Non-Technical Summaries of Publications
Mid-Atlantic Shorelines Project, May 2016

Submerged Aquatic Vegetation:

Patrick, C. J., D. E. Weller, X. Li, and M. Ryder. 2014. Effects of Shoreline Alteration and Other Stressors on Submerged Aquatic Vegetation in Subestuaries of Chesapeake Bay and the Mid-Atlantic Coastal Bays. Estuaries Coasts 37:1516-1531. DOI 10.1007/s12237-014-9768-7.

We related the abundance of SAV in subestuaries to the prevalence of shoreline hardening and to watershed land cover, shoreline land use, and other potential stressors. Major findings include:

1. SAV abundance in a subestuary is negatively related to agriculture and development in its watershed and to armoring and wetlands along its shoreline.
2. Wetlands and forest in the watershed and forested shoreline were all positively related to SAV abundance in a subestuary.
3. Since 1984, SAV abundance has continued to increase in subestuaries with less than 5.4% riprap but not in subestuaries with more riprap.
4. SAV responses to stressors differed among salinity zones, probably because the zones are dominated by different SAV species.

Patrick, C. J., and D. E. Weller. 2015. Interannual variation in submerged aquatic vegetation and its relationship to water quality in subestuaries of Chesapeake Bay. Marine Ecology Progress Series 537:121-135. DOI 10.3354/meps11412.

We analyzed patterns of year-to-year variation in SAV abundance in 91 subestuaries in three salinity zones of Chesapeake Bay, and we related those patterns to water quality variables thought to influence SAV abundance. Major findings include:

1. Year to year changes in SAV abundance are highly synchronized among subestuaries in the salty polyhaline zone and less synchronous in fresher water.
2. Fluctuations in SAV abundance differ among the salinity zones.
3. The water quality variables related to SAV abundance differed among the salinity zones.
4. High phytoplankton levels during periods of SAV germination and seedling development may be especially damaging to SAV.
5. SAV communities in the three salinity zones differed in their year-to-year dynamics and responses to stressors, so the communities may need different conservation and restoration strategies.

Patrick, C. J., D. E. Weller, and M. Ryder. 2016. The relationship between shoreline armoring and adjacent submerged aquatic vegetation in Chesapeake Bay and nearby Atlantic Coastal Bays. Estuaries and Coasts 39:158-170**. DOI 10.1007/s12237-015-9970-2.**

We contrasted the abundance of SAV directly adjacent to segments of natural and armored shoreline, and we tested whether the effects of armoring on SAV differed among salinity zones or with the dominant land cover of the local watershed of subestuaries. Major findings include:

1. Salinity and watershed land cover modified the effect of shoreline armoring on adjacent SAV.
2. SAV abundance was lower next to bulkhead in the polyhaline and mesohaline zones.
3. The effects of armoring were strongest in polyhaline subestuaries with forested watersheds.
4. Bulkhead in the polyhaline zone had a stronger negative effect on SAV further offshore (100-250 m) than onshore (0-100 m).
5. Redesigning or removing shoreline armoring structures may benefit nearshore SAV in some settings.

Sciance, M. B., C. J. Patrick, D. E. Weller, M. N. Williams, M. K. McCormick, and E. L. G. Hazelton. 2016. Local and regional disturbances associated with the invasion of Chesapeake Bay marshes by the common reed *Phragmites australis*. Biological Invasions Online First. DOI 10.1007/s10530-016-1136-z.

