

Marsh Vegetation Analysis of Delaware Blackbird Creek Using Ground Surveys and Aerial Photography

Kris Roeske¹ & Gulnihal Ozbay^{2*}

The marsh surface vegetation in the downstream portions of Blackbird Creek has been subject to loss of biodiversity over the past several decades due largely to the expansion of a non-native subspecies of the common reed (*Phragmites australis* subspecies *australis*). This may be considered a highly disturbed ecosystem due to the invasion of *Phragmites* and the intensive management (i.e. herbicide spraying) has occurred since the early 1990's. We aimed to document the presence/absence of *Phragmites*, average cover class, stem density, and average stem height at the six sites for 2 years. A decrease in total richness (sites pooled) was observed confirming that only specific plants are capable of thriving in the zone most prone to prolonged tidal inundation. Average cover class was lowest at the end location for Phrag site 2 and the highest at Phrag site 4. The tallest average live vegetation was observed at Phrag site 4, as well as the average height of 10 randomly selected stems. The combination of ground survey and aerial photography techniques are invaluable for conducting research in hard to access areas, when other methods of obtaining aerial photography are not financially feasible, or in areas which are subject to unfavorable weather conditions.

Keywords: Marsh vegetation survey, ground survey, aerial photography, *Phragmites*, *Spartina*

1. Introduction

A large tidal creek, Blackbird Creek focused on this study is located in north-central Delaware. It drains 80 square kilometers into the Delaware Bay and is comprised as 51% agriculture, 48% forested land, and 1% urban development. Blackbird Creek is a tidal system for the lower 22 kilometers of the waterway, making it an extremely important ecosystem for many ecologically and economically important species. As a nursery, it is home to several fish species especially in their juvenile stages, including weakfish (*Cynoscion regalis*), white perch (*Morone americana*), channel catfish (*Ictalurus punctatus*), black drum (*Pogonias cromis*), white catfish (*Ameiurus scatus*), atlantic menhaden (*Brevoortia tyrannus*), alewife (*Alosa pseudoharengus*), American eel (*Anguilla rostrata*), striped bass (*Morone saxatilis*), and many others. Perhaps a flagship species in this ecosystem is the blue crab (*Callinectes sapidus*).

Blackbird Creek is a watershed where there is great potential for eutrophic conditions. Over half of the watershed is comprised of agricultural land. These lands are fertilized heavily to accommodate the timely growth of corn, soybeans, and sorghum grass. This is a concern for local nekton of commercial and ecological importance. Eutrophication is a common problem for wetlands downstream of agricultural lands, partially because the nutrient loading tends to favor the growth of aggressive, invasive, often weedy, plant species which displace native plants. Drexler and Bedford (2002), for example, showed that inflow of nutrient rich water into a New York wetland led to growth of monotypic stands of grasses in an otherwise diverse ecosystem. In extreme cases, such as the Chesapeake Bay, nitrogen and phosphorous loading causes algae growth so great that the blooms block out sunlight to submerged aquatic vegetation, a crucial habitat for larval and juvenile fish and crabs (Boesch et al., 2001).

The ecosystem services provided by wetlands are wide-reaching. These include maintenance of water quality, regulation atmospheric gases, protection of shorelines, and sustenance indigenous species (Gittman et al., 2016; Clarkson et al., 2013).

¹ Department of Agriculture and Natural Resources, Delaware State University, Dover, DE 19901

² Professor and Extension Specialist in Natural Resources, Department of Agriculture and Natural Resources, Delaware State University | E-mail: gozbay@desu.edu | Tele: 1+(302) 233 8453 | Fax: 1+(302) 857 6476

While these systems do tend to be fairly capable of adapting to and mitigating human impacts, it is becoming more apparent that it is the understanding of the resilience of wetlands that will be the key to predicting how such an ecosystem will accommodate long-term issues such as climate change, sea level rise, and permanent change due to human use.

A report by the Department of Interior, in conjunction with the U.S. Fish and Wildlife Service (Dahl, 1990), states that over the past two centuries the continental United States has seen a 53 percent reduction in total wetland acreage, with Delaware losing approximately 54 percent of its original wetland habitat (Dahl, 1990). It is generally accepted that this loss of habitat cannot be reclaimed or fully restored to historic structure and function in the near future, and thus represents a constant reminder of the importance of the ongoing management of the remaining wetlands throughout the U.S. (Lotze et al., 2006). Of particular concern in regards to the overall goal of maintaining the presence of functioning native wetland ecosystems, especially over the past several decades, is the enigmatic invasion of a non-native subspecies of *Phragmitesaustralis* (henceforth referred to as NN Phrag).

The dramatic yet silent nature of the invasion by the non-native form of *Phragmitesaustralis* has prompted the use of not only standardized vegetation survey and mapping methodologies, but cutting edge technology for mapping the presence/absence of a particular species and determining the rate at which it is expanding. The ability to obtain accurate, high resolution, and up to date aerial photography has resulted in the development and implementation of adaptive management strategies over large spatial scales (Teal and Weishar, 2005). Kentula et al. (1992) state “we must learn from what we have done and use that information to improve future resource management.” This statement directly applies to the ongoing issue with NN *Phragmitesaustralis*, especially when taking into account the considerable amount of resources that have been and are continuing to be dedicated to the eradication of this plant. For example, the U.S. Geological Survey reports that an estimated annual expense of \$4.6 million is spent on *Phragmites* removal programs encompassing over 200,000 acres with no statistically significant relationship existing between money spent and management success (Great Lakes Restoration Initiative [GLRI], 2013). Standardized metrics such as species identification, percent plant cover, density, and a list of dominant vegetation are useful for classifying sites on small spatial scales (Kentula et al., 1992). But the expansive nature of the problem with *P. australis* has prompted the use of more sophisticated approaches which are striving to increase the area we are able to accurately sample while decreasing the effort and time required to do so. This increase in the scale of mapping often times comes at the cost of a decrease in the resolution of the resulting images for interpretation. Often times this makes identifying particular vegetation to the genus or species level difficult if not impossible (Miyamoto et al., 2004). Artigas and Pechmann (2010) and Miyamoto et al. (2004) have utilized tethered helium balloons for ground truthing remotely sensed vegetation data with promising results. Artigas and Pechmann (2010) achieved 90% accuracy in vegetation classification when utilizing these two methods in conjunction. Miyamoto et al. (2004) were able to identify 58 distinct species with their mapping techniques. Because the structure and function of any managed ecosystem are of vital importance, being able to accurately monitor species biodiversity, spatial heterogeneity, and phenological changes to the vegetation community, especially in areas that are currently being managed, are not easily accessible by foot, or are frequently subjected to unfavorable weather conditions such as fog or cloud cover, is of utmost importance to the success of an ongoing management plan (Miyamoto et al., 2004).

Klemas et al. (2000) conducted a thorough investigation regarding the presence, expansion, and control efforts of *Phragmitesaustralis* at the National Estuarine Research Reserve System (NERRS) sites which included our study site Blackbird Creek. They were concerned with changes in the *P. australis* cover over the previous two decades. According to their study, Blackbird Creek is 19.1 km in length, has a total area of 1699 ha, with 99% of the surrounding land being composed of agriculture and forested land. They list the physical alterations to the creek as being few in number, and the *P. australis* control level is considered to be extensive. In 1979, prior to any documented restoration activities in Blackbird Creek, the areal coverage of *P. australis* was 371.18 ha, or 26.5% of the total area (Klemas et al., 2000). Over the subsequent 14 years that area increased to 45.4% of the total area with the number of distinct patches of *P. australis* decreasing (Klemas et al., 2000). The authors attribute this to the rhizomatous, monotypic growth patterns observed by non-native *P. australis* and other perennial grasses, where disparate stands expand and can eventually become a conglomeration with neighboring patches. Average *P. australis* patch area also increased over this 14 year period from 0.58 to 3.10 ha. Since the mid 1980's the downstream portion of the creek, which encompasses five of our six sample sites, has seen somewhat inconsistent *P. australis* control efforts in the form of aerial herbicide application as well as prescribed burns (Klemas et al., 2000). However, as Klemas et al. (2000) reported, much of the gain in *Phragmites* coverage was in areas that had previously undergone control efforts.

