EVALUATION OF SPOTLIGHT SURVEYS
FOR MONITORING MINK POPULATIONS
IN COASTAL SOUTH CAROLINA

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EVALUATION OF SPOTLIGHT SURVEYS FOR MONITORING MINK POPULATIONS IN COASTAL SOUTH CAROLINA

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Masters of Science
Wildlife and Fisheries Biology

by
Michael Waller
December 2010

Accepted by:
Greg K. Yarrow, Committee Chair
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Patrick G. Jodice
ABSTRACT

Annual commercial fur harvest data suggests a decline in South Carolina’s mink (Mustela vison) populations over the past century (Butfiloski and Baker 2005). In 1990, DNR began conducting assessments of South Carolina’s coastal marshes, revealing mink populations to be scarce to absent in the northern coastal regions (Baker 1999). Since 1999, restoration efforts have re-established mink populations in the Cape Romain National Wildlife Refuge and additional areas in the northern coastal marshes of South Carolina. Because mink are a species of high conservation priority throughout the coastal zone of South Carolina, it is important to develop and implement a reliable population monitoring program that will direct future management and aid in the recovery of coastal mink populations (Kohlsaat et al. 2005).

Spotlight survey data were used to evaluate the relationship of various environmental variables and survey counts during each year of the study (2008 and 2009). Results indicated that actual tide height (P< 0.001) and creek size (P< 0.001) were correlated to mink observations during spotlight counts during 2008 (r² = 0.291), while actual tide height (P= 0.026), creek size (P= 0.039), and Julian date (P< 0.001) were significant variables during 2009 (r² = 0.225). Actual tide height, predicted tide height, and creek size were also used with 2008 spotlight counts to predict survey counts during 2009. Results showed that predicted mink counts, based on actual tide heights (r² = 0.133, P< .001) and predicted tide heights (r² = 0.11, P< 0.001), were correlated to observed counts for 2009 spotlight surveys. A method was also developed to determine
optimal survey tide height. Results from the analysis indicated that at a tide height of at least 1.85 meters (6.05 feet) above mean lowest low water level (MLLW), the probability of observing mink was significantly greater (P= 0.035) than at a lower tide height. Survey data were also used in power analyses to determine the probability of spotlight surveys to detect changes in mink counts over multiple survey seasons. Results indicated that an increase in annual spotlight survey effort, length of monitoring effort (5 or 10 years), a less restrictive probability of making a type I error (i.e. alpha level), and a decrease in the standard deviation of survey counts improves the probability of detecting annual changes (increasing and decreasing) in mink survey counts.
DEDICATION

I would like to dedicate this work to my beautiful wife, Brittany, who has been there to encourage me every step of the way. Without your love and support I would not be where I am today. I would also like to dedicate this work to my family who has supported and provided for me throughout the years.
ACKNOWLEDGEMENTS

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CHAPTER ONE

BIOLOGY, STATUS, AND CONSERVATION OF AMERICAN MINK

INTRODUCTION

Historically, the American mink (Mustela vison) has been one of the most commercially valuable furbearers in North America. Their range extends throughout the eastern United States and Canada, with the exception of extreme desert and high arctic regions (Eagle and Whitman 1987). Once the object of great demand for trapping in the Southeast, mink are considered a species of high conservation priority throughout South Carolina (Kohlsaat et al. 2005). Mink densities vary throughout the state with populations highest in the southern coastal marshes and Piedmont region (Butfiloski and Baker 2005).

