ABSTRACT

PORTER, KIMBERLY MARIE. Vegetative Impact of Feral Horses, Feral Pigs, and White-tailed Deer on the Currituck National Wildlife Refuge. (Under the direction of Christopher S. DePerno).

The Currituck National Wildlife Refuge (CNWR), located in the northern most part of North Carolina's Outer Banks, is inhabited by populations of feral horses (*Equus caballus*), feral pigs (*Sus scrofa*), and white-tailed deer (*Odocoileus virginianus*). Concern has been raised about the potential impact of these species on the vegetation of the Outer Banks. To assess impact, we created two replicate exclosure plots within maritime forests, brackish marshes, maritime grasslands. Within each habitat, an electric fence divided each habitat into two sections: including or excluding horses. Feral pigs and white-tailed deer were present on both sides of the electric fence. On each side of the electric fence within each habitat, we created and sampled from three different 5 x 5 m plots for a total of 36 plots. The first plot was a fenced exclosure 3 m high that excluded all wildlife. The second plot was a fenced exclosure that was raised 1 m above the ground and extended to a height of 3 m, allowing feral pigs and deer to enter but excluding horses. The third, a control plot, was not fenced. Within each plot we created two 1 m transects, and randomly selected and tagged grasses, forbs, shrubs and trees with numbered zip ties. Each month from May 2010 through May 2012 we measured the distances from base to tip of tagged herbs and the distance from branching point to terminal bud on branches of shrubs to quantify grazing and browsing. We investigated plant growth in the presence and absence of horses, and examined the relationships between animal disturbances on various plant taxa or in various habitat types. We

used a linear model to analyze plant growth rate. We used length ratio adjusted by the number of days as the response variable, and we used a base-10 log transformation to normalize the response variable. Also, we investigated plant length reduction caused by wildlife disturbances. Out of 1105 tagged plants, we detected 87 disturbances; 80 where horses were present and 7 where horses were excluded, which was a significantly different ($p<0.001$). Overall, horses were responsible for 84% of disturbances. Most disturbances occurred in brackish marshes on *Schoenoplectus pungens*. We detected a significant positive effect of treatment on plant growth where horses were present ($P = 0.035$), but not where they were excluded ($P = 0.32$). The total length reduction for *Schoenoplectus pungens* was 443cm which equated to a 39 - 100% loss in biomass and the total length reduction for *Vaccinium* spp. was 58.5 cm, equating to a 2.4% - 12.5% biomass loss. Based on our research, at current population levels, feral horses, feral pigs, and white-tailed deer have a negative effect on the vegetation of the Currituck National Wildlife Refuge. We recommend this study be continued to further monitor the exclosures and determine wildlife impacts on the CNWR.

Vegetative Impact of Feral Horses, Feral Pigs, and White-tailed Deer in the Currituck National Wildlife Refuge

by
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DEDICATION

This is dedicated to my mom, Mary Porter.

BIOGRAPHY

Kimberly Porter was born in Limestone, Maine and grew up in the town of North Attleboro, Massachusetts. She attended the University of Massachusetts where she received a B.S. in Biology and graduated *magna cum laude*. Upon completion of her degree, she worked as a field assistant to graduate students studying the behavior of chestnut-sided warblers and prairie rattlesnakes. She spent a year teaching English in Japan and then worked in the biotech industry for a short time before returning to school to pursue a graduate degree. During her career as a graduate student, she worked as a teaching assistant in the Department of Biology and in the Department of Forestry and Environmental Resources. Upon completion of her degree, Kimberly hopes to work as a biologist focusing on preservation of native vegetation and habitats.

