Considerations for Integrating Marine Heatwave Information to Indicate Potential Impacts to Fisheries

Climate Resiliency Workgroup Meeting, August 17, 2023

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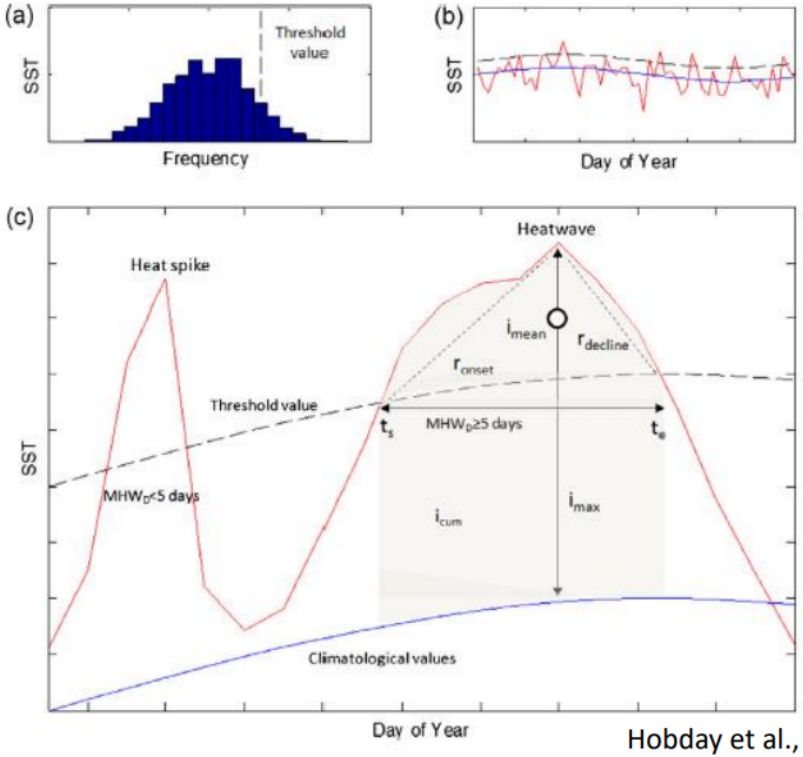
Acknowledgements: Jamileh Soueidan, CRC and Emily O'Keefe, CRC-NOAA Intern

Common Definition in Scientific Literature (slide from Shunk et al. presentation)

MHW Definition
(Hobday et al., 2016)

"A **discrete prolonged anomalously warm** water event in a particular location"

- **Anomalously warm**:
  90th percentile above climatology
- **Prolonged**:
  Period of at least 5 days
- **Discrete**:
  2-day gap between two 5-day intervals