Mink are small, semi-aquatic mammals in the weasel family, Mustelidae. They have short legs and an elongated tubular body with a dark brown coat and white markings on the throat, chest, and belly (Larivière 1999). Males are approximately 10 percent larger than females, with weights of adult females ranging from 0.7 to 0.11 kg and adult males ranging from 0.9 to 1.6 kg (Eagle and Whitman 1987, Larivière 1999). Like other Mustelids, mink have two well developed anal glands that can be emptied when under stress, emitting a strong musky odor (Larivière 1999). Mink also deposit feces and secretions as territorial markings in prominent places to enhance the range of scent (Brinck et al. 1978, Larivière 1999).
Mink breed once a year and are often polygamous, breeding with multiple partners (Eagle and Whitman 1987). Males and females are fertile within their first year and can breed for seven years or more (Dunstone 1993, Lindscombe et al. 1982). In most areas, breeding season typically occurs from late February to April, with peak breeding around March (Allen 1984). Mink exhibit delayed implantation, in which the embryo can remain dormant for up to 30 days before implantation. Young are typically born 28 to 30 days after implantation in April or May (Dunstone 1993). Litter size ranges from 2 to 10 kits, with a typical litter consisting of 3 to 4 kits. Weaning usually occurs around 7 to 8 weeks and young remain with the family group until they disperse in early fall (Lindscombe et al. 1982, Larivière 1999).

Mink are opportunistic carnivores that feed on a variety of aquatic and terrestrial prey. In the coastal marsh ecosystem, common food items include small fish, blue crabs, fiddler crabs, insects, mud minnows, marsh hens, and marsh rice rats (Butfiloski and Baker 2005). Although fish and invertebrates comprise a majority of their diet, no particular food item is consistently more important in mink diets (Lindscombe et al. 1982). Mink diet varies with season, habitat type, and availability of prey (Allen 1984). When prey items are highly abundant, mink may exhibit a preference for eating aquatic prey first, semi-aquatic prey second, followed by terrestrial prey (Allen 1984). In coastal areas, mink prefer to forage in intertidal, i.e. area that is exposed at low tide and underwater at high tide, and marsh areas when they are not submerged (Birks and Dunstone 1985).
Mink occupy a variety of aquatic habitats including streams, rivers, lakes, swamps, and freshwater and saltwater marshes (Allen 1984, Eagle and Whitman 1987). They prefer shallow, slow moving or stationary bodies of water and avoid exposed or open areas (Dunstone 1993, Gerell 1969). In marine environments, mink favor areas with shallow vegetation and tidal slopes that provide protection from waves (Ben-David et al. 1995, Larivière 1999, Bonesi and MacDonald 2004). When tide levels rise to the top of the marsh grasses, mink utilize accumulations of dead Spartina (*Spartina alterniflora*), known as rafts or mats, or other floating debris (Butfiloski and Baker 2005). Beaches with small rocks are avoided because of the low abundance of prey (Ben-David et al. 1995). Mink use multiple core areas, which may be comprised of different foraging habitats and multiple den sites (Bonesi et al. 2000, Dunstone 1993). Dens are located under rock piles, bridge crossings, stream bank holes, and under tree roots and are typically selected based on proximity to preferred foraging areas or high concentrations of prey items (Linn and Birks 1981). In saltwater habitat, however, mink rarely utilize permanent dens due to constant tidal fluctuations (Butfiloski and Baker 2005).

Mink home range is greatly dependent on habitat quality, food availability, and age and sex of individuals (Linn and Birks 1981). In areas of quality habitat and abundant food sources, mink tend to utilize smaller home ranges (Eagle and Whitman 1987). In coastal areas, mink tend to have smaller home ranges and greater densities (Dunstone and Birks 1985). Gender-specific mean home range sizes are $6.91 \pm 1.41$ km$^2$. 


for males and $2.28 \pm 0.89$ km$^2$ for females in coastal marsh habitat (Peeples 2001). Comparative linear home ranges for male and female mink are 1.90 km and 1.46 km respectively in lacustrine habitats, 2.53 km and 2.16 km respectively in riverine habitats, and 1.50 km and 1.09 km respectively in coastal habitats (Dunstone and Birks. 1985). Home range of juvenile males is smaller than adult males, but larger than adult female (Eagle and Whitman 1987). In marine environments, intra-sexual overlap is low while intersexual overlap is generally higher (Dunstone and Birks 1985, Larivière 1999).

