Rising Water Temperature STAC Workshop Effort Progress Update

Tidal: Julie Reichert-Nguyen (NOAA) and
Amy Goldfischer and Alex Gunnerson (CRC)

Watershed: Katie Brownson (USFS) and Spencer Tassone (UVA)

Overall STAC Workshop Objectives

- Summarize the major findings on the ecological impacts of rising water temperatures due to climate change
  - Include science-based linkages between causes and effects
- Develop recommendations on science improvement needs and potential management options to mitigate and/or adapt to these impacts
  - Consider how to build resilience with available management instruments: E.g., best management practices, habitat restoration, fisheries management, land conservation, monitoring, modeling, analyses, indicators

CBP Workgroups and Partners Supporting Effort

STAR
Climate Resiliency
Monitoring
Modeling

Fisheries GIT
Forage
Fish Habitat
Oysters
Blue Crab

Habitat GIT
SAV

Federal Agencies
U.S. EPA
USGS
NOAA
USFS

State Agencies
MDNR
MDE
VADEQ

Academic Institutions
VIMS
ODU
UMCES
UMD (NOAA Satellite Service)
Penn State

NGO
TetraTech
CRC
CSN
J&J Consulting
Woods & Water Consulting

Timeline

March 2021
Start of funding

June 21, 2021
Pre-Workshop

Special CRWG meeting to support development of synthesis papers

January 12, 2022
STAC Workshop DAY 1

Focus: Discuss scientific understanding and begin identifying management implications

Webpage: Synthesis papers and summary presentations

March 15, 2022
STAC Workshop DAY 2

Focus: Recommend management options and identify science improvements needed

~ June 2022
Complete STAC Report

Day 1 STAC Workshop Objectives

Separate tidal and watershed workshop tracks that aimed to:

- Discuss ***interconnections*** between increasing water temperature and the ***important drivers*** resulting in temperature rise
- Synthesize current scientific understanding of ***ecological impacts*** of increasing water temperature
    - Identify particularly vulnerable species, landscapes, and communities
    - Identify specific aspects with greatest potential to adversely impact tidal and freshwater ecosystems and habitats
- Identify critical ***knowledge gaps***
- Consider a range of ***management implications***

Tidal Summary (Draft)

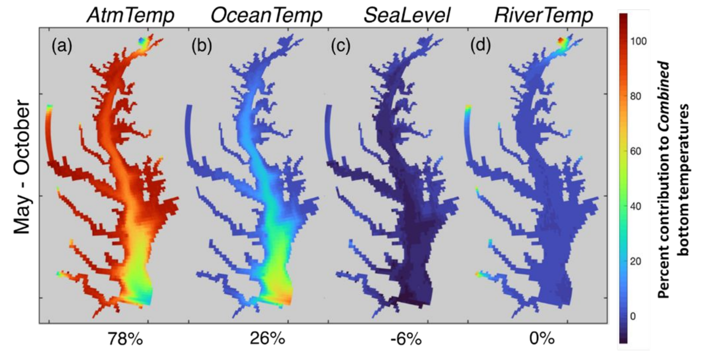
Questions for CRWG meeting participants (put your thoughts in chat):

- Are there any findings or management implications that are missing?
- Are there any differing opinions on findings?
- Are there any research efforts you know of that can help inform knowledge gaps or management?

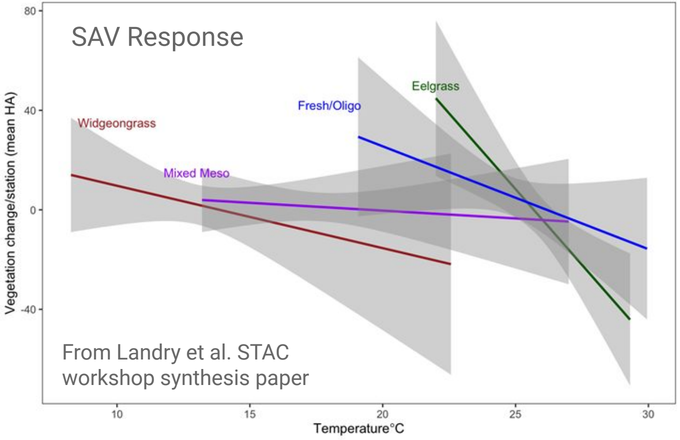
Tidal Storyline (Draft)