Klemas et al. (2000) also reported an interesting trend in the appearance of new stands of *P. australis* between the periods of 1979 to 1988 and 1988 to 1993. From 1979 to 1988 nearly 92% of the new stands appeared downstream of Taylors Bridge, whereas between 1988 and 1993 over 50% of the new *Phragmites* patches occurred in the upper portions of Blackbird Creek, posing a considerable threat to the continuity of the watershed. Starting in 1995, as part of the multi-faceted Estuary Enhancement Program (EEP) proposed by Public Service Electric and Gas (PSEG) which served to mitigate egg and larval fish loss at the intakes of the Salem Nuclear Power Plant, a yearly aerial application of the herbicide Glyphosate with a surfactant has been applied to select areas within the boundary of the Rocks site. This restoration site is bound to the west by Stave Landing Road, to the south by Blackbird Creek, and to the north by the Appoquinimink River (PSEG, 2012). The area of treated marsh has varied from year to year with 26, 95, 99, 84, 82, 59, and 45ha being sprayed with herbicide in the years 2000, 2001, 2002-2004, 2005, 2006, 2007-2008, and 2009-2011, respectively. While there has been a decrease in the area sprayed from early 2000 to the beginning of our study, the fact that *P. australis* dominated marsh is still present throughout the system reflects the enduring and invasive nature of the plant.

For this study, we aimed to document the presence/absence of *Phragmites*, average cover class, stem density, and average stem height at the six sites that we sampled. Leonard et al. (2002) conducted a study to elucidate any potential differences between the flow dynamics and sedimentation rates of marshes dominated by *Spartina alterniflora* or *Phragmites australis* within the Chesapeake Bay. They found that on average, during non-storm conditions, the flow patterns, total suspended solids concentrations, and sediment deposition rates were not different among their sites. This provides important insight for our project especially when considering how marsh structure and function may be impacting blue crab use of the system in question. Other variables that are altered when an invasive plant becomes the dominant vegetation (e.g. cover class, stem density, canopy height, etc.) may be the more dominant factors related to changes in the population dynamics and patterns of marsh use of the fauna in question.

2. Materials and Methods

2.1. Vegetation Surveys

In order to determine the accuracy of the vegetation classification which was initially assigned to each site selected in this study (Mixed, *Phrag*, or *Spartina*), as well as any differences in various metrics regarding the physical structure of the vegetation, two vegetation surveys were conducted during August 2012 and 2013. As indicated by Able and Hagan (2003), August is when peak vegetative growth may be observed. Not only was the diversity of vegetation present of interest, but the estimated percent coverage of each species in a particular quadrat, the dominant vegetation type, the height of the tallest standing live vegetation, the length of 10 randomly selected live stems, and the stem density were also recorded. Percent coverage was designated as one of six cover classes which are summarized in Table 1. The dominant vegetation was determined visually and was based on the highest designated cover class for that particular quadrat. Stem density was determined by counting the number of live and dead standing stems. The design for each survey was slightly different between years, but each consisted of thirty six 0.25m² quadrats (six at each site) for a total of 72 quadrats (Figure 1a). Because the survey design was modified between 2012 and 2013 to better reflect the intertidal zones in question, the data for these years was analyzed separately. Figure 1b shows the orientation of the quadrats at each site for each year. For the 2012 survey, two transects at each site, one on both side of the creek at the center pole marker for each 300m long site (i.e. 150m) was surveyed at three distances from the marsh edge (0.5m, 5m, and 10m). The values from corresponding quadrats from either side of the creek in relation to distance from the marsh edge were summed and averaged. For the 2013 survey, two replicate quadrats were deployed 0.5m from the marsh edge at the start, middle, and end points (i.e. 0m, 150m, 300 m) on the side of the creek that the crab traps were deployed on. The values for each replicate were summed and averaged for each site and location within the site.

2.2. Aerial Survey

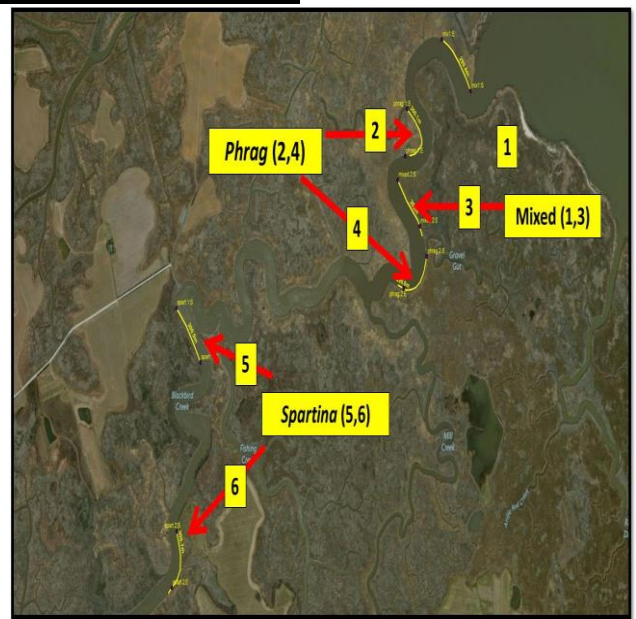
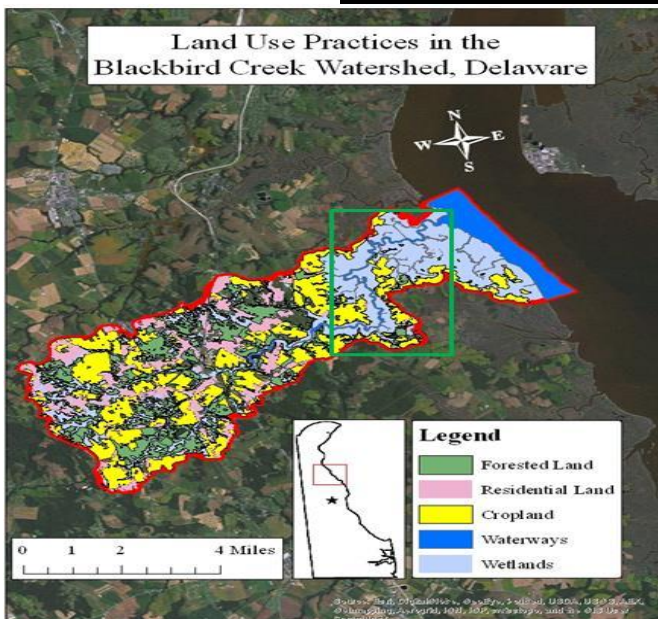
Because the study site is currently under management, the distribution of vegetated and unvegetated marsh surface can vary considerably from year to year depending on where management efforts are focused. The herbicides used for *Phragmites* removal are non-selective and thus will kill any green vegetation they come in contact with. The growth pattern of NN *Phragmites* often results in mixed stands early on in the invasion which are impossible to selectively spray via aerial applications. We conducted four flyovers, with the assistance of the Delaware State University Aviation Program, in order to obtain up to date, high resolution aerial photography of each of the sample sites within Blackbird Creek (Figures 6 through 11).

These flyovers were conducted on June 21st and August 24th 2012, and June 28th and September 18th 2013. A SONY Cyber-shot DSC-HX200V (18.2 MP Exmor R CMOS Digital Camera with 30x Optical Zoom and 3.0-inch LCD (Black), Effective Sensor Resolution – 4920 x 3699 = 181,990,080 pixels, 1080/60p HD Video Capture, 10 fps Burst Mode, MS Duo/SD/SDHC/SDXC Compatible) was utilized for obtaining the photos. Actual size of the HX200V sensor is 6.16 x 4.62mm. The sensor has a surface area of 28.5mm² and a pixel density of 63.79 MP/cm². There are approximately 18,200,000 photosites (pixels) on this area.