We summarized digital maps of the distributions of *Phragmites* and of potential stressors (especially human land use and shoreline armoring) at two spatial scales: for 72 subestuaries of the Chesapeake Bay bay and their local watersheds and for thousands of 500 m shoreline segments. We developed statistical models that use the stressor variables to predict *Phragmites* prevalence (% of shoreline occupied) in subestuaries and its presence or absence in 500 m segments of shoreline. Major findings include:

1. The prevalence of agriculture was the strongest and most consistent predictor of *Phragmites* presence and abundance, probably because *Phragmites* can exploit the resulting elevated nutrient levels to enhance its establishment, growth, and seed production.
2. *Phragmites* was also positively associated with riprapped shoreline, probably because riprap creates disturbances that provide colonization opportunities.
3. The *Phragmites* invasion was less severe in areas with more forested watersheds and natural shorelines.
4. Invasion was low in highly developed watersheds and highest along shorelines with intermediate levels of residential land use, suggesting that highly disturbed systems are uninhabitable even to invasive species.
5. Management strategies that reduce nutrient pollution, preserve natural shorelines, and limit nearshore disturbance of soils and vegetation may enhance the resistance of shorelines to invasion.

Tidal Wetlands:

Hazelton, E.L.G., T. Mozdzer, D. Burdick, D.F. Whigham, and K. M. Kettenring. 2014. *Phragmites australis* management in the Unites States: 40 years of methods and outcomes. AoB Plants. http://aobpla.oxfordjournals.org/content/6/plu001.full.pdf

Invited Review in Special Issue: *Phragmites australis* in North America and Europe.
This is publication #14-001 of the NOAA/CSCOR Mid-Atlantic Shorelines project.

Originally part of a symposium organized by Dennis Whigham and Andy Baldwin in Prague, CZ, we conducted a comprehensive review of *Phragmites* management in the U.S. to determine what we know and elucidate gaps in our understanding. We report the following major findings:

-Most studies are short in their duration, and that there are seldom sufficient monitoring efforts to determine the long-term impact of management efforts.
-The large majority of studies focused on the impact of herbicides on *Phragmites*, either alone, or in combination with other methods (such as mowing, or burning); although there were a rare few that looked at purely mechanical removal.
-Management studies rarely looked at the composition of plant communities that developed after *Phragmites* was removed. Most of them only looked at the impact of treatment on the invader, or other general categories of organisms.
-In order to aid future management efforts, we frame our findings in the context of recent research on *Phragmites* spread and reproduction and recommend a more holistic, watershed-scale approach to managing the reed.

Kettenring, K.M., D.F. Whigham, E.L.G. Hazelton, S.K. Gallagher, and H.M. Baron. 2015. Biotic resistance, disturbance, and mode of colonization impact the invasion of a widespread, introduced wetland grass. Ecological Applications, 25: 466-480.

The invasive grass, *Phragmites australis*, is widespread in wetlands and moist, disturbed areas in the Chesapeake Bay and across North America. There is much interest in understanding what factors are important for the ability of *Phragmites* to invade wetlands. In this study, we focused on the role of disturbances, areas where wetland vegetation has been removed, trampled, or buried by soil, in allowing *Phragmites* to take hold. We looked at the importance of small disturbances (<0.5m in diameter) across different wetland vegetation types and whether disturbances were important for the two modes of *Phragmites* spread: seeds and rhizomes (underground stems). The results of our study show that disturbances are critical for the ability of *Phragmites* to invade by seed. Seed germination and seedling emergence were much higher in areas where high marsh plant communities (vegetation dominated by *Iva frutescens*, *Schoenoplectus americanus*, *Scirpus patens*, and *Distichlis spicata*) were disturbed than places where the vegetation was left intact. Invasion by seed into areas dominated by *Typha angustifolia* was low regardless of the presence of a disturbance. *Phragmites*' ability to invade via fragments of rhizomes was not affected by the presence of disturbance or the type of vegetation, and occurred at low rates overall. Our findings provide evidence that small-scale within-wetland disturbances are important for the invasion of the non-native lineage of *Phragmites* by seeds in brackish tidal wetlands in Chesapeake Bay. Efforts to reduce disturbances, large and small, in wetlands can be used to limit *Phragmites* invasion by seed, but invasion by rhizome is still likely to occur at low rates across many plant communities irrespective of the presence of disturbance.

McCormick, M.K., H.E.A. Brooks, and D.F. Whigham. 2016. Microsatellite analysis to estimate realized dispersal distance in Phragmites australis. Biological Invasions. DOI 10.1007/s10530-016-1126-1.

