Task 3

Project activity: Marsh Function Model: fish and invertebrate habitat provision by living shorelines

Objective: Comparatively evaluate fish and invertebrate habitat quality of living shorelines and reference marshes along a continuum of shorescape settings.

Methods: To assess fish and invertebrate habitat use and quality, we are randomly sampling 13 pairs of living shorelines (created marsh and stone sill) and reference fringing marshes in areas low, moderate, and high marsh connectivity during summers of 2018 and 2019. Marsh connectivity is defined by the distance to the nearest marsh and presence of barriers to nearshore movement by forage and juvenile nekton, such as deep water and shoreline armoring. Fish sampling will occur in three habitats of the created and natural marsh ecosystem – shallow water (seine), marsh and marsh edge (fyke net), and marsh surface (minnow trap). Fish condition, diet, and food availability will be determined for two abundant species – mummichog and Atlantic silverside to quantify habitat quality. Fish community measures and other metrics (e.g., diversity, abundance/biomass of nursery species, forage fish, and juvenile blue crabs, fish condition, and stomach fullness) will be derived from fish collections to statistically evaluate marsh habitat function along the continuum of shorescape connectivity.

Marsh invertebrate composition of the marsh and stone sill structure will be quantified by surveying 6 transects from low to high marsh (and on the sill if present). Invertebrate community measures and species specific metrics will be derived from the surveys and used to statistically evaluate marsh habitat function. We have observed that ribbed mussels tend to be absent or in low abundance in many living shorelines. We are experimentally evaluating the potential causes of low mussel recruitment with the intent to enhance the presence of this important marsh species. In addition, site and shorescape characteristics that may influence marsh habitat use are being collected by drone (e.g., marsh area, stone sill size and configuration, presence and area of seagrass beds), and on site (e.g., marsh plant composition, slope, sediment organic matter and grain size) to inform the analyses.

Progress to date: We conducted preliminary sampling of a subset of paired sites (n=3) in 2017 to ensure proposed sampling effort was adequate. We have nearly completed the first year of nekton sampling of the complete set of paired sites (n=13). Invertebrate surveys will be conducted in Sept-Oct 2018. Following sampling, data will be compiled for analysis.

Task 3

Project activity: Shifting patterns of ribbed mussel (Geukensia demissa) distribution and their ecosystem services in response to sea level rise

Objective: Identify spatial patterns of current and future ribbed mussel distribution and ecosystem services using combined field, laboratory, and GIS observations.

Methods: We conducted field observations of 30 marshes around the Chesapeake Bay to obtain base distributions of mussels within and among marshes. Statistical analysis applying landscape ecology methods were used to find spatial factors contributing to observed variation, allowing us to create a spatial model of ribbed mussel distribution. Laboratory measures of core incubations with ribbed mussels provided estimates of ecosystem service rates such as filtration and N removal. The model and service estimates were then spatially applied to current marsh habitat and compared to future (2050) estimates of marsh distribution assuming a 0.62 m in the Chesapeake Bay. We are also developing an R package to simulate ribbed mussel densities within a marsh as a function of erosion rates, sea level rise, recruitment, and mortality annually up to 50 years into the future.

Progress to date: The model of ribbed mussel distribution is in press. Manuscripts of the ecosystem services and future projections are in prep. The dissertation containing all of the above work except the R package is complete and accepted for publication. The R package is in development.