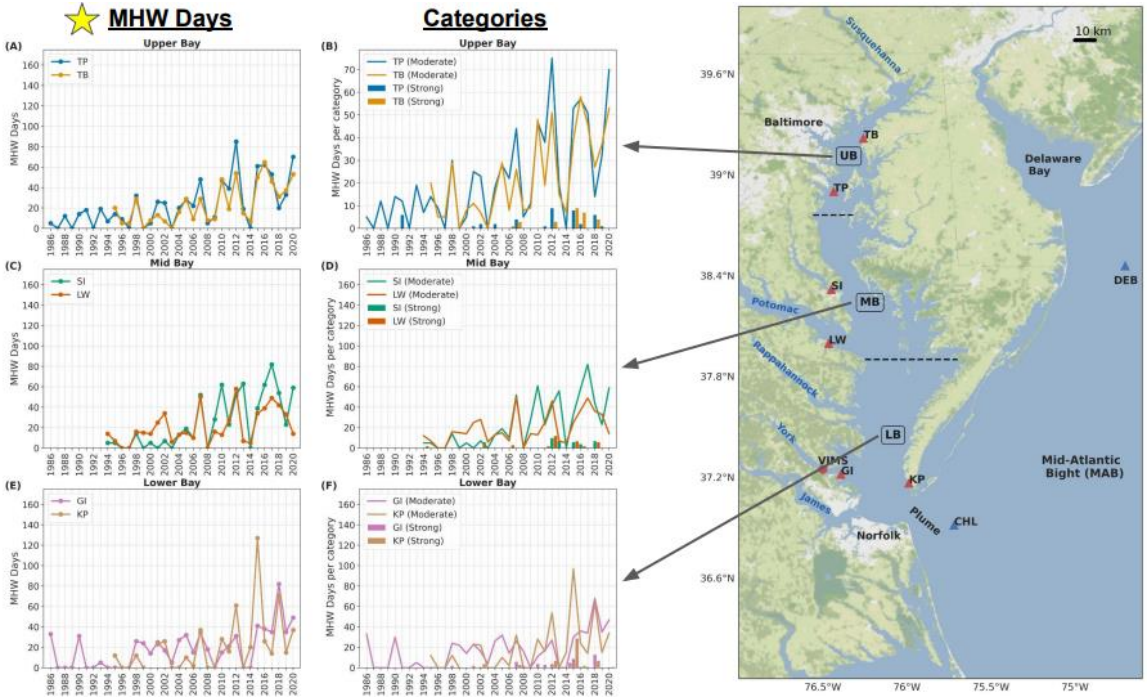
Hobday et al., 2016

Common Marine Heatwave Descriptive Characteristics

- Frequency: the number of marine heatwave events that occur every year.
- Duration: the length of each individual marine heatwave, in days.
- Intensity: how hot it is during the marine heatwave event (expressed as the maximum or average)
- Cumulative Intensity: Integral of marine heatwave intensities over a time period (℃ x days) – combines magnitude and duration of heat anomalies
    - Good indicator of thermal stress to ecosystem

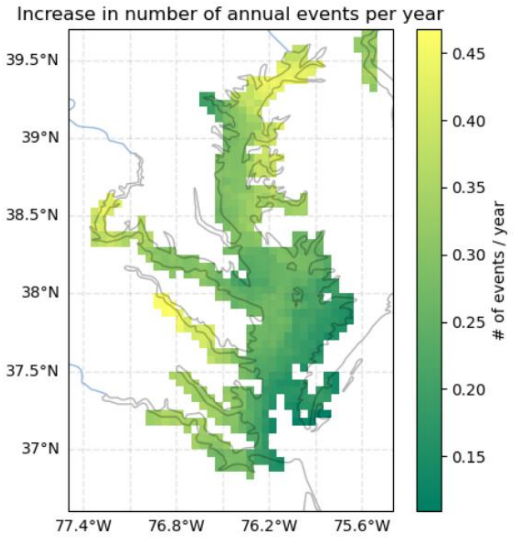
Chesapeake Bay Marine Heatwave Research: In situ data (Mazzini & Pianca 2022)

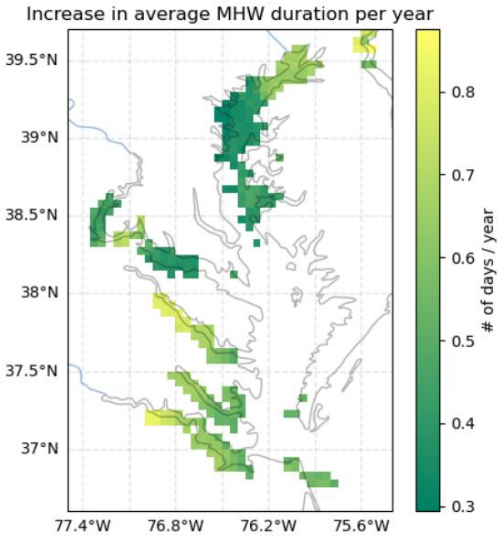
- Significant long-term trends (1986-2020) were detected for MHW frequency, MHW days, and yearly cumulative intensity
- If trends persist, by the end of the century the Chesapeake Bay will reach a semi-permanent MHW state, when extreme temperatures will be present over half of the year.



