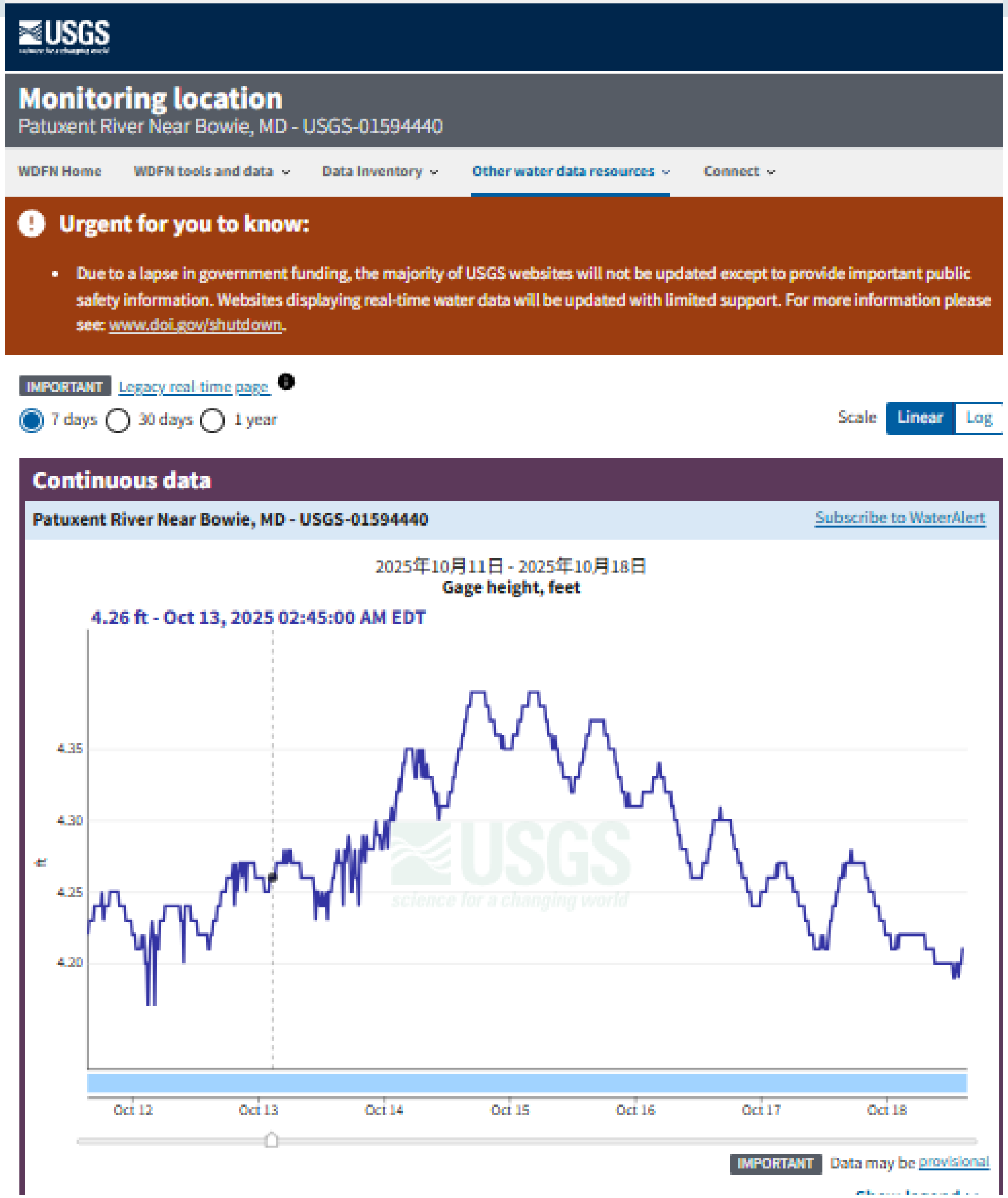
Methods

➢ *Environmental data*

- Salinity
- Water temperature
- Freshwater discharge rates

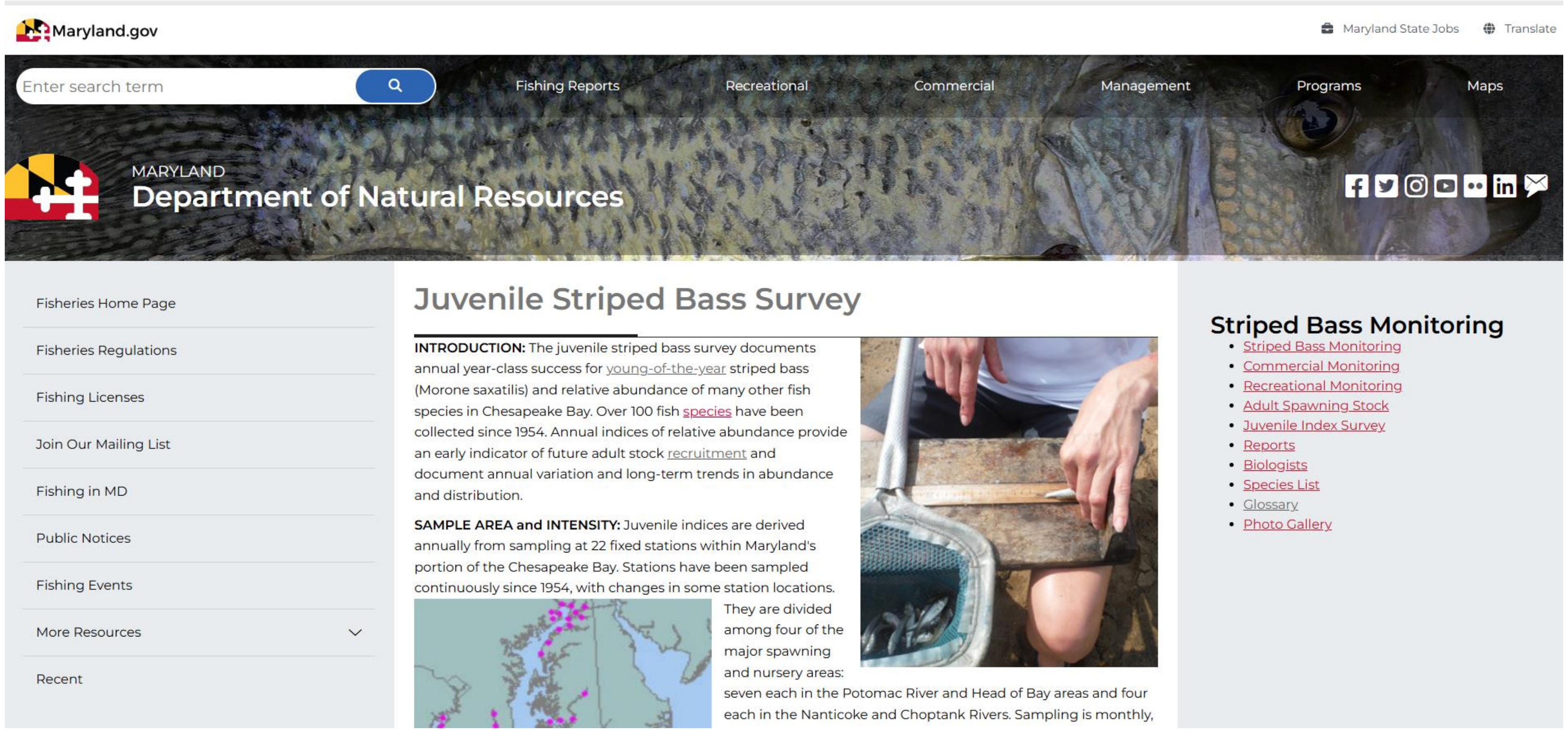
Distributed Lag Non-linear Model (DLNM) was applied to study the effect of freshwater discharge