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1. Introduction

White-tailed deer (*Odocoileus virginianus*), feral horses (*Equus caballus*), feral pigs (*Sus scrofa*), cattle (*Bos* spp.), sheep (*Ovis* spp.) and goats (*Capra* spp.) all have the potential to negatively impact the vegetation in grass-shrub communities and salt marshes and may lead to a decrease in annual above ground plant growth (Wood et al., 1987). Furthermore, non-native feral pigs and feral horses alter plant and wildlife diversity in plant communities (Levin et al., 2002; Seimann et al., 2009). At Shackleford Banks, North Carolina, salt marshes were heavily impacted by non-native ungulates including horses, cattle (*Bos* spp.), sheep (*Ovis* spp.) and goats (*Capra* spp.) (Wood et al., 1987). On Assateague Island, feral horses affected the natural growth competition between *Spartina alterniflora* Loisel, and *Distichlis spicata* (L.) Green in salt marsh communities (De Stoppelaire et al., 2004).

Few natural communities of coastal barrier islands are fully intact, and overgrazing by wildlife (e.g., feral horses, feral pigs, and white-tailed deer) is of particular concern (Rheinhardt and Rheinhardt, 2004; Schafale and Weakley, 1990). Feral horses have been shown to alter the composition of entire communities through grazing and trampling. In estuarine communities, the diversity of fishes and birds was greater in ungrazed plots compared to plots grazed by horses (Levin et al., 2002). A simulated removal of *Spartina alterniflora,* a grass species often consumed by horses, resulted in reduced fish survival (Levin et al., 2002). Grazing can decrease the rate of succession from grassland habitats to scrub-shrub habitats, and can inhibit maritime forests from expanding (Wood et al., 1987). LIDAR surveys showing topographical differences in grazed and ungrazed plots indicate that horses led to a decrease in dune elevation, while ungrazed plots increased in elevation (De Stoppelaire et al., 2004). Feral horses may limit maximum plant height (Freedman et al., 2011; Rheinhardt and Rheinhardt, 2004; Seliskar, 2003) and preferential grazing by horses exerts pressure on palatable plant species contributing to the alteration of species presence or abundance in salt marshes (Furbish and Albano 1994). In addition to grazing, horse trampling can impact fragile barrier island vegetation (Rheinhardt and Rheinhardt, 2004; Turner, 1987). Simulation studies on Cumberland Island National Seashore, Georgia, demonstrated that horse trampling had a greater impact than grazing alone (Turner, 1987), as the trampling of soft, damp soil can degrade soil structure (Jensen, 1985). Also, tidal freshwater marshes may experience significant horse disturbances in the spring when new plants are just beginning to flush (Rheinhardt and Rheinhardt, 2004).

Feral pigs can impact vegetation as various plant structures (i.e., roots, bulbs, tubers, leaves, fruits, and seeds) compose the majority of the diet of feral pigs (Adkins and Harveson, 2006; Chimera et al., 1995; Cuevas et al., 2010; Everitt and Alaniz, 1980). In forest understories, species with diaspores greater than 250 mg were twice as abundant in the absence of feral pigs, indicating that feral pigs may have an effect on plant species composition (Siemann et al., 2009). Soil alterations by feral pigs can alter the native and exotic species composition and affect plant ground cover biomass (Cushman et al., 2004). Pig rooting behavior can lead to increases in tree root exposure and to decreases in soil nutrients, ground cover, and habitat suitability for some wildlife species (Singer et al., 1984).

Grazing and browsing by white-tailed deer can decrease local plant species survivorship, growth, and reproductive success (Boerner and Brinkman, 1996; Ruhren and Handel, 2003; Waller and Alverson, 1997). Areas with larger white-tailed deer populations have lower plant species diversity within forest, wetland, and savannah sites (Urbanek et al., 2012). White-tailed deer grazing within maritime forests has the potential to negatively impact maritime forest regeneration and, on the Outer Banks in particular, this combined with increasing development may accelerate maritime forest degradation (Sherrill et al., 2010). Furthermore, preferential browsing by high numbers of white-tailed deer has been linked to an increase in exotic plants (Eschtruth and Batttles, 2009).