Chesapeake Bay Marine Heatwave Research: Satellite data (Wegener 2022)

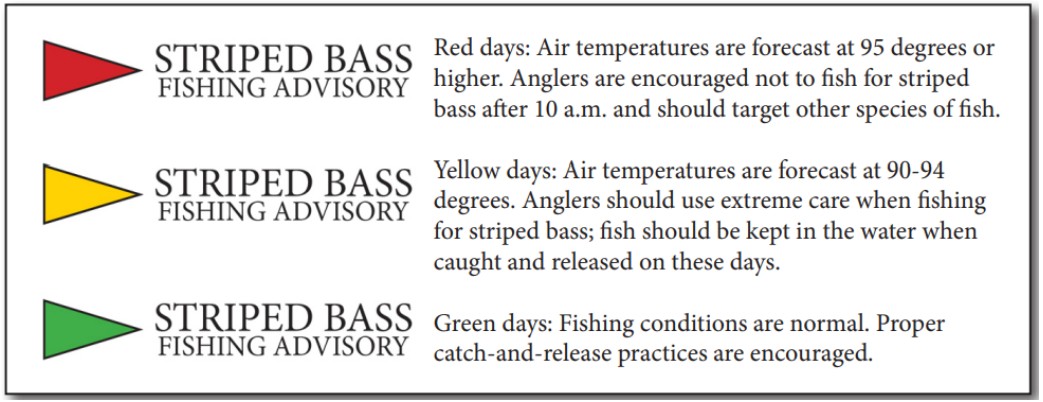
- Almost entire Bay has significant increases in the number of annual marine heatwave events (2002-2020).
- Spatial structure indicates marine heatwave cumulative intensity driven by increases in duration (not max intensity).
- Marine heatwave characteristic maps show significant spatial variation.
- Satellite analysis consistent with buoy-wide analysis.





Stakeholder Interest - Recommendation from Rising Water Temperature Workshop

- Convene an interdisciplinary team of scientists, resource managers, meteorologists, and communicators to design and create a publicly available marine heat wave alert system.
- Connect alert system with habitat preferences of key species and guidance on fishing behavior. Consider incorporation of other key parameters (e.g., dissolved oxygen, salinity).



Example from Maryland Department of Natural Resources

Relevant CRWG Actions (2023-2024 Workplan)

- 1.2 Coordinate the development of prioritized climate change indicators in connection with clear management objectives with corresponding workgroups and natural resource outcomes
    - a. Support cross-workgroup discussions to identify user case scenarios on how best to incorporate living resource-related outcome needs (e.g., fish habitat, SAV) when developing the Bay Water Temperature Change climate change indicator. Meet with potential data providers/analysts (e.g., NOAA, ITAT) to assess feasibility of approaches and support to develop and maintain the indicator(s). Review and consider recommendations from the Rising Water Temperature STAC Workshop report.

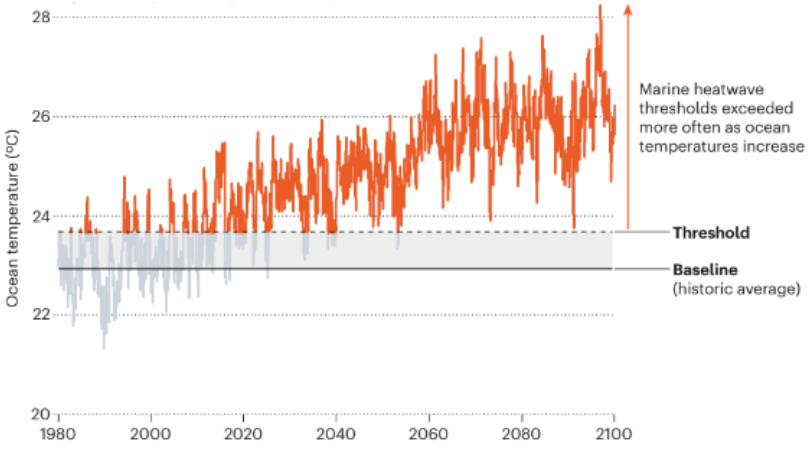
- 1.6 Increase capacity in understanding multiple climate and other co-occurring environmental stressors on living resources
    - a. Assess a multi-stressor index for key fish species (e.g., striped bass) that includes marine heat waves and dissolved oxygen based on recommendations expressed during the Rising Water Temperature STAC workshop.

