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Predicting the distribution of cobia, *Rachycentron canadum*, seasonally, for mid-century, and for end-of-century

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Dissertation Overview

Climate change has contributed to warming and hypoxia throughout coastal ecosystems, which may impact future species distribution, phenology, and habitat selection. To make predictions it is necessary to first understand the impacts changing conditions have on underlying physiological mechanisms. By combining both correlative and mechanistic models, we will be able to achieve a more comprehensive understanding of how warming and hypoxia may impact species in the future. Further, under a changing climate it becomes imperative that management is prepared to act dynamically. This research proposes to collect habitat data from telemetry and physiology data from respirometry experiments to together determine the suitable habitat of cobia (*Rachycentron canadum*). Then the suitable habitat will be used to forecast the distribution of these species seasonally, for mid-century, and end-of-century within the Chesapeake Bay and the U.S. East Coast. Projections will be distributed to state and federal managers so they will have the flexibility to make decisions based on where species are expected to be at different time scales.

Methods

Habitat preference data will be collected from cobia fitted with internal temperature and depth archival tags (TDR) and pop-off satellite archival tags (PSATs, collected by John Graves and Douglas Jensen at VIMS). TDR data will only be useable if cobia are caught by fishermen and the tag is returned to us.

Physiology data will be collected by measuring the change in the metabolic rate of cobia under warming and hypoxia using respirometry (Fig. 1). Specifically we will be measuring maximum metabolic rate (MMR), which is defined as the maximum rate at which a fish can intake oxygen, while standard metabolic rate (SMR) is the minimum metabolic rate needed to sustain life (Fry & Hart 1948, Clark et al. 2013). The difference between MMR and SMR is termed aerobic scope (AS), within which an individual is able to undergo all life process such as growth, reproduction, digestion, and movements (Clark et al. 2013). We also will be measuring the critical oxygen saturation (S_{crit}), which is the oxygen concentration below which a fish can no longer maintain its SMR (Brill et al. 2015). If a fish remains in water with oxygen concentrations below its S_{crit}, it will suffer a mortality.

Habitat preference and physiology data will be combined and used to develop a suitable habitat model for cobia in the Chesapeake Bay and along the U.S. East Coast. Various climate models will be incorporated into the suitable habitat model so that cobia distribution in the Chesapeake Bay and along the U.S. East Coast can be projected seasonally (i.e. 9 months in advance), as well as for mid-century and end-of-century.

Preliminary Results

During the summer of 2017, 13 cobia were fitted with TDR tags. To date, we have not received any TDRs back from cobia fishermen. We expect to receive some tags back this upcoming summer and also plan to put more tags out (another 37 tags). John Graves' group deployed multiple PSATs at the end of the 2017 summer and is currently hearing back from these tags.

During the spring and fall of 2017, respirometry has been conducted on 13 cobia at 24°C and one cobia at 28°C. I will conduct the remaining respirometry trials at 28 and 32°C during the 2018 summer. Based on preliminary data (at 24°C), cobia MMR, SMR, and AS were 214±36 mg/kg/h, 98±13, and 116±39 mg/kg/h, respectively. The S_{crit} of cobia at 24°C was 2.0±0.6 mg/L, which is equivalent to 27±8% oxygen saturation, which suggests that cobia are relatively hypoxia tolerant. This suggests that at 24°C, cobia are not about to handle oxygen concentrations below 27±8%. These physiology metrics will be compared to the same metrics measured at 28°C and 32°C after completion of the experiments this summer.

The suitable habitat models are expected to be completed by Spring 2019. Following the completion of the suitable habitat models, the forecasted distributions of cobia within the Chesapeake Bay and along the U.S. East Coast should be completed by Spring 2020.