From 2000 to 2010, the resident human population of Currituck County increased from about 18,000 to 23,500 (30%) (U.S. Census Bureau, 2010). Annual tourism to the Currituck National Wildlife Refuge (CNWR) adds an additional 25,000 visitors (USFWS, 2008). Increases in human populations and property development may reduce the available habitat for wildlife, potentially resulting in increased grazing impacts in the remaining habitat (USFWS, 2008).

In 2007, a management plan which was signed between the Corolla Wild Horse Fund, County of Currituck, North Carolina Coastal Reserve and National Estuarine Research Reserve (Department of Environment and Natural Resources), and the Currituck National Wildlife Refuge (CNWR) mandated that no more than 60 horses be present in the Currituck Outer Banks (Corolla, 2007). The management plan called for the adoption, relocation, or use of horse fertility contraceptives to maintain the target population level. However, a recent aerial survey counted at least 121 horses on or in close proximity to the CNWR (M. Hoff, Currituck National Wildlife Refuge Manager, pers. comm.). In January 2013, Congressman Walter Jones reintroduced the Corolla Wild Horse Protection Act (H.R. 126), which, at the time of this publication, is awaiting review by the US House of Representatives. This legislation would require a minimum population of 110 horses and would allow for the introduction of horses from the Cape Lookout National Seashore to increase horse herd genetic diversity (House of Representatives 2013, H.R. 126).

Management of wild horses has become controversial. While some groups support the protection of horses (e.g., Corolla Wild Horse Fund Incorporated 2012), others view the horses as exotic species that compete with native species (e.g., USFWS 2008). Furthermore, although feral horses, feral pigs, and white-tailed deer have had documented negative impacts on plant communities, the effects at CNWR are unknown. Therefore, our objective was to quantify vegetation impacts by wildlife within different habitats at CNWR by determining number of disturbances, overall biomass change and plant daily growth.

2. Material and methods

2.1 Study area

The CNWR is an 1850 ha refuge on North Carolina's Outer Banks barrier islands (Figure 1). The refuge is located 1.2 km north of Corolla in Currituck Co., North Carolina, and is comprised of a variety of habitats, including evergreen maritime forests, fresh and brackish marshes, dune grasses, maritime dry and wet grasslands, and maritime shrub swamps (Schafale and Weakley 1990; USFWS 2008). The refuge serves to protect native wildlife, including threatened and endangered species such as piping plovers (*Charadrius melodus)*, red-cockaded woodpeckers (*Picoides borealis*), bald eagles (*Haliaeetus leucocephalus*), loggerhead sea turtles (*Caretta caretta*), and leatherback sea turtles (*Dermochelys coriacea*) (USFWS, 2008). Also, the CNWR is used for hiking, bird watching, photography, and waterfowl and feral pig hunting. No trails, paved roads, or facilities are available within the refuge, and visitors may only enter the refuge on foot (USFWS, 2008).

2.2 Experimental design

In winter 2010, we established sampling sites in evergreen maritime forests, brackish marshes, maritime wet grasslands, and maritime dry grasslands. Within each habitat, an electric fence divided the area into two sections: one with horses and one without. Feral pigs and white-tailed deer were present in both sections. The electric fence to the north and all exclosure plots were erected in 2010; the electric fence further south was installed in 1994 (Figure 2). On each side of the electric fence within each habitat, we established three different 5 x 5 m plots (Figure 2). The first plot was a fenced exclosure 3 m high that excluded all focal wildlife species. The second plot was a fenced exclosure, raised 1 m above the ground and extended to a height of 3 m, allowing feral pigs and white-tailed deer to enter but not horses. The third plot (i.e., the control) was not fenced and marked only by boundary stakes. We created two replications for the brackish marsh and maritime forest habitats and one replication for the maritime wet grassland and maritime dry grassland habitats for a total of 12 sampling locations, which included 24 fenced exclosure plots and 12 unfenced control plots. Within each plot, we created 2 randomly placed 1 m transects. Within each transect, we randomly selected individuals from multiple possible plants of the same species by assigning each a color, and then drawing straws to determine which individual would be tagged. We made species diversity comparable for tagged plants by selecting prevalent species within a given habitat, thereby making all exclosures within a habitat comparable. We modified methodology of Seimann et al. (2009) and randomly selected and tagged branches of shrubs within an exclosure. We randomized branches to tag in the same manner as was done within the transects. All selected plants were tagged with numbered zip ties; herbaceous species were tagged at the base of the plant, woody species were tagged on particular branches. The total area represented by our combined 5 x 5 m plots was 900 m^2, which represents 0.049% of the total refuge size. Within these plots, the combined length of our sampled transects was 72 m.