Steps toward a Marine Heatwave Fish Impact Indicator - Summer 2023 Efforts

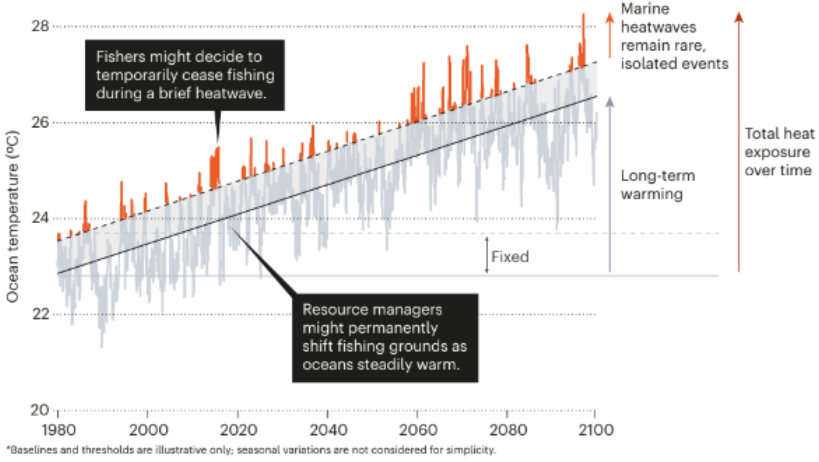
- Reviewed different marine heatwave definitions.
- Conducted interviews with marine heatwave, environmental condition, and fish habitat researchers:
  - Got input on how best to characterize marine heatwaves in connection with fish impacts.
  - Began determining which descriptive characteristics would be most useful to connect with fish impacts.
- Testing marine heatwave analysis with available continuous data
  - NOAA Chesapeake Bay buoy and satellite data

Marine Heatwave Definitions (Amaya et al. 2023)

- Fixed baseline - defining heat relative to historical temperature (includes long-term warming trend; currently used by climatology research community)



- Shifting baseline - defining heat relative to increasing average temperatures (removes long-term warming trend; definition now being used in 2023 State of Ecosystem Report)



Interviewees

- Questions focused on how best to characterize marine heatwaves in connection with fish impacts (used striped bass for discussions as an example).

Marine Heatwave Researchers	Fish Habitat / Environmental Condition Researchers
Vince Saba, Ryan Rykaczewski, Dillion Amaya, and Andrew Ross (NOAA)	Rachel Dixon, Mary Fabrizio, and Troy Tuckey (VIMS)
Ron Vogel (NOAA) and Rachel Wegener (UMD) – Satellite	Tom Parham and Jim Uphoff (MDNR)
Piero Mazzini, Nathan Shunk, Cassia Pianca (VIMS)	Yang Jiao (University of Maryland)