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



Methods

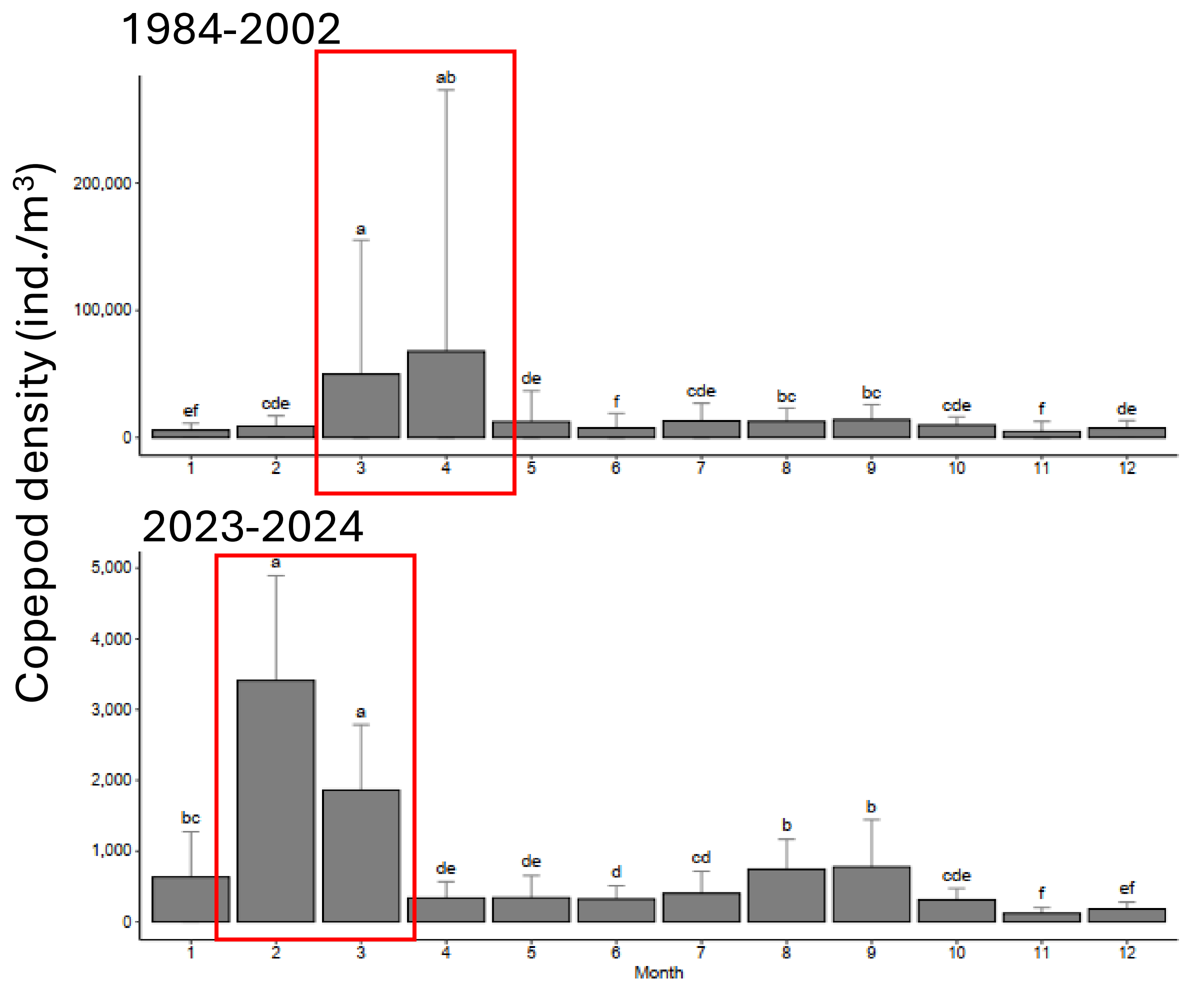
➢ *Striped bass recruitment data*



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

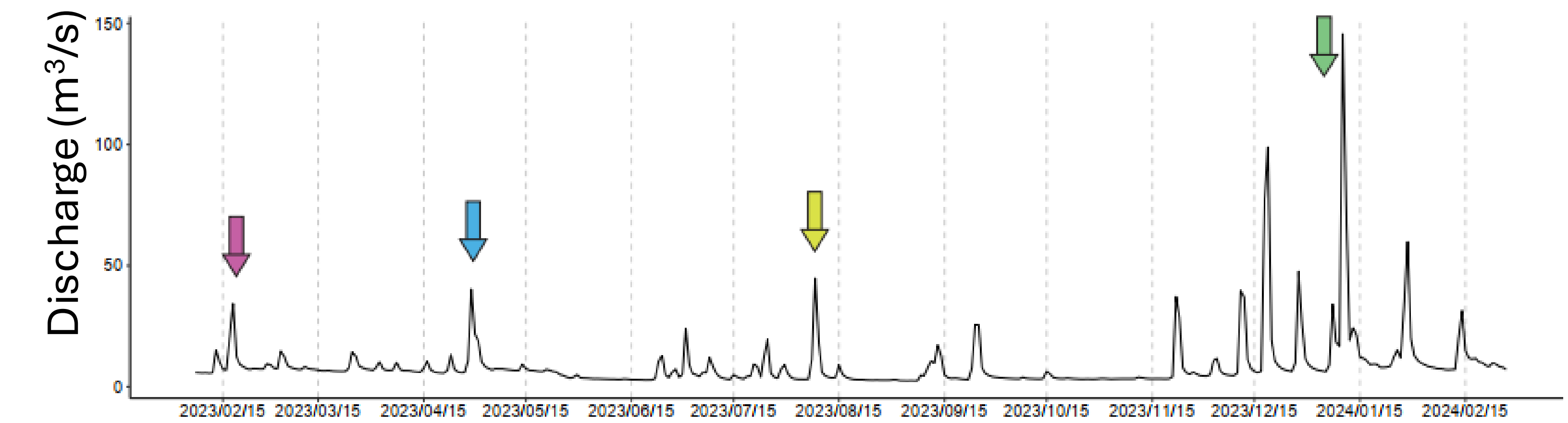
Results

➢ Copepod Density