In addition to these flyovers, a camera rig which was attached to a tethered helium balloon was deployed to obtain aerial imagery along the course of all six of our study sites within Blackbird Creek. The materials and rig setup were obtained and deployed by Dr. Andrew Augustine and were based off of the tutorials provided at <<http://publiclab.org/wiki/balloon-mapping>>. The balloon was flown at approximately 76m, but this height was likely considerably variable between pictures due to the oblique angle of the line formed between the anchor point (i.e. the boat) and the camera rig due to wind action and the fact that it was being towed from the boat. A CANON Powershot A800 (10 MP Digital Camera with 3.3x Optical Zoom (Black), Maximum Video Resolution – 640-480, Effective Sensor Resolution -10,000,000 pixels) was utilized for this portion of the aerial photography set to take photos at a constant interval while deployed. The balloon flyover was only conducted once during the 2012 summer on August 22nd. August was chosen as the month to obtain this aerial imagery based on the anticipation of peak vegetative growth as noted by Able and Hagan (2003). Orthophotos from SONY Cyber-shot DSC-HX200V from each site were generated using the AirPhoto Special Edition v. 2.53 and were visually interpreted to determine the presence/absence of *Phragmites australis*. The visual interpretation was compared to the data from the vegetation surveys and other photographs taken from ground level to increase the degree of correct species identification.

Table 1. The cover class designated to each range of estimated percent cover.

Range of Cover (%)	Cover Class
0 to 5	1
5 to 25	2
25 to 50	3
50 to 75	4
75 to 95	5
95 to 100	6



(a)

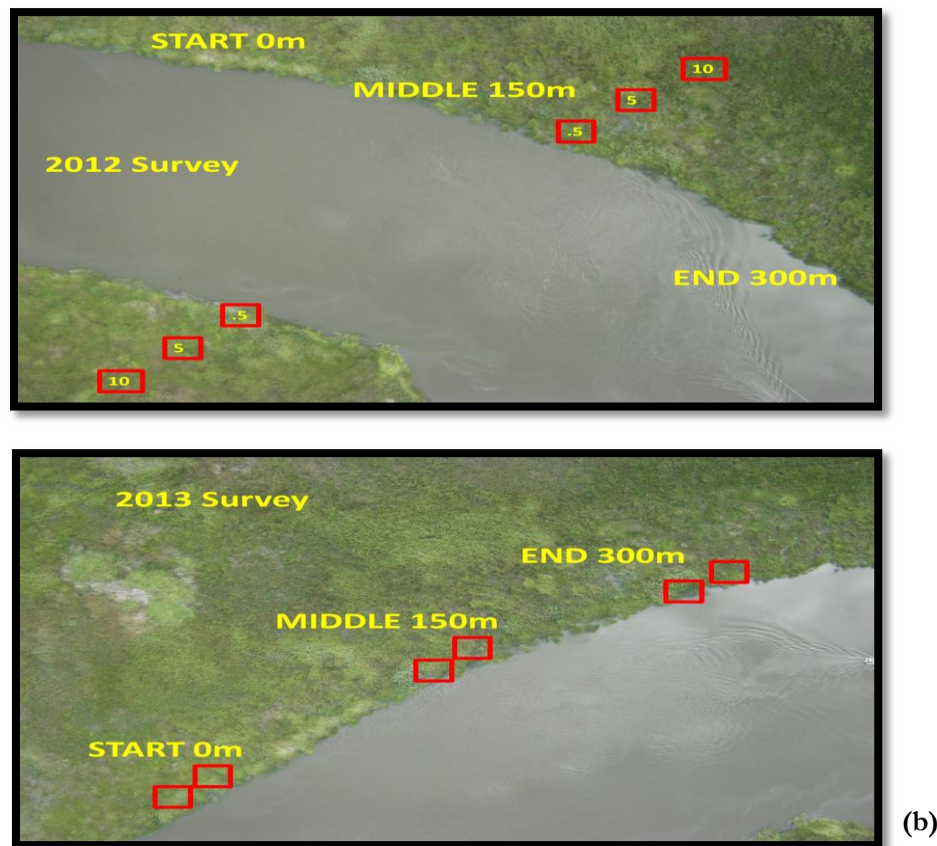


Figure 1. (a) Maps of the six study sites in the Blackbird Creek; and (b) The design for the vegetation analysis conducted in 2012 and 2013 (top and bottom, respectively). Red boxes indicate approximate locations of the sampled quadrats. For 2012, the quadrats were placed 0.5, 5, and 10m from the marsh edge at the middle pole marker on either side of the creek, whereas in 2013 replicate quadrats were sampled 0.5m from the marsh edge at the start, middle, and end pole markers at each site on the side of the creek where crabs traps were deployed.

3. Results

3.1. 2012 Vegetation Survey

The number of species present at each site is displayed in Figure 2. The number of unique species detected at any given site did not exceed 6 nor did it fall below 2. Across all six sites a total of 10 unique species were identified including *Spartina alterniflora*, *Spartina patens*, *Spartina cynosuroides*, *Shoenoplectus americanus*, *Scirpus robustus*, *Polygonum punctatum*, *Polygonum hydropiperoides*, *Bolboschoenus robustus*, *Atriplex patula*, and the non-native form of *Phragmites australis*. Average cover class ranged from a low of 1.5 to a high of 6 (Figure 3a). At least 1 quadrat from Mixed and *Spartina* sites obtained a cover class value of 6, indicating 95 to 100% cover. NN *Phrag* and *Spartina* cover class designations never fell below 3 whereas 2 quadrats within mixed sites were designated an average cover class of 1.5. The average tallest live vegetation ranged from a low of 102.5cm at site 1 (Mixed) to a high of 290cm at site 4 (*Phrag*) with the average across all 6 sites at 193.06cm (Figure 3c). The tallest live vegetation measured at a *Spartina* site did not exceed 171cm which was lower than the shortest value for a *Phrag* site which was measured at 174cm. Taking all 6 sites into consideration, the average stem density was 45.83 stems / 0.25m² (Figure 3b). Average stem density ranged from 21 to 87 stems / 0.25m² with 8 of the densest averages (i.e. 44% of the samples) were found in Mixed or *Phrag* sites. The average height of 10 randomly selected live stems had a range of 96.71 to 235.6cm with the average height across all 6 sites coming in at 157.94cm (Figure 3d).

Eight of the tallest averages for 10 randomly selected stems (i.e. 50% of the samples) were designated Mixed and *Phrag* sites. The average height of 10 randomly selected stems for any *Spartina* quadrat did not exceed 136.6cm. The average cover class (i.e. 1-6) and the average stem density (i.e. live and dead standing stems / 0.25m²) among sites was not significantly different based on a one-way ANOVA ($F_{5,12} = 2.70$, $p = 0.073$, $F_{5,12} = 2.86$, $p = 0.063$, Figures 3a and b).

The average tallest standing live vegetation was significantly different by site ($F_{5, 12} = 11.02$, $p = 0.000$, Figure 3c) but this was not consistent among sites with the same vegetation classification. A Tukey Post Hoc revealed that sites 1, 5, and 6 (i.e. mixed, *Spartina*, *Spartina*, respectively) had significantly lower average tallest vegetation than sites 4 and 3 (i.e. *Phragmites* and mixed). Site 2 (i.e. *Phragmites*) was the only site which was not significantly different from any of the other sites. The average stem height of 10 randomly selected live standing stems was found to be significantly different among sites ($F_{5, 12} = 30.36$, $p = 0.000$, Figure 3d). Site 1 (i.e. mixed vegetation) had significantly smaller average stem heights than sites 2, 3, and 4. Sites 5, 6, and 2 had significantly smaller average stem heights than sites 3 and 4. Again, there was some inconsistency among the average stem heights from sites with similar vegetation treatments, but both *Phragmites* dominated sites had taller average stem heights than either *Spartina* sites. A general regression was run to determine if the average stem density was dependent on vegetation classification (Mixed, *Phragmites*, *Spartina*) or distance from the edge (0.5, 5, 10m) and was not found to be significant for vegetation type, distance from the edge, or the interaction of vegetation type and distance from edge ($r^2 = 0.627$, $p = 0.060, 0.155, 0.343$, respectively).