Adjusting management efforts to accommodate the dispersal distances of target species can be key in slowing, containing, or eradicating invasive species. However, dispersal distance is often difficult to measure. We analyzed patterns of genetic relatedness to estimate realized dispersal distance for the invasive wetland grass, Phragmites australis. We found that most dispersal was <100m and very little dispersal extended beyond 500m. This suggests that management of P. australis may need to consider

dispersal from stands up to 500m from an area that is being managed, perhaps at the scale of whole subestuaries. Results of this study demonstrate that analysis of dispersal patterns can be used to develop landscape-scale approaches to the management of invasive species.

Macrofauna:

Balouskus, R.G. and T.E. Targett. 2012. Egg deposition by Atlantic silverside, Menidia menidia: substrate utilization and comparison of natural and altered shoreline type. Estuaries & Coasts 35:1100-1109.

Egg deposition by the intertidal spawning fish Atlantic silverside was compared among six shoreline types (*Spartina alterniflora*, *Phragmites australis*, sandy beach, riprap, riprap-sill, and bulkhead) and various substrates at each shoreline type. In spring 2010, egg density was measured daily near Roosevelt Inlet, Delaware Bay. Over 3,000,000 eggs were collected during 50 sampling days. Eggs were deposited at all six shoreline types, with >93% of eggs collected from *Spartina* shorelines. Choice of substrate for egg attachment was similar across shoreline types with >91% of eggs collected from filaments of the green alga *Enteromorpha* spp., a disproportionately high utilization rate in comparison with *Enteromorpha* spp.'s relatively low coverage. This study demonstrates that *S.alterniflora* shoreline, in association with *Enteromorpha* spp., is the preferred spawning habitat for Atlantic silverside and that hardened shorelines and shorelines inhabited by *Phragmites* support substantially reduced egg densities.

Balouskus, R.G. 2012. Effects of altered shorelines on macrofauna and diel-cycling hypoxia in tidal tributaries of Delaware Bay and Delaware Coastal Bays. M.S. Thesis. University of Delaware, Newark, DE. 193p.

In the first section of the thesis, quantitative seine sampling was used to examine the spatiotemporal use of the shore-zone along five shoreline types by fish and blue crabs. Weekly seining was conducted along *Spartina alterniflora* marsh, *Phragmites australis* marsh, sandy beach, riprap, and bulkhead from August through September 2009 and June through September 2010. Over the two-year study, in total 102,343 individuals in 28 species of fish and 3,607 blue crabs were collected in the shore-zone of marsh tributaries in Indian River Bay and Pepper Creek. The greatest abundances of fish were collected from the shore-zone of native *Spartina* marsh, while the greatest abundances of blue crabs were caught in the shore-zone of *Phragmites* marsh. Individual species had unique relative abundances at specific hardened and unhardened shorelines. Total fish abundance was greatest when dissolved oxygen (DO) was above the EPA dissolved oxygen criterion of 2.3 mg O2/l for the survival of aquatic organisms, though this relationship differed among fish species and shoreline type.

The second part of the thesis specifically examined the spatiotemporal use of a riprap-sill structure in Indian River Bay by fish and blue crabs. Wetland managers generally consider riprap-sill structures (a type of 'living shoreline' consisting of a rock sill placed low in the intertidal zone with native vegetation planted between the sill and shore) to be more ecologically sound than riprap for shoreline stabilization in estuaries. However, little research has been conducted comparing the macrofauna associated with these structures with that inhabiting the more traditionally applied riprap. Fish and blue crab abundance and diversity were compared along the riprap-sill shoreline and adjacent riprap shoreline

as well as along adjacent natural *Spartina* marsh from June through September 2010. Seining was conducted to quantitatively sample the shore-zone and shallow subtidal regions, and minnow traps were used to determine presence/absence of fishes in the upper intertidal zone of each shoreline type. In total, 9777 fishes and 548 blue crabs were collected by seine from the shore-zone of all three shoreline types. Greatest abundance and density of fishes were caught along the *Spartina* shoreline. Species densities and composition were generally more similar between the *Spartina* and the riprap-sill shoreline than between riprap-sill and traditional riprap shoreline. This study demonstrates that although *Spartina* shoreline is inhabited by the highest abundance and density of fishes, riprap-sill structure provides a better alternative than traditional riprap in terms of abundance and diversity of shore-zone estuarine fish and blue crabs. [A manuscript (Balouskus and Targett) from this chapter is under review by Transactions of the American Fisheries Society.]