Rising water temperatures in Chesapeake Bay:

- Largely influenced by atmospheric and ocean temperatures.
- Influences physical, chemical, and biological processes - have direct and indirect effects on the Bay's living resources and habitats.
- Results in varying direct and indirect ecosystem responses given the different sensitivities of Bay's fish, crab, shellfish, benthic and pelagic forage, and SAV communities to temperature change.

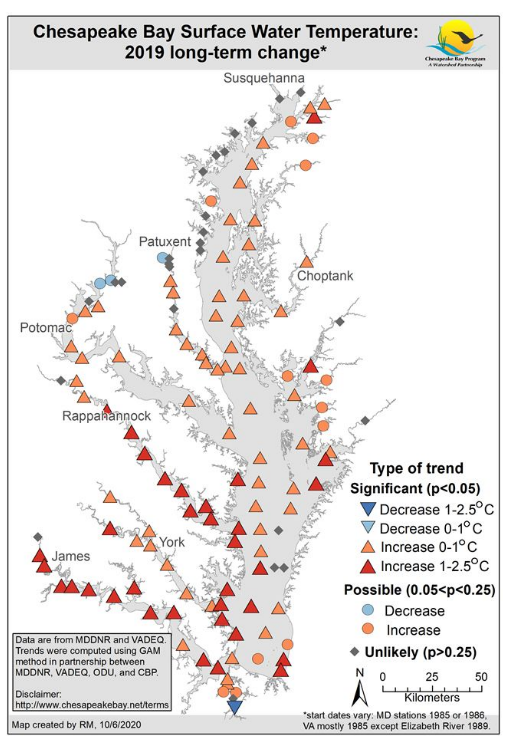


Hinson et al. 2021



From Landry et al. STAC workshop synthesis paper

Tidal Storyline Continued (Draft)







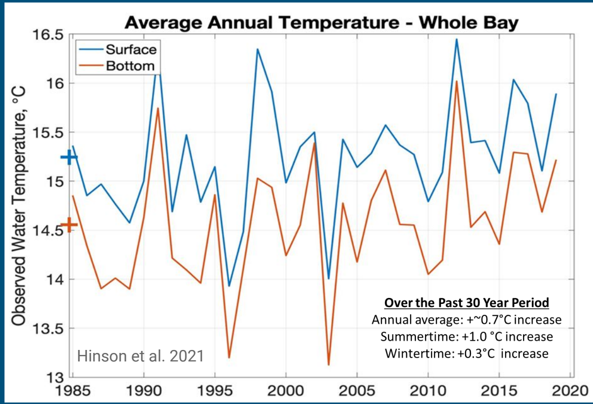
- Warming temperatures create new spatio-temporal habitat niches allowing for species to extend their range into the Bay (e.g., cobia, red drum) and thrive (e.g., shrimp). Also allows for new warm water pathogens.
- Enhancements to the Partnership's current modeling tools are needed to better understand the influences of rising water temperatures on living resources and habitats.
- Having the right monitoring and tidal water temperature change analyses in place to collect and organize data in response to management needs is critical to inform improved decision-making.