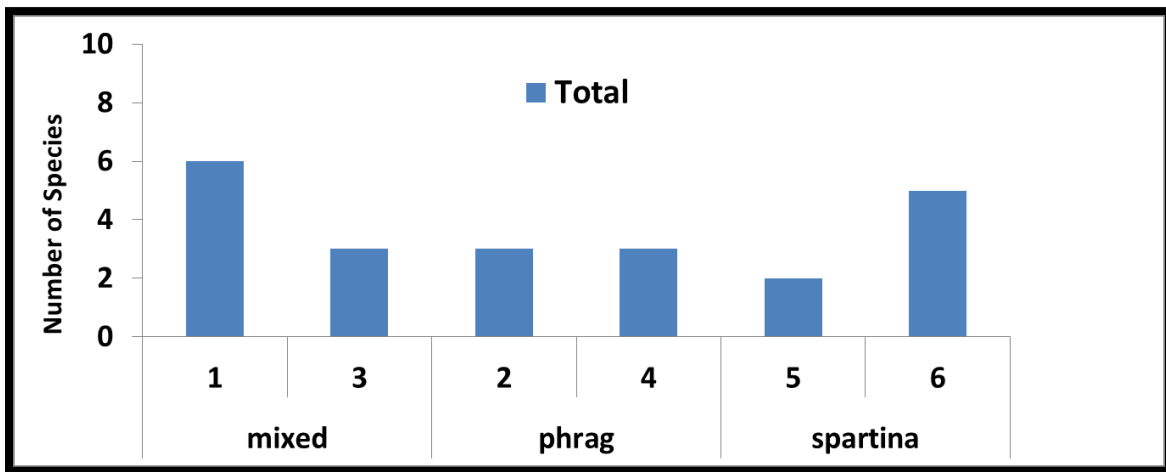
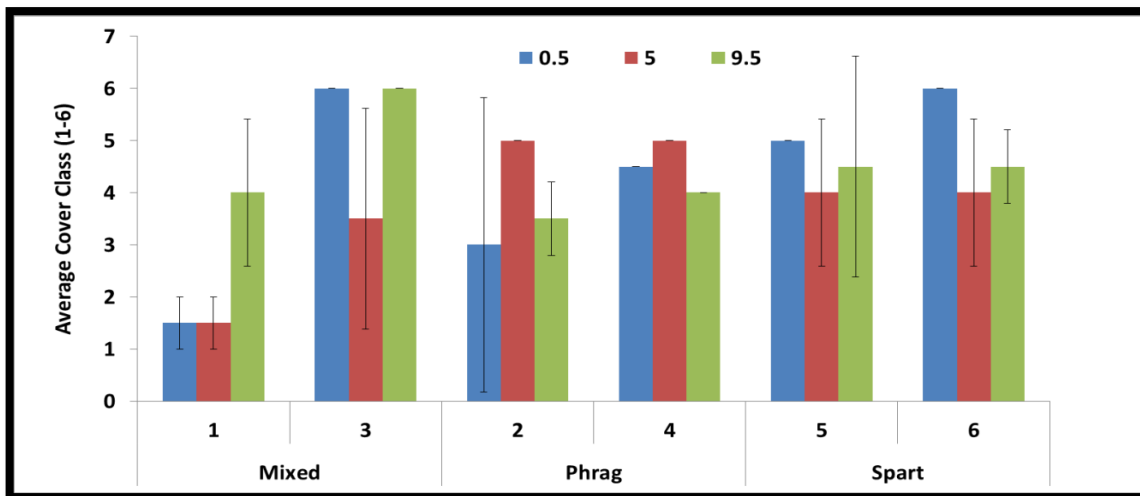


Figure 2. The total number of species sampled at each site.



(a)

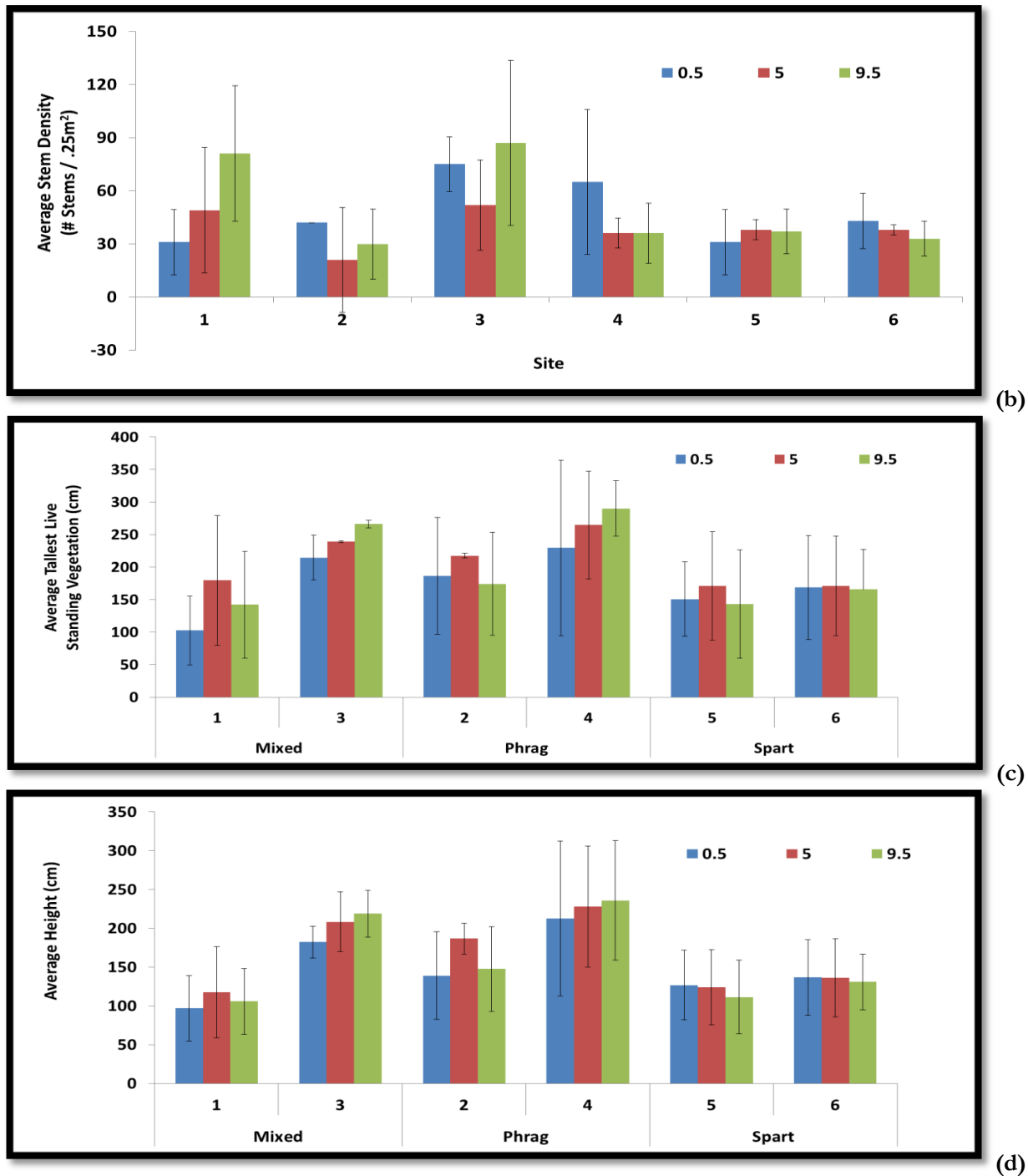


Figure 3. (a) The average cover class for each site and each distance from the marsh edge; (b) The average stem density at each site and distance from the marsh edge; (c) The average tallest live standing vegetation from each site and distance from the marsh edge; and (d) The average height of ten randomly selected live standing stems at each site and distance from the marsh edge.

3.2. 2013 Vegetation Survey

The number of species found at each site is displayed in Figure 4. The range of species detected was from a high of 4 at site 1, and a low of 2 at sites 2 and 5. Six unique species were detected at all of the sites, a decrease of four species when compared to the 2012 survey. The observed species included *Spartina alterniflora*, *Spartinacynosuroides*, *Spartina patens*, *Phragmites australis*, *Scirpus robustus*, and *Polygonum hydropiperoides*. Average cover class ranged from a low of 1.5 at site 2, to a high of 5.5 at site 4 (Figure 5a).