In the third part of the thesis, multi-parameter water quality meters were positioned in the subtidal zone immediately adjacent to each of five shoreline types, *Spartina* marsh, *Phragmites* marsh, sandy beach, riprap, and bulkhead, within four tributary regions of Indian River Bay and Pepper Creek. Multi-parameter sondes were alternated among each tributary region once at 2 week intervals to record differences in water temperature and DO concentrations during the summer of 2010. Measurements were recorded when tributaries were experiencing severe diel-cycling hypoxia (July 15th-September 9th, 2010). Negligible differences were found in water temperature among shoreline types. The subtidal area directly adjacent to *Spartina* shorelines experienced less severe diel-cycling hypoxia than other shoreline types. This was particularly evident between the hours of 0200 and 1000, when DO concentrations are typically at their lowest, and water adjacent to *Spartina* shorelines had greater DO concentrations than did water adjacent to other shoreline types,.

The fourth part of the thesis examined how Atlantic silverside (*Menidia menidia*) utilized six different shoreline types (*Spartina* marsh, *Phragmites* marsh, sandy beach, riprap-sill, riprap, bulkhead) for egg deposition. Atlantic silverside is among the most abundant forage fish species in Mid-Atlantic estuaries, and is an important prey for piscivores such as striped bass, Atlantic mackerel, bluefish, and others. Atlantic silverside eggs are demersal, adhesive, and are laid in estuarine intertidal zones. From April 14th to June 10th, 2010, egg deposition was measured daily at several sites near Roosevelt Inlet, Delaware, near the mouth of Delaware Bay. Bottom substrates utilized for egg attachment were noted at each shoreline type. Over 3,000,000 eggs were collected during 50 sampling days. Eggs were deposited at all six shoreline types, with >93% of eggs collected from *Spartina* shorelines. Choice of substrate for egg attachment was similar across shoreline types with >91% of eggs collected from filaments of the green alga *Enteromorpha* spp., a disproportionately high utilization rate in comparison with *Enteromorpha* spp.'s relative coverage. This study demonstrates that *Spartina* shoreline, in association with *Enteromorpha* spp., is preferred spawning habitat for *M. menidia*, and that hardened shorelines and shorelines inhabited by *Phragmites* support substantially reduced egg densities. [A manuscript (Balouskus and Targett 2012) from this chapter was published in Estuaries and Coasts… see above.]

Torre, M.P. 2014. Shore zone habitat use by fishes and crabs in Delaware Bay: beach vs riprap shorelines. M.S. Thesis. University of Delaware. 92p.

Several types of hardening structures are becoming more common in the Mid-Atlantic region. This study assessed spatial and temporal differences in species composition, overall density, and densities

of individual species of fish and crabs along natural (beach) and hardened (riprap) shorelines in Delaware Bay. Riprap is the primary shoreline stabilization structure used in high energy beach and surf zones in the Mid-Atlantic.