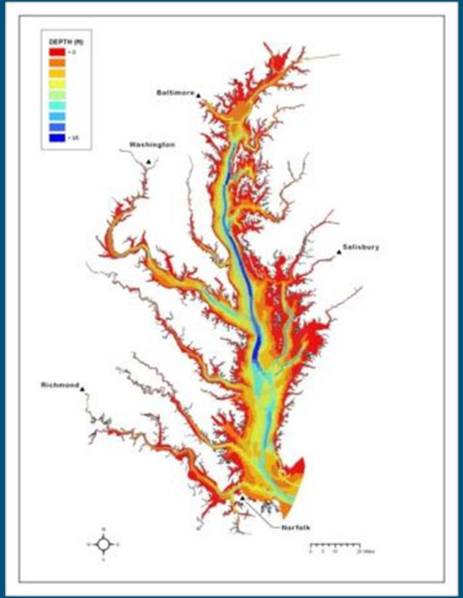
Tidal Storyline Continued (Draft)

- Management options targeting adjustments to fisheries catch, seasons, and quotas, and reassessing submerged aquatic vegetation (SAV) community expectations to account for warming habitats likely needed given global drivers.

- Differing opinions on the effectiveness of watershed BMPs in reducing hot water plumes in tidal tributaries to minimize exacerbated warming for some nearshore habitats in the short to mid-term timeframe (rural vs. urban vs. no substantial effect)

- Actions utilizing nature-based, habitat-forming, carbon sequestering BMPs (e.g., tidal wetlands, forest buffers) could mitigate or reduce vulnerabilities of global temperature increases within a mid to long-term timeframe (end of century).





Day 1 STAC Workshop - Tidal Questions

- What are the direct and indirect positive and negative effects of rising water temperatures on fisheries (e.g., blue crab, oysters, striped bass, summer flounder, forage) and submerged aquatic vegetation (SAV) resources?
- What do we know and not know about temperature sensitivities of the resource?
- What are key factors to consider for the resource to inform management action?
- What are the management implications across the different fisheries and SAV resources?
- What temperature analyses would be useful for management purposes?

Oysters

- **Ecological impacts**
  - Positive impacts: faster growth rate & earlier maturation; increased plankton (food) availability; longer active feeding/filtering; reduced winter mortality
  - Temperature effect alone is least concerning–other climate change impacts like ocean acidification (OA), changes in precipitation and salinity have more significant direct, negative impacts on oyster health and survival
  - Indirect, negative impacts: increased harmful algal blooms, hypoxic conditions, fouling, and pathogens/disease occurrence; alteration in food sources (more abundance, but lesser quality); non-native predators moving into Bay
- **Temperature sensitivities**
  - Growth rates, fecundity, reproduction thresholds, spawning, calcification rates
  - **Knowledge gaps**: Maximum spawning temp; impact on growth rates, gender transition & time to first spawn; response to heat waves; temperature-disease interactions; temp effect on filtering capabilities and long-term survivability

Oysters

- **Key factors to consider for management decisions**
  - **Disease prevalence:** increases in disease pressure; temp-disease interactions
  - **Seasonal shifts:** longer spawning season; more production in spring; less favorable conditions in summer
  - **Multiple stressors & survival:** OA and salinity changes from increases in freshwater flow; increased hypoxia and harmful algal blooms; temperature increases
  - **Extreme events/anomalies**: how does long exposure to heat waves and other extremes affect vitality?

- **Management implications**
  - Restoration: locations & techniques may need to change; co-locating oyster restoration with SAV, wetlands, and/or riparian forest buffers to maximize resilience
  - Fishery: changing harvest regulations and limits; may need more monitoring/management of diseases
  - Aquaculture: more labor may be required due to more fouling and faster growth rates
  - Temperature-driven changes in vital/survival rates of oysters may affect estimates of nitrogen and phosphorus removal as well as other ecosystem services

Submerged Aquatic Vegetation (SAV)

- **Ecological impacts**
  - Increasing shallow water temps directly affect SAV physiology, productivity, reproduction & survival
  - Indirect impacts play a role in SAV survival (sea level rise, pathogens, hardened shorelines)
  - Frequency & duration of heat waves affect eelgrass primarily; all communities affected to some extent
  - Loss of diversity in tidal freshwater/oligohaline species