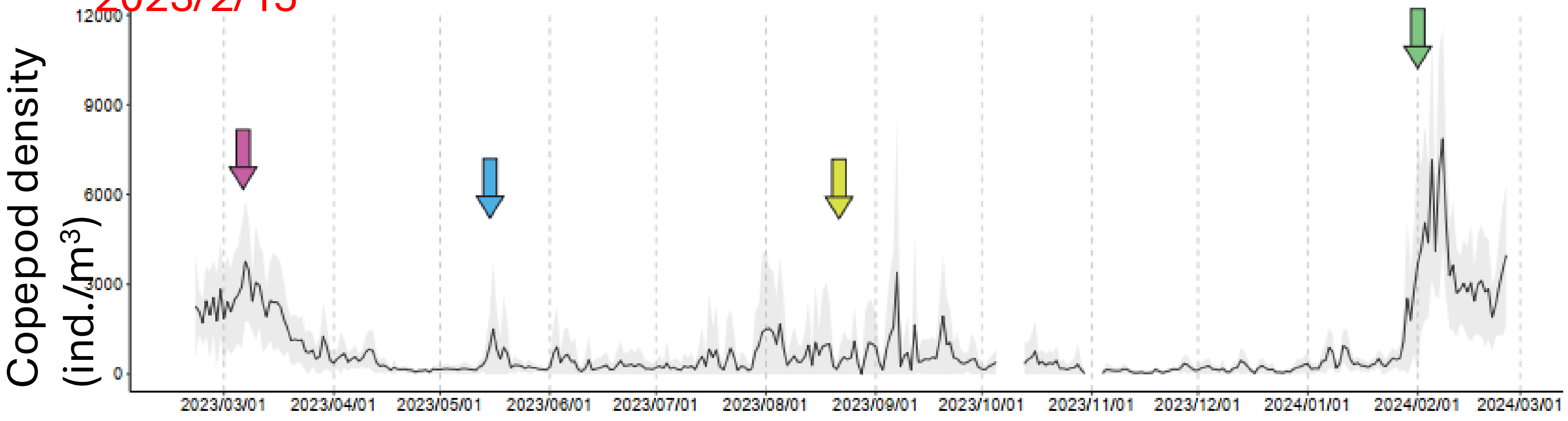


- Copepod density peaked in spring (Mar.-Apr.) in 1984-2002
- Copepod density peaked in late winter and early spring (Feb.-Mar.) in 2023-2024
- The spring peaking time was 1-2 months earlier than 30 years ago