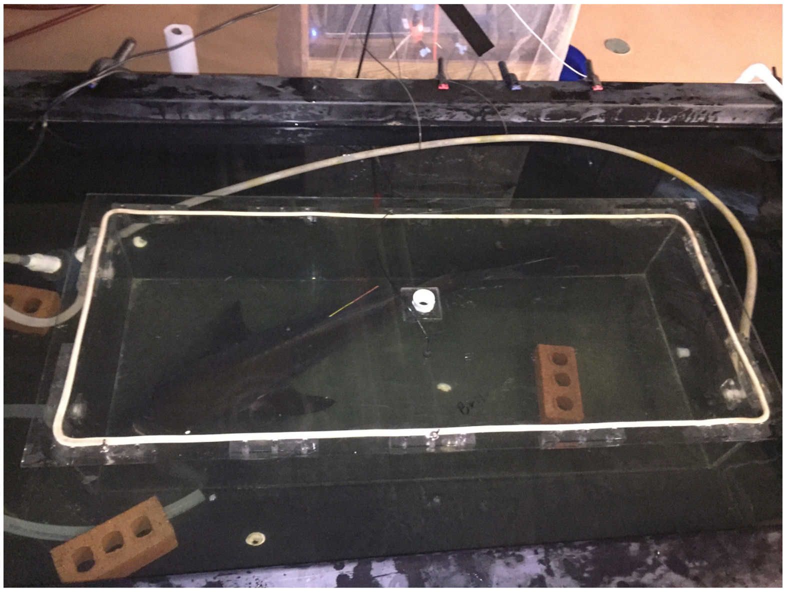

Figure 1. A cobia inside the respirometer where its metabolic rate will be measured for approximately 25 h.

Discussion

Hypoxia in Chesapeake Bay is driven by many factors, including sea level, streamflow, and most importantly temperature. Nutrients drain into the bay during the spring so that by the time summer arrives, algae blooms dominate the surface waters. Once these blooms die and sink to the bottom, bacteria break them down, reducing the amount of dissolved oxygen in the water. Further, an increase in temperature, promotes stratification in the water, preventing hypoxic bottom water from mixing with the oxygenated surface waters. During wet years, the extent and severity of hypoxic waters increases as a result of increased streamflow, nutrients, and thus algae blooms. Although the extent and severity of hypoxia varies from year to year, dissolved oxygen is the lowest at the very bottom (<2 mg/L) along the deepest parts of the bay. As depth decreases the severity of hypoxia decreases (Murphy et al. 2011). However, as a result of climate change we are expected to see an increase in the volume of dissolved oxygen levels between 3-5 mg/L (Irby et al. in review). These are often oxygen levels that although may not be lethal to fish, could have sublethal effects by affecting fish distribution, growth, reproduction, feeding, etc (Kemp et al. 2005, Horodysky et al. 2015).

The fact that cobia S_{crit} is around 2.0 mg/L (at 24°C) suggests that it may not be impacted as much by climate change compared to a species that has an S_{crit} above 3 mg/L. However, we expect to see an increase in S_{crit} at higher temperatures (>28°C). Cobia seem to have similar S_{crit} values compared to other economically important fish species such as striped bass (S_{crit} = 2.0-2.5 mg/L at 20 – 28°C; Lapointe et al. 2014) and summer flounder (S_{crit} = 2.0-2.4 mg/L at 22 – 30°C; Capossela et al. 2012). In addition, species like striped bass have displayed a temperature-oxygen squeeze where hypoxic water forces them further up in the water column, but the warmer temperatures at the surface actually forces them further down (Lapointe et al. 2014). This idea suggests that as conditions worsen, species like striped bass will experience a habitat reduction. It is unclear now, but cobia may experience the same habitat reduction in the future.

The thermal habitat preference of cobia is currently unknown. However, as we collect both tagging and physiology data for my dissertation this will be better understood. Information on thermal habitat preference will allow us to anticipate if cobia will distribute further north into Maryland, Delaware, New Jersey, and New York as a result of climate. Seasonal forecasts will allow us to predict where cobia may be as they migrate up the coast throughout the year.

Predicting future distributions of cobia will allow management to act more dynamically in space and time. Dynamic ocean management (DOM) is a management strategy that is designed to change in space and time in response to changes in the natural environment and its users (Maxwell et al. 2015). DOM can be informed by species forecast models and integrated with the existing management framework to appropriately allocate resources and regulations (Lewison et al. 2015, Maxwell et al. 2015). Currently DOM is being used to improve the ability to maintain target catch within quota limits and reduce bycatch. For example, in the New England multispecies groundfish fishery, data are collected for discard species and undersized individuals of the target species in almost real time and used to create a move-on rule for fishermen, which maximizes profits and reduces discards (Dunn et al. 2014, Lewison et al. 2015). In the Australian southern bluefin tuna (*Thunnus maccoyii*; SBT) fishery, a habitat model developed from satellite-tagged SBT has been used to create management zones that prevent fishermen without quota from fishing in areas with high SBT expected occurrence and prevent bycatch of SBT by those fishermen (Hobday et al. 2011, Lewison et al. 2015, Hobday et al. 2016). DOM is particularly useful for mobile and migrating species because these species often move across management boundaries. I believe that DOM is an effective complementary management strategy to current frameworks, particularly at a time when management needs to respond more rapidly in space and time under a changing climate. Cobia's migratory behavior makes them a perfect species to apply this type of management strategy to. The forecast models created from my dissertation will provide management with information that will allow them to be more flexible.

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