- **Temperature sensitivities**
  - Longer growing season & increased productivity from CO_2 fertilization effect for SAV in general, but thermal stress impacts from sediment biogeochemistry (sulfide tox), disease susceptibility, etc.
  - Eelgrass is more vulnerable to temp increase in turbid water; SAV more resilient in clear water.
  - **Knowledge gaps**: impact of temp variability; effect on stable vs recovering beds vs seedlings, some species have more knowledge gaps than others on ranges & temp thresholds

Submerged Aquatic Vegetation (SAV)

- **Key factors to consider for management decisions**
  - **Timing**: Temp-induced changes in SAV communities affect use by finfish and crabs
  - **SAV Recovery:** Recovery rates and potential after thermal stress
  - **Facilitated migration**: Introduction of heat-tolerant eelgrass genotypes and/or subtropical species (however, still require clear water/high light)

- **Management implications**
  - Water quality management and maximizing water clarity is key for SAV; SAV more resilient to temp stress in clear water
  - Loss of eelgrass in lower Bay may impact Baywide restoration goals - while widgeon grass may fill the niche in most areas, there will be ecological consequences (timing of emergence for spring habitat)
  - Shoreline development affects SAV recovery, expected with sea level rise
  - More info required to manage fresh and brackish species response to increasing temps

Blue Crab

- **Ecological impacts**
  - Positive impacts (direct): lower winter mortality, maturation size reached more quickly, potential improved juvenile survival, potential for increased growth due to a longer growing season (assuming prey availability)
  - Negative impacts (indirect): tropical parasites and disease, increased predation by southern species like red drum, loss of SAV would remove potential nursery and foraging habitats
  - Unsure: ocean circulation influence, increased precipitation intensity

- **Temperature sensitivities**
  - Warmer temps lead to faster maturation, lower winter mortality, greater food consumption in warmer water, SAV density linked to juvenile survival, avoidant behavior from decreasing oxygen, upper temp threshold of 30 ℃ for mortality, smaller females at mating may lead to increasing vulnerability to predation and diminishes fecundity per brood
  - **Knowledge gaps**: detailed information on female spawning and mating, increased predation from southern species, impact of tropical parasites, impact of heat waves, discard mortality rates for peeler industries under low Dissolved Oxygen and warmer temps, genetic capacity to adapt, spatial scales for temp prediction relevant to Blue Crab, quantification of Blue Crab production by SAV types

Blue Crab

- **Key factors to consider for management decisions**
  - **Timing:** diminished food availability in winter, seasonal shifts to earlier springs
  - **Life stage and sex:** female maturation at smaller size
  - **Geographic location:** greater effects in shallow tributaries compared to mainstem
  - **Parasites & disease:** new tropical diseases and parasites enabled by warmer temps

- **Management implications**
  - Change in harvest schedules relative to the fishery?
  - Efficacy of Winter Dredge Survey (WDS)? Relative abundance index?
  - Monitoring for threats from shifting predator distributions and tropical parasites
  - Revised female specific management strategies
  - Incorporating environmental conditions like temperature and habitat when managing fishery

Forage

- **Ecological impacts**
  - Positive Impacts: increased white shrimp populations in VA, increased growth rate of forage (assuming no food and water quality limitations)
  - Negative Impacts: possible increased hypoxia/reduced bottom habitat, water quality degradation (indirect), reproductive development, pollutants on benthic invertebrates
  - Unsure: changes in: habitat availability, species distributions, predator-prey overlap in space and time
- **Temperature sensitivities**
  - Limited knowledge of: Zooplankton distribution (and potentially abundance?), benthic community composition, distribution and abundance of bay anchovy on baywide scale, springtime warming impacts on annual forage abundance
  - **Knowledge gaps**: life stage (egg maturation & spawning), changes to reproduction & growth for key species, invasives effect on forage, combined effects of stressors (temp, salinity, etc.), genetic capacity to adapt to temp changes, Chesapeake Bay specific temp info for Forage, benthos distribution & abundance (infauna & epifauna)