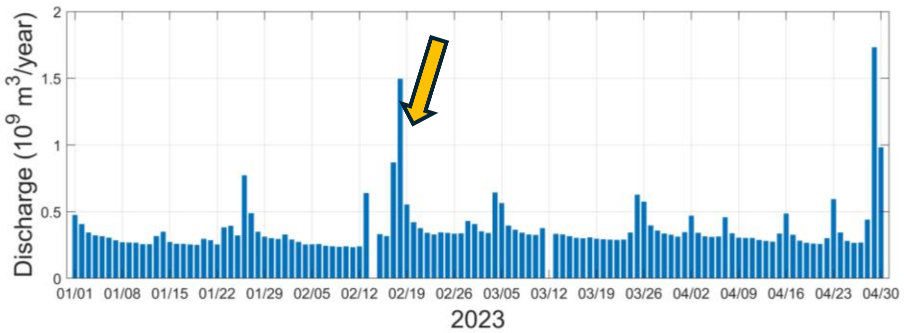
Results

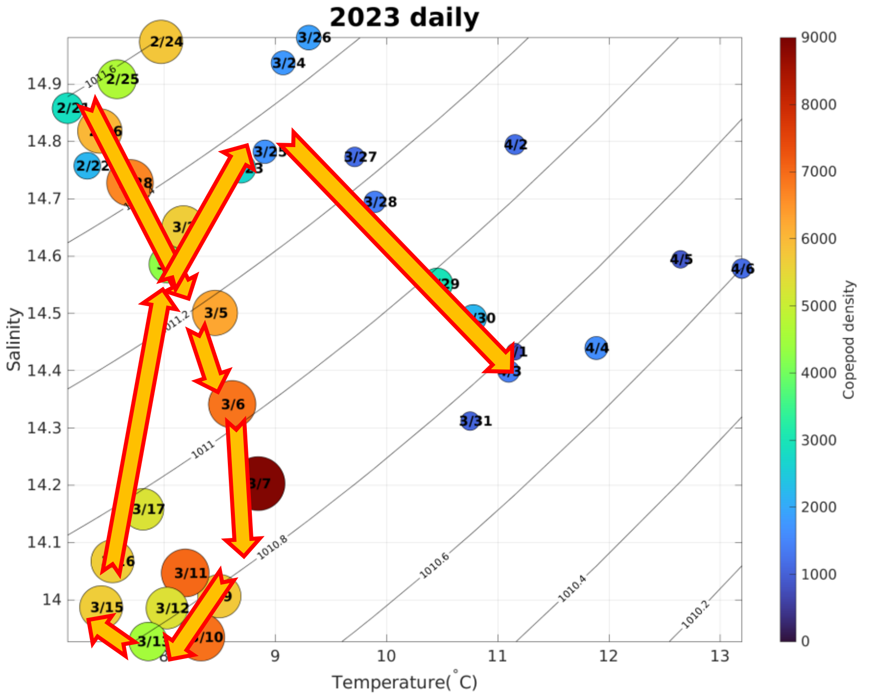


2023/2/15

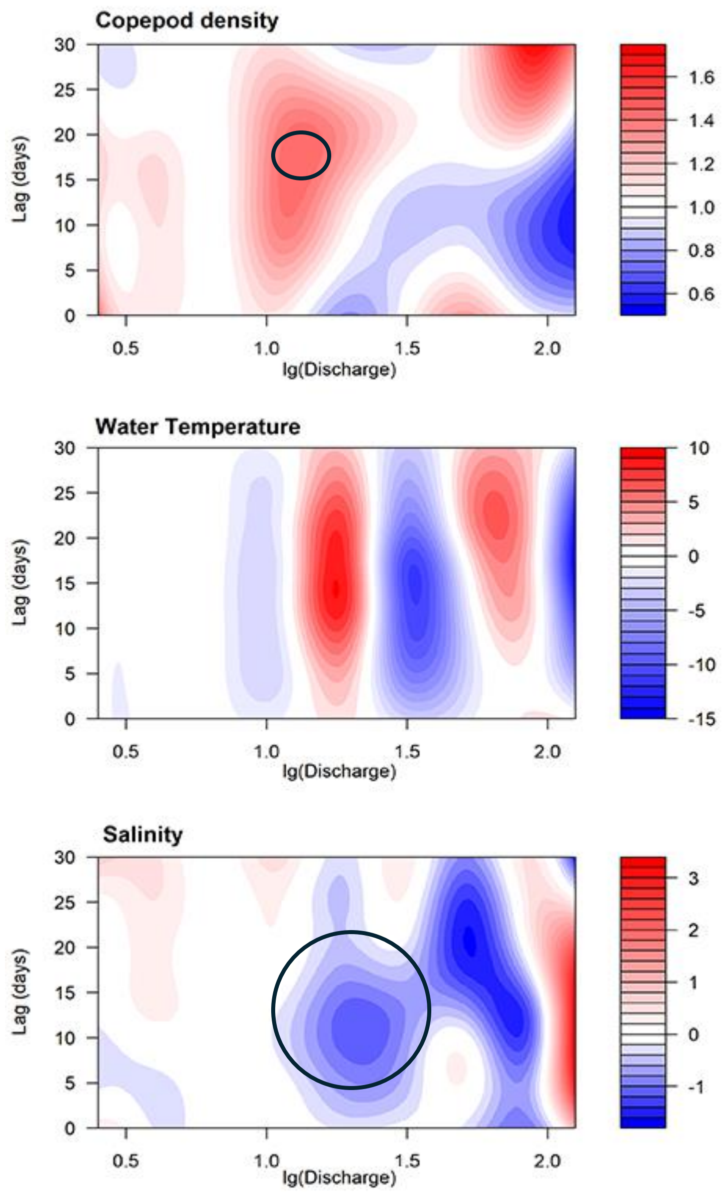


2023/3/1





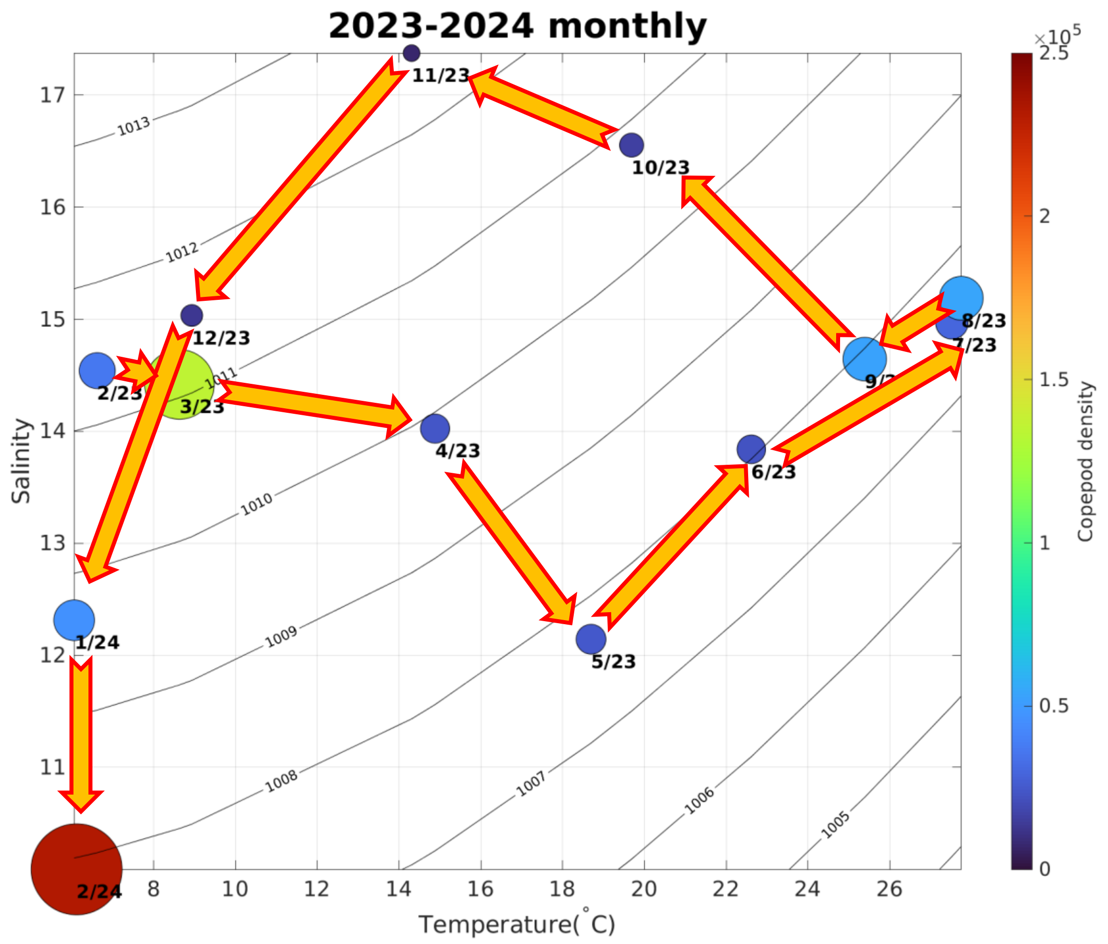