2.3 Data collection and analyses

From May 2010 until May 2012, we collected monthly measurements on tagged plants including distance from base to tip of herbs and distance from branching point to terminal bud on woody plants in order to quantify grazing and browsing intensity. We recorded clear signs of wildlife disturbances that led to length reduction or disappearance of tagged plant (e.g., horse trampling, grazing or browsing with hoof marks present in the area, fecal piles, digging indicative of pigs, deer beds, and deer bite marks).

Past exclosure research has shown differential effects of animal disturbance on habitat and plant species (Seliskar 2003; De Stoppelaire et al. 2004; Freedman et al. 2011). Therefore, we compared plant disturbances between the sections where horses were excluded and those where horses were present. We collected data on the number of disturbances on tagged plants, and calculated the percentages of plants that were disturbed by wildlife for each side of the electric fence. Additionally, we examined which habitats experienced wildlife disturbances, how many disturbances occurred in each habitat, which plant taxa were most impacted, and the wildlife species were responsible for the disturbances. We conducted a Chi-square test using the total number of plants inside and outside the electric fence divided into two categories: disturbed and undisturbed (Microsoft, 2007).

To determine plant growth rate, we only considered measurements collected in the growing season in a given year. We defined the starting point for the growing season as the first interval of growth for the particular plant and the ending point as first frost of the fall. Data for individuals with fewer than two observations within a growing season were omitted. Data on tagged plants that were browsed or shortened by natural events were included only if at least two undisturbed measurements were available prior to the event within the season. We excluded data from the maritime wet grassland for this analysis because of sampling problems (i.e., flooding). We analyzed plant growth using linear regression, and used species, habitat, exclusion treatment, inside or outside the electric fence and growing seasons as covariates, with growth within-growing season defined by $\log_{10}$((max length – initial length)/number of days). We used ANOVA to determine differences in treatments by comparing treatment plots to control plots where horses were present and where horses were excluded. We used R-2.15.2 for these analyses (R Core Team, 2012).

We calculated the total shoot length reduced due to wildlife disturbances by subtracting the length measurement at the date of the disturbance from the previous length measurement. To provide context of the significance of this disturbance to individual plants, we compared average length reductions to documented standard taxonomic maximum and minimum heights for the given plant taxa (Radford et. al 1968; Smith, 2002). The calculations were as follows:

1. (total length reduction we calculated) / ((number of tagged individuals of a species disturbed) * (maximum known length of plant))
2. (total length reduction we calculated) / ((number of tagged individuals of a species disturbed) * (minimum known length of plant)).

3. Results

We tagged 1105 plants; 288 in maritime forests, 492 in brackish marshes, and 325 in maritime grassland habitats. We detected 87 disturbances; 80 where horses were present, and 7 where horses were excluded. The level of disturbance experienced by these sections was significantly different (X^2 =59.6, df = 3, P <0.001) (Table1). We detected 37 disturbances in brackish marshes which amounted to 42.5% of all disturbances found (Table 1). Among all habitats, we documented 18 plant taxa that experienced disturbances; 15 disturbances impacted *Schoenoplectus pungens* (Vahl) Palla, a common brackish marsh species and 7 impacted *Vaccinium* spp. (Table 2). Fifty nine disturbances (68% of all disturbances) impacted facultative, facultative wetland, or obligate wetland species. Of the disturbances to *Schoenoplectus pungens,* 60% were attributed to horses (n=9), 13% to deer (n=2), and 27% were due to unknown causes (n=4). Overall, horses were responsible for 83% (n=72) of all documented disturbances, white-tailed deer were responsible for

9% (n=8), and 8% (n=7) were due to unknown sources. We detected a significant effect of treatments on plant growth where horses were present ($F=5.73$, $df=2$, $p=0.0035$) but not where horses were excluded ($F=1.14$, $df=2$, $P=0.32$) (Figure 3).

