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Influence of anthropomorphic changes to landscapes on wetland birds on Mount Desert Island, Maine

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Influence of anthropomorphic changes to landscapes on wetland birds on Mount Desert Island, Maine

A Thesis

Presented to the Department of Environmental Studies

Antioch University New England

In Partial Fulfillment

of the Requirements for the Degree of

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ABSTRACT

The tidal-marshes of eastern North America and their connected watersheds are important transitional zones between terrestrial and marine communities (Reinhold 1977; Mitsch and Gosselink 1993). The Atlantic tidal marshes of North America support the highest level of vertebrate endemism among similar habitats anywhere (Greenberg and Maldonado 2006). The coastal location of tidal marshes, however, requires that they compete with people for limited space, as over 60% of the residents of the United States live along the coast (Burlington 1999). To better understand how the bird species of tidal wetlands are being affected by encroaching human development point count surveys were conducted during the breeding season on four watersheds on Mount Desert Island in Maine. Our study included historical data beginning in 1999 and 2002 and concluding in 2010 and 2011. We determined rate of development by locating the development on aerial photos for the years of the research. We calculated three community metrics for each visit to a survey point: species richness, relative abundance, and Simpson Index, as well as a species level abundance for Nelson's Sparrow (*Ammodramus nelsoni subvirgatus)* and Swamp Sparrow (*Melospiza georgiana*). As percent of development within the watershed increased, the relative abundance and the Simpson's Index significantly decreased throughout all of the watersheds, while species richness and the abundance of the wetland obligates showed no significant changes. Future research and more periodic surveys will help to understand how the development or other local changes to the wetland ecosystem is

affecting the bird populations. The information collected in this study will provide information to developers and land planners to increase the knowledge of the importance of watersheds and the birds that inhabit them. The data can also influence land planning through-out coastal Maine and New England.

INTRODUCTION

The tidal-marshes of eastern North America and their connected watersheds are important transitional zones between terrestrial and marine communities (Reinhold 1977; Mitsch and Gosselink 1993). Tidal marshes absorb power from ocean storms (Daiber 1986), improve estuarine water quality (Heinle and Flemer 1976; Valiela and Teal 1979; Dame et al. 1992; Valiela et al. 2000; Koch and Gobler 2009), and support the reproduction of many estuarine and marine organisms (Boesch and Turner 1984). Furthermore, the Atlantic tidal marshes of North America support the highest level of vertebrate endemism among similar habitats anywhere (Greenberg and Maldonado 2006). The preservation of this unique natural resource is therefore primarily an eastern North American responsibility.

The coastal location of tidal marshes, however, requires that they compete with people for limited space, as over 60% of the residents of the United States live along the coast (Burlington 1999). This stress on coastal marshes has led to a loss of over half of the wetland habitats within the United States, causing drastic declines in wetland-dependent bird populations (Tiner 1984; Dahl1990). The risk of habitat degradation is also high, because tidal marshes are subjected to anthropogenic disturbance from terrestrial influences, such as housing or industrial development.

Urban development in wetland drainages degrades and fragments wetland habitats (Benoit and Askins 1999). The list of potential causes of degradation is long, but includes nitrogen loading from fertilizers (Bertness et al. 2002), contamination by heavy metals (Shriver et al. 2006), the spread of invasive plants (Benoit and Askins 1999), increases in nest predation (Greenberg 2006), changes in salinity due to upland damming (Sipple 1971), direct tidal manipulations (Diaber 1986; Erwin et al. 1994; Wolfe 1996). There is also an increase in impervious surfaces, pollution from road salt, and possible changes to the hydrology of the marsh (Ward et al. 2010). These changes have the potential to disrupt bird community structure (Benoit and Askins 2002) and cause declines in individual avian species, such as sharp-tailed sparrows (*Ammodramus spp.*) that are specialized to the ecosystem. Today wetlands are mostly protected against direct destruction from development, but development within the watershed causes increased problems.

To maintain the integrity of remaining Atlantic tidal marshes at both local and regional scales will require periodic monitoring of marsh health. These observations will allow us to identify possible upland changes that can cause down-stream effects, so that we may endeavor to avoid or reverse them in the future. Long term monitoring of the birds that inhabit the marshes of Mount Desert Island will create a database that will allow study of past, present and future alterations of the bird communities.

In this study, we use birds as indices of marsh health to assess historical changes across four marshes and their surrounding watersheds in the greater Acadia region. Each of these respective drainage basins has experienced different degrees of human impact over the last decade, ranging from relatively undeveloped, increased residential use, and changes in mixed residential and industrial use. Due to the close proximity of these four sites to one another, all of the wetlands examined here have experienced similar degrees of climatic impacts such as, storm surges and sea level rise. By comparing the bird community composition of these four tidal marshes, we will begin to understand (A) whether temporal changes in marsh integrity are caused by regional drivers, (B) whether changes are caused by local upland land use and development, and (C) what mitigating actions land owners and land use managers can implement to lessen these affects.

Birds are excellent indicators of tidal marsh health (DeLuca et al. 2004), as they are easy to detect and their reproductive output, which is relatively easy to quantify, is sensitive to changes in marsh vegetation and hydrology (Wilson et al. 2007). Further, birds are extremely sensitive to habitat disturbance from human development and habitat fragmentation within a watershed. Studies of wetland habitats have shown that bird populations reflect the influences from various land uses more than any other taxa (Whited et al. 2000). Thus, understanding how marsh-bird communities have changed over the past several decades will help assess changes in overall ecosystem health as well as assist us in the future preservation of salt marshes throughout Maine and other areas.

There are many species of birds that use the marshes of Mount Desert Island, Maine, but nearly all of the birds that breed in or on the periphery of the marshes are migratory. Recent declines in populations of these types of birds can be linked to habitat loss, whether on the wintering grounds or breeding areas (Sillet & Holmes 2002). Many of the Acadian marsh-breeding species, however, have wide ecological niches, and thus variation in their populations reflects integrated changes across a number of different ecosystems. To assess change in the overall health of the Acadian tidal marshes, we focused on both a number of broad, bird-community indices as well as the two most obligate, wetland breeders, Nelson's Sparrows (*Ammodramus nelsoni)*, and Swamp Sparrows, (*Melospiza georgiana*), whose populations we presumed would be more tightly tied to marsh integrity.

Nelson's Sparrows inhabit marshes and wet meadows in three disjunct populations in North America; one of these populations, (*A. n. subvirgatus*) breeds in tidal marshes along the North American coast from Maine to Labrador and Newfoundland (Shriver et al. 2011). Nelson's Sparrows are extremely susceptible to population changes due to altered habitats (Shriver et al. 2011), making them an excellent candidate index for tidal-marsh health. In the greater Mount Desert Island region, this species breeds only in tidal saltmarshes.

Swamp Sparrows are wetland-obligate breeders across eastern North America (Mowbray 1997). Around our study areas, they breed both along the shrubby, brackish fringes of tidal marshes and in a wider variety of freshwater marshes.

The tidal marshes of Mount Desert Island face the combined threats of sea-level rise, climate change, and changes in the land use of their drainage basins. To predict the future impacts of these threats, we visited three marshes that had been surveyed eight to eleven years prior and one previously un-surveyed marsh to describe: (A) how the tidal marsh bird community has responded to recent changes and (B) how current watershed land uses affect avian populations. Understanding how bird communities of the watersheds are responding to the change in land use practices will help to understand any future changes due to climate change and sea-level rise.

METHODS

Study Areas

To determine possible changes in wetland avian populations related to anthropogenic development practices we surveyed four wetlands on Mount Desert Island (MDI hereafter). MDI is located in Hancock County (44°20'34.18”N, 68°18'25.6962”W), and is the largest island off the coast of Maine. Currently, MDI is primarily residential, with many parts of the island still quite rural. Housing development is the fastest-growing type of land use practice in the United States (Schlossberg et al. 2011). The total population of year-round residents on MDI was 9,571 during the 2010 US Census, down nearly a thousand people from the prior 2000 census (U.S Census Bureau, 2010). Furthermore, these numbers only reflect the year-round residents of the island; thousands more people spend the summer on the island and contribute to the demand for housing development. These pressures bring increased stressors to wetland bird populations.

The four wetlands surveyed for this project are located on Mount Desert Island in Hancock County, Maine (Figure 1). Two of the marshes are at least partly located within the boundary of Acadia National Park (Northeast Creek, NEC, and Bass Harbor Marsh, BHM). Two additional marshes were surveyed outside the park: Babson Creek (BAB), which is owned by a state-wide land trust, and Jones Marsh (JON), which is privately owned (Figure 2).

Northeast Creek is found on the northwest part of MDI (44°25’6.68”N, 68°18’48.32”W), in the town of Bar Harbor. The marsh is estuarine wetland with riverine and palustrine influences (Cowardin et al. 1979). There is a tidal creek that flows under a state highway bridge, restricting the tidal flow that feeds the marsh. The saline part of this marsh is relatively small, though the channel opens up into a large, tidal freshwater marsh. Northeast Creek is the least saline of the marshes surveyed, but still has a brackish, open sedge area bordered by shrubs and boreal forest (Wilson 2009). This watershed was originally surveyed in 2002 by researchers funded by the National Park Service. This wetland was resurveyed in 2010 and 2011.

Bass Harbor Marsh is an estuarine wetland with riverine and palustrine components (Cowardin et al. 1979), bordered by a spruce-dominated boreal forest. It is located on the south side of MDI in the towns of Southwest Harbor and Tremont (44°15'24.15"N, 68°20'32.57"W). This wetland is completely located within the park lands. Bass Harbor Marsh has the strongest tidal influence, and is the largest salt marsh of all four marshes in this study. Above the salt marsh is a tidal freshwater wetland. In this marsh there are two bridges that restrict tidal flow. One of the bridges crosses Adam’s Brook on State Route 102 as it enters the main body of salt marsh, and the other bridge restricts the riverine outflow from the entire marsh basin. This watershed was originally surveyed in 1999 by the Maine Department of Inland Fisheries and Wildlife and in 2002 by researchers funded by the National Park Service.

Jones Marsh lines the northern border of MDI near the bridge that connects the island to the mainland in the town of Bar Harbor (44°25'10.59"N, 68°21'5.33"W) and has an estuarine component that leads into a palustrine wetland (Cowardin et al. 1979). State route 3 bisects the marsh and restricts tidal flow via a bridge and culvert system. There is also a man-made salt pond at the top of the marsh closest to the ocean. This watershed was originally surveyed in 1999 by the Maine Department of Inland Fisheries and Wildlife.

In addition to these three historically surveyed marshes, we also surveyed Babson Creek Marsh for the first time. This marsh was selected because of its similarity to BHM and JON and its relatively high density of Nelson's Sparrow. Babson Creek is located along state route 102 in Mount Desert, Me (44°22'30.64"N, 68°19'37.67"W) at the head of Somes Sound. Babson Creek is a 14.58 ha marsh with estuarine components (Cowardin et al. 1979) that leads to forested wetlands. The entire outflow of Babson Creek is also impacted by a bridge that restricts tidal flow, and a second bridge restricts freshwater flow from a creek at the head of the marsh.

All of these marshes have similar characteristics. They are all strongly influenced by tides, support many avian guilds, and are tidally restricted by bridges. They also likely experience very similar regional stressors, as the distance between the two furthest marshes (BHM and JON) is only 19 km.

Survey Methods

To quantify the change in the avian communities of three marshes (Northeast Creek, Bass Harbor Marsh, and Jones Marsh and the state of the community at a fourth marsh Babson Creek Marsh), we surveyed each marsh three times throughout the breeding seasons (June, July and August) of 2010 and 2011 following methods comparable to two historical surveys (Hodgman et al. 2001, Wilson et al. 2009).

*Maine Department of Inland Fisheries and Wildlife (Maine IF&W) (*Hodgman et al. 2001*):* – This project surveyed BHM and JON at fixed points placed greater than 200m apart and 50m away from any upland edge. We matched our contemporary surveys to these points using historically plotted GPS points and maps. Following the prior researchers' methods, the presence and distance (up to 200m) of birds that were seen or heard using the saltmarsh were recorded for a 10-minute period. This included feeding birds in flight if they were actively foraging in the marsh (e.g. terns and swallows). Bass Harbor Marsh had four points that followed this protocol (all of which were located in the salt-marsh section of the wetland; Figure 3) and JON had three (Figure 4). We followed this methodology on the new marsh we surveyed (BAB) as well, because of its similarities to BHM and JON. Babson Creek (Figure 5) had only one point, because the marsh is fairly small and wouldn't allow the distance needed between points or the space from an upland edge for additional points. The original surveys completed by Hodgman et al. (2001) were completed between June and

August. Our study followed the original timing of the surveys and visited all the points three times.

National Park Service (NPS) (Wilson et al., 2009) – This study used a different method for each year of their surveys (2001 and 2002) to survey BHM and NEC watersheds. This study focused not only on the salt marsh but the entirety of the tidal zone into freshwater marsh habitat. During the first year (2001) the researchers used a different set of randomly selected points in each survey period, and during the second year they used fixed points that were visited three times during the survey period. For the purpose of our project, we visited the fixed, non-random points from 2002 for each of our two seasons. We matched the location of contemporary surveys to the historical points using original GPS points and maps with BHM having twelve points (Figure 6) and NEC having fourteen (Figure 7). Some points were omitted because of GPS error or inability to access. For the points conducted by Wilson et al. (2009), we recorded all birds seen and heard within five minutes inside a 250 m, fixed-diameter circle.

Wilson et al. (2009) completed their point count surveys three times between late May and the end of June. To get a better view of the breeding season with a lower risk of sampling migrants, we shifted the time-frame of surveys to June to August. Only the last two surveys of their project and the first two surveys of our project were analyzed together. Also, for the 2002 surveys some points in BHM and NEC were omitted for unknown reasons. We resurveyed all the points covered by Wilson et al. (2009) for both watersheds.

The surveys that took place in 1999 (Hodgman et al. 2001) and in 2002 (Wilson et al.2009), followed different methodologies such as listening distance and time spent listening. For our research we followed each original survey's methods for each of their original points. Points located in the salt marsh of Bass Harbor Marsh overlapped, but were surveyed following the corresponding survey technique. Surveys following both methodologies began a half hour before sunrise and finished within four hours after sunrise, and surveys were not completed if it was raining, excessively foggy, or windy (> 30km/h).

GIS Methods

To compare watershed development rate to historical and contemporary survey results, we determined how much of each watershed was developed versus undeveloped using aerial photos from the Maine Office of GIS Data Catalog (http://www.maine.gov/megis/catalog/). To get a baseline of the development before the first survey began we used the 1996-1998 (USGS & MEGIS 2001) photo set to identify developed areas present in 1998. The first survey was conducted in the summer of 1999. We then used the closest available aerial photos for the entire span of all the projects used for this study to the current year (2003-2005) (USGS & MEGIS 2008), 2009 (USDA-FSA 2009) and 2011(USDA-FSA 2011). The two sets of aerial photos for 1996-1998 and 2003-2005 were photo sets that were taken between the years of 1996-1998 and then the next were 2003-2005, while 2009 and 2011 were taken that year not over multiple years. The only year the bird surveys were completed that had corresponding aerial photos was 2011. To determine the development for the year where the bird surveys were conducted, we assigned a level of development to each site as the predicted amount of development for that year assuming a linear rate of change in development between the nearest two sets of aerial photos. Using ArcMap 10 we defined watershed areas using the Watershed Boundaries of Mount Desert Island and Lands of MDI Municipal Zones shape file (College of the Atlantic GIS Laboratory 1987), and added the area of the wetlands as defined by the United States Fish and Wildlife Service's National Wetland Inventory (U. S. Fish and Wildlife Service 2011). Within each watershed area, we counted all buildings and created polygons for all disturbed (whether it was urban, agriculture or industrial development) and undisturbed areas (including the area of the wetland itself) for each photo year. From these data we calculated the total amount and relative percentage of developed and undeveloped land for each survey year. All GIS analysis was displayed using ArcMap 10.