Results



Distributed Lag Non-linear Model (DLNM) results:

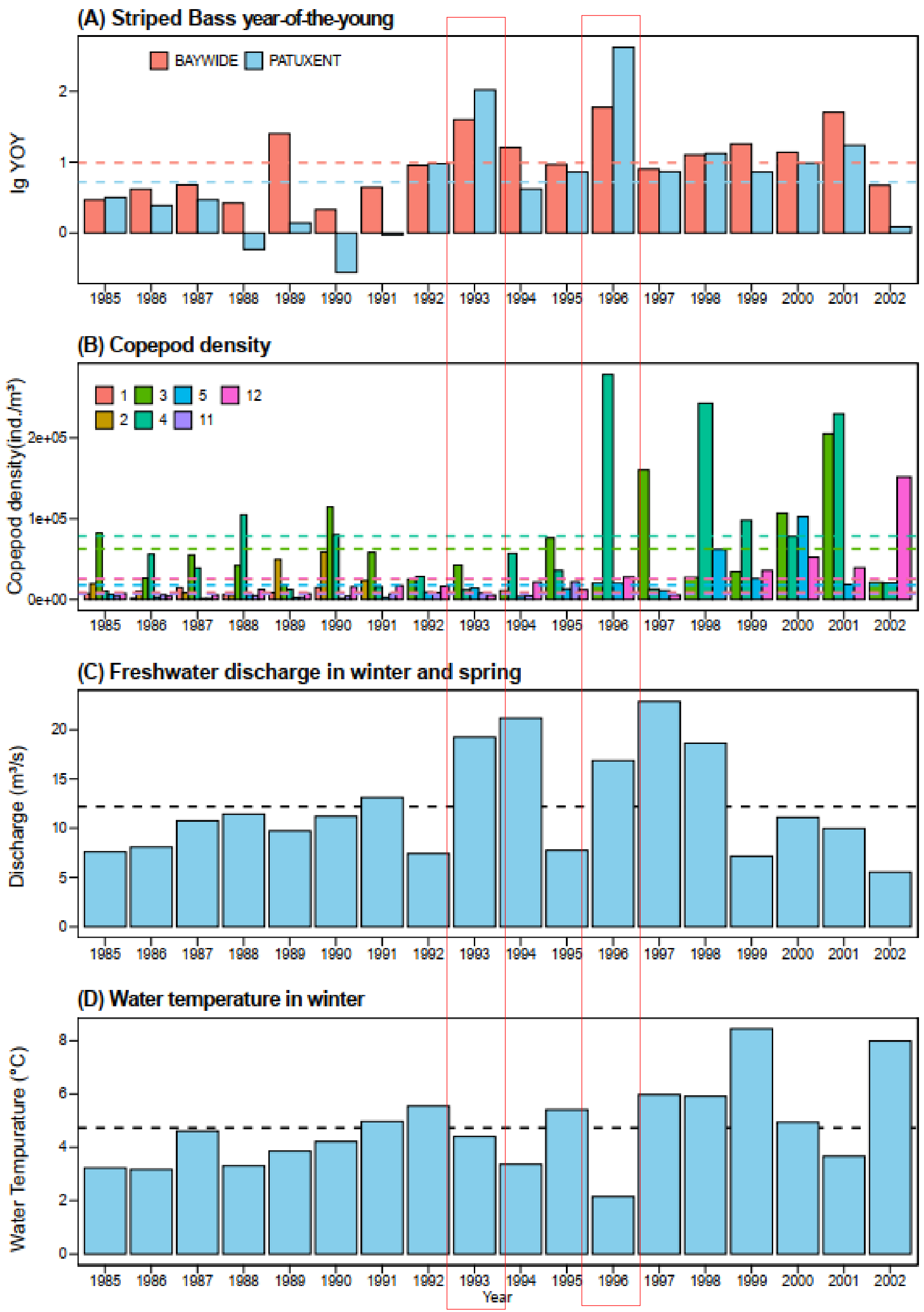
- Moderate freshwater discharge had a positive effect on copepod density with the strongest effect estimated at 27.5 m^3/s and a 17-day lag
- No obvious effect on water temperature; other factors influence T more, likely seasonality
- Negative effect on salinity