Forage

- **Key factors to consider for management decisions:**
    - **Changing Habitat:** Temp stratification (informs distribution and abundance), effects of land use and development on abundance and diversity, availability of refugia relative to sea level rise (tidal marsh), effects of habitat shifts (oyster reefs and SAV)
    - **Predator-prey interactions:** needed to inform multi-species stock assessments
    - **Extreme events:** the frequency and duration of heat waves
    - **Responses of infauna vs epifauna:** potentially epifauna see greater impacts?
    - **Monitoring:** limitations of fishery surveys (sampling gear, coverage in space and time), need for better spatial coverage of bottom water temp data

- **Management implications**
    - **Need more research to evaluate the forage base and understudied species, standardization of methods for sampling and regional definitions for measuring restoration success**
    - Changes in forage composition and abundance due to warming temps and potential competition for resources from invasives
    - Model conditions for forage species and establish forage indicators and thresholds for suitable habitats and manage predator stocks accordingly
    - Water Quality is key as soft bottom mud is the predominant habitat; shading and cooling rivers with watershed BMPs is not likely to make a positive impact
    - Effects of marsh and SAV loss on forage populations

Finfish-Predator (Striped Bass)

- **Ecological impacts**
  - Positive impacts: possible increased growth of juvenile striped bass
  - Negative impacts: seasonal changes in nursery performance, timing of striped bass migrations, reduced summer habitat for adult striped bass (elevated water temp and decreased dissolved oxygen), reduced accessibility to forage resources

- **Temperature sensitivities**
  - Spawning timing and larval survival and growth; overall, good understanding of temp thresholds for striped bass during different life stages
  - **Knowledge gaps**: effects of season-specific warming and extreme events (marine heat waves, high rainfall events) on early life stages and overall recruitment; adaptability and tipping points; suitable habitat and distribution of striped bass given multiple stressors; prey availability given effects on spawning timing

Finfish-Predator (Striped Bass)

- **Key factors to consider for management decisions:**
  - **Seasonal shifts:** change in spawning timing/ water quality and predator-prey mismatches
  - **Multiple stressors:** habitat “squeeze” from low bottom DO and warming surface waters; increased disease mortality
  - **Fishing practices:** Gear effects on populations given the spatial and temporal habitat compression (fish more concentrated due to less available habitat)
  - **Prey composition & availability:** changes in zooplankton and benthic communities during early life stages
  - **Extreme events/anomalies:** increase in extreme rain events along with heat wave timing could drastically diminish habitat; do extreme events drive fish response?

- **Management implications**
  - Rising temps along with other increases in other stressors could exacerbate already high mortality rates for striped bass (>50%); build in buffers for ecosystem uncertainty in catch quotas
  - Ecosystem based management incorporating climate change impacts to food web structures & habitat availability
  - Adjustments to fishing practices (catch and release) incorporating habitat compression considerations
  - Factor in rising water temps in recruitment estimates under current management formula
  - Collect more long-term fish and prey data to model carrying capacity of Chesapeake Bay in relation to temp and DO conditions to improve models

Common Themes - Tidal

- Species composition and distribution
- Invasive species/pathogens
  - New species moving into Bay that offer ecosystem benefits
- Direct versus indirect effects of temperature change
  - Direct positive biological effects (growth rates, lower mortality), but indirect, negative habitat effects (loss, unsuitable)
- Timing mismatches - spawning, food availability, habitat availability
- Multiple stressors (low dissolved oxygen, changes in salinity and precipitation/ freshwater flow)
- Extreme events (e.g., heat waves, increased freshwater flows)
- Ecosystem-based management
- Co-location of restoration efforts (e.g., SAV and oysters) to maximize resilience benefits