Average stem density had a range of 26.5 to 126.5 stems / 0.25m² at sites 1 and 4, respectively (Figure 5b). Average *Spartina* stem density never fell below 86.5 stems / 0.25m². The average tallest vegetation followed a similar trend with the lowest value of 81cm occurring at site 1, and the highest value of 277.5cm occurring at site 4 (Figure 5c). The average height of ten randomly selected live standing stems also saw a low and high value at sites 1 and 4 at 81.95cm and 217.85cm, respectively (Figure 5d). Average cover class, stem density, tallest vegetation, and stem height were not significantly different among sites ($p = 0.346, 0.437, 0.223,$ and $0.092,$ respectively). A general regression was run to determine if average stem density was dependent on vegetation classification or location (start, middle, end) and was not significant for vegetation type, location, or the interaction of vegetation and location ($r^2 = 0.442, p = 0.289, 0.312,$ and $0.805,$ respectively).

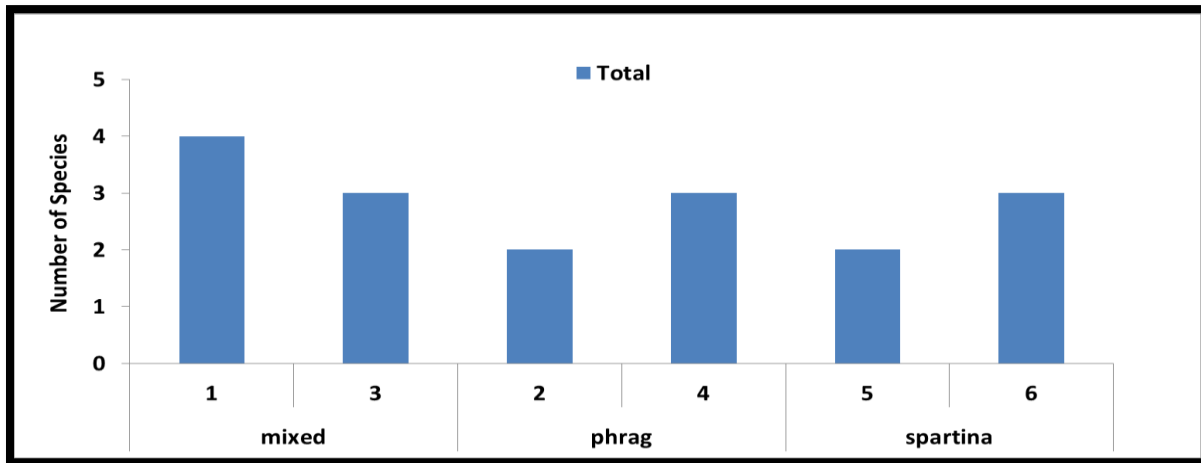
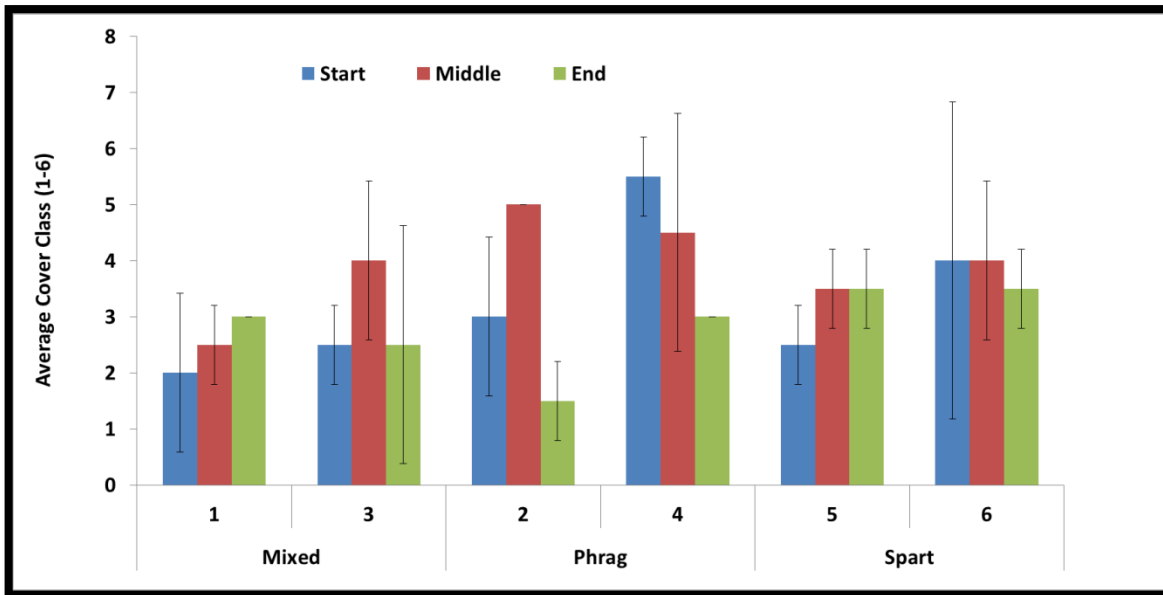
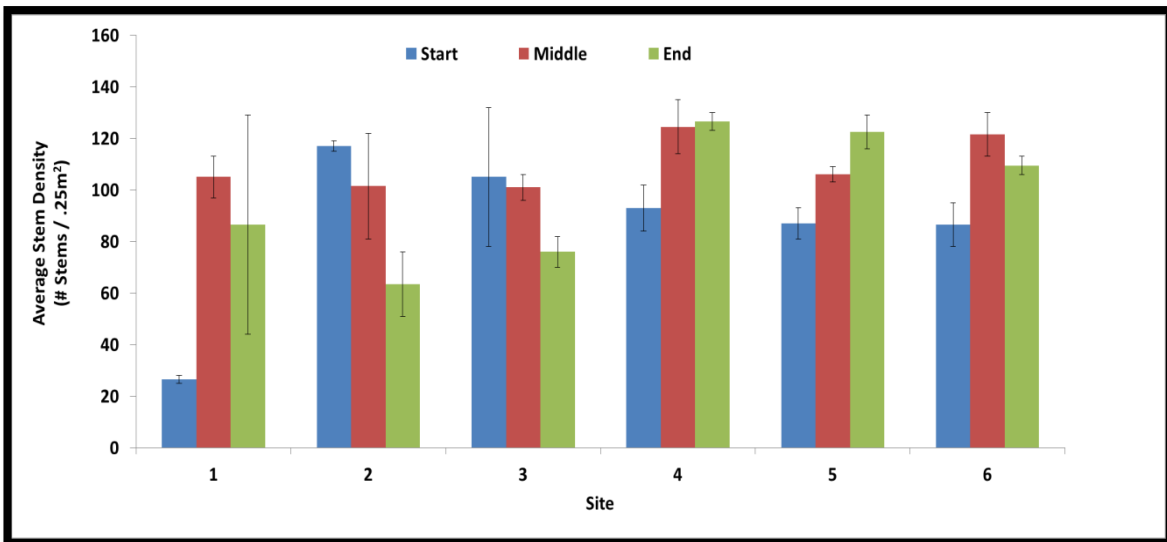


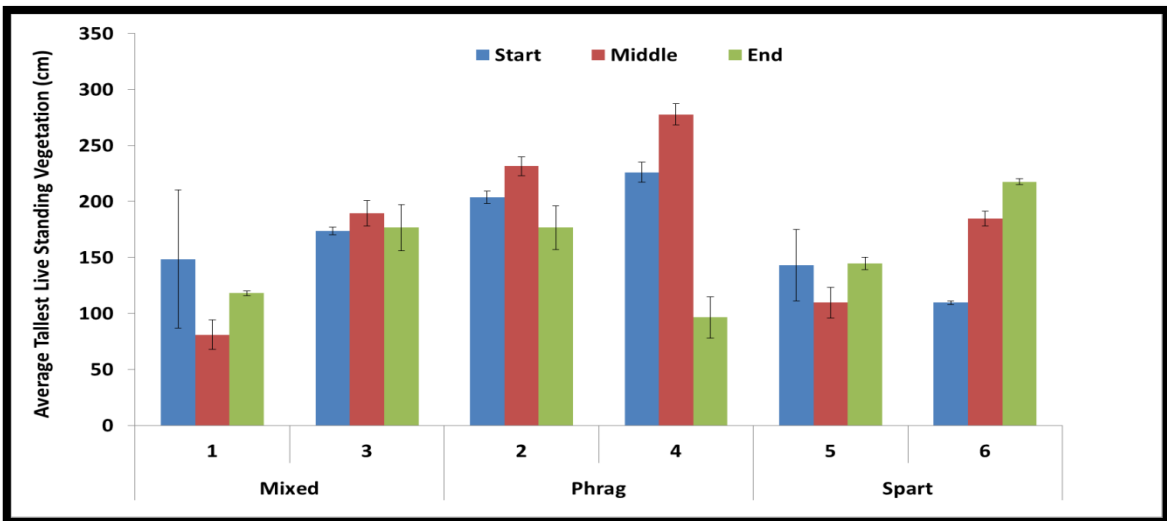
Figure 4. The total number of species sampled at each site.



