

Land Use Impacts: The Effects of Non-Native Grasses on Marsh and Aquatic Ecosystems

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Foreword

Tidal marsh systems serve as great examples of dynamic ecosystems that can provide numerous lessons in restoration ecology. The ecosystem services which are provided by naturally functioning marsh habitats, in conjunction with the diverse assemblages of nekton which utilize those habitats, have long been underappreciated. Unfortunately, misplaced beliefs and unintentional but harmful actions persist in the face of some of the most large-scale and coordinated scientific efforts towards achieving the preservation, remediation, and reclamation of these spatially dynamic systems. An important aspect of the restoration process is to gauge the success of any management practices that have been employed. Our program focus over the past five years has been to look at the impacts of land use and land cover on aquatic health and marsh habitat. Progress towards any goals should be consistently monitored to ensure that responses to habitat management put the ecosystem on a satisfactory trajectory in terms of achieving desired structure and function.

As discussed by Dahl [1], the United States Department of Interior, in conjunction with the United States Fish and Wildlife Service concluded that 53% of the total wetland acreage in the continental United States has been lost over the past two centuries, with Delaware losing approximately 54% of its original wetland habitat. This loss cannot be reclaimed or fully restored to its historic structure and function in the near future, and represents the importance of persistent and ongoing management of these remaining native wetlands. Of particular concern, especially over the past several decades, is the rapid invasion of a non-native subspecies of *Phragmites australis* [2]. The intrinsic value that *Phragmites* provides to the habitats in which it is found has often been determined from anecdotal reports of decreases in biodiversity and natural marsh function that in some areas have only recently been quantified using GIS and aerial imaging technology [3-6].

Naturally occurring variations in salt marsh topography will undoubtedly result in different flow dynamics, sedimentation rates, degrees of tidal inundation, and the availability of standing water on the marsh surface regardless of whether or not *Phragmites* is present [7]. However, it has been demonstrated in multiple cases that in areas where *Phragmites* is prevalent, the increased levels of biomass result in an altered soil chemistry, a shift in the availability of primary production, an elevated marsh surface, smoothed topography (i.e. the loss of rivulets), restricted flow to the marsh interior, an increase in shade and litter cover, and lowered or altered pathways for nutrient availability, especially nitrogen, for marsh nekton [8-12]. Due to this apparent degradation of habitat quality with regard to marsh structure and function, *Phragmites* removal programs have been initiated with variable successes in regards to the restoration of so called pre-*Phragmites* biodiversity [13]. Some research has demonstrated that resident nekton displays no preference for *Spartina* over *Phragmites* in an experimental setup [14], but studies in natural habitats appear to contradict these findings [15-16].

Blackbird Creek, a largely forested watershed located in northern Delaware, is characterized by extensive salt marshes and large native

populations of saltmarsh cord grass (*Spartina alterniflora*). It provides many recreational activities and is exposed to varying degrees of anthropogenic effects which disturb the ecosystem. Monitoring of ecosystem changes and established management practices has been ongoing since the mid-1970's [17].

Blue crabs and various other species flourish among the marsh grasses, whose leaves, roots, and stems provide much needed food sources and shelter from predators. Many Delaware coastal wetlands, including Blackbird Creek, have been subject to a loss of biodiversity over the past several decades, largely due to the invasion of the common reed (*Phragmites australis*). It may be considered a highly disturbed ecosystem due to this invasion and to the intensive management (i.e. herbicide spraying) that has occurred since the early 1990's (Figure 1a, 1b).

Healthy populations of submerged aquatic vegetation (SAV) and structured bottoms are two features which are severely lacking throughout the Delaware estuary [18]. The subtidal environment of Blackbird Creek can be described as muddy and unstructured, forcing juvenile crabs and fish to seek out other suitable refuge and nursery-providing habitat. Thus, they generally benefit from the relatively shallow streams and creeks with accessible intertidal zones that, in their native form, consist of a mosaic of marsh vegetation which provides structure in comparison to the otherwise unstructured subtidal



Figure 1a: Aerial photo of Blackbird Creek taken by Andrew Augustine. (Figure taken from Roeske 2014).