Data Analysis Methods

We calculated three community metrics for each visit to a survey point: species richness, relative abundance, and Simpson's Index. We ran these three metrics for every visit to a point with in the marsh surveyed including the previous survey's (Hodgman et al. 2001 & Wilson et. al. 2009) raw data. Our analytical results differed from the previous studies by analyzing the three metrics. The two previous studies goals were to determine the presence of all species associated with the wetlands. Their methodology did not include preforming these metrics. We obtained the raw data from each survey and ran the tests on that data as well as our current data.

To determine the species' level effects, we also calculated the abundance of our two wetland specialists: Nelson's Sparrow and Swamp Sparrow. This analysis will help to show if the two populations of the wetland dependent species are being altered by the possible change to the habitat.

We constructed a series of repeated-measures mixed models in SAS 9.2 to predict the results of individual point counts for both modern and historical surveys. We used repeated-measures models to account for interdependence across multiple visits to each point both within the year surveyed and across the years and a mixed model to allow our intercepts to vary with the date of survey. Candidate fixed effects were year, marsh, percent of development, absolute acreage of development, and all two-way interactions with year.

We then selected the best performing model among all possible combinations of our fixed effects (except for models including both percent development and absolute development simultaneously) using the Akaike Information Criterion adjusted for small sample size (AICc), considering models with ΔAICc < 2.0 to be equivalent. We included the random effect of sampling date and controlled for repeatedly sampling points, both historical and modern, in all of our models, including the null. Post-hoc, model-corrected means were calculated from the best performing models using least squares means, and all reported means are presented with standard errors.

RESULTS

Changes in Marsh Conditions

Bass Harbor Marsh – Bass Harbor Marsh was the only marsh that was surveyed by both past projects. In 1999, Maine IF&W (Hodgman et al. 2001) studied the saltmarsh of BHM and recorded species that were seen using the marsh and found 15 species for the season, with a mean of 3.33 species per point (CI 1.19, SE. 0.54). We redid the same points for 2010 and 2011 and found 20 species for the 2010 season, with a mean of 5.33 species per point (CI 1.45, SE. 0.61) and 12 species for the 2011 season with a mean of 3.67 species per point (CI 1.60 , SE. 0.76) (Figure 8).

The NPS (Wilson et al. 2009), studied the entire wetland complex of BHM and recorded species that were seen or heard using the wetlands and found 46 species for the season of 2002 with a mean of 10.24 species per point (CI 1.45, SE. 0.69). We redid the same points for 2010 and 2011. We found 50 species in 2010 with a mean of 8.87 species per point (CI 1.36, SE. 0.67) vs. 40 species for the 2011 season with a mean of 6.70 species per point (CI 1.17, SE. 0.57) (Figure 9).

Bass Harbor Marsh, despite being largely inside the boundaries of a national park, showed increases in development within the watershed. The Bass Harbor Watershed is 2157.00 ha. In 1998 the Bass Harbor Marsh watershed began with 90.56 ha (4.20%) of developed land. In the next four years (2003), development in Bass Harbor Marsh watershed increased to 117.14 ha (5.43%). Ten years later (2009), development within the watershed had increased to 138.75 ha (6.42%). By the final year of the surveys, 146.35 ha (6.78%) of the watershed was developed (Figure 10).

Jones Marsh- The surveys conducted on the salt marsh section of Jones Marsh were conducted in the years of 1999, 2010 and 2011. Maine IF&W (Hodgman et al. 2001, detected 16 species in 1999, with a mean of 4.00 species per point (CI 2.24, SE. 0.97). We completed two more years of research at the same points and found 16 species in 2010, with a mean of 5.44 species per point (CI 1.49, SE. 0.65), and 10 species using the marsh in 2011, with a mean of 4.33 species per point (CI 1.54, SE. 0.67) (Figure 11).

The first survey for Jones Marsh was completed by Maine IF&W in 1999. Jones Marsh is by far the smallest of the watersheds in area of all the watersheds sampled with 163.64 ha. Being the smallest the developed areas are also closer to the survey areas. In 1998, there were 154.54 ha of undeveloped land. Only 6.36 ha of the land were developed, representing 2.87% of the entire watershed. Even though there were not any point counts completed in 2002, we still analyzed development of the watershed to compare to the other watersheds. The amount of developed land in 2003 was 18.02 ha (10%). The next year the avian surveys were completed was 2010. In 2009 the development increased to 21.83 ha, with 12.42% of the watershed now developed. Research ended in 2011 with the final year of point counts and development analysis. The current amount of development in the watershed is 22.39 ha and a percent of 12.77 (Figure 12).

Babson Creek- Babson Creek's salt marsh was the only wetland that wasn't visited in the past. Research on this marsh began with our project. There was one point on this marsh that was visited three times from June to August in 2010 and 2011. We recorded 12 species in 2010 with a mean of 7.00 species for the point (CI 4.30, SE. 1.00), and 20 species with a mean of 8.67 species for the point (CI 6.25, SE. 1.45) species in 2011 (Figure 13).

The point count surveys for Babson Creek didn't begin until 2010. There is only two years of point count data for this watershed, although all the years of the development data exist. The first year of development data is the same as the other watersheds (1998). The total area of Babson Creek is 1023.27 ha. In 1999 the amount of development of the marsh was 101.41 ha, with only 9.91% of the watershed actually developed. The next year of development analysis was 2003. In these years the development increased to 165.15 ha and the percent of development increased to 16.14. In 2009 the amount of development was 169.50 ha giving the watershed a 16.56 percent development. The final year of surveys for Babson Creek was 2011. In this final year the amount of developed property was 173.64 ha (16.97%) (Figure 14).

Northeast Creek- Northeast Creek had a total of fourteen points (although not all the points were visited in each survey period in 2002). In 2002 Wilson et al. (2009) detected 46 species with a mean of 9.57 species for the point (CI 1.53, SE. 0.75), and we detected 51 species in 2010 with a mean of 6.83 species for the point (CI 0.72, SE.

0.36) and 42 species in 2011 with a mean of 5.40 species for the point (CI 0.74, SE. 0.37) (Figure 15).

The point count survey of Northeast Creek didn't begin until 2002, although we assessed development starting in 1999 for comparison with the other marshes. Northeast Creek is the largest of all the watersheds surveyed with 2678.05 ha. Northeast Creek began 309.57 ha (11.56%) of developed land in 1998. In the next three years, development in the Northeast Creek watershed increased to 389.36 ha (14.55%). In the ten years (2009) since the original gathering of development data, the watershed of Northeast Creek has increased development to 398.12 ha (14.87%). By 2011, 405.39 ha (15.14%) of the NEC watershed was developed (Figure 16). Of the watersheds that have been included in all the point count surveys, Northeast Creek has the highest percent increase of development, with a total of 15% in 2011. Northeast Creek was also the marsh with the highest percent of development at the commencement of the surveys.

Statistical Analyses

Abundance – The model that best predicted bird detections over our entire study period included the effects of site (N = 231, X^2 = 3.51, P= 0.03), the percent development of that site (X^2= 4.41, P = 0.04), and their interaction (X^2 = 4.01, P = 0.02) (Table 1). This model outperformed the null model (which included the random effect of date; ΔAICc =

380). This model also out-performed the next highest ranked model (∆AICc = 13.9), which included the effect of year (also site, percent of the watershed developed, and the interaction between year and site); this means that once we modeled the effect that percent of development had on abundance there was no effect for year. In the top model bird abundance decreased with development within each site (Figure 17). Further, there was more variation in abundance in the marshes with less development, such that largely undeveloped marshes possessed both relatively high and low bird abundances. Although, the marshes surveyed that were relatively developed possessed only low bird abundances.

Species Richness- The best model for species richness also included the effect of site, percent development, and their interaction. This model outperformed both the null (∆AICc = 165.8), and the next highest ranked model (∆AICc = 19.9) (Table 2), although none of the variables in the top model were statistically significant when the effects of site (N = 231, $X^2 = 0.64$, $P = 0.53$), the percent development of that site ($X^2 = 1.75$, $P = 0.19$), and their interaction ($X^2 = 0.24$, $P = 0.79$) were included (Figure 18). Over the twelve years of the survey period there was no significant change in the species richness in any of the marshes surveyed.

Simpson Index- The highest ranked model for the Simpson Index was again the model with site (N = 231, $X^2 = 3.95$, $P = 0.02$), percent development (X^2 7.63=, $P = 0.006$), and their interaction (X^2 = 3.35, P = 0.04). Species richness showed a relationship with percent development within and across sites that was very similar to the pattern for the abundance of birds detected (Figure 19), likely because there were no differences in species richness (and the index combines abundance and species richness). This model outperformed the null model (ΔAICc = 4.5) (Table 3), which was also the next highest ranked model.

Wetland Specialist Species- Nelson's sparrows were only detected in the saline marshes (BAB, BHM, and JON). The highest ranked model for the number of Nelson's sparrows detected included the effects of site (N = 125, X^2 = 0.35, P = 0.55) and percent development (X^2 = 0.59, P = 0.45). This model outperformed the null model (ΔAICc = 131.1) and the next highest ranked model (ΔAICc = 2.5), which included percent development, year, and their interaction (Table 4). None of these final variables were significant, however, and there appears to be no trends between Nelson's sparrow abundance and percent development (Figure 20).

Swamp Sparrows were only detected in the two marshes with shrub components (NEC and BHM). The highest ranked model included the same three variables as the best models for abundance and diversity which were site, percent development and their interaction. This was the best model that predicted Swamp Sparrow detections over our entire study period included the effects of site (N = 222, X^2 = 1.29, P= 0.26), the percent development of that site (X^2= 4.81, P = 0.03), and their interaction (X^2 =

0.72, P = 0.40) (Table 5). This model outperformed both the null model (ΔAICc = 112.8) and the next highest ranked model, which included site and percent development without their interaction (ΔAICc = 9.2) (Figure 21). In these two marshes, percent development increased with the number of swamp sparrows detected.

DISCUSSION

To determine possible future threats to the tidal wetlands of Mount Desert Island we visited three tidal wetlands and resurveyed historical point counts (BHM, NEC, JON); we also added one new marsh (BAB) to the monitoring effort. Although, Babson Creek was newly added to the project we still looked at the percent development for the entire timeframe of the project to get a wider view of the increased development on MDI. We surveyed the four marshes to determine how tidal marsh bird community has responded to recent changes in and how the current watershed uses have affected the avian populations.

Other research has found that abundance of birds seems to reach its highest amount as development increases. This is a result of an increase in the birds that take advantage and thrive in the fragmented habitats of human areas (Tratalos et al. 2007; McKinney et al. 2011). We found that on the watersheds surveyed on Mount Desert Island the abundance of birds significantly decreased throughout the time of our project. Our results showed that the percent of development near each of the marshes increased with every time step, while the abundance of birds decreased. Our analysis demonstrated that the increase of percent development was better at indicating changes in abundance in the marsh bird communities than the change in time alone. The results for the Simpson’s Index were similar to the results for abundance. We found that the increase in the percentage of development also significantly decreased the

Simpson's Index. This leads us to believe that there is the possibility that regional drivers such as the percent of development may be a factor or correlated with the cause in the decrease of bird abundance and Simpson's Index.

We did not find a significant relationship between species richness of the selected wetlands, and the percent of development increase within the watersheds. Northeast Creek also has the highest percent of development of the watersheds. In the most current year of research, Northeast Creek was only 15% developed. Other research has shown that species richness seems to reach its highest amount in low to medium levels of development (Tratalos et al. 2007; McKinney et al. 2011). Our results show that the amount of the development within all the watersheds surveyed is still at a low enough percentage to not significantly affect the species richness of the marshes. The possible ways in which the increased development might affect avian populations, is there will be an increase in species diversity but a decrease in native bird diversity (Blair 1996).

We also looked into the species of birds that are only found in the wetlands on the island. The two species were Nelson's Sparrow and Swamp Sparrow. Nelson's Sparrows were not breeding or regularly seen in the Northeast Creek watershed but they were present in the other three watersheds. They most likely were not found in Northeast Creek because of the lack of appropriate habitat inside the point count area. The Nelson's Sparrow did not show any significant changes to their population on the marshes surveyed. Swamp Sparrows were found in Northeast Creek and Bass Harbor

Marsh but not Babson Creek or Jones Marsh, also most likely due to lack of appropriate habitat. Bass Harbor and Northeast Creek have both a fresh water shrub marsh that is necessary for Swamp Sparrows (Mowbray 1997). The population of Swamp Sparrows significantly increased with the increase of the percentage of development. This may be because of the expansion of suitable habitat on the borders of the marsh. When Hodgman et al. (2001) surveyed Bass Harbor Marsh in 1999 there were no Swamp Sparrows recorded. The increased shrub component may be correlated with the increase of the percent of development in the watersheds. Both of these marshes have a fresh water shrub marsh that is a necessity for Swamp Sparrow (Mowbray 1997). Possible reasons for an increase in Swamp Sparrows may be tidal restrictions to the tidal inlets because of the construction of bridges and other anthropomorphic changes to the flow of the tide. The plants in a marsh are set in a strict zonation from low marsh cordgrass (*Spartina alterniflora*), high marsh marsh hay (*Spartina patens*) then rushes are located along the terrestrial border (Bertness et al. 2002). Shrubs are also located at the terrestrial border. Bertness et al. (2002) has shown that shoreline and watershed development can cause an increase in nitrogen, this increase and the effects from restricting the tidal flow to the marsh may be a reason for increased shrubs. The increase in Swamp Sparrows may be because they are taking advantage of the encroaching shrubs.

The marshes we selected to study are located very close to each other and located on an island where a large percentage is owned by the National Park Service or other types of conservation agencies. This limits the allotted space that development can occur over time on the island and keeps most development away from the wetlands surveyed, though some areas of the watershed are not protected and development abuts the wetlands. We are assuming that any development inside the watersheds of the selected wetlands will have an impact on the avian communities that use the wetlands. Impacts from housing developments are far reaching throughout ecosystems. They affect the patterns of land cover, even when the numbers of houses is small (Tratalos et. al 2007). Most new development on the island seems to be completed in clustered neighborhoods with the highest increase between the years of 1999 and 2003. There have been additional studies that have shown that bird populations have been declining in the last few decades. As stated earlier the increase of development affects the bird population by altering the species composition within the urbanized area (Blair 1996). Abundance also seems to reach its highest amount as development increases. This is a result of an increase in the bird species that are able to take advantage and thrive in the fragmented habitats of human areas (Tratalos et al. 2007, McKinney et al. 2011). Some examples of birds moving into habitats that they were previously not found in are Northern Cardinal (*Cardinalis cardinalis*), Tufted Titmouse (*Baeololphus bicolor*) and Song Sparrow (*Melospiza melodia*) (USGS 2012) this could be a partial reason for changes to the marsh bird communities.

It has been stated that birds may be increasing their northern ranges due to climate change creating new habitats for them. As some avian species are increasing northward they are not increasing southward and on average some North American bird species are increasing their northern ranges by 2.35 km per year (Hitch & Leberg 2007).