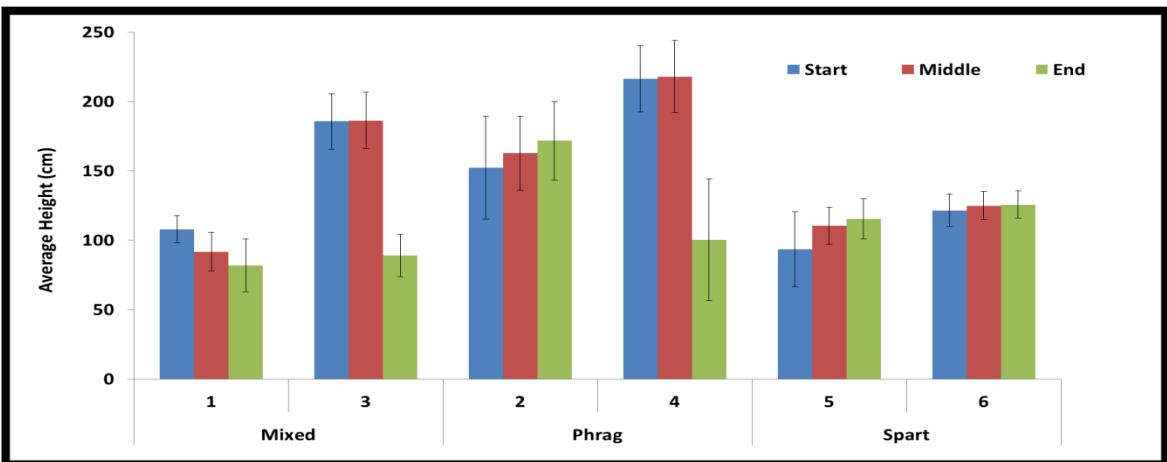
(a)



(b)



(c)



(d)

Figure 5. (a) The average cover class for each site and location within the site; (b) The average stem density at each site and location within the site; (c) The average tallest standing live vegetation for each site and location within the site; and (d) The average height of ten randomly selected live standing stems from each site and location within the site.



(a)

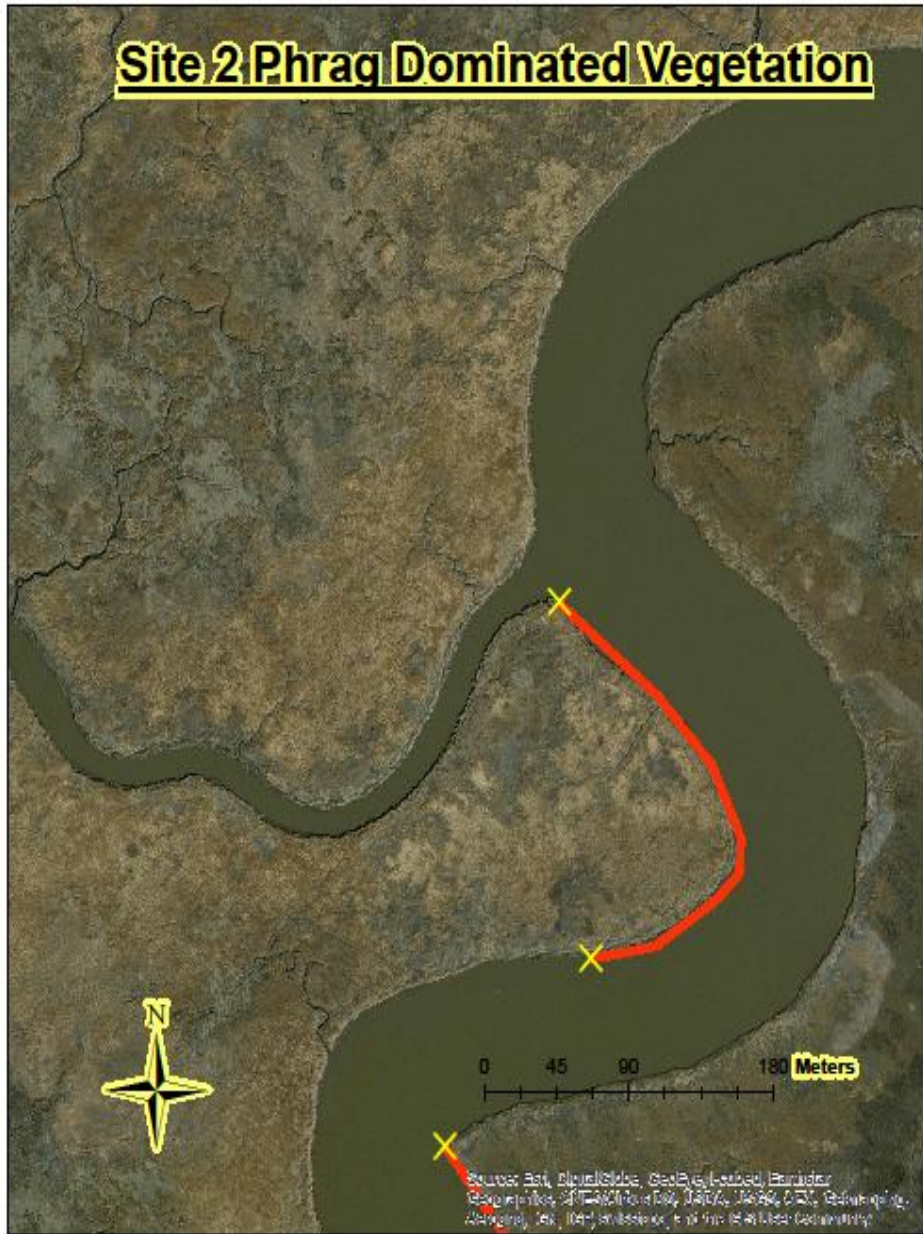


(b)



(c)

Figure 6.(a) Stitched orthophoto of mixed vegetation at site 1. Unfortunately, only the south side of the creek, opposite the side that crab traps were deployed, was captured during the balloon deployment; **(b)** Photo of site 1 from the 2013 flyover conducted on September 18th. This site is considered to be a part of the Rocks tract which has been managed by PSEG for the Estuary Enhancement Program; and **(c)** Ground level image of site 1 displaying the mixed vegetation composition.





(b)



(c)

Figure 7.(a) Stitched orthophoto of Phragmites vegetation at site 2. Dead patch composed mainly of standing Phragmites stalks clearly visible; (b) Photo of site 2 from 2013 flyover conducted on September 18th; and (c) Ground level image of site 3 displaying the beginning of the Phragmites stand.