Although current information is lacking on the population status of mink throughout much of the South Carolina, particularly in parts of the northern coastal zone, mink are considered to be in decline statewide (Baker 1999, Butfiloski and Baker 2005). Despite a decrease in harvest pressure between the 1940’s and 1970’s, annual commercial fur harvest records indicate a decline in South Carolina’s mink population since the 1930’s (Baker 1999, Eagle and Whitman, 1987). Historical records show that annual mink harvests reached a high of 11,408 animals in 1938-39, falling to below 1000 by 1960 (Baker 1999). Since 1990, the average number of mink taken by commercial trappers and hunters was only 19 mink per year, which is well below the 30 year average harvest of 108 mink per year (Butfiloski and Baker 2005). Unfortunately, harvest records offer limited information on the distribution and abundance of coastal mink populations. Pelts obtained from coastal marshes are usually poor in quality, and, as a result, there has been little interest in trapping these areas (Baker 1999).
In the 1980’s, the South Carolina Department of Natural Resources (SCDNR) began investigating the status of mink populations in South Carolina (Baker 1999). Mail surveys in South Carolina revealed that 40% of trappers believed that wild mink populations were declining throughout the state (Baker 1999). Trappers in Georgia and North Carolina indicated similar beliefs about declines of mink in their states (Baker 1999). Mink age structure data from South Carolina was also compared to data from other states revealing a population with little recruitment, which may partially explain low harvest pressure throughout the state (Carmichael and Baker 1989, Baker 1999).

Although mink were historically found in most major waterways in the U.S. and Canada, many populations have declined or disappeared within the last century. Early extirpations were likely related to habitat loss, human encroachment, and environmental pollutants (Baker 1999). The decline of mink populations throughout South Carolina is most likely associated with human related activity, although over harvest is considered to be an unlikely reason (Baker 1999, Butfiloski and Baker 2005). High harvest pressures may have decreased mink population early in the century, but mink populations should have recovered in the 1960’s when harvest pressures declined (Baker 1999).

Habitat loss may have contributed to mink population declines as areas have become more developed, pollutants in waterways have increased, and habitats have becomes more fragmented. However, it is difficult to evaluate how mink habitat has changed over time due to a lack of historic data on habitat availability and conditions in
South Carolina (Butfiloski and Baker 2005). Mink are adaptable in their use of habitats and may modify daily habits according to human activity and habitat changes (Allen 1984, Linn and Birks 1981). They will inhabit sub-optimum habitats as long as an adequate food source is available (Linn and Birks 1981). While habitat quality in some areas has been clearly and negatively altered, in others areas across South Carolina, mink habitat appears reasonably intact (Baker 1999). Although anecdotal, observations by experienced commercial trappers indicate that mink populations are very low or absent in areas of former abundance, even though quality mink habitat still remains (Baker 1999, Osowski et al. 1995). While habitat loss may be a factor in mink population declines throughout the state, it is likely not the only factor responsible for declines (Baker 1999). However, the pressure from habitat loss and fragmentation may be stressful enough to increase the susceptibility and impact of environmental contaminants on mink (Osowski et al. 1995).

Mink are extremely vulnerable to the accumulation of environmental contaminants due to their position near the top of the food chain and diverse diet. Therefore, they are considered to be an important indicator species of pollution in aquatic environments (Aulerich and Ringer 1974, Carmichael and Baker 1989). Studies have shown that mink have a high level of sensitivity to environmental pollutants, particularly organic mercury compounds, polychlorinated biphenyls (PCBs), and organochlorine pesticides. These pollutants can negatively impact reproduction in mink and can also cause lethal and other sub-lethal effects (Platonow and Karstad 1973,
Aulerich et al. 1974, O’Shea et al. 1981). Contaminants are a particular concern since much of the minks’ diet is fish (40%), and PCBs and mercury are known to occur in relatively high concentrations in some fish species throughout the state (Butfiloski and Baker 2005).