While doing other work on Bass Harbor Marsh, we observed species that might be showing northern range increases. We observed a Saltmarsh Sparrow (*Ammodramus caudacutus*) and a Little Blue Heron (*Egretta caerulea)*, both species that breed in southern Maine but not on MDI. Both of these species were not found in multiple years and were not present for the entire breeding season (pers. obs.). Northern Cardinals were observed during the point counts on Bass Harbor Marsh in 2010 and 2011 throughout the entire season. They were not recorded in any of the previous surveys. This movement of birds northward may be changing the species composition within the watersheds.

As well as new species possibly moving into the watersheds, some bird species have been recorded arriving on the breeding ground significantly earlier (Miller-Rushing et al, 2008). We studied how the percent of development may alter the marsh ecosystem, but another possible influence on the tidal marsh bird community may be climate change. Impacts on birds that may be due to climate change include earlier breeding, increased survival, larger clutches and earlier nesting, change in diet and increased ranges northward (Murphy-Klassen et. al. 2005). Some species that are not arriving significantly earlier are nesting earlier. This means that when a bird arrives at its breeding grounds it is under immediate pressure to start nesting (Murphy-Klassen et. al 2005). Both Nelson's and Swamp Sparrows might start to breed earlier. The previous studies on the marshes have found Nelson's Sparrows arriving during the first to second week in June (Wilson et. al. 2009 and Hodgman et. al. 2002). In 2010 we observed our first Nelson's Sparrow May 24. Doing periodic surveys early and late into the breeding season may give more information on the populations of the wetland birds for future research. By continuing with this research by adding future years of data, there will be a better understanding of how the percent of development or other possible regional stressors on the island is affecting the birds with in the watersheds and the connected wetlands.

Global climate change is predicted to increase sea levels. As sea levels rise tidal mud flats will be converted into salt marshes. Research in the United Kingdom, has focused on the increase of Spartina species of grass and have found a rapid decrease in Dunlin (*Calidris alpine)* (Galbraith et al. 2002). Other areas of Europe have also experienced the decrease of shorebird numbers as mudflats are changed to salt marshes (Galbraith et al. 2002). The quickness and unpredictability of global climate change will cause a change in the available habitats for the birds on Mount Desert Island. This will require birds to adapt to the new habitats or they might be extirpated from the island.

To continue preserving the wetlands on Mount Desert Island the priority of conservation should not only be on the wetlands themselves but include the entire watershed. Our research shows that while the wetland specialists have not showed any significant decline in their populations, overall bird abundance has significantly decreased as the percent of development increases in the watersheds. These results show that the focus of conservation should be on the entire watershed not only the wetlands. Future research and more periodic surveys will help to understand how the development or other local changes to the wetland ecosystem is affecting the bird populations and help to understand what is the driving force in the possible decline of birds that use the watershed as a breeding ground. The information collected in this study will provide information to developers and land planners to increase the knowledge of the importance of watersheds and the birds that inhabit them. The data can also influence land planning through-out coastal Maine and New England.

LITERATURE CITED

Alberti, M. 2005. The effects of urban patterns on ecosystem functions. International Regional Science Review 28: 168-192.

Benassi G., C. Battisti, L. Luiselli and L. Boitani. 2009. Area-sensitivity of three reed bed bird species breeding in the Mediterranean marshland fragments. Wetlands Ecology and Management 17: 555-564.

Benoit L. K. and R. A. Askins. 1999. Impact of the spread of *Phragmites* on the distribution of birds in Connecticut tidal marshes. Wetlands 19: 194-208.

Benoit L. K. and R. A. Askins. 2002. Relationship between habitat area and the distribution of tidal marsh birds. Wilson Bulletin 114: 314-323.

Bertness M. D., P. J. Ewanchuk, and B. R. Silliman. 2002. Anthropogenic modification of New England salt marsh landscapes. Ecology 99: 1395-1398.

Blair R. 1996. Land use and avian species diversity along an urban gradient. Ecological Applications 6: 506-519.

Boesch, D. F., and R. E. Turner. 1984. Dependence of fishery species on salt marshes: The role of food and refuge. Estuaries 7: 460-468.

Boorman, L.A. 1999. Salt marshes-present functioning and future change. Mangroves and Salt Marshes 3:227-241.

Burlington, L. B. 1999. Ten year historical perspective of the NOAA damage assessment and restoration program. Spill Science & Technology Bulletin 5: 109-116.

College of the Atlantic GIS Laboratory, 1987. Watershed Boundaries of Mount Desert Island and Lands of MDI Municipalities. College of the Atlantic GIS Laboratory.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. US Fish and Wildlife Service, Washington,DC. FWS/OBS-79/31: 131

Daiber, F.C. (ed). 1986. Conservation of tidal marshes. New York: Van Norstrand Reinhold.

Dahl, T. E. 1990. Wetland losses in the United States: 1780s to 1980s. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC, USA.

Dame, R., T. Chrzanowski, K. Bildstein, B. Kjerfve, H. McKellar, D. Nelson, J. Spurrier, S. Stancyk, H. Stevenson, J. Vernberg and R. Zingmark. 1986. The out-welling hypothesis and north inlet, South Carolina. Marine Ecology-Progress Series 33: 217-229.

DeLuca, W.V., C.E. Studds, Rockwood L.L., Marra P.P. 2004. Influence of the land use in the integrity of marsh birds communities of Chesapeake Bay, USA. Wetlands, 24: 837-847.

Erwin, R. M. 1996. Dependence of waterbirds and shorebirds on shallow-water habitats in the mid-Atlantic coastal region: An ecological profile and management recommendations.Estuaries 19:213-219.

Galbraith, H., R. Jones, J. Clough, S. Herrod-Julius, B. Harrington, G Page. 2002. Globalclimate change and sea level rise: potential losses of Intertidal habitat for shorebirds. Waterbirds: The International Journal of Waterbird Biology 25: 173-183.

Greenberg, R. 2006. Tidal marshes: Home for the few and highly selected. in Terrestrial Vertebrates of Tidal Marshes: Evolution, Ecology, and Conservation (R. Greenberg, J. E. Maldonado, S. Droege, and M. V. McDonald, Eds.). Studies in Avian Biology No. 32. 1-9

Greenberg, R. G., and J. E. Maldonado. 2006. Diversity and endemism in tidal marsh vertebrates. in Terrestrial vertebrates of tidal marshes: Ecology, evolution, and conservation (S. Droege, R. Greenberg, J. Maldonado, and M. V. McDonald, Eds.). Studies in Avian Biology No. 32. 32-53

Heinle, D. R., and D. A. Flemer. 1976. Flows of materials between poorly flooded tidal marshes and an estuary. Marine Biology 35: 359-373.

Hitch, A.T. 2007. Breeding distributions of North American bird species moving north as a result of climate change. Conservation Biology 21:534-539.

Hodgman, T.P., and P.U. Wilson. 2001. Saltmarsh Birds. pages127-137 in A Survey of Rare, Threatened, and Endangered Fauna in Maine: East Coast and Eastern Interior Regions (1999-2000) (A.P Weik, P. deMaynadier, and T.P. Hodgman, eds.). Maine Department of Inland Fisheries and Wildlife, Bangor, Maine.

Hodgman, T.P., W.G. Shriver and P.D. Vickery. 2002. Redefining range overlap between the sharp-tailed sparrows of coastal New England. Wilson Bulletin 114: 38-43.

IPCC. 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on

Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Koch, F., and C.J. Gobler. 2009. The effects of tidal export from salt marsh ditches on estuarine water quality and plankton communities. Estuaries and Coasts 32: 261-275.

Maine Library of Geographic Information (MLGI). U.S Geological Survey, Maine Office of Geographic Information Systems (MEGIS), 2008, Ortho 1F 2003-2005, retrieved from http://www.maine.gov/megis/catalog/.

Maine State Planning Office, Census State Data Center. 2010. Retrieved 11/28/12, from http://www.state.me.us/spo/economics/census.

Master, T. L. 1992. Composition, structure, and dynamics of mixed-species foraging aggregations in a southern new-jersey salt-marsh. Colonial Waterbirds 15: 66-74.

McKinney, R.A., K. B. Raposa, and R.M. Cournoyer. 2011. Wetlands as habitat in urbanizing landscapes: Patterns of bird abundance and occupancy. Landscape and Urban Planning, 100: 144-152.

Mensing, D.M., S.M. Galatowitscg, and J.R. Tester. 1998. Anthropogenic effects on the biodiversity of riparian wetlands of a northern temperate landscape. Journal of Environmental Management 53: 349-377.

Miller-Rushing, A.J., T.L. Lloyd-Evans, R.B. Primack, and P. Satzinger. 2008. Bird Migration times, climate change and changing populations. Global Change Biology 14:1959-1972.

Mitsch, W.J., and J.G. Gosselink (eds). 1993 Wetlands. New York, NY: Wiley.

Mowbray, T.B. 1997. Swamp Sparrow (Melospiza georgiana), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.proxy.antioch.edu/bna/species/279doi:10.2173/bna.279.

Murphy-Kalssen, H.M., T.J. Underwood, S.G. Sealy, and A.A. Czyrnyj. 2005. Long-term trends in spring arrival dates of migrant birds at Delta Marsh, Manitoba, in relation to climate change. Auk 122:1130-1148.

Rahmstorf, S. 2007. A semi-empirical approach to projecting future sea-level rise. Science 315: 368-370.

Reinold, R.J. 1977. Mangroves and salt marshes of eastern United States. in Wet coastal ecosystems of the world, ed. V.J. Chapman, 1: 157–166. Amsterdam: Elsevier.

Sauer, J. R., J. E. Hines, and J. Fallonv .2008. *The North American Breeding Bird Survey, Results and Analysis 1966 - 2007*. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Schlossberg, S., D.I. King and R.B. Chandler. 2011, Effects of low-density housing development on shrubland birds in western Massachusetts. Landscape and Urban Planning, 103: 64-73.

Shriver, W. G., and J. P. Gibbs. 2004. Effects of sea-level rise on the population viability of Seaside Sparrows. Pp. 397-409 in Species Conservation and Management: Case Studies (Edited by H. R. Akcakaya, M. Burgman, O. Kindvall, C. C. Ward, P. Sjogren-Gulve, J. S. Hatfield and M. A. McCarthy), Oxford University Press.

Shriver, W.G, T.P. Hodgman, J.P. Gibbs, and P.D. Vickery. 2004. Landscape context influences salt marsh bird diversity and area requirements in New England. Biological Conservation, 119: 545-553.

Shriver, W.G., D.C. Evers, T.P. Hodgman, B.J. MacCulloch and R.J. Taylor. 2006. Mercury in sharp-tailed sparrows breeding in coastal wetlands. Environmental Bioindicators 1: 129-135.

Shriver, W. G., T.P. Hodgman and A. R. Hanson A. R. 2011. Nelson's Sparrow (Ammodramus nelsoni), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.proxy.antioch.edu/bna/species/719 doi:10.2173/

Sipple, W., 1971. The past and present flora and vegetation of the Hackensack Meadowlands. Bartonia 41:4–56.

Sillet, T.S., R.T. Holmes. 2002, Variation in survivorship of a migratory songbird throughout its annual cycle. Journal of Animal Ecology 71: 296-308.

Tiner, R. W. 1984. Wetlands of the United States: current status and recent trends. U.S. Fish and Wildlife Service, National Wetlands Inventory, Washington, DC, USA.

Tratalos, J., R.A. Fuller, K.L. Evans, R.G. Davies,S.E. Newson, J.J.D. Greenwood, and K.J. Gaston. 2007. Bird densities are associated with household densities. Global Climate Change, 13: 1685-1695.

U.S. Census Bureau, 2010 Census of Population and Housing, *Population and Housing Unit Counts*,CPH-2-21, Maine U.S. Government Printing Office, Washington, DC, 2012.

U.S.D.A-F.S.A Aerial Photography Field Office, 2009. NAIP 2009. Retrieved from http://www.maine.gov/megis/catalog/.

U.S.D.A-F.S.A Aerial Photography Field Office, 2011. NAIP 2011. Retrieved from http://www.maine.gov/megis/catalog/.

USGS Patuxent Wildlife Research Center. 2013. North American Breeding Bird Survey Internet data set, 10 January 2013 (http://www.pwrc.usgs.gov/bbs/retrieval/).

U. S. Fish and Wildlife Service. 2010. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. http://www.fws.gov/wetlands/

U.S Geological Survey, Maine Office of Geographic Information Systems (MEGIS), 2001. Black and White Orthos Photos 1996-1998, retrieved from http://www.maine.gov/megis/catalog/.

Valiela, I., and J. M. Teal.1979. Nitrogen budget of a salt-marsh ecosystem. Nature 280: 652-656.

Valiela, I., G. Tomasky, J. Hauxwell, M. L. Cole, J. Cebrian and K. D. Kroeger. 2000. Operationalizing sustainability: Management and risk assessment of land-derived nitrogen loads to estuaries. Ecological Applications 10: 1006-1023.

Ward, M.P., B Semel, J.R. Herket. 2010. Identifying the ecological causes of long-term declines of wetland-dependent birds in an urban landscape. Biodiversity Conservation 19: 3287-3300.

Warren, R. S., and W. A. Niering. 1993. Vegetation change on a northeast tidal marsh - interaction of sea-level rise and marsh accretion. Ecology 74: 96-103.

Whited, D., S. Galatowitsch, J.R. Tester, K. Schik, R.Lehtinen, J. Husveth. 2000. The importance of local and regional factors in predicting effective conservation; Planning strategies for wetland bird communities in agricultural and urban landscapes. Landscape and Urban Planning 49: 49-65.

Wilson, M.D., B.D. Watts, D.F. Brinker.2007. Status Review of Chesapeake Bay Marsh Lands and Breeding Marsh Birds. Waterbirds. 30, p 122-137.

Wilson, P.U., J.R. Longcore, J.R. Sauer and K. Anderson.2009. Avian use of Northeast Creek and Bass Harbor Marsh in Acadia National Park 2001-2002. Natural Resource Report NPS/NETN/NRR—2009/144. National Park Service, Fort Collins, Colorado.

Wolfe, R.J. 1996. Effects of open marsh water management on selected tidal marsh resources: a review. Journal of the American Mosquito Control Association, 12: 701-712.

Tables

Table 1. AICc model predictor showing the best model for determining change in bird abundance is the percent of development for each site.

Model	AICc	ΔAICc
site % develop site*% develop	1796.5	0
year % develop site site*year	1810.4	13.9
year year*develop develop site site*year	1824.3	27.8
year year*site develop site	1829	32.5
site % develop	1836.8	40.3
year year*% develop % develop	1844.2	47.7
year year*develop develop site	1844.3	47.8
site develop site*develop	1847	50.5
site develop	1855.2	58.7
% develop	1857.4	60.9
develop	1871.5	75
year year*develop develop	1876.3	79.8
year year*site site	2140.9	344.4
site	2156.8	360.3
null	2176.5	380
year year*% develop % develop site	NA	
year % develop % develop *year site site*year	NA	

* indicates interaction

Table 2. AICc model predictor showing the best model for determining change in species richness is the percent of development for each site.

Model	AICc	ΔAICc
site % develop site*% develop	1162	0
year % develop site site*year	1181.9	19.9
site % develop	1191.7	29.7
year year*% develop % develop	1199.1	37.1
site develop	1208	46
year year*develop develop site	1212.3	50.3
site develop site*develop	1212.5	50.5
develop	1227.8	65.8
year year*develop develop	1232.4	70.4
prctdev	1253.2	91.2
year year*site site	1322.8	160.8
null	1327.8	165.8
site	1336.7	174.7
year year*site develop site	NA	
year year*develop develop site site*year	NA	
year year*% develop % develop site	NA	
year % develop % develop *year site site*year	NA	

* indicates interaction

Table 3. AICc model predictor showing the best model for determining change in Simpson's Index is the percent of development for each site.