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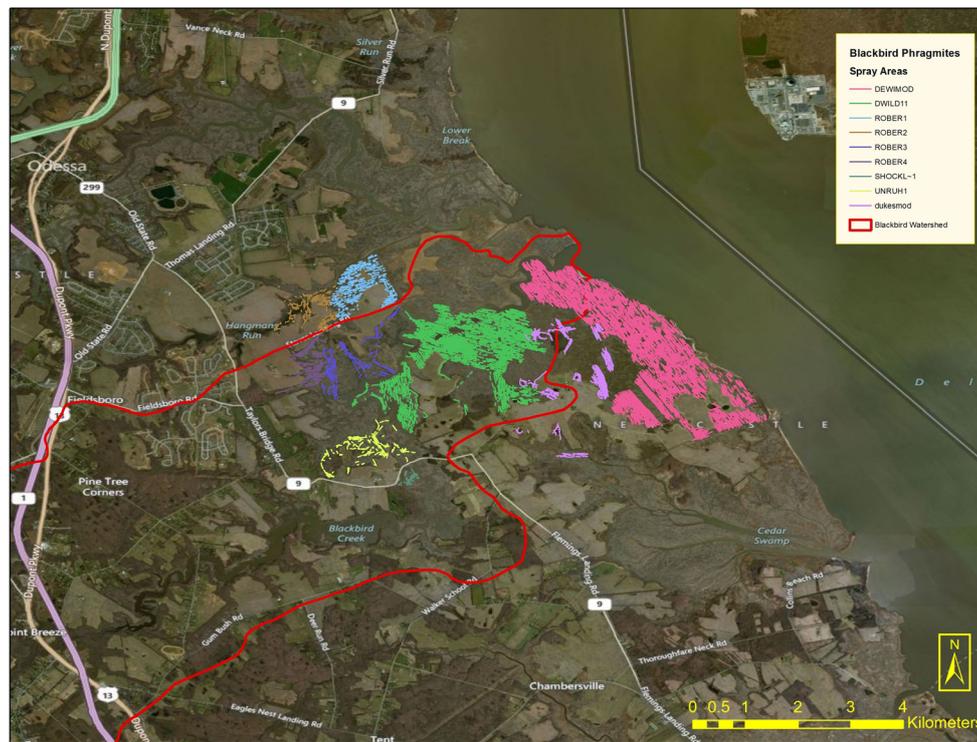


Figure 1b: Blackbird Creek Map in 2011 with areas showing aerial treatments of herbicide in locations which were deemed to contain approximately 50 percent or more *Phragmites*. Map kindly provided by Jason Davis, Delaware Fish and Wildlife (Figure taken from Roeske 2014).

habitats. These microhabitats found within most tidal salt marshes in the region provide a means of protection from predation, safe mating and molting opportunities, and a source of nutrition [19-20]. With this knowledge in mind, it follows that any drastic changes to the marsh vegetation assemblages will result in subsequent alterations to the value of nearby habitats.

The generalist nature and widespread distribution of blue crabs (*Callinectes sapidus*) throughout the Delaware Bay, from both a temporal and spatial perspective, indicates the importance of these types of systems to sustain the health of blue crabs and other economically and ecologically important species in the face of anthropogenic and environmental stresses [21]. Some of the more prominent issues facing wetland habitats include past, present, and future changes in land use and land cover, such as habitat encroachment and destruction, agriculture and historic diking of estuarine habitat, shoreline hardening, shoreline erosion, and both direct and indirect anthropogenically induced alterations to the structure and function of the actual marsh surface such as hydrology, topography, vegetation community, nutrient retention, tidal flooding, detritus accumulation and availability to secondary producers. Long the subject of controversy, various studies have examined fish, macro-invertebrate, turtle and avian species diversities in the monocultures of *Phragmites* and the research outcomes have been highly variable regarding the direction and magnitude of impact of *Phragmites australis* on habitat suitability for marsh nekton. However, it is a different story for the birds and turtles where significant negative impacts of this deleterious species recorded on the diversity and abundance of birds (i.e. willet, seaside sparrow, sharp-tailed sparrow) and turtles [22-23]. Anecdotal reports of decreases in biodiversity and natural marsh function in some areas have only recently been quantified using GIS and aerial imaging technology

[24]. Thus it would be pertinent for managers to maintain the health of these areas by preventing any further alterations, especially from the invasion of *Phragmites australis*.

The physical and mechanical methods for controlling *Phragmites* include the removal of dikes, the construction of controlled wetlands, raising the water table, modification of micro-topography [25-26],



Figure 2a: Dense monoculture of dead and living non-native *Phragmites australis* within Blackbird Creek. If left unmanaged, vast stretches of wetlands may become engulfed by this highly productive, genetically diverse, and hard to control subspecies, potentially resulting in the displacement of countless numbers of native ecologically and commercially important flora and fauna in the process (Picture taken by Roeske).