The total length reduction for *Schoenoplectus pungens* was 4.43 m and the range of reduction was between 39.4% and 100% loss in biomass (Smith, 2002). We detected a total length reduction of 0.59 m for *Vaccinium* spp. which indicated a biomass loss between 2.4% to 12.5% (Radford et al., 1968).

4. Discussion

The presence of feral horses can lead to significant impacts on vegetation and habitat structure (De Stoppelaire et al., 2004; Freedman et al., 2011; Jensen, 1985; Rheinhardt and Rheinhardt, 2004; Seliskar 2003; Turner 1987). Our study demonstrated a marked increase in disturbances where horses were present compared to areas where they were excluded. Additionally, horses may have been responsible for 6 of the 7 disturbances in the excluded area due to a two-week power outage. We detected few disturbances from white-tailed deer and none from feral pigs.

Our results indicated that treatment had a positive effect on growth of vegetation on the side of the fence where horses were present. A similar study focusing on the vegetation of primary sand dunes showed significant differences in plant growth measurements inside and outside of exclosures (Seliskar, 2003). However, in our study, treatments were located in areas where horses were present and excluded. No significant treatment effect was detected where horses were excluded, suggesting that horses were primarily responsible for the plant growth differences. Future monitoring of exclosures and control plots would be useful to further document these differences.

Some of our electric fences and all of the exclosures were created only months before monitoring began and, prior to that time, horses, pigs and white-tailed deer had access to the entire refuge and likely impacted vegetation throughout the refuge. Past studies have shown that *Schoenoplectus pungens* decreased in total biomass and in growth when the rhizomes of mother and daughter clones were cut and a complete year was necessary after the cutting was discontinued for the effects to cease (Poor et al., 2005), suggesting that a full year is necessary for this species to recover. Vascular plants may take several years to recover after a period of intense herbivory (Crete and Doucet, 1998; Hansen et al., 2007; Henry and Gunn, 1991; Manseau et al., 1996). Despite the short time period between the end of the fence construction and the start of our sampling, we documented significant differences in plant growth between treatments in areas where horses were present. This is remarkable because the vegetation in horse excluded sections likely had not fully recovered when sampling began. Additionally, our exclosure plots accounted for less than 1% of the entire refuge. Therefore, it is likely that we only captured a small part of the overall impact from horses and only a fraction of difference to be expected as the areas exclusion history lengthens.

Other studies documented horse impact on various marsh habitats including salt marshes, tidal freshwater marshes (Furbish and Albano, 1994; Rheinhardt and Rheinhardt, 2004), grasslands (Freedman et al., 2011; Rheinhardt and Rheinhardt, 2004), and sand dunes (De Stoppelaire et al., 2004; Seliskar, 2003). Although many habitats may be impacted by wildlife, marshes may be particularly susceptible to degradation as marsh soil is soft and easily affected by trampling (Jensen, 1985). In our study, brackish marshes received the highest number of disturbances of all 3 habitats types. *Schoenoplectus pungens* received the highest number of disturbances of all plant taxa monitored. We believe that loss of biomass should be considered when making further management decisions. Demographic studies may be useful in modeling the impact on *Schoenoplectus pungens*, and the overall impact on marsh species diversity and abundance over time.