Model	**AICc**	**ΔAICc**
site % develop site*% develop	-187.1	0
null	-182.6	4.5
site	-179.1	8
year year*site site	-166.2	20.9
% develop	-165	22.1
site % develop	-165	22.1
year % develop site site*year	-162.5	24.6
year year*% develop % develop	-160.1	27
year year*develop develop site site*year	-155.5	31.6
site develop	-149.7	37.4
develop	-144.9	42.2
year year*site develop site	-144.4	42.7
site develop site*develop	-136.6	50.5
year year*develop develop site	-132.2	54.9
year year*develop develop	-121.8	65.3
year year*% develop % develop site	NA	
year % develop % develop *year site site*year	NA	

* indicates interaction

Table 4. AICc model predictor showing the best model for determining change in Nelson's Sparrow is the percent of development for each site.

Model	AICc	ΔAICc
site % develop	444.9	0
year year*% develop % develop	447.4	2.5
% develop	448.5	3.6
year year*site develop site	455.9	11
site develop	462.1	17.2
site % develop site*% develop	463.4	18.5
site develop site*develop	463.4	18.5
year year*develop develop site site*year	466.5	21.6
develop	469.2	24.3
year year*develop develop site	469.6	24.7
year year*develop develop	476.9	32
site	547.9	103
year year*site site	554.5	109.6
null	576	131.1
year % develop site site*year	NA	
year year*% develop % develop site	NA	
year % develop % develop *year site site*year	NA	

* indicates interaction

Table 5. AICc model predictor showing the best model for determining change in Swamp Sparrow is the percent of development for each site.

Model	**AICc**	**ΔAICc**
site % develop site* % develop	623.9	0
site % develop	633.1	9.2
year % develop site site*year	635.7	11.8
% develop	638.2	14.3
year year* % develop % develop	641.2	17.3
site develop	650.1	26.2
year year * site develop site	653.2	29.3
develop	656.3	32.4
site develop site *develop	658.6	34.7
year year* develop develop site	666.4	42.5
year year * develop develop	676.9	53
site	694.9	71
year year * site site	706.2	82.3
null	736.7	112.8
year year * develop develop site site * year	NA	
year year* % develop % develop site	NA	
year % develop % develop * year site site*year	NA	

* indicates interaction

Figures

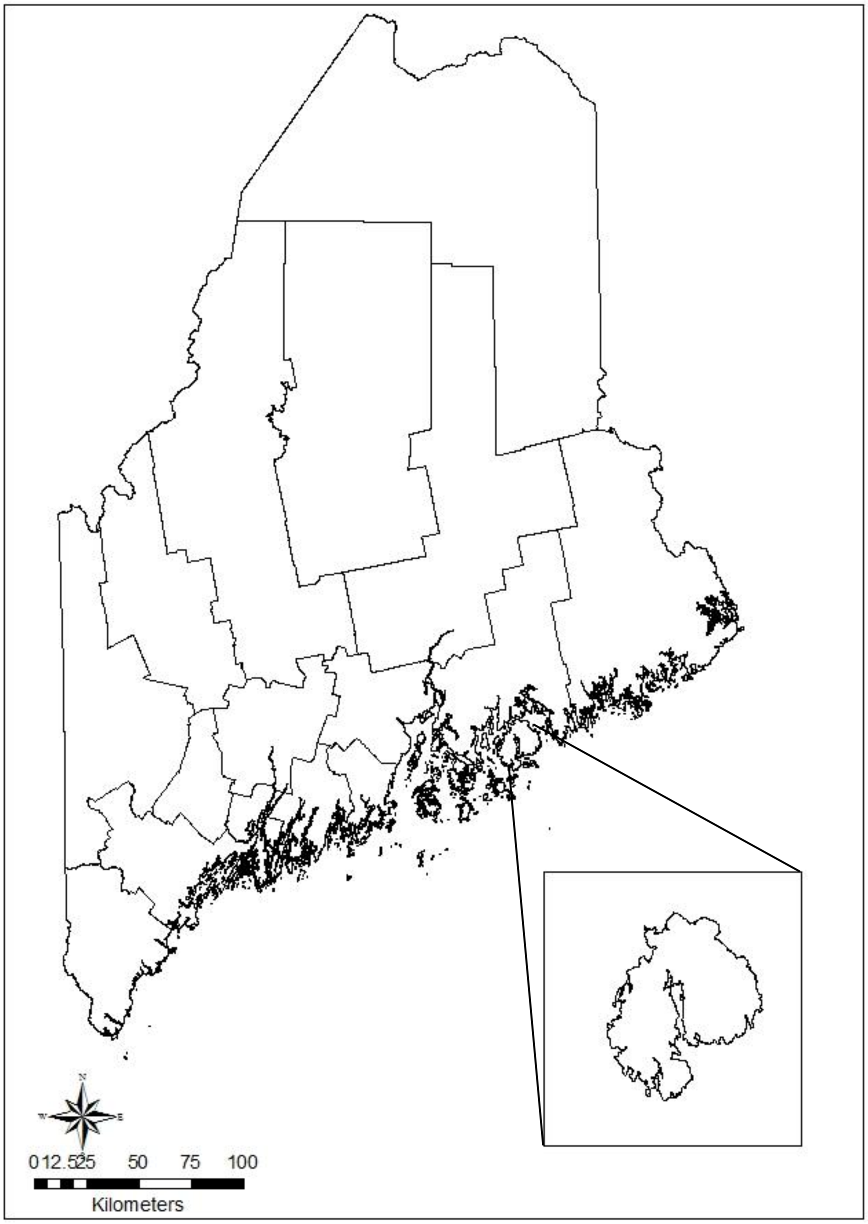

Figure 1. The location of Mount Desert Island in the state of Maine.

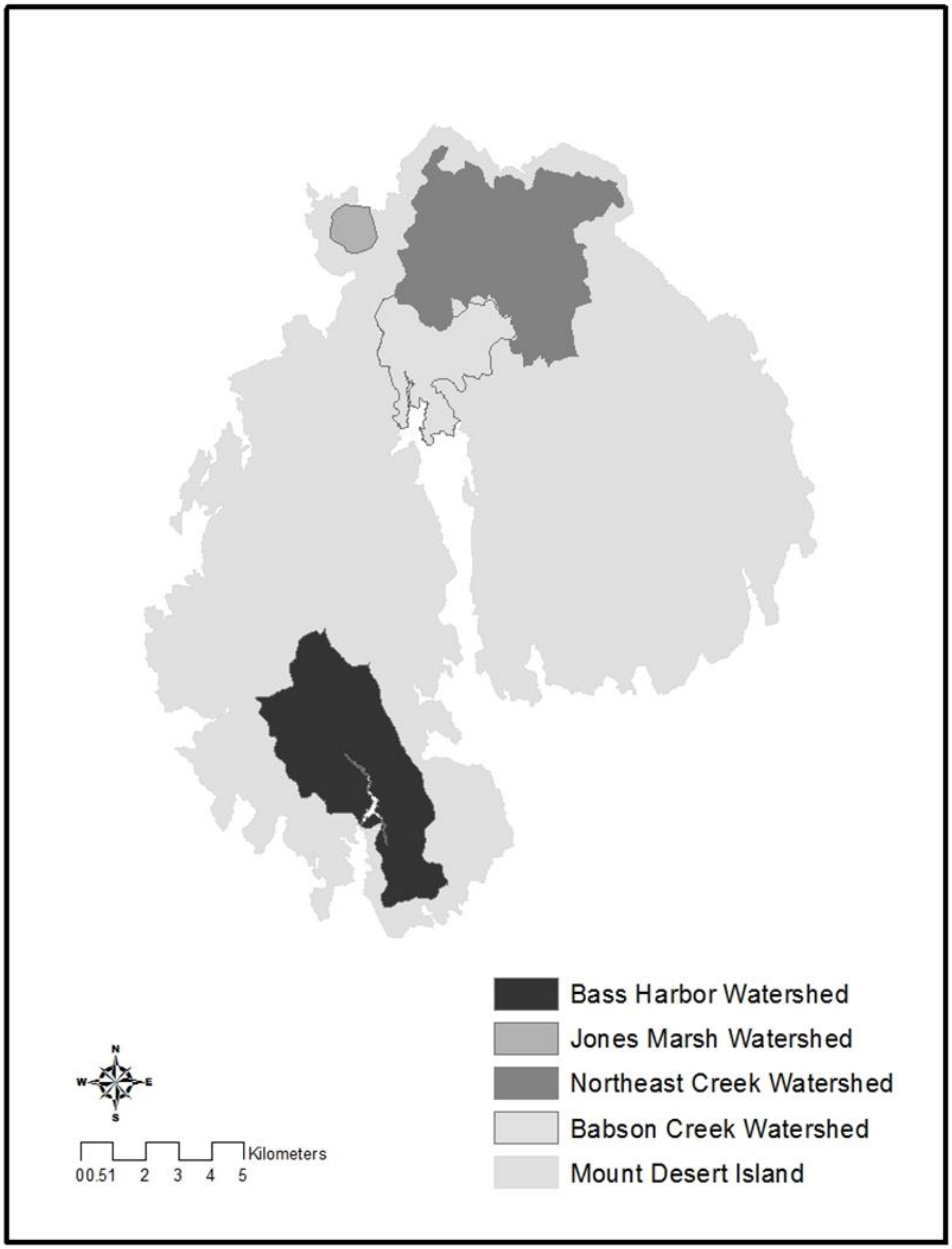

Figure 2. Location of the Jones Marsh, Northeast Creek, Babson Creek and Bass Harbor Marsh watersheds on Mount Desert Island.

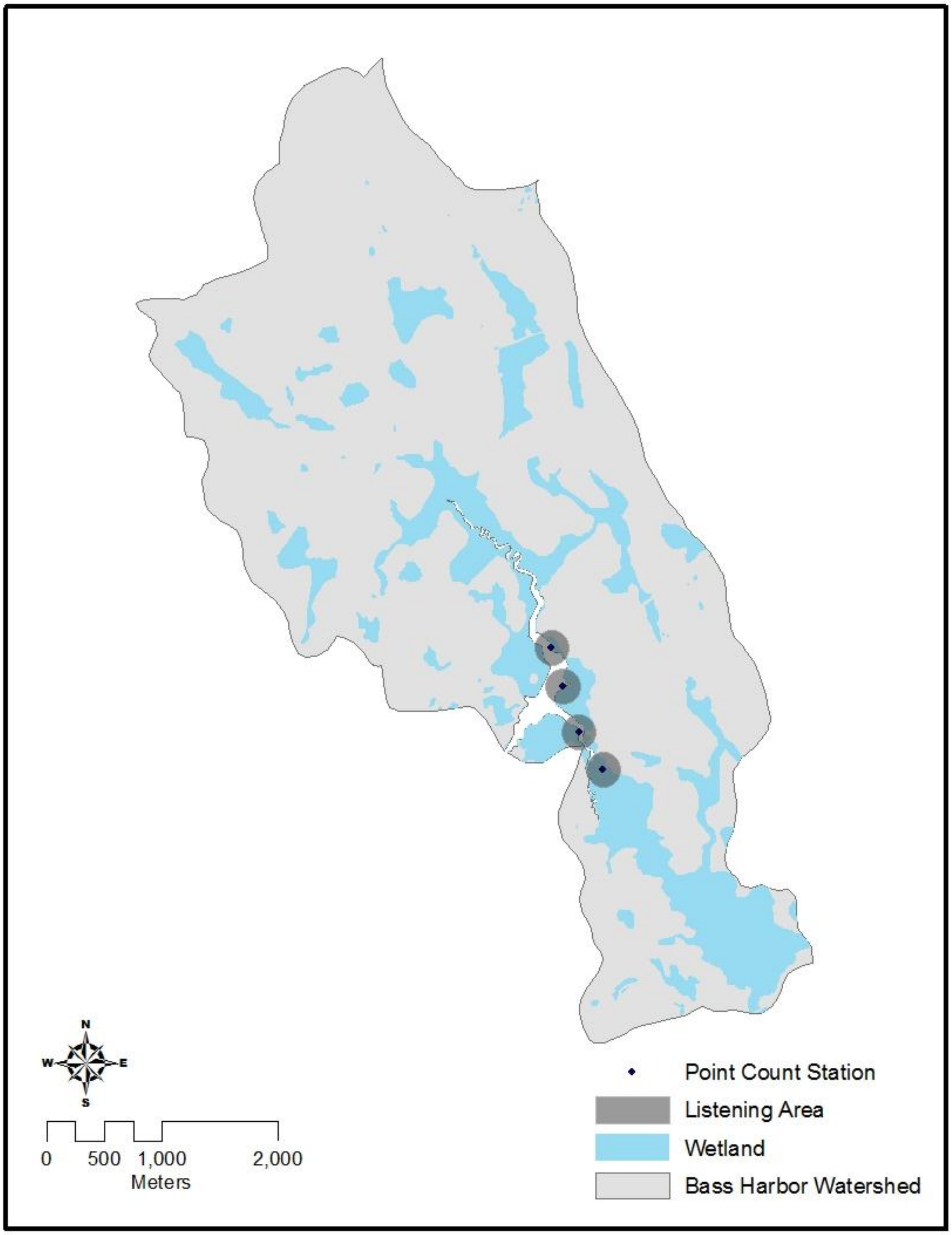

Figure 3. Location of Maine Inland Fisheries and Wildlife (1999, 2010, and 2011) point count stations in Bass Harbor Marsh.