Interview Highlights - Data Considerations

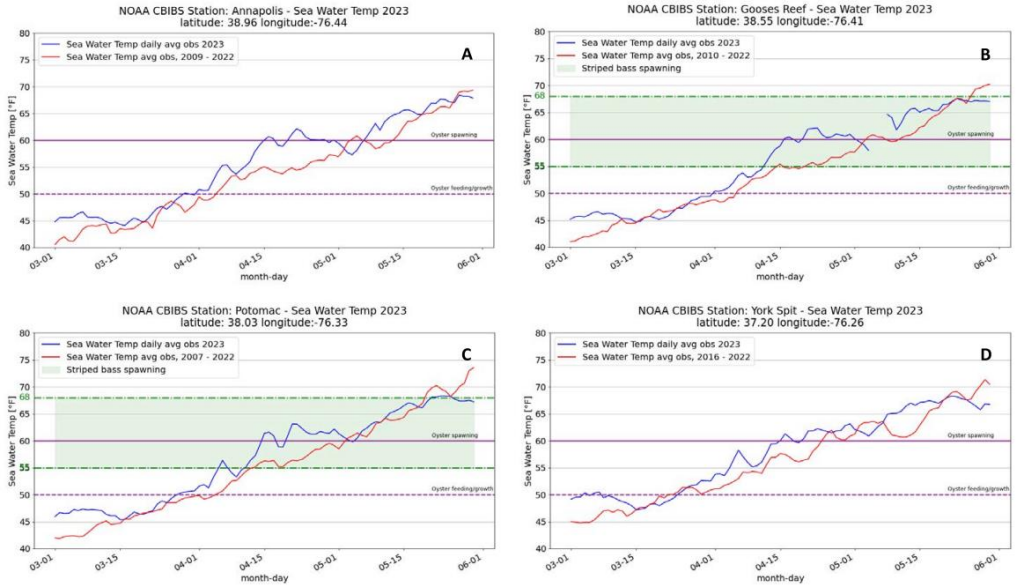
- Ideally, want 30-100 years to establish climatology trend; NOAA observational buoy data in Chesapeake Bay limited to 13 years:
  - Can still do analyses, but recognize that timeframe may not be representative of changes in climate; look into data of El Nino Southern Oscillation and North Atlantic Oscillation.
  - Any detrending for a shifting baseline should be re-evaluated when more data is added.
- Satellite data – MUR might be better choice for nearshore/tributaries due to finer resolution (has extreme cold bias though), while Geopolar would be useful for the mainstem.
- Indicator needs to be relatable to audience – plan more meetings with stakeholders to review and provide input during development process.
- Integrate information on future climatology from climate change scenarios to inform tipping points where Chesapeake Bay habitats will likely not be tolerable for a species of fish.

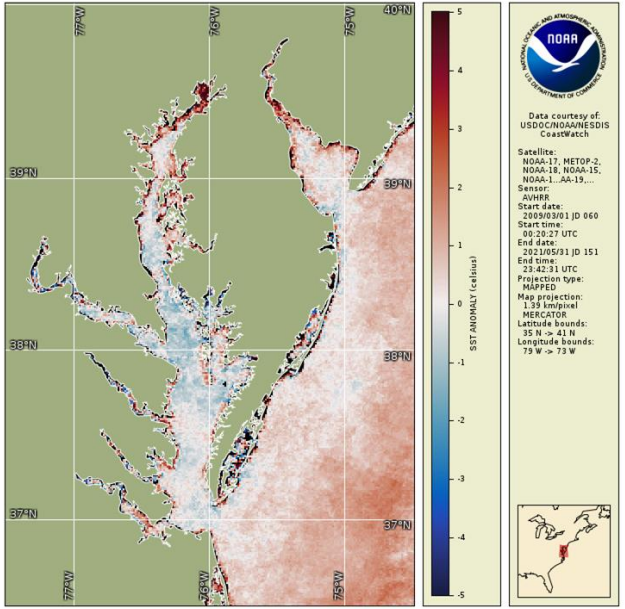
Interview Highlights - Connecting with Fish Impacts

- Both marine heatwave definitions have value depending on the fish impact question:
  - Fixed baseline could indicate shifts in community structure – e.g., decrease in striped bass and increase in species from the south (e.g., red drum).
  - Shifting baseline could indicate acute stress on present species in Bay (periods of higher vulnerability).
- 90th percentile and duration of 5 days not based on impacts to fish; warrants potential refinement of definition to relate better to fish – will likely vary by species.
- ~82℉ (28℃) proxy threshold indicating habitat squeeze for striped bass.
- Back to back extreme marine heatwave events above optimal temperature threshold for the fish could be most problematic – determine indices of cumulative temperature stress.
- Engage with physiologists to increase understanding of fish response to warming temperatures and extreme events; fill data gap on the adaptive response.
- Extremes can happen throughout the year (not just summer); this could have implications depending on the life stage of fish being evaluated.