Overall, the number of disturbances was low when considering the total number of tagged plants, which has raised questions about how likely horses are to use the land in close proximity to our exclosures. Horses are known to have defined home ranges and groups of horses may spend months or years within these boundaries (McCort, 1984; Miller, 1983). Seasonal changes which affect food quality and water availability may contribute to movements of horses within their home ranges and to the habitats used in a given season (McCort, 1984; Miller, 1983). Hence, focal horse studies would be valuable in elucidating horse habitat use, distribution, movements, and activity budgets on CNWR. Additionally, there is a lack of research documenting ungulate behavior in the presence of fences, especially in areas large enough for wildlife to avoid structures altogether. Demographic data is needed so that trends can be modeled. In the future, cameras may be useful in monitoring wildlife to determine if exclosures are altering horse, pig or white-tailed deer behavior. Also, human dimension studies may provide a more complete picture about how local residents and tourists view the horses.

5. Conclusions

Where horses were present, we documented a negative impact to plants and their growth rates. Brackish marshes received the highest number of disturbances. *Schoenoplectus pungens*, a prevalent marsh species, experienced the highest number of disturbances and, when disturbed, lost up to 100% of its biomass. Based on our research, we recommend that exclosure plots and electric fences be maintained and monitored in all habitats, and that additional efforts be made to exclude horses from brackish marshes wherever possible.

Although our study was conducted over a short time period and our study area represented less than 1% of the refuge, we were able to document differences in plant growth between treatments in areas where horses were present. Further, we believe we only captured a small part of the overall impact from horses. We believe the number of disturbances by horses and effect of horses on plant growth would likely increase with an increase in horse population levels. Conversely, we would anticipate a decline in the number of disturbances and effect of horses on plant growth if the horse population were reduced. Additionally, we believe that many tourist are interested in simply catching a glimpse of the horses, and, like other areas containing populations of free roaming horses, high population levels may perpetuate the view of these animals as nuisances (Donovan, 2007; Rubenstein, 2001). Therefore, we recommend decreasing the number of horses to reduce habitat damage and to ensure that sightings are appreciated by the public and viewed as a novelty.

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TABLES:

Table 1. Number of disturbances in the presence and absence of horses within three habitats, Currituck National Wildlife Refuge, North Carolina, 2010–2012.

	Horses Present	Horses Absent	Total
Maritime Forest	26	5	31
Brackish Marsh	36	1	37
Maritime Grassland	18	1	19
Total	80	7	87

Table 2. Number of wildlife disturbances by plant taxon and the Southeast wetland indicator status, Currituck National Wildlife Refuge, North Carolina, 2010–2012.

Taxa	Number of disturbances	Wetland indicator status (Southeast)
Schoenoplectus pungens	15	OBL
Unknown grass	13	
Vaccinium spp.	7	FACU, FACW
Juncus spp.	6	FACW, OBL
Spartina patens	5	FACW
Typha spp.	6	OBL
Distichlis spicata	5	FACW+
Rhynchospora spp.	5	FACW, OBL
Spartina patens	5	FACW
Baccharis halimifolia	4	FAC
Dichanthelium spp.	4	FACU, FAC
Eupatorium spp.	3	FACU, FAC, FACW
Carex spp.	2	FACU, FAC, FACW, OBL
Chasmanthium spp.	2	FACW-
Sagittaria lancifolia	2	OBL
Centella asiatica	1	FACW
Hydrocotyle spp.	1	FACW, OBL
Iva frutescens	1	FACW+
Pinus taeda	1	FAC

OBL: Obligate wetland; almost always is a hydrophyte, rarely located in uplands
FACW: Facultative wetland; usually a hydrophyte but occasionally found in uplands
FAC: Facultative; commonly occurs as either a hydrophyte or non-hydrophyte
FACU: Facultative upland; usually in non-wetlands but occasionally in wetlands
UPL: Obligate upland species; almost always occurs in non- wetlands
The positive sign indicates that taxon is more frequently located in wetlands. The negative sign indicates less frequently (USFWS 1988). When a taxon was not identified to species, wetland indicator statuses were taken from all species known to exist in the Outer Banks.