Results



Discharge-driven water mass controls:

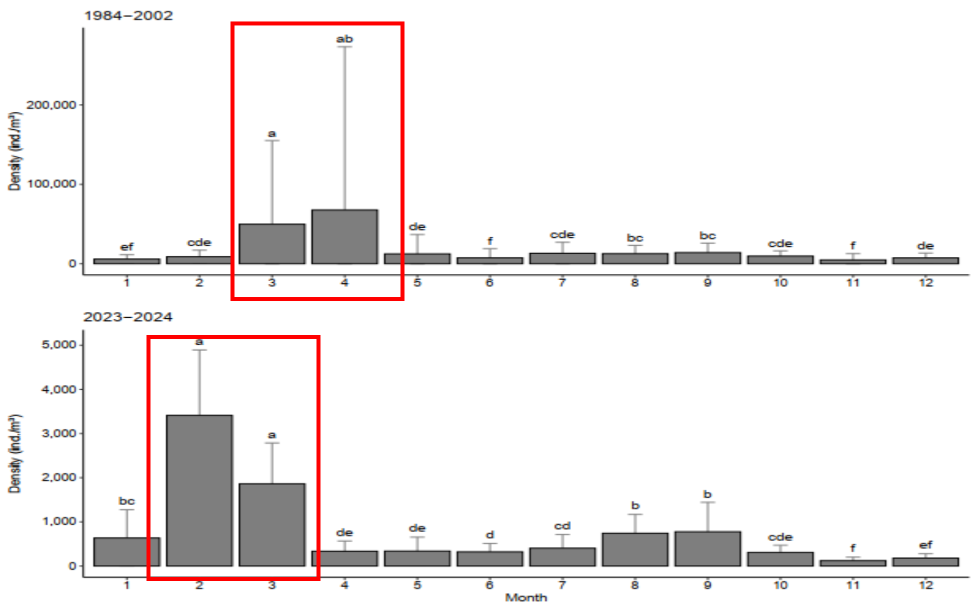
- Copepod density was elevated during winter and early spring (December to March), a period characterized by cold and relatively fresh water masses
- Copepod density declined in late spring to early autumn (April to September) with a warm water mass.