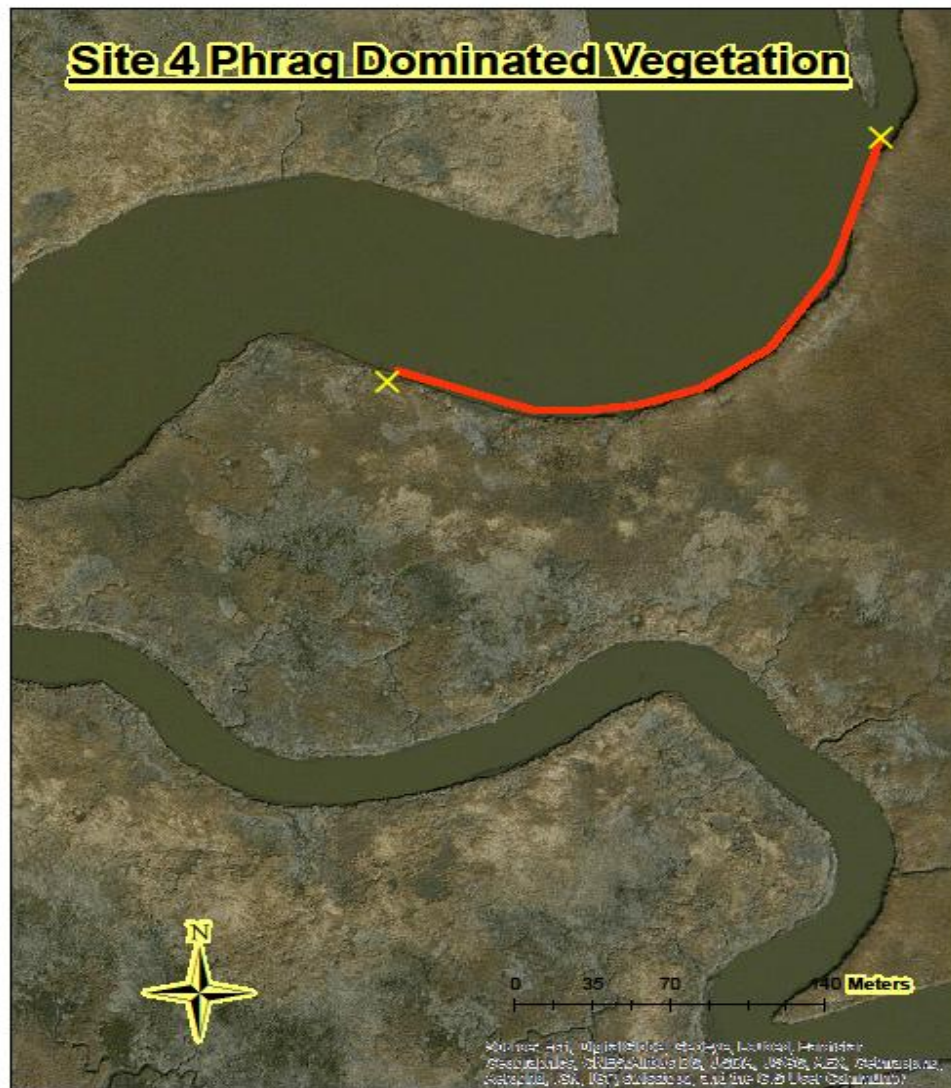


(b)

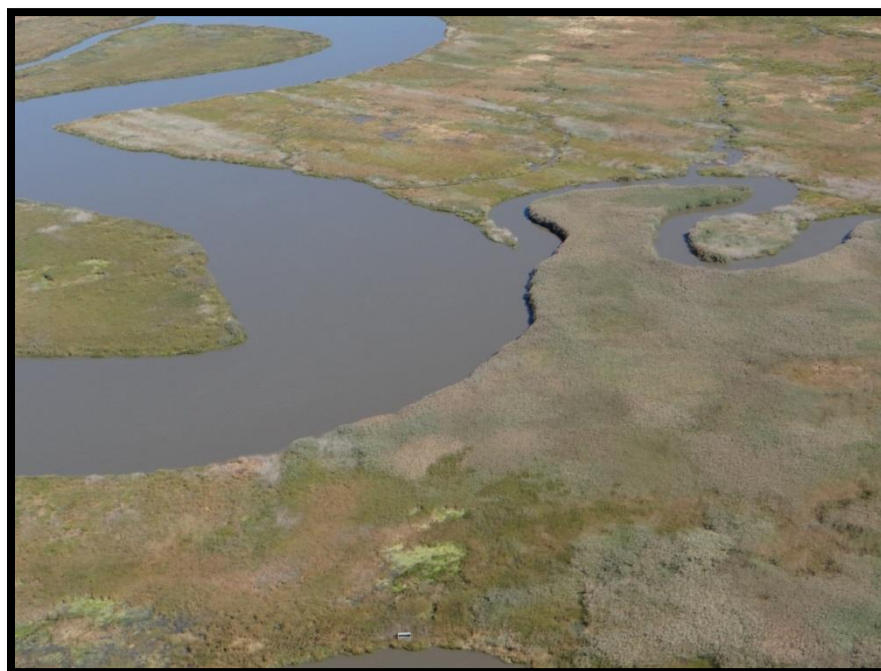


(c)

Figure 8. (a) Stitched orthophoto of mixed vegetation at site 3; (b) Photo of site 3 from 2013 flyover conducted on September 18th. Evidence of herbicide spraying on patches located behind the marsh edge; and (c) Ground level image of site 3 displaying a sparse stand of *Phragmites* mixed with *Spartina*.



(a)



(b)



(c)

Figure 9. (a) Stitched orthophoto of *Phragmites* vegetation at site 4; (b) Photo of site 4 from 2013 flyover conducted on September 18th; and (c) Ground level photo of site 4 displaying a monotypic stand of *Phragmites*.



(a)



(b)



(c)

Figure 10. (a) Stitched orthophoto of *Spartina* vegetation at site 5; (b) Photo of site 5 from 2013 flyover conducted on September 18th; and (c) Ground level image of site 5 displaying *Spartina* marsh vegetation devoid of *Phragmites*.



(a)



(b)



(c)

Figure 11. (a) Stitched orthophoto of *Spartina* vegetation at site 6; (b) Photo of site 6 from 2013 flyover conducted on September 18th; and (c) Ground level image of site 6 displaying *Spartina* dominated marsh devoid of *Phragmites*.

4. Discussion and Conclusions

Because our sites were selected during April, approximately four months prior to what is considered peak vegetative growth, some discrepancies became apparent among the classification (i.e. mixed, *Phrag*, *Spartina*) of the sites.

The vegetation composition along the tail end portions of the *Phragmites*-dominated sites 2 and 4 in particular, was not consistent with the classification of being dominated by *Phragmites*. This is an unfortunate but hard to overcome issue revolving around any type of field study that requires the use of replicate sites for different treatments. Both of the *Spartina* designated sites, 5 and 6, were devoid of any large stands of *Phragmites* along the marsh edges as evidenced by the aerial photography and vegetation surveys, and thus represented accurate native vegetation habitats. The mixed sites both contained stands of NN *Phrag* and *Spartina*, but for site 1 this was only evident on the side that crab traps were placed on. The largest discrepancy in vegetation classification between the *Phragmites* dominated sites existed at site 2. While we did document a large continuous stand along the marsh edge for approximately the first 2/3 of the site which encompassed the locations of the first two traps, the remainder of the site did not contain high densities of *Phragmites*. There was a minor presence of *Spartina alterniflora* directly in front of the *Phragmites* stand but it did not appear to extend past 0.5m onto the marsh surface. There was also a large patch of dead/unvegetated marsh surface directly behind the stand of *Phragmites* which was the result of management efforts in prior years. Site 3, one of the mixed vegetation sites was also the focus of *Phragmites* removal in past years and had patches of considerable size of dead *Phragmites* stalks as evidenced in the aerial and ground level photography. These discrepancies are likely the cause of a lack of significant differences being detected among sites with differing vegetation classification and may have contributed to the highly variable nature of the faunal abundance at sites with similar marsh surface vegetation classifications.

Leonard et al. (2002) reported average stem densities at two distances from the marsh edge (i.e. 1 and 3m) for sites dominated by *Phragmites* and sites dominated by *Spartina*. In their study, it was apparent that moving away from the marsh edge resulted in an increased stem density value (i.e. *Phrag* 1m = 325 stems / m², 3m = 400 stems / m², *Spartina* 1m = 682 stems / m², 3m = 731 stems / m²), and that stem density was greater at the *Spartina* sites at both distances from the marsh edge than the *Phragmites* site. In the 2012 survey stem density only appeared to follow this trend at sites 1, 3, and 5, but it was not significant. Stem densities were also found to be similar between the *Phrag* and *Spartina* sites. McFarlin (2012) found stem densities at healthy *Spartina* sites to be 143 ± 15 / m² which was similar to our results from the 2012 survey at sites 5 and 6. Species richness was low at all sites as expected from an intertidal salt marsh where plants are required to deal with daily inundation by water with variable salinity as well as anoxic sediment conditions. Site 5, which touted the lowest richness value at only 2 species, contained large colonies of *Spartina alterniflora* and *Spartina cynosuroides*, both native plants which are typical of these marsh systems. Average cover class reached the highest percentages at mixed and *Spartina* sites which is likely due to the high density growth of individual colonies which in some cases occupied nearly the entire quadrat. Some of the lowest average cover class values were also observed at mixed sites which can be attributed to areas of nearly bare/dead marsh surface, a direct result of herbicide spraying in past seasons. *Phragmites* and *Spartina* average cover classes were consistently above 3, indicative of the monotypic and somewhat homogenous nature of these areas. As expected, the average tallest vegetation was largest at *Phragmites* sites, with some specimens reaching over two meters in height. These differences in height may hold important implications for organisms which are sensitive to changes in canopy cover. The native *Spartina* sites appeared to have more consistent stem heights when moving onto the marsh surface, with sites 1, 5, and 6 displaying significantly smaller average living stem heights and sites 4 and 3. While no significant differences in stem density were observed among the sites, *Phragmites* and mixed sites displayed the highest average densities.