Figure 2b: Natural marsh absent of non-native *Phragmites australis*. *Spartina alterniflora* and *Spartina cynosuroides* are observed among several other typical native marsh plants and in most cases both plant and animal diversity is greater than in a marsh that is considered to be undergoing a late stage of non-native *Phragmites* invasion (Picture taken by Roeske).



Figure 2c: Summer undergraduate interns in the field collecting soil, water, and plant samples in Blackbird Creek (Picture taken by Roeske).

prescribed burning of selected marsh areas, and rotary mowing where possible. The most effective management strategies have utilized a combination of the aforementioned removal techniques with the logic that constant stress through mowing, burning, herbicide treatment, increased salinity, etc. will encourage native plant colonization while pushing out *Phragmites*. It is also important to note that burning alone may actually reinvigorate the populations in subsequent years and thus should be utilized in a strategic manner over the course of several growing seasons if any permanent removal is to be accomplished [27].

Structure, function, and change are part of common terms utilized into landscape and habitat restoration jargon. If structure is restored, but function and/or change is neglected, restoration will not be achieved. This holds true for any combination of these three terms in that they are intimately connected. Without function, there cannot be

any structure. Without change, you have a static environment, which is never the case in the natural environment. And if one thinks of the problem of the invasion of *Phragmites* as a landscape level problem, site based restoration will not suffice as it only addresses that particular habitat. Thus, all of the current and future management efforts must be viewed as “habitat restoration” and not “ecological restoration.” This has several important implications including the fact that while some species may benefit from the removal of *Phragmites*, other species might very well experience deleterious consequences, likely due to the management efforts themselves and not the actual removal or presence of *Phragmites* [13]. In the case of *Phragmites* invasion, it appears that both biotic and physical thresholds have been crossed (Figure 2a, 2b, 2c). The dispersal of plants and animals is altered, and the physical functions of the affected marshes have been transformed to certain degrees.

The program focus over the last five years in Delaware Blackbird Creek has been to monitor blue crab and other aquatic species in relation to the land use, water quality, and salt marsh habitat. These efforts also include investigating microbial load and diversity associated with *Spartina alterniflora*- and *Phragmites australis*-dominated sites in Blackbird Creek. Microbes including Proteobacteria, Vesicular arbuscular mycorrhizae (VAM) fungi, and diatoms have also been investigated. Biological indicators such as a diatoms are species that respond to changes in environmental conditions and can be used to

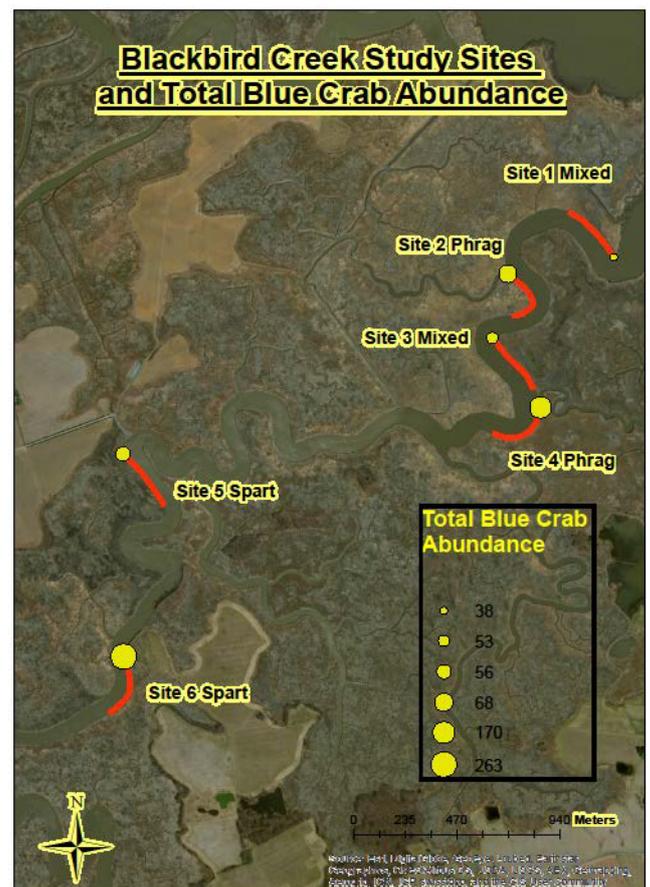


Figure 3a: The physical arrangement and total abundance of blue crabs at the research sites within Blackbird Creek starting with site 1 near the mouth of the creek, and ending with site 6, approximately 2 miles inland (Map by Roeske).