FIGURES:

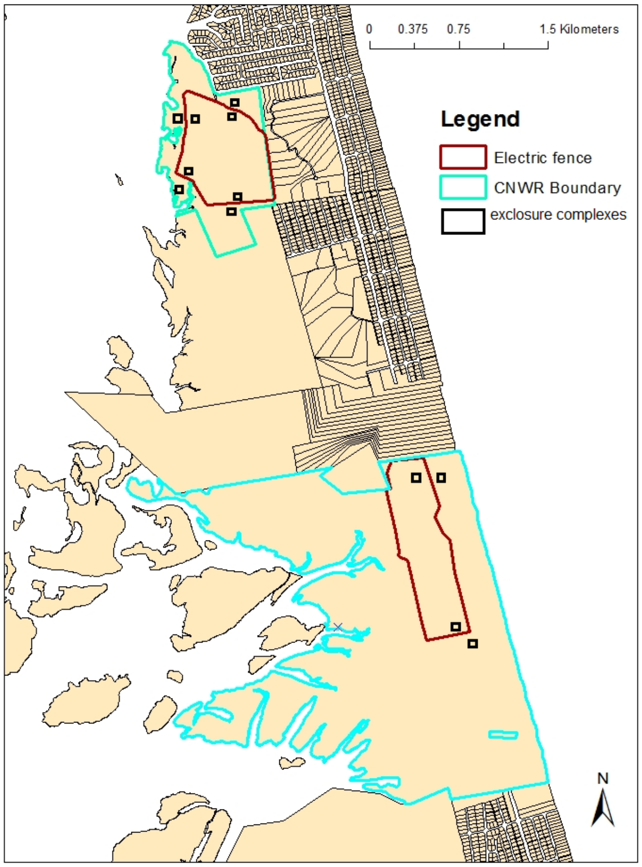


Figure 1. Currituck National Wildlife Refuge Station Landing Marsh Unit and Swan Island Unit, Currituck National Wildlife Refuge, North Carolina, 2010–2012.

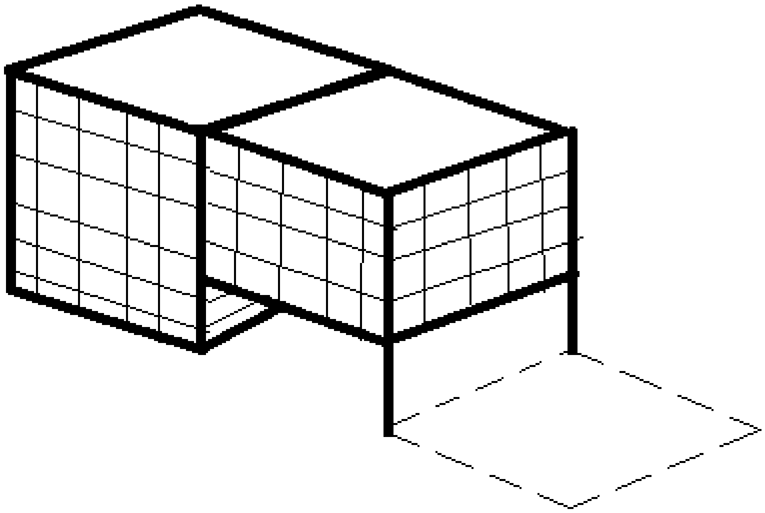
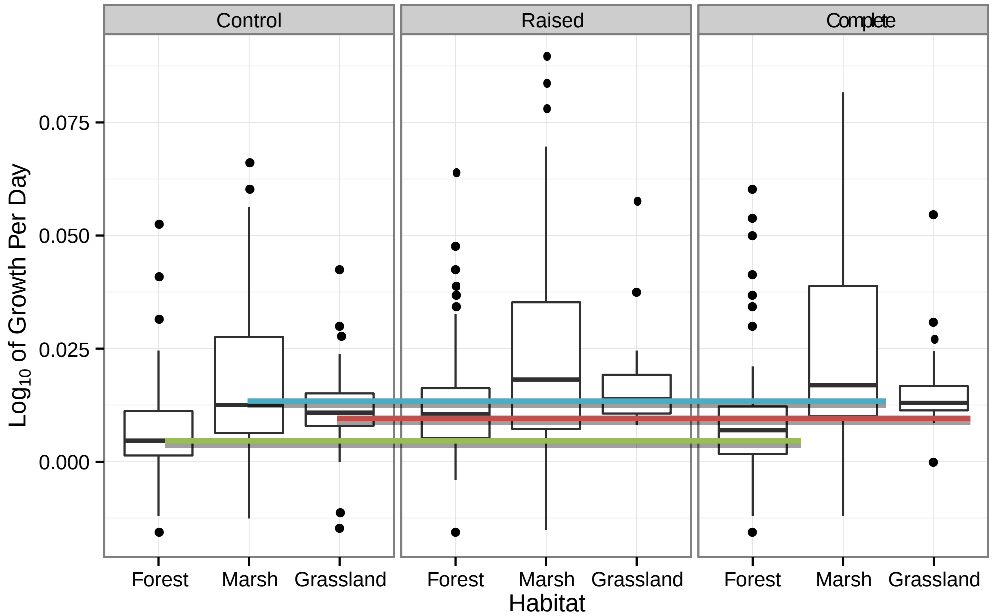