In the first part of the thesis, quantitative seine sampling was used to examine fish and crab abundance along adjacent sections of both shoreline types at three locations along the southwestern shoreline of Delaware Bay. Sampling occurred from June through late September, 2012 and 2013. During 2013, the shore zone assemblage at the Lewes Beach site in lower Delaware Bay was also sampled during both day and night hours. Over the two years of this study 14,198 fish and crabs were captured, comprising 51 species. Dominant species were Atlantic silverside (*Menidia menidia*), silver perch (*Bairdiella chrysoura*), bay anchovy (*Anchoa mitchilli*), Atlantic menhaden (*Brevoortia tyrannus*), weakfish (*Cynoscion regalis*), and mummichog (*Fundulus heteroclitus*). Overall nekton density was higher along beach shorelines at 2 of 3 locations. Habitat preferences between beach and riprap hardened shorelines existed among several abundant species. Atlantic silverside, striped killifish (Fundulus majalis), spot (*Leiostomus xanthurus*), and white perch (*Morone americana*) being consistently more dense along beach shorelines. Bay anchovy was the only species that showed (at one location) significantly higher density along riprap than beach. Nekton density and species richness were also higher at night along both beach and riprap shorelines. Densities of bay anchovy, weakfish, and spot were higher at night and density of bluefish was higher during the day. These results demonstrate the impacts, on macrofauna, of altering beach habitat with riprap structures in high energy beach and surf zones in the Mid-Atlantic. [A manuscript (Torre and Targett) from this chapter is under revision for publication in Marine Ecology Progress Series.]

The second part of the thesis examined food habits of predatory fish species. Diet composition and stomach fullness were measured in juvenile weakfish and bluefish (*Pomatomus saltatrix*) captured during the shore zone sampling described above. Diet was compared between natural (beach) shorelines and adjacent hardened (riprap) shorelines at three locations along the southwestern shoreline of Delaware Bay during July and August, 2013, to assess differences in shore zone habitat function. Both species showed contrasting patterns of food habits between shoreline types. Overall, weakfish diet was dominated by mysid shrimp. However, diet was significantly different between beach and riprap shorelines at both sites, with bay anchovy contributing more to the diet along riprap at one *site and horseshoe crab larvae at the other. Bluefish were only available from one site, and their diet was more* diverse, consisting of the fishes bay anchovy and Atlantic silverside, and mysids; but diet composition differed significantly between beach and riprap during both July and August. Bluefish also had significantly higher feeding activity (stomach fullness) along beach shorelines than riprap during August, only. These results show that differences between beach and riprap shorelines can affect the feeding of shore zone fishes, and thus impact the functional value of the shore zone through altered prey fields or capture efficiencies, or both. [A manuscript (Torre and Targett) from this chapter is under review by Estuarine, Coastal and Shelf Science.]

Crum, K.P. 2011. Comparison of mummichog (Fundulus heteroclitus) growth rates and movement patterns at altered and natural estuarine shorelines. Honors B.S. Thesis. University of Delaware, Newark, DE. 65p.

The purpose of this study was to determine the impact of shoreline alteration on *Fundulus heteroclitus* growth and movement. The small home range of *F. heteroclitus* allowed 35-65m long stretches of *Spartina alterniflora*, *Phragmites australis*, riprap, and bulkhead shorelines in Pepper Creek, Delaware to be discreetly sampled, and growth and movement compared. Mummichogs were collected with unbaited wire mesh minnow traps and tagged with individually identifiable sequential Decimal Coded Wire Tags in July, 2010 . Of the 725 *F. heteroclitus* tagged and released, 89 (12%) were recaptured during August and September, 2010. Mummichogs displayed high site fidelity, although movements as long as ~475m were recorded. Growth rates were greatest along riprap shoreline, intermediate at bulkhead shoreline, and lowest at *Spartina* and *Phragmites* shorelines. A concurrent study in Pepper Creek found the density of *F. heteroclitus* to be ~8X higher along grass than along hardened shoreline and it appears growth rate may be at least partially related to density-dependent factors. However, by combining mummichog density differences with growth rates from the present study, estimates of relative productivity were lower along bulkhead and riprap than at *Spartina* and *Phragmites* shorelines. Growth rates of mummichogs along *Spartina* shorelines in the present work were less than reported by previous studies in *Spartina* marsh. The narrow, fringing nature of the marshes (a few m wide) in study area likely affected growth rates along *Spartina* shorelines in the present study. Therefore, these results may underestimate the mummichog growth benefits of *Spartina*, and possibly *Phragmites*, shorelines associated with more extensive marshes, relative to growth along hardened shores.