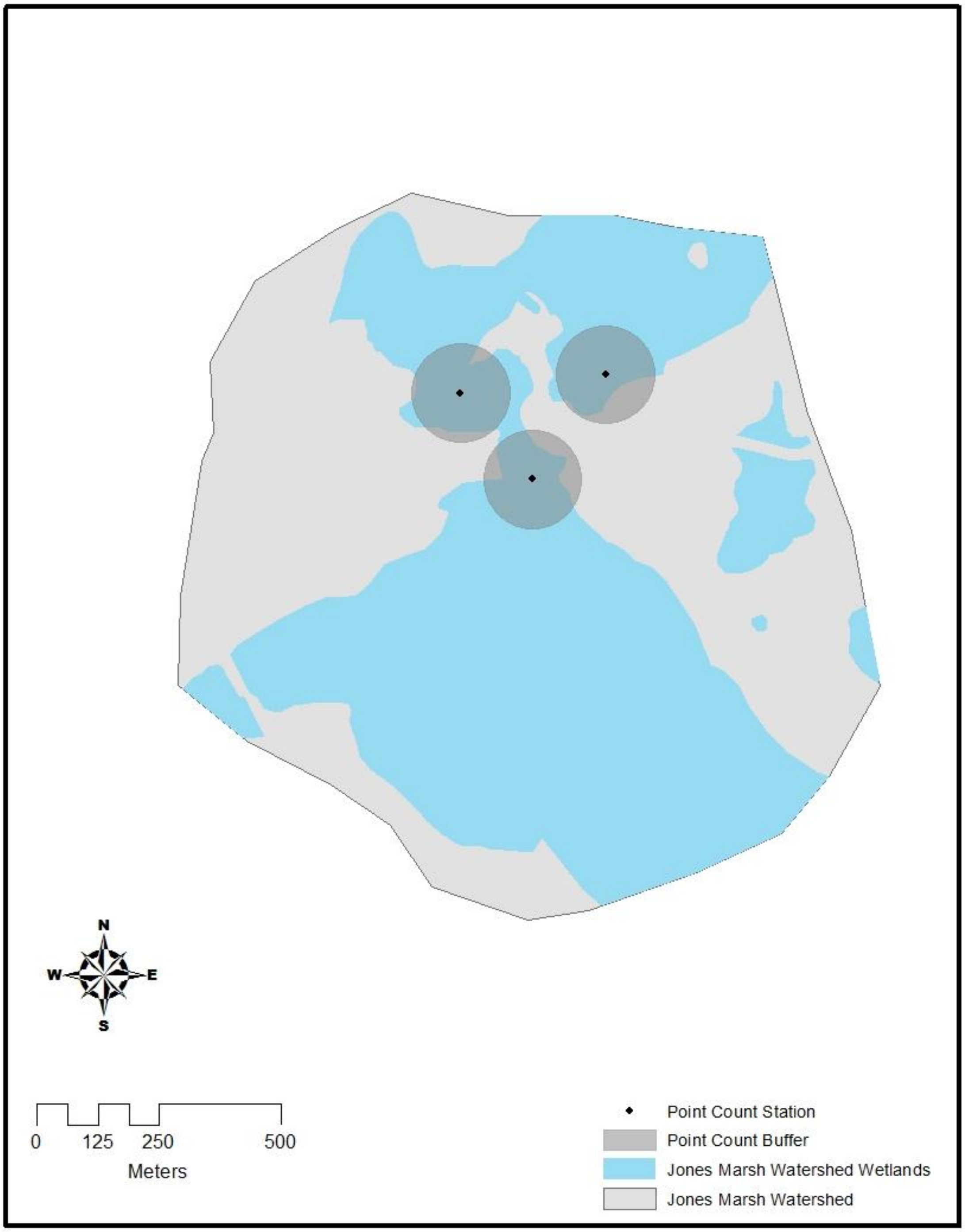

Figure 4. Location of Maine Inland Fisheries and Wildlife (1999, 2010, and 2011) point count stations on Jones Marsh.

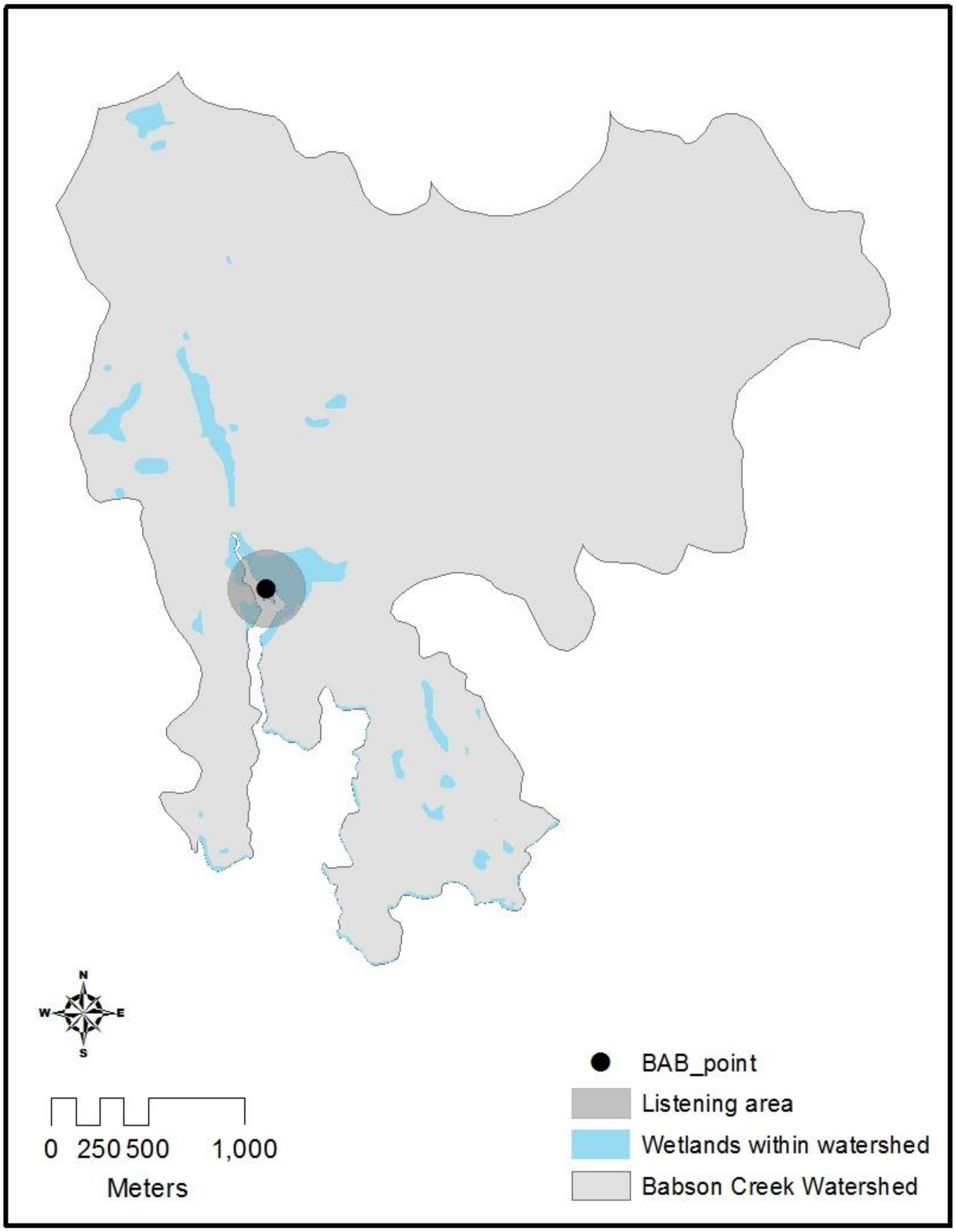

Figure 5. Location of point count station for Babson Creek Watershed (2010 and 2011)

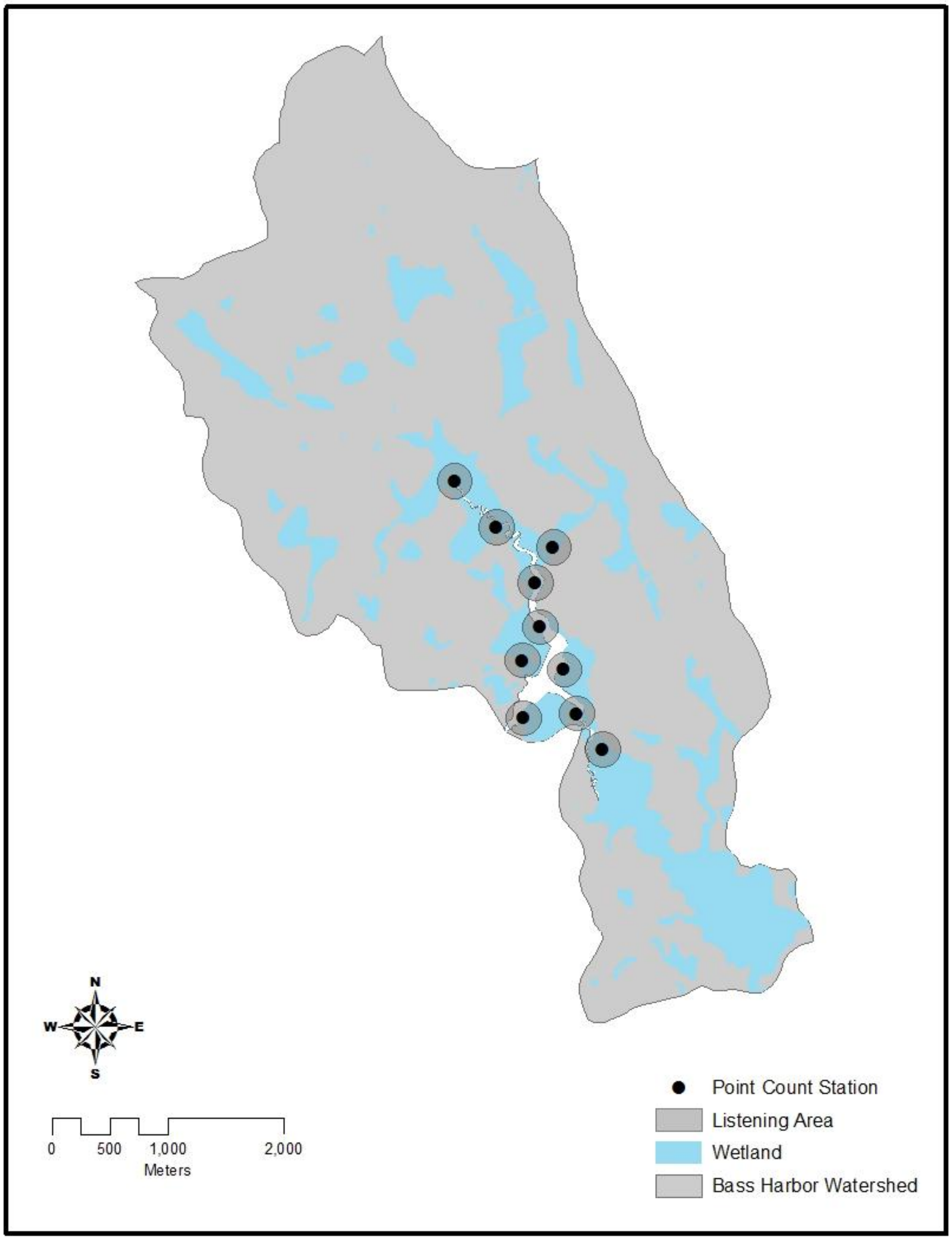

Figure 6. Location of National Park Service point count station for Bass Harbor Marsh Watershed (2002, 2010 and 2011)

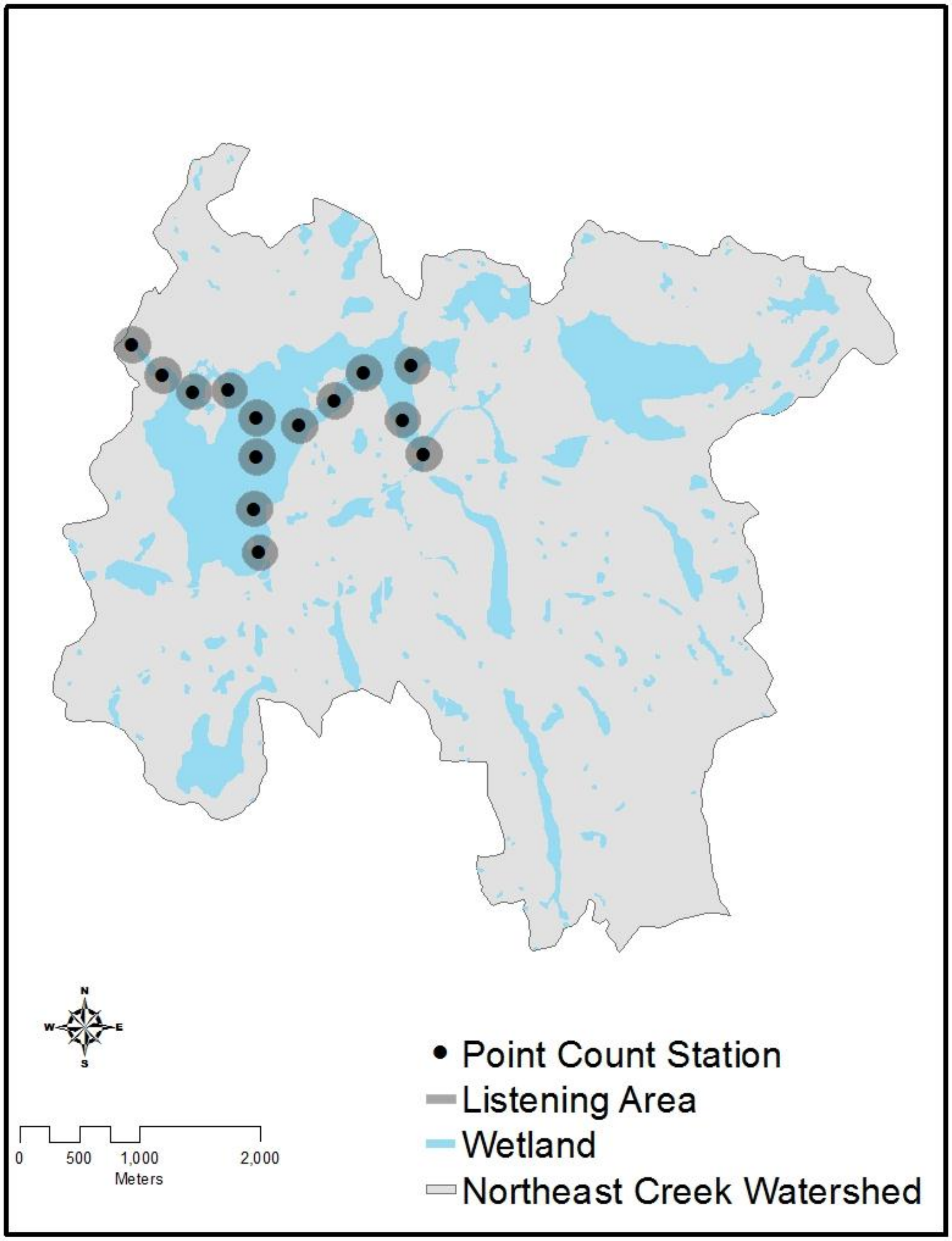

Figure 7. Location of National Park Service point count station for Northeast Creek Watershed (2002, 2010 and 2011)

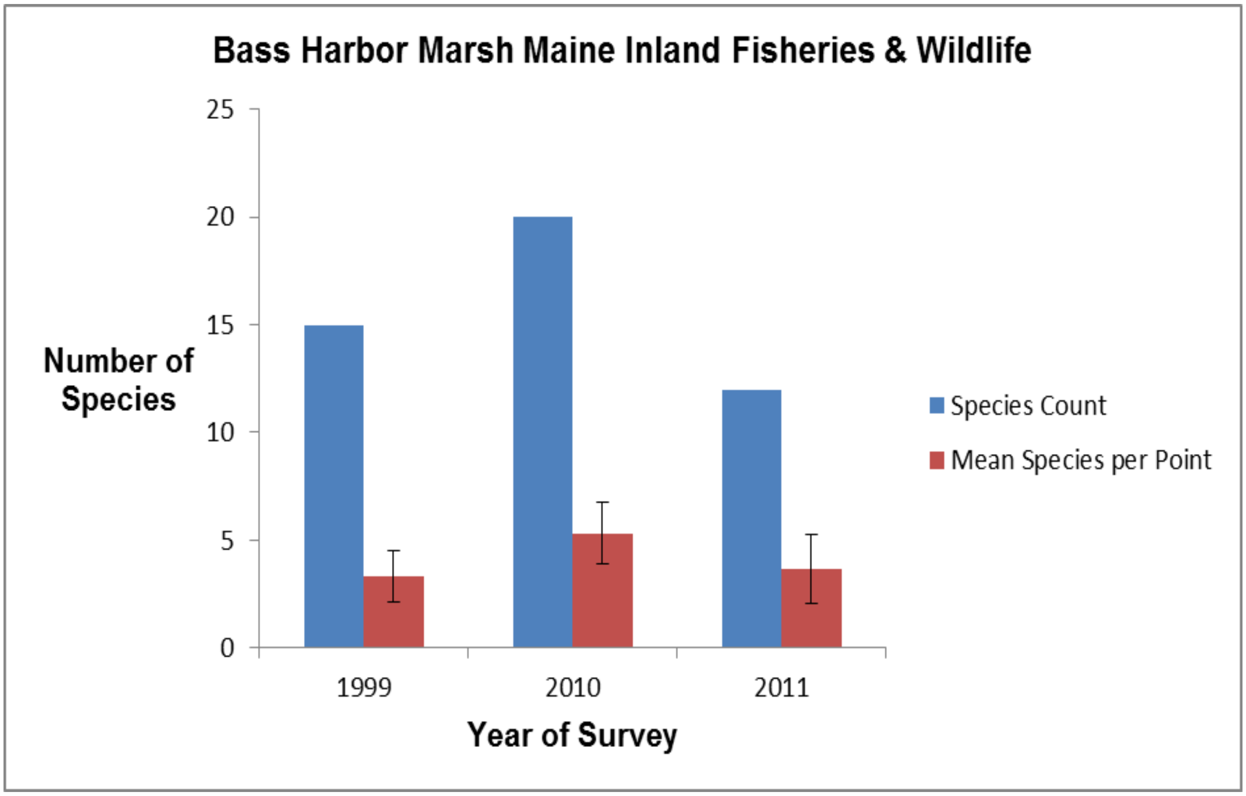

Figure 8. Number of species counted during each sampling seasons from 1999 to 2011 of the Maine Inland Fisheries and Wildlife designated points for Bass Harbor Marsh, with the mean per point. Error bars represent the 95% confidence interval.