Figure 2. Three different 5 x 5 m plots; the first was a fenced exclosure 3 m high, the second a fenced exclosure raised 1 m above the ground and extended to 3 m, and the third, a control, was not fenced, Currituck National Wildlife Refuge, North Carolina, 2010–2012.

a)



b)

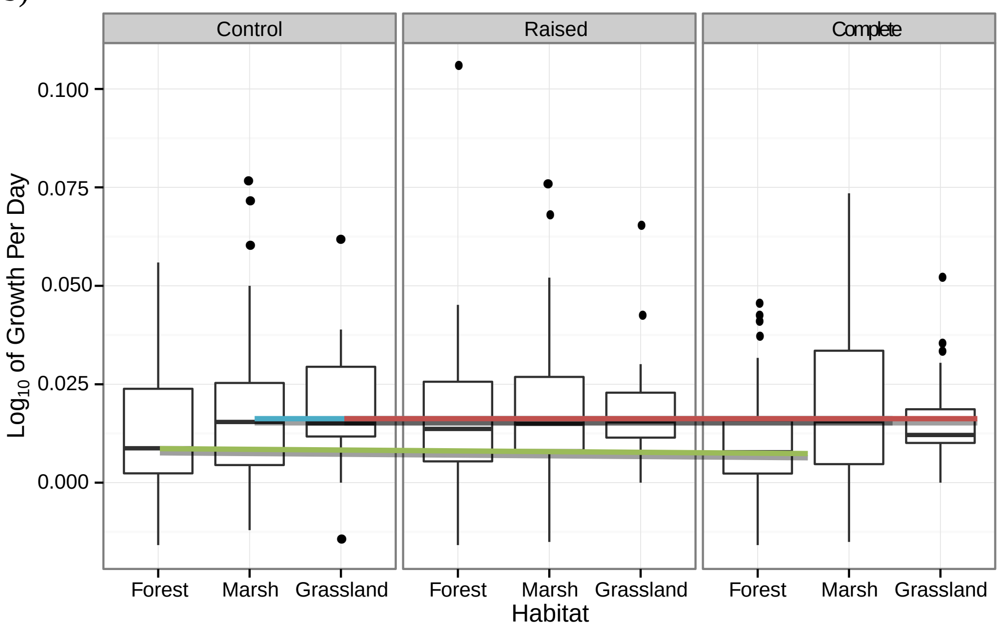


Figure 3. Comparison of daily growth in forest, brackish marshes, and grassland habitats for control plots, raised exclosures and complete exclosures where (a) horses were present; effects of treatments are significantly different (F=5.73, df=2, P=0.0035) (b) horses were excluded; effects of treatment were similar (F=1.14, df=2, P=0.32), Currituck National Wildlife Refuge, 2010–2012.