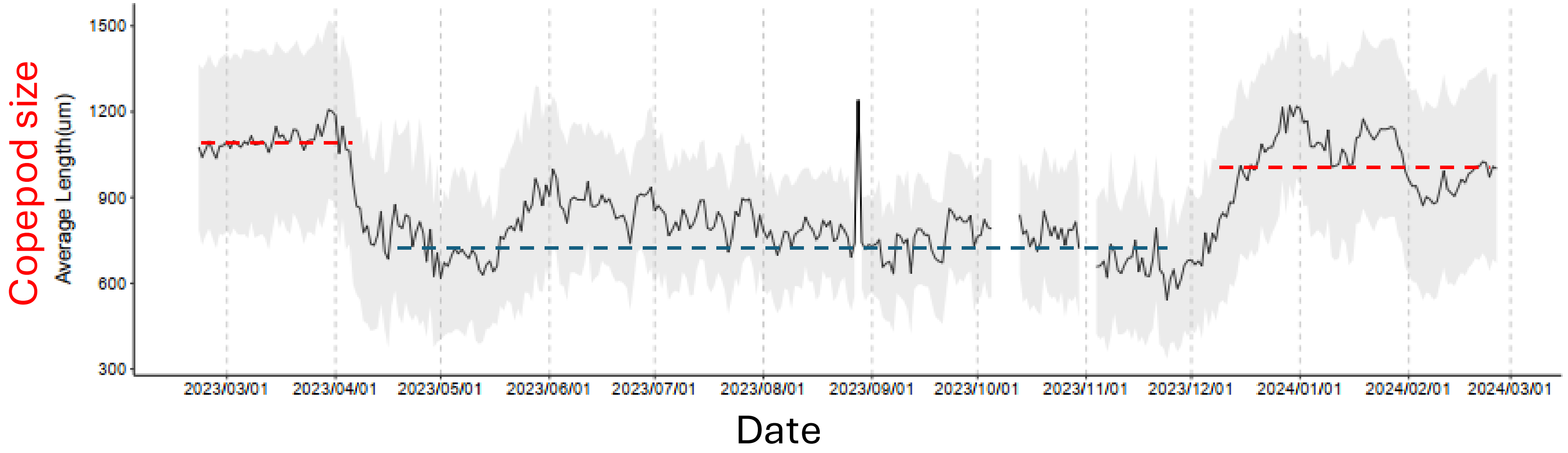


- Indices for young-of-the-year (YOY, per haul) striped bass were elevated during cold, wet years (e.g., 1993 and 1996).
- Low YOY during dry years with below-average discharge, even when winter temperatures were cold (e.g., 1985-1990 & 2002)
- YOY in 2023-2024 were near historical low.

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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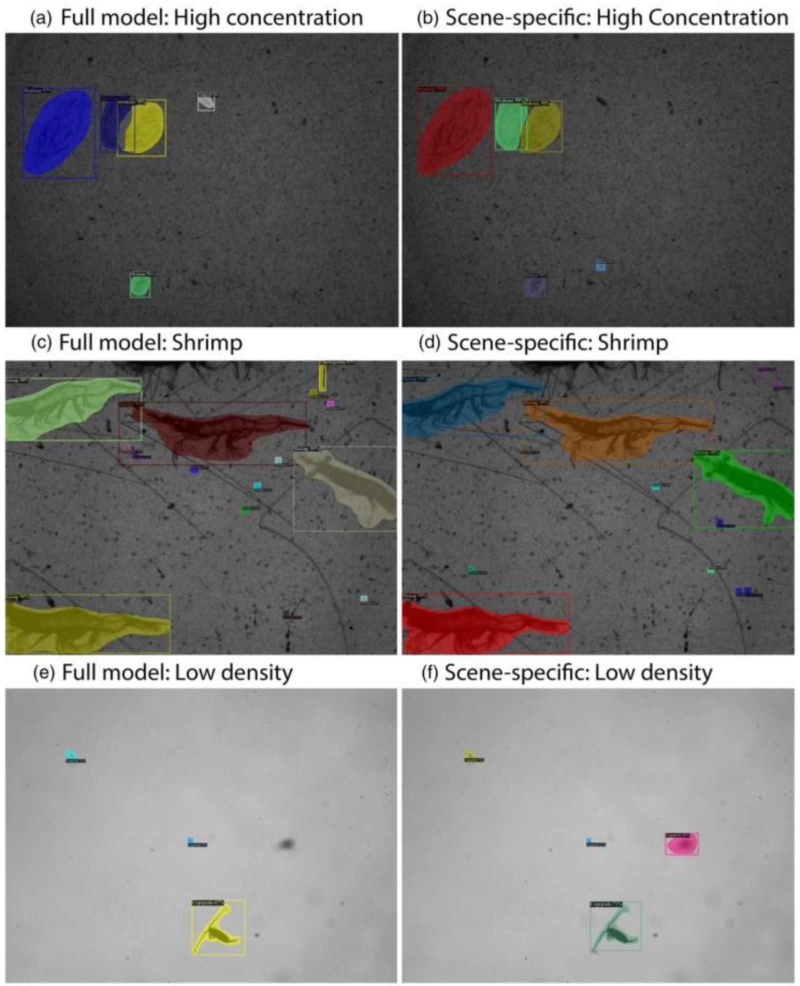

Fig. 5. Examples of processed underwater plankton images from three different scene categories using the full model and scene-specific models.

(Bi et al. 2024)

- 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

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.

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NOAA CHESAPEAKE BAY

Thank you!

Questions?