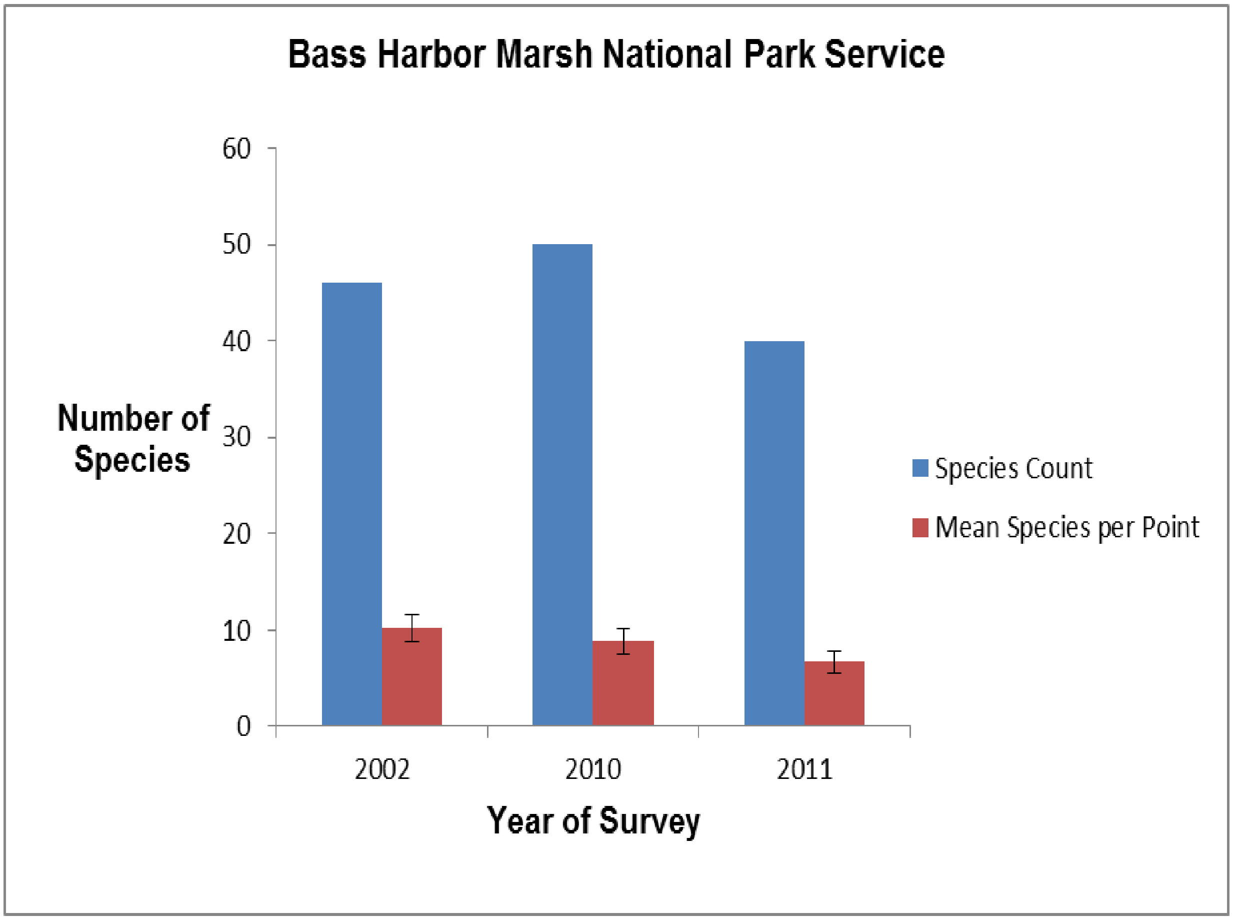

Figure 9. Number of species counted during each sampling seasons from 2002 to 2011 of the National Park Service designated points for Bass Harbor Marsh, with the mean per point. Error bars represent the 95% confidence interval.

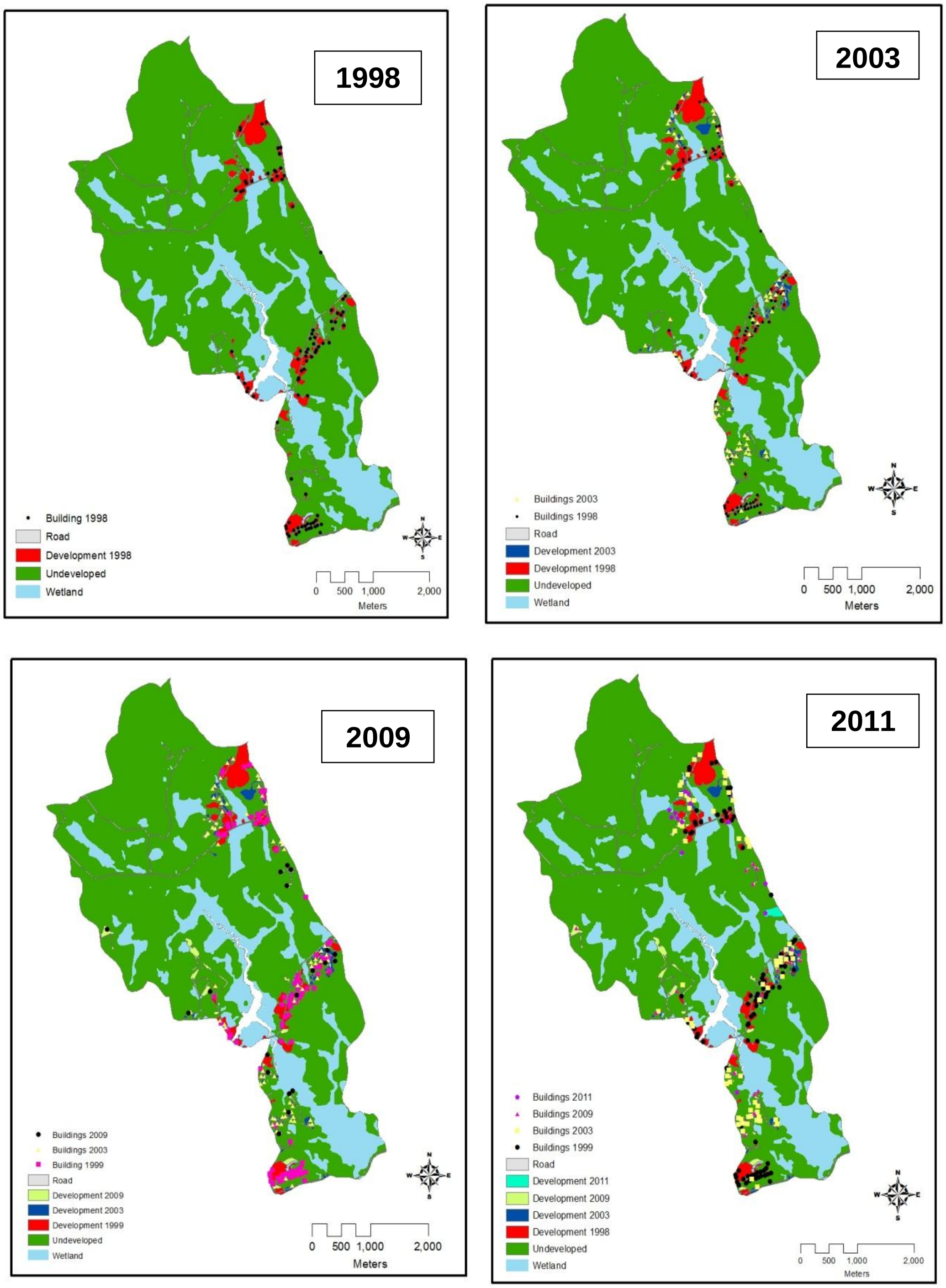

Figure 10. Land use of Bass Harbor Marsh 1998 to 2011, representing the increase of development within the watersheds

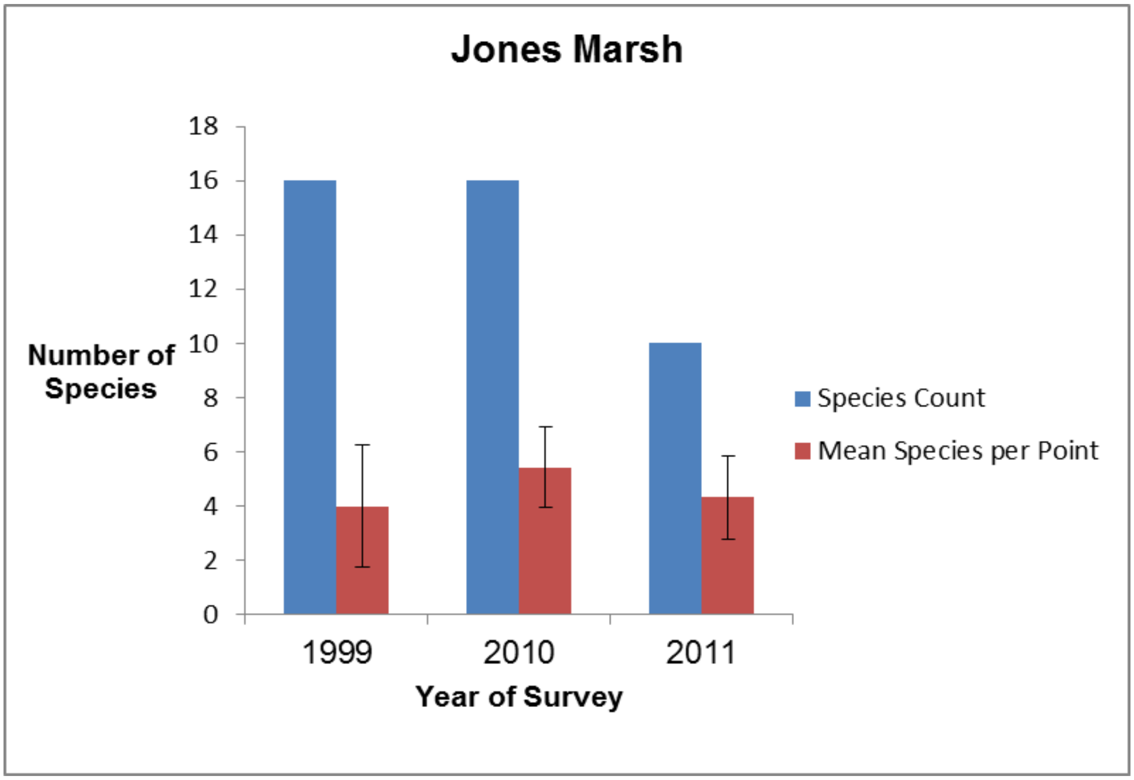

Figure 11. Number of species counted during each sampling seasons from 1999 to 2011 of the Maine Inland Fisheries and Wildlife designated points for Jones Marsh, with the mean per point. Error bars represent the 95% confidence interval.

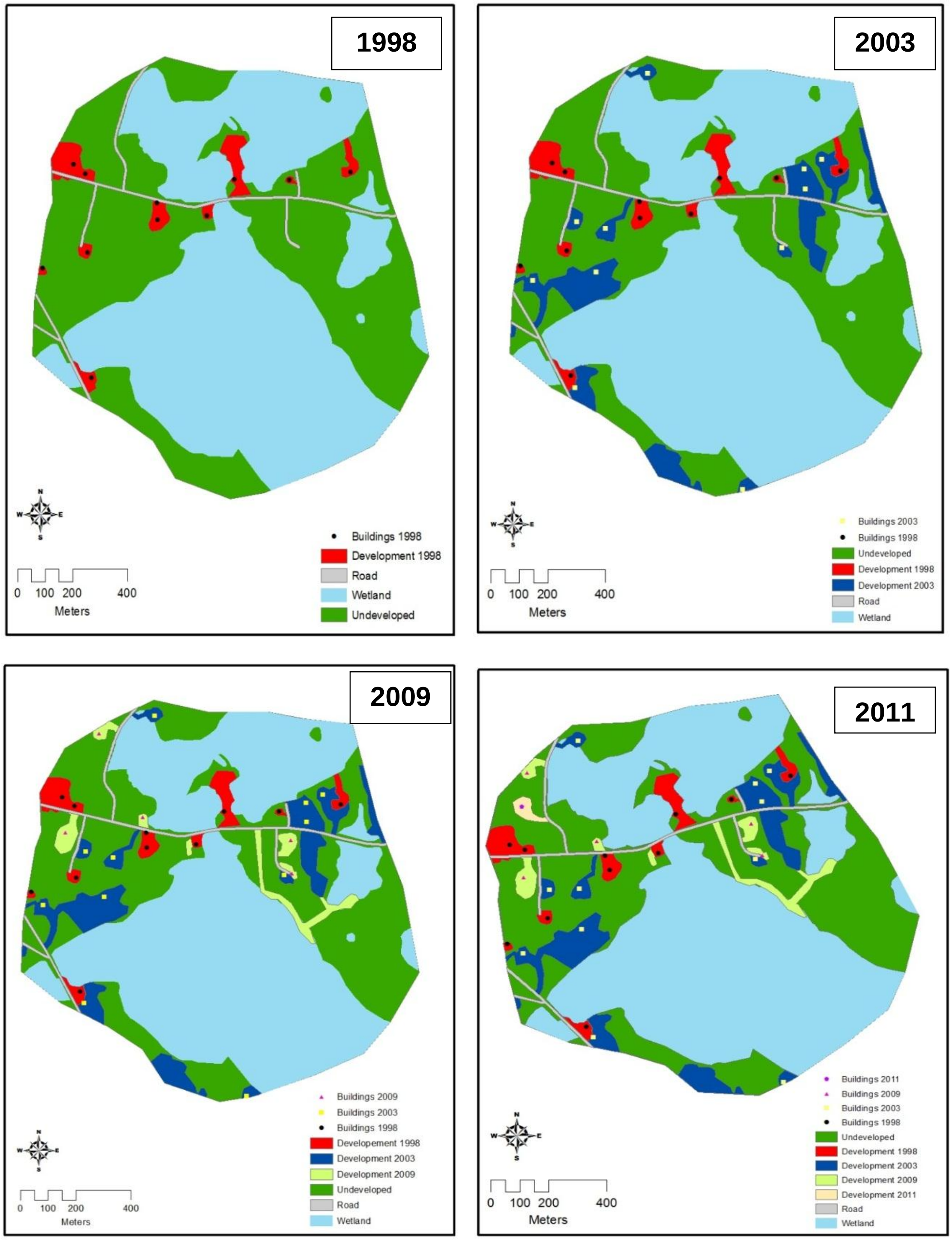

Figure 12. Land use of Jones Marsh 1998 to 2011, representing the increase of development within the watershed