In 2013, even with the change in the design of the vegetation survey, a similar pattern in richness was observed. This indicates that at least to the extent that our survey moved onto the marsh surface (i.e. 10m from the marsh edge), one should not expect a major shift in the diversity of the vegetative community. However, a decrease in total richness (sites pooled) was observed which is consistent with the notion that only specific plants are capable of thriving in the zone most prone to prolonged tidal inundation. Average cover class was lowest at the end location for site 2, and the highest value was observed at site 4. Unlike the 2012 survey however, no plot displayed a cover class of 6 which was observed more frequently as distance from the marsh edge increased. Again, the tallest average live vegetation was observed at site 4, as well as the average height of 10 randomly selected stems. No significant differences were detected for the average cover class, stem density, tallest vegetation, or stem height. This result is somewhat surprising considering the structural differences between native marsh plants and NN *Phragmites australis*, but is likely due to the fact that distance from the marsh edge was not a factor in this particular survey design.

The aerial flyovers, in conjunction with the attempt at mapping each of the sites using imagery obtained from a camera rig attached to a helium balloon resulted in accurate, high resolution documentation of the vegetation communities present throughout the study area. The images obtained from the balloon flyover were often taken at oblique angles which caused considerable distortion during the mosaicking process.

It was determined that quantifying the percentage of *Phragmites* present at each site based on the stitched images would not be accurate due to the distortion resulting from the orthophoto process. While several control points and landmarks were visible in the resultant images, and in light of the variability of the crab and fish dynamics among sites with the same vegetation classification, the value of determining the exact percent of *Phragmites* present was minimal in relation to the time required to obtain such information.

The pictures then serve the sole purpose of documenting the presence/absence of *Phragmites* along the selected 300m stretches of Blackbird Creek as stands of *Phragmites* are easy to visually identify from the photos. In conjunction with the ground level images taken at each site, these methods were extremely effective, especially from a financial and time investment standpoint, in obtaining photography which can facilitate species level identification (Miyamoto et al., 2004). Thus the combination of these techniques are invaluable for conducting research in hard to access areas, when other methods of obtaining aerial photography are not financially feasible, or in areas which are subject to unfavorable weather conditions, especially when up to date and high resolution photos are required for analysis. Including these parameters, modifying the layout of the sites which were sampled in relation to the vegetation present, and adding additional creeks to the study may improve the ability to detect the possible interactions between marsh surface vegetation and the fauna in question.

Acknowledgement

This project is funded by the DuPont Clear into the Future Fellowship Program and NSF-EPSCOR Seed Grant, and partially by the USDA Evans-Allen Grant, and USDA- NIFA Capacity Building Grant. Authors would like to thank Dr. Andrew Augustine for his assistance throughout the project timeline with obtaining aerial photography and mapping study sites with GIS. Special thanks to Michael Mensinger of DNREC – DNERR for his assistance with the field sampling, and undergraduate interns, Andrew Kluge and Amy Cannon for their assistance for the field sampling and laboratory analyses. Authors would also like to thank Grant Blank, Brian Reckenbeil, Cory Janiak, and Michael Cinelli for their assistance with the field supplies, photo taking, boat preparation and maintenance, basic survivorship skills in the field.

References

- Able, K.W. and Hagan, S.M. (2003). Impact of Common Reed, *Phragmites australis*, on Essential Fish Habitat: Influence on Reproduction, Embryological Development, and Larval Abundance of Mummichog (*Fundulus heteroclitus*). *Estuaries* 26, 40-50.
- Artigas, F. and Pechmann, I. C. (2010). Balloon imagery verification of remotely sensed *Phragmites australis* expansion in an urban estuary of New Jersey, USA. *Landscape and Urban Planning* 95, 105-112.
- Boesch, D.F., Brinsfield, R.B. and Magnien, R.E. (2001). Chesapeake Bay eutrophication: scientific understanding, ecosystem restoration, and challenges for agriculture. *Journal of Environmental Quality* 30, 303-320.
- Clarkson, B. R., Ausseil, A.-G. E. and Gerbeaux, P. (2013). Wetland ecosystem services. In *Ecosystem Services in New Zealand—Conditions and Trends*. eds J. R. Dymond (Lincoln: Manaaki Whenua Press), 192–202.
- Dahl, T.E. (1990). Wetlands Losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 13pp.
- Drexler, J.Z. and Bedford, B.L. (2002). Pathways of nutrient loading and impacts on plant diversity in a New York peatland. *Wetlands* 22(2), 263-281. doi:10.1672/0277-5212(2002)022[0263:PONLAI]2.0.CO;2
- Great Lakes Restoration Initiative (GLRI). (2013). Innovative Phragmites Control Strategies. Retrieved from <http://cida.usgs.gov/glri/projects/invasive_species/Phragmites_control.html>
- Gittman, R. K., Peterson, C.H., Currin, C.A., Fodrie, F.J., Piehler, M.F. and Bruno J.F. (2016). Living shorelines can enhance the biogenic structure and nursery role of threatened estuarine habitats over time. *Ecological Applications* 26(1), 249-63. <http://www.esajournals.org/doi/pdf/10.1890/14-0716.1>.

- Kentula, M. E., Brooks, R. P., Gwin, S. E., Holland, C. C., Sherman, A. D. and Sifneos, J. C. (1992). An Approach to Improving Decision Making in Wetland Restoration and Creation. United States Environmental Protection Agency, Office of Research and Development Washington D.C. USA. EPA600/R-92/150 (NTIS PB92217306) 176pp.
- Klemas, V. V., Knecht, R. W., Sain, B. C., Yan, X. H., Field, R. T., Price, K. S., Badiey, M., Wong, K. and Zheng Q. (2000). Improving the Management of Coastal Ecosystems through Management Analyses and Remote Sensing/GIS Applications. Experiences from the Delaware Region. Graduate College of Marine Studies, University of Delaware.
- Leonard, L.A., Wren, P.A. and Beavers, R.L. (2002). Flow Dynamics and Sedimentation in *Spartina alterniflora* and *Phragmites australis* Marshes of the Chesapeake Bay. *Wetlands* 22, 415-424.
- Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Kidwell, S. M., Kirby, M. X., Peterson, C. H. and Jackson, J. B. C. (2006). Depletion, Degradation, and Recovery Potential of Estuaries and Coastal Seas. *Science* 312, 1806- 1809.
- McFarlin, C. R. (2012). Salt Marsh Dieback: The Response of *Spartina alterniflora* to Disturbances and the Consequences for Marsh Invertebrates. Marine Sciences Program, University of Georgia, Athens, GA. Ph.D. Dissertation. http://purl.galileo.usg.edu/uga_etd/mcfarlin_caroline_r_201205_phd.
- Miyamoto, M., Yoshino, K., Nagano, T., Ishida, T. and Sato, Y. (2004). Use of Balloon Aerial Photography for Classification of Kushiro Wetland Vegetation, Northeastern Japan. *Wetlands* 24, 701-710.
- PSEG. (2012). Cedar Swamp and the Rocks Phragmites-Dominated Wetland Restoration Sites Blackbird and Appoquinimink Hundreds. New Castle County, Delaware. 2011 EEP Site Status Report.
- Teal, J.M., and Weishar, L. (2005). Ecological engineering, adaptive management, and restoration management in Delaware Bay salt marsh restoration. *Ecological Engineering* 25, 304-314.