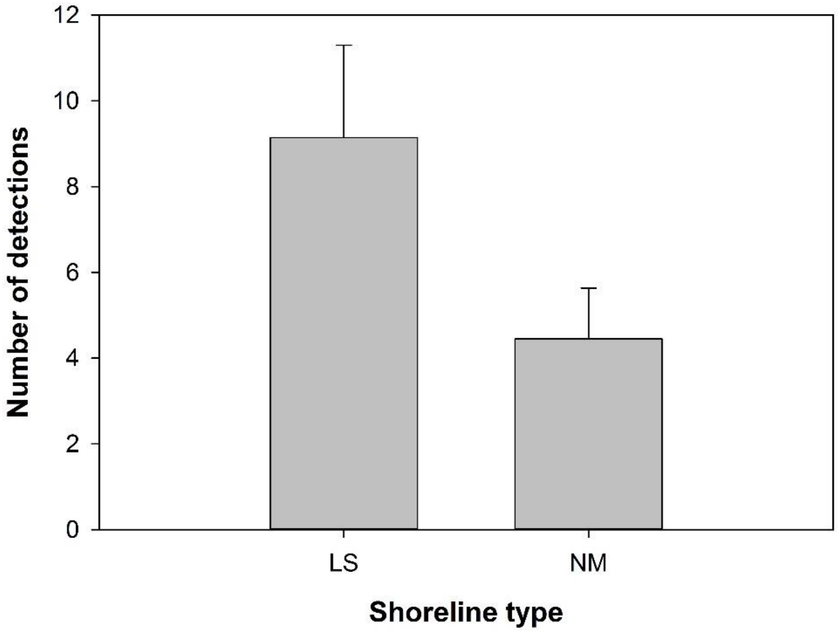
Task 3

Project activity: Assessing habitat provisioning of living shorelines for diamondback terrapin (*Malaclemys terrapin*)

Objective: Over the last 50 years, diamondback terrapin populations have decreased across most of their range. Among many factors contributing to population declines are bycatch in fishing gear and loss of marsh habitat. In addition, a recent study showed that terrapins avoid areas dominated by shoreline armoring. Shoreline armoring is increasing as more property owners attempt to curb property loss due to sea level rise. A less drastic way to protect shorelines from erosion is to implement living shorelines. However, the degree to which living shorelines provide habitat provisioning for terrapins has not been evaluated. Here, we compare terrapin space use between living shorelines and natural fringe marshes.

Methods: Terrapins are sampled three times for 30-min between mid-May and July (comprising the terrapin nesting season) each year. For each sampling occasion, observers note factors that could influence terrapin detection, such as glare, temperature, wind speed (m/s), and precipitation. Once a terrapin is detected, we note size (small vs. large) on the basis of the head and coloration (black, black-white, and white). This will enable us to test whether habitat provisioning of living shorelines differs by sex and/or among size classes. We use coloration to reduce sampling the same individual multiple times, which could bias density estimate positively. The proposed sampling and data structure enables us to estimate terrapin density adjusted for imperfect detection. We can model the detection process on the basis of covariates collected during each sampling occasion. We will model density of terrapins in the context of the shorescape, particularly in relation to the proportion of marsh and shoreline armoring.

Progress to date: We detected at total of 104 terrapins in 2018, but not all data are entered at this point. Detection distance ranged between 14-145 m from observer. The number of observations per site must exceed a minimum of 60 to provide a robustly estimate terrapin densities at the site level adjusted for imperfect detection.



Three factors could contribute to elevated terrapin detections at living shoreline marshes relative to natural fringing marshes. First, the living shoreline sites are comprised of *Spartina* grasses planted in sand fill trucked into the constructed marsh location. Because the grasses often do not fully cover the sandy soils, the open beach areas may serve as a visual attractant to female terrapins looking from the water towards land to identify suitable nesting areas. Our initial surveys have detected terrapin nests in the uplands adjacent to living shoreline marshes but not adjacent to natural fringing marshes. Second, the rocky sills placed in front of the living shoreline marshes to reduce wave energy are fully surrounded by water at high tide, and thus may serve as basking sites for terrapins. Natural fringing marshes do not have safe haul-out sites for basking; terrapins may preferentially congregate near the rocky sills to bask. Analysis of videos taken to determine wading bird use of rocky sills may provide evidence of this activity. Finally, the rocky sills also provide habitat for forage species eaten by terrapins (e.g., snails, worms, crabs). Ongoing surveys of invertebrate and fish use of natural and living shoreline marshes will determine whether more food potentially is available to terrapins adjacent to living shorelines.