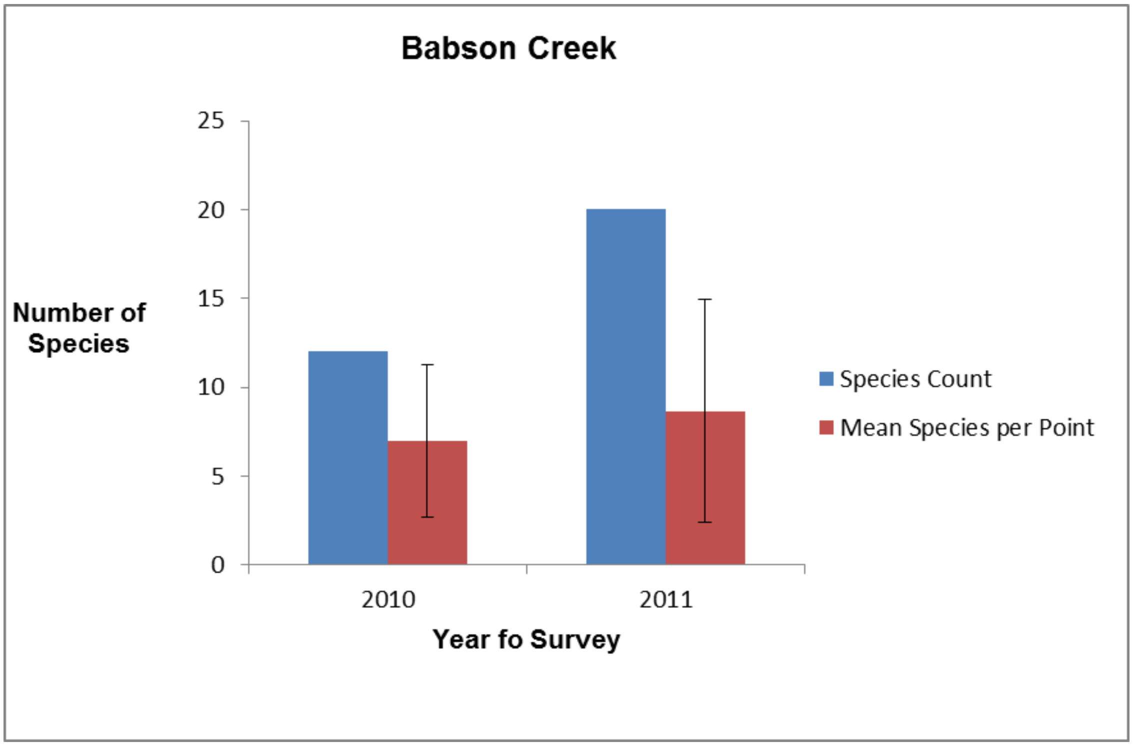

Figure 13. Number of species counted during each sampling seasons of 2010 and 2011 of Babson Creek Watershed, with the mean per point. Error bars represent the 95% confidence interval.

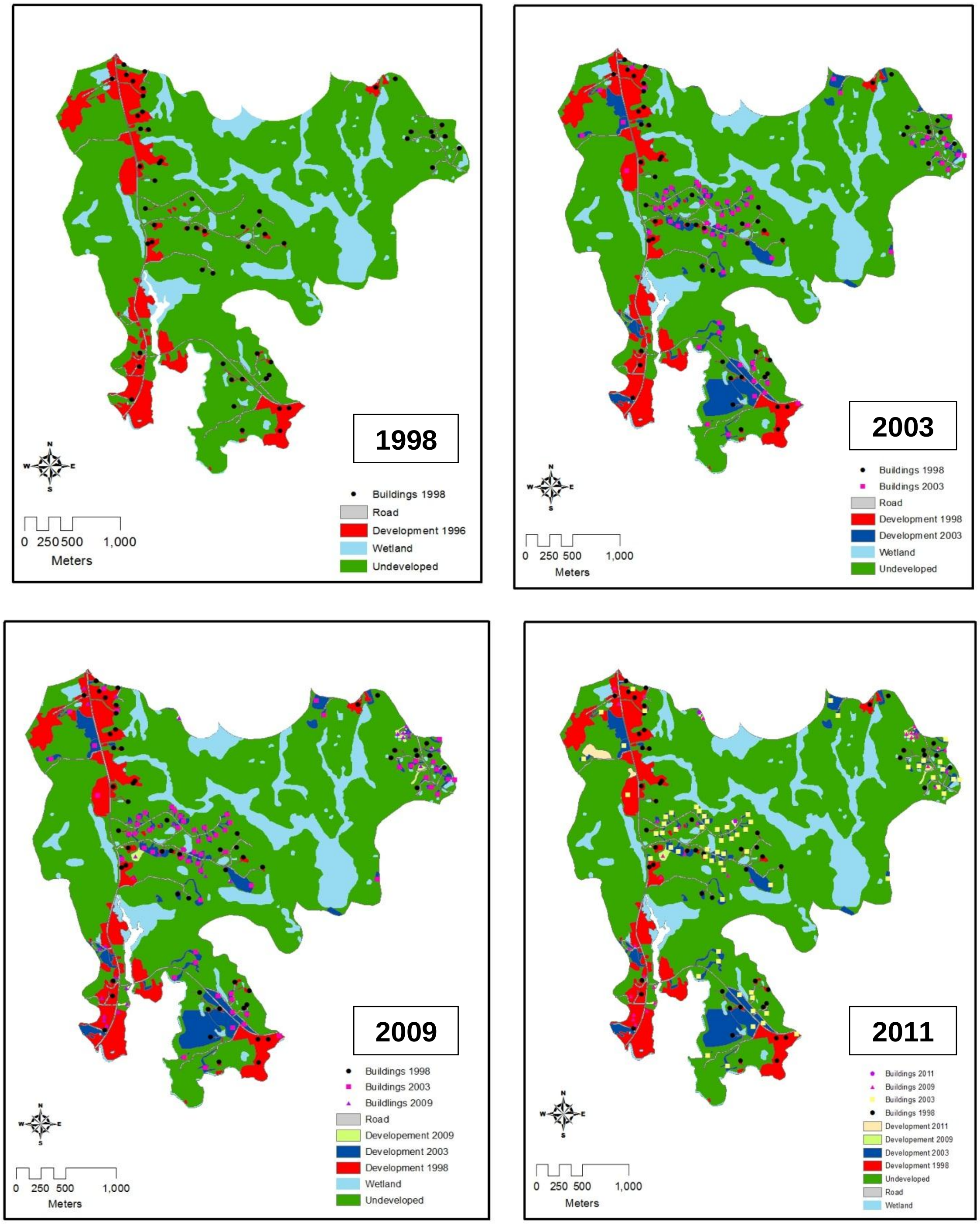

Figure 14. Land use of Babson Creek 1998 to 2011, representing the increase of development within the watersheds

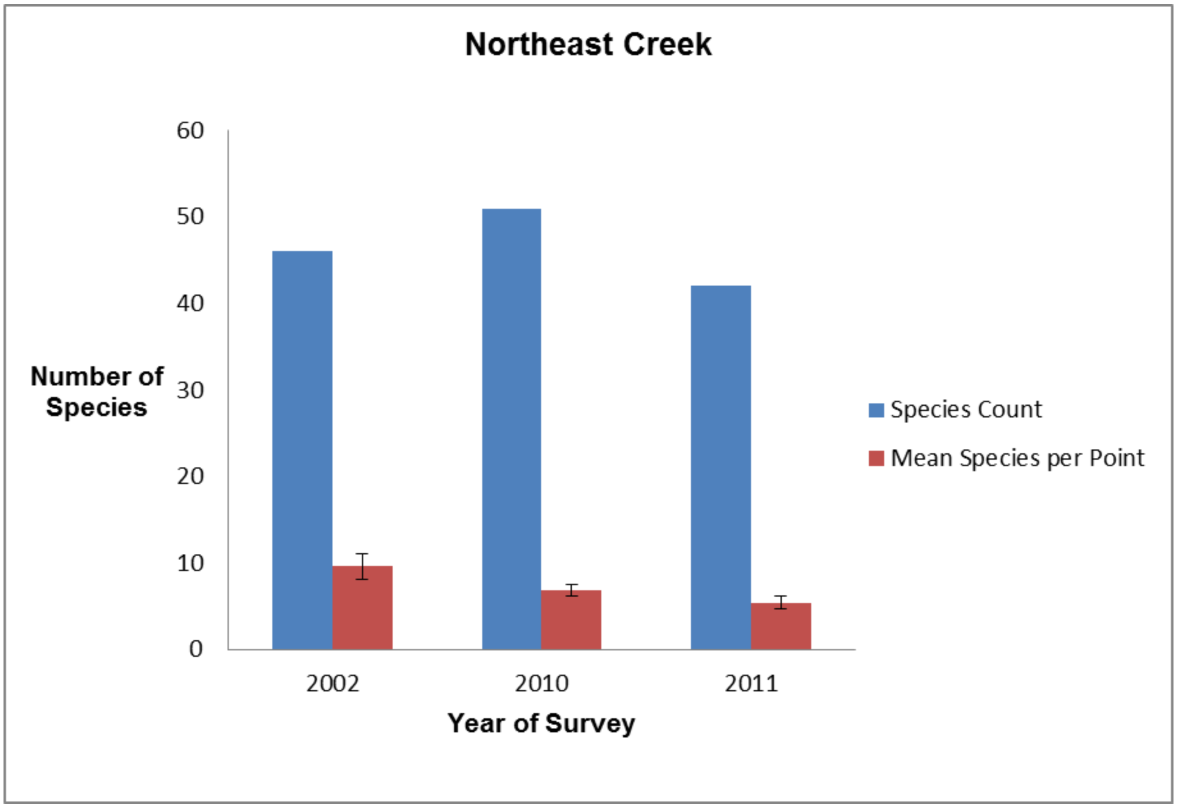

Figure 15. Number of species counted during each sampling seasons of 2002 to 2011 of Northeast Creek Watershed, with the mean per point. Error bars represent the 95% confidence interval.

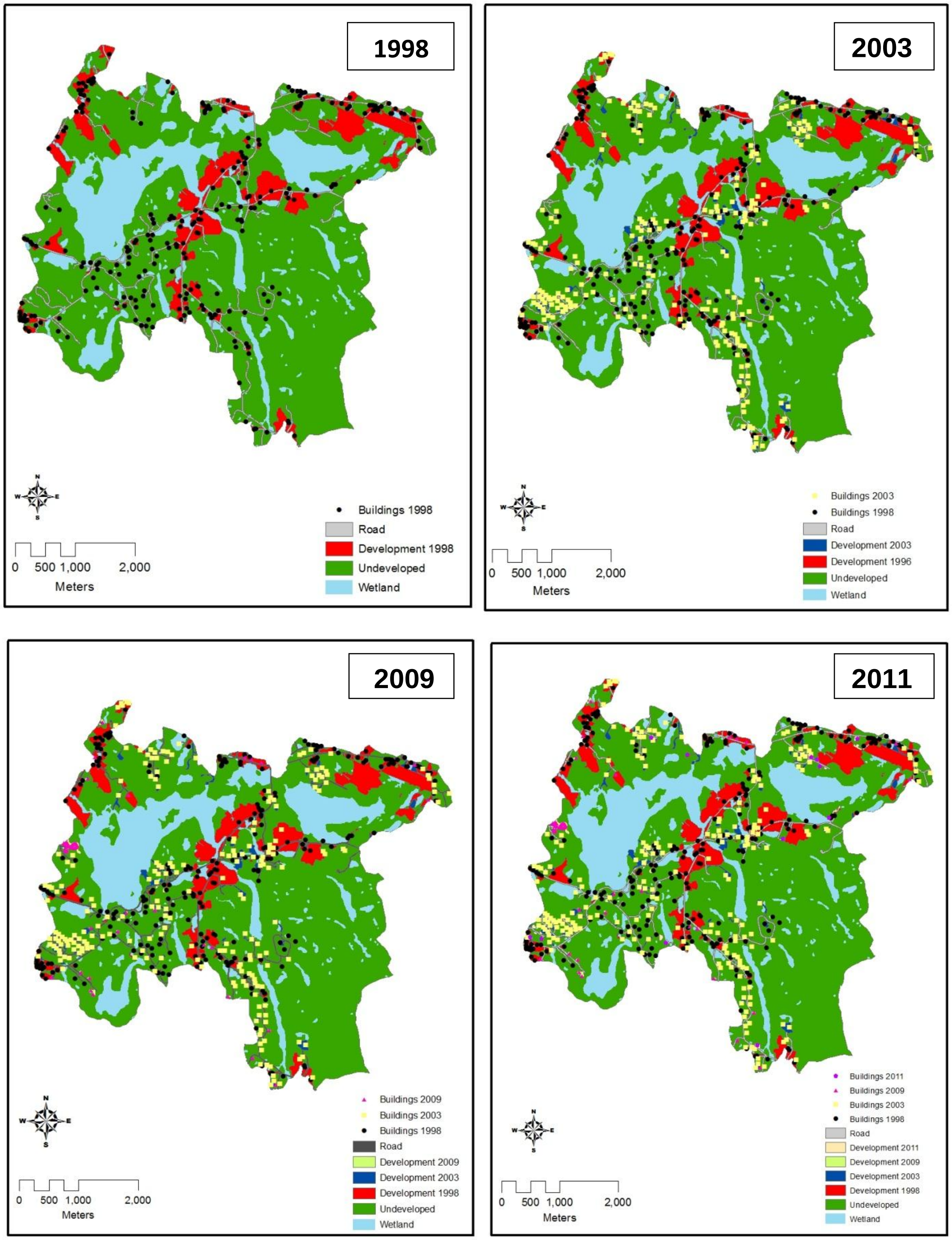

Figure 16. Land-use of Northeast Creek Watershed from 1999 to 2011 representing the increase of development.