NOAA Chesapeake Bay Seasonal Summaries

- Quarterly reports using existing environmental observational data to craft narratives about impacts on living resources (e.g., water temperature/SST anomalies, salinity, flow)

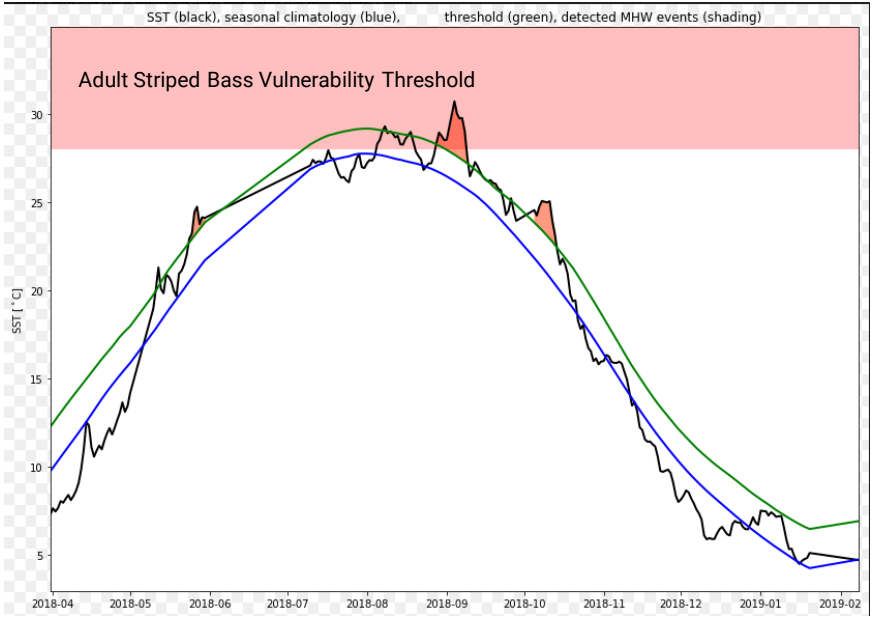




NOAA Chesapeake Bay Seasonal Summaries – Integration of Marine Heatwave Information

- Goal: Characterize marine heat waves (e.g., intensity, duration, and frequency) related to living resource thresholds in seasonal summaries.
- Heard from interviewed researchers that it would be beneficial to have marine heatwave information in communication documents to start raising awareness.
- Can refine and make more robust as more data and research findings become available.

Example



SST = Surface Sea Temperature

New Relevant Research

- University of Maryland Center for Environmental Science (Lead PI: Nesslage): Using Time Series Analysis of Linked Rare Events to Quantify Impacts of Climate Change of Fish and Shellfish in the Chesapeake Bay
  - Using time series analysis and machine learning to identify links between biological and environmental rare events (includes extreme temperatures, salinity, and dissolved oxygen).
  - Species being evaluated: striped bass, menhaden, black sea bass, blue crab, summer flounder, bay anchovy, blue catfish, red drum, and cobia.
  - Funded through NOAA Chesapeake Bay Office Fisheries Research FY23 Grant
  - Project timeline: October 2023-September 2024

Incremental Steps towards a Marine Heat Wave Fisheries Alert Indicator(s)

- Need to start somewhere – testing marine heatwave descriptive characteristics within NOAA Chesapeake Bay seasonal summaries (staff are available to support this; NOAA could potentially become the data provider for an indicator and run analyses).

- Create conceptual data visualizations using both marine heatwave definitions and get stakeholder feedback on what would be most valuable for fish impacts:
  - Sort out best common marine heatwave descriptive characteristics to use; consider new descriptive characteristics: spatial (e.g., % of total habitat affected by extreme marine heat waves) and temporal (e.g., length in between consecutive marine heatwave events).

- Future Considerations:
  - Integrate research on subsurface DO and temperature trends during marine heat wave events (Shunk presentation)
  - Build in fish habitat considerations and relevant thresholds (Fabrizio and Parham presentations)
  - Explore use of marine heatwave forecasts (NOAA Physical Sciences Laboratory)