Figure 3b: Blue crab picture (Picture taken by Roeske).

monitor the health of an environment or ecosystem. The microbial distribution of these microbes in soil, roots, and leaves has been monitored and related to the physical and nutrient components of samples from different seasons in order to understand their effect on microbial distribution relative to plant growth and distribution since microbes are influenced strongly by plant phenology. Specific molecular analysis for Proteobacteria testing has been performed spatially and temporally to identify and compare microbial communities associated with two dominant marsh grasses (*Phragmites australis* and *Spartina alterniflora*). Vesicular arbuscular mycorrhizae (VAM) are fungi that effectively increase the nutrient availability to the host plants. Microscopic and molecular analysis of plant roots was carried out for the detection of the fungi and a seasonal study was conducted to determine their presence and abundance during the growing season and the death phase. Diatom population dynamics were determined by genetic analysis in order to infer seasonal and spatial water quality trends.

Comparable studies have suggested that changes in fish and invertebrate habitat may be the result of the invasion of *Phragmites* in the mid-Atlantic region. Low abundance of both male and female crabs are found near the mouth of Blackbird Creek, with peak abundances occurring at inland sites. *Phragmites*-dominated sites show a trend towards presence of larger crabs while *Spartina*-dominated sites show a trend toward smaller individuals and crabs in the pre-molt stage. A relatively high degree of molting was observed in mixed and *Spartina* designated sites. Fish abundance appears to be correlated with crab abundance across study sites. The *Phragmites* sites and *Spartina* sites displayed high relative abundance values (Figure 3a, 3b). Along with information about aquatic fauna, total phosphorous, nitrate, and nitrogen are high in areas dominated by *Spartina* and mixed marsh grass species, and *Phragmites*-dominated areas are not rich in any major nutrients. Marsh grass diversity seems to affect the soil nutrients and microbial community. VAM fungi were observed within the roots of *Spartina alterniflora*. These fungi were also observed in the invasive *Phragmites* when they exist along with *Spartina*. These fungi help the plants with uptake of nitrogen and phosphorus from the soil. The benthic diatom community differs among the sites studied, and a good correlation between the benthic diatom community and water quality was observed. Sites high in dissolved oxygen and moderate in nutrients provided diverse benthic diatom assemblages. The dominant diatom

in *Spartina* and mixed marsh areas was *Navicula phyllepta*, where nitrate-nitrogen and total nitrogen were found in high concentrations. According to Underwood and Barnett [28] *N. phyllepta* is predominant in soils with nitrate-nitrogen and ammonium. In areas dominated by *Phragmites*, *Cylindrotheca closterium*, a diatom abundant in saline conditions [29] has been identified. *Thalassiosira* sp. is abundant in marsh areas near agricultural sites. Thus, microbial diversity varies with marsh habitat in which the soil nutrient composition is being impacted by land use and altering habitat quality for resident nekton.

Blue crabs are known to choose sites based on habitat quality. Some marshes may provide less value to actively feeding/molting crabs. This may have important implications for adults that utilize the marsh surface for feeding. The length of time of tidal inundation may be lower at *Phragmites* sites than *Spartina* sites because of the nature of the root structures which can result in increased detrital accumulation and raised marsh surfaces during late stage *Phragmites* invasion

The effort to monitor marsh grass habitat provides enhanced insight into the importance of how marsh surface vegetation is utilized by blue crabs and resident fish and to advance the management and restoration efforts that have been, and are currently, in place for the elimination of *P. australis*. Also, the type of marsh grass affects the soil nutrients, and thereby influences the micro- and macroorganisms living in the marsh environment. Studying the microbial community with respect to native and invasive marsh grasses will help us identify stress tolerant microbes and microbial genes that play a role in helping plants deal with salt and other stresses, which may be potentially applied to terrestrial plants.

The Blackbird Creek watershed is comprised of only four percent urban development and thus provides an opportunity to study an area that has had little anthropogenic impact relative to other watersheds. Our research program is now focusing on how trophic dynamics can be affected as a function of various land uses. In Blackbird Creek, there are several areas designated as cropland. An understanding of crop rotation in these plots both within and between seasons, coupled with a complete survey of aquatic nekton would provide insight into whether changes in crops across years affect trophic interactions and food web dynamics. Additionally, this project delves into the effectiveness of riparian buffers as blockades for fertilizer runoff. With sites associated with buffers, it will be useful to identify different food web characteristics, especially if there are inconsistencies in the nutrient levels between those sites. While this is intriguing, it would be even more beneficial if a second watershed was considered-one with more urban areas and anthropogenic effects. If similar work was done in each of these watersheds, we may be able to discern the effects of different land uses on Delaware's coastal waterways.

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