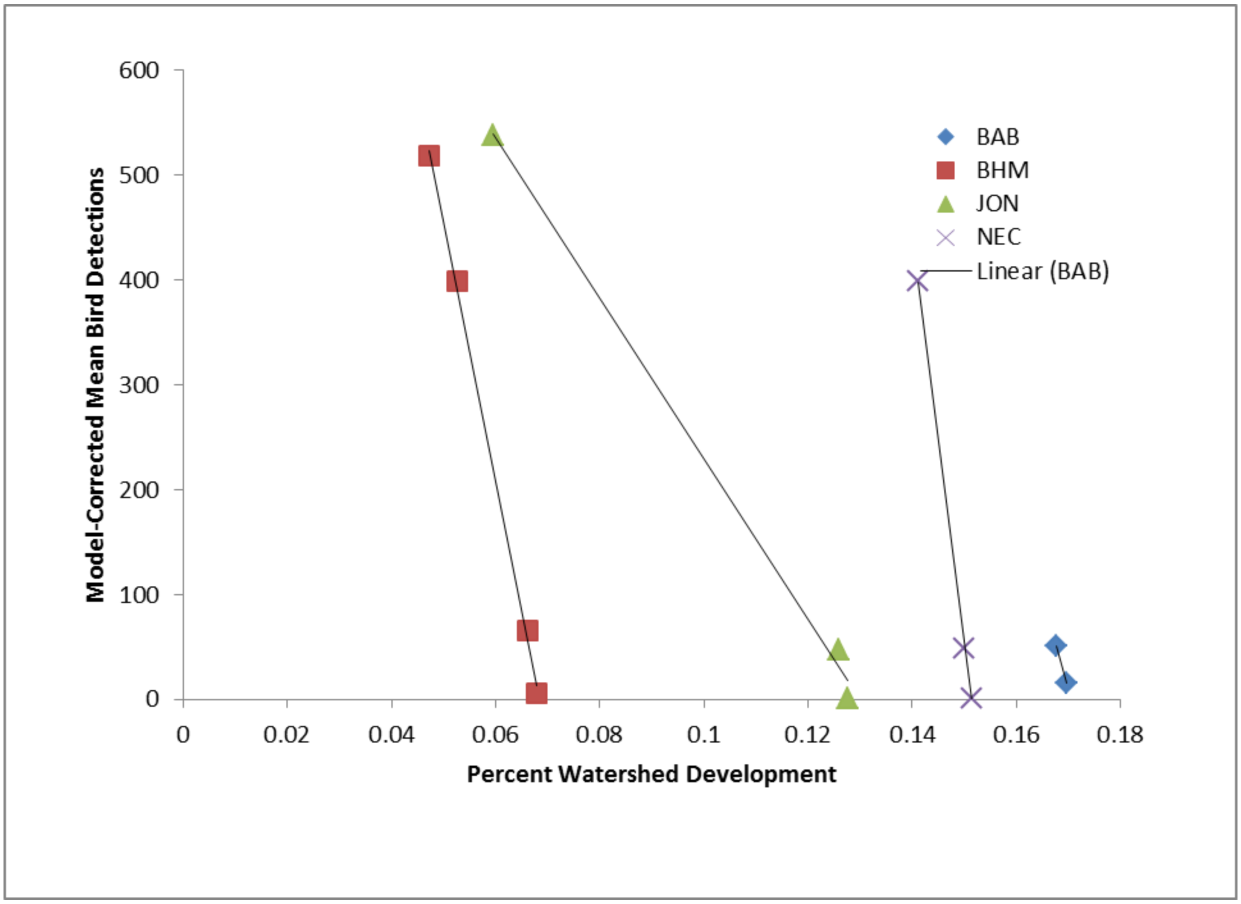

Figure 17. Model-corrected mean for bird abundance and the increase of the percent of development on the four watersheds from 1999 to 2011.

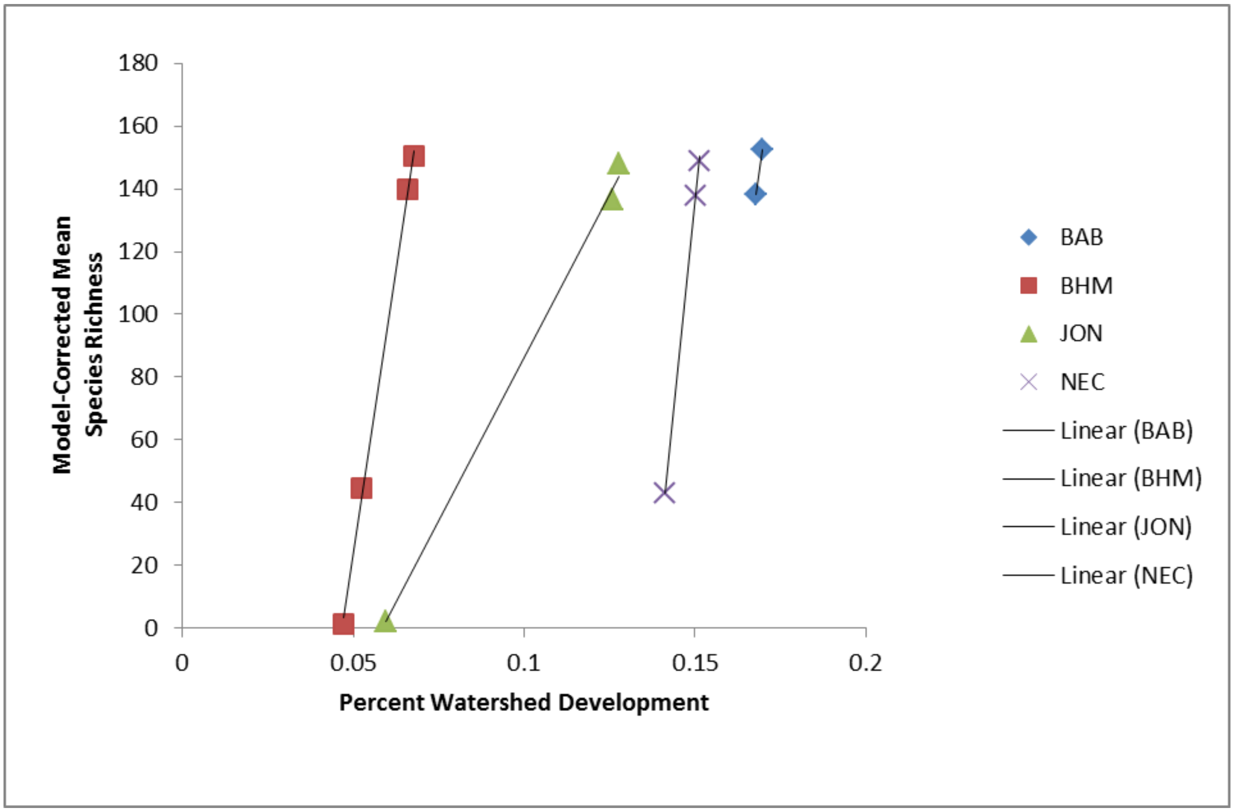

Figure 18. Model-corrected mean for species richness and the increase of the percent of development on the four watersheds from 1999 to 2011.

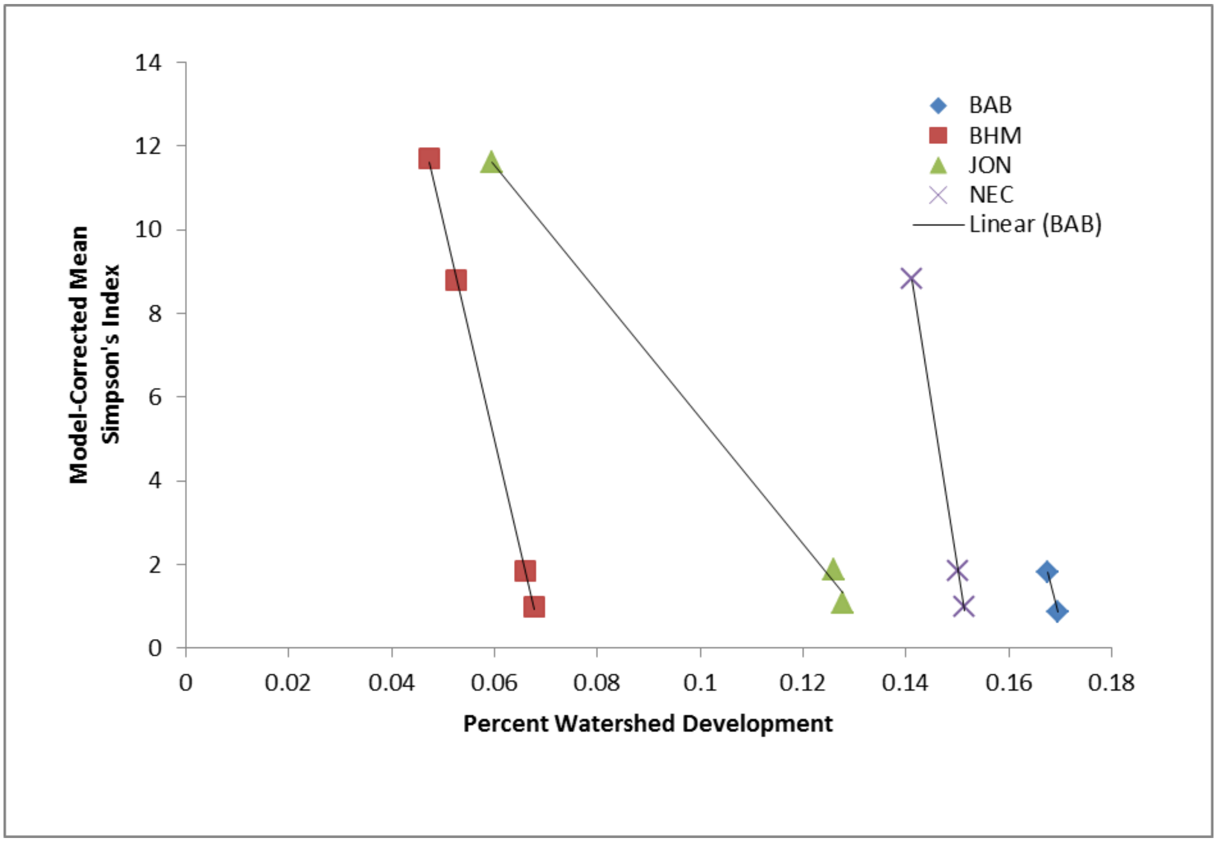

Figure 19. Model-corrected mean for Simpson's Index and the increase of the percent of development on the four watersheds from 1999 to 2011.

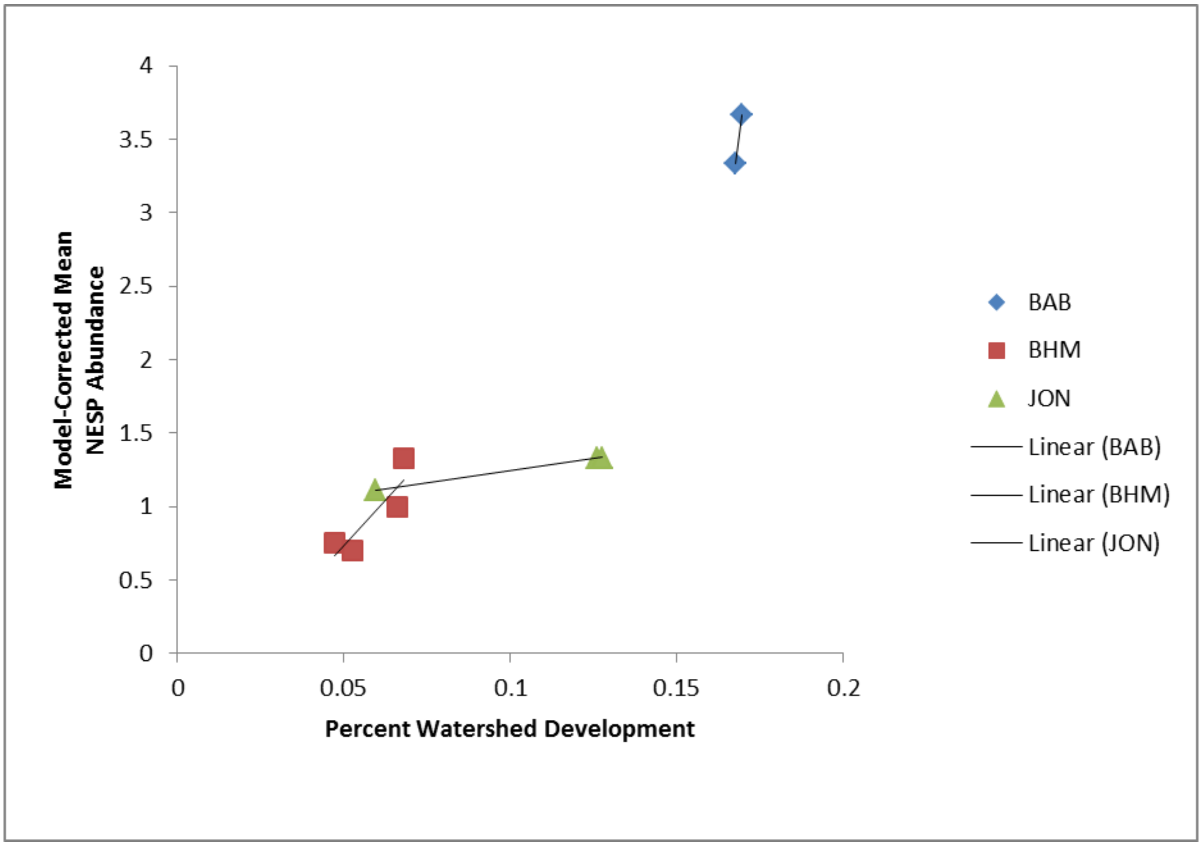

Figure 20. Model-corrected mean for Nelson's sparrow abundance and the increase of the percent of development on the watersheds they were present from 1999 to 2011.

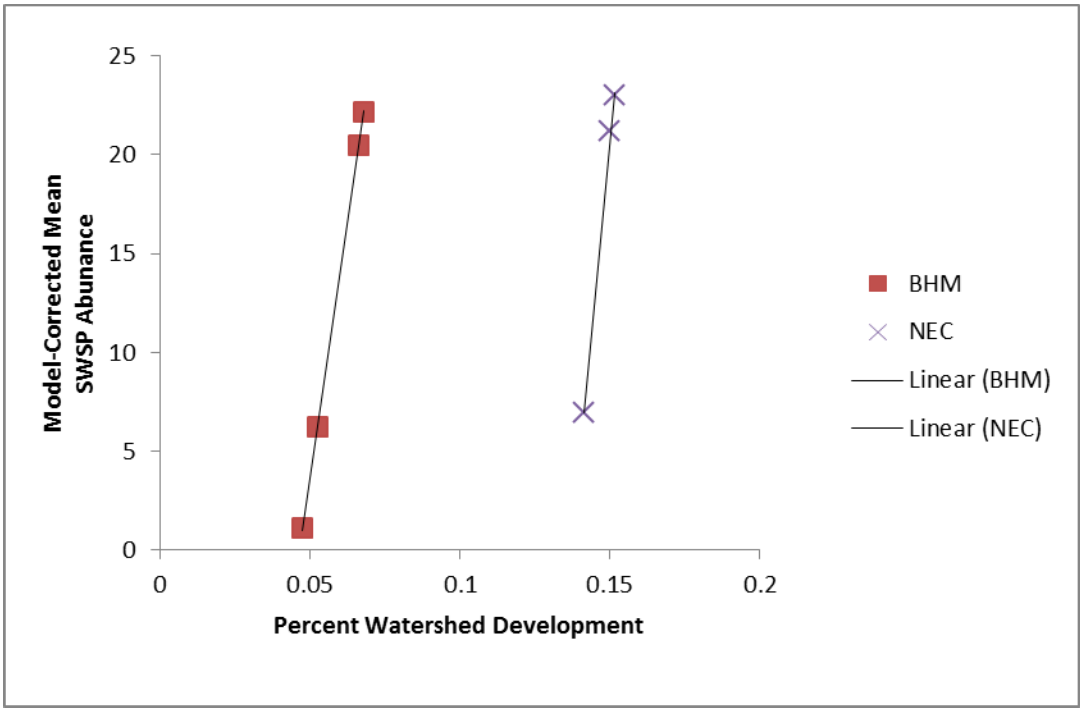

Figure 21. Model-corrected mean for Swamp Sparrow abundance and the increase of the percent of development on the watersheds they were present from 1999 to 2011.