In 1990, the SCDNR investigated the impact of environmental toxicants on mink in the Coastal Plain of Georgia, North Carolina, and South Carolina (Osowski et al. 1995). Osowski et al. (1995) found mercury concentrations in mink kidneys in high enough concentrations to cause sub-lethal effects on reproduction, growth and behavior (Wren et al. 1986, Osowski et al. 1995). Also, liver PCB and dieldrin concentrations were higher than those known to cause reproductive problems in pen-reared mink (Osowski et al. 1995). Existing data on environmental contaminants in waterways throughout the Coastal Plain of South Carolina, and known sensitivity of mink to these contaminants suggest that environmental contaminants may be a factor in the population decline of mink (Osowski et. al. 1995).

A mink restoration and monitoring project was initiated by SCDNR in 1999 to re-establish populations in the northern coastal marshes, where populations appeared extirpated (Baker 1999). Efforts began as a research project to study the feasibility of re-establishing mink populations in the Cape Romain National Wildlife Refuge (CRNWR) and other areas in coastal South Carolina. Several unsuccessful attempts were made to reintroduce mink to coastal areas in South Carolina from Acadia Parish, Louisiana. The effort was not successful and all mink died before they could be released (Peeples et al.
Sixty-two mink were then captured from the North Edisto River, Ace Basin, and around Hilton Head Island of South Carolina and successfully relocated to the marshes of CRNWR (Butfiloski and Baker 2005). After successful restoration to CRNWR, mink relocation efforts continued to three additional areas in the northern coastal marshes of South Carolina. In 2002, stocking efforts continued in North Inlet (17 adults, 35 kits) and Murrells Inlet (25 adults), and Dewees Island (13 adults) in 2004 (Butfiloski and Baker 2005).

During the 1990's, SCDNR began conducting spotlight surveys to assess the populations of mink throughout South Carolina’s coastal marshes. Spotlight surveys were conducted during flood tides (2.2 meters over MLW), which only occurred several times monthly and were usually associated with harsh and unpredictable weather conditions (Butfiloski and Baker 2005). Flood tides surveys were performed during daylight flood tides as well as night time tides (Baker 1999). However, night surveys resulted in higher counts due to the increased distance at which mink could be observed due to eye shine (Baker 1999). Surveys in coastal regions north of Charleston indicated mink populations to be scarce or absent even though habitat appeared suitable and available to support mink populations (Baker 1999).

Although assessments of coastal mink populations have been conducted in South Carolina since 1990, significant post-restoration population data is lacking due to limited manpower and a lack of consistency among surveys. Because mink are considered a species of high conservation priority throughout the coastal zone of South
Carolina, it is essential to develop and implement a reliable monitoring program to help guide future management decisions to aid in the recovery of coastal mink populations. Furthermore, it is important that survey methods are cost-effective and efficient techniques that provide accurate assessments of mink distribution and abundance. With plans of continued restoration efforts in the northern coastal marshes of South Carolina, successful management of mink populations requires a monitoring program that requires minimal effort to accurately estimate mink population trends.

Consequently, the goal of this project was to refine and standardize high tide mink spotlight surveys as a monitoring program for coastal mink populations. The primary objectives were to 1) evaluate the effects of environmental variables on nocturnal spotlight survey counts for American mink; and 2) evaluate the effects of annual survey effort, survey frequency, variability among surveys, and acceptable alpha level on the probability of spotlight surveys to detect annual trends in mink survey counts.
STUDY AREA

The study was conducted at the Cape Romain National Wildlife Refuge (CRNWR) in Charleston County, South Carolina (Figure 1.1). CRNWR encompasses nearly 26,817 ha of salt marsh and barrier island habitat spanning 35 km of South Carolina’s coastline. Approximately 11,331 ha of the refuge are preserved within the National Wilderness Preservation System as a Class I Wilderness Area (USFWS 2010). The refuge is located in the Southern Coastal Plain of South Carolina and is a part of the Carolinian-South Atlantic Biosphere Reserve (USFWS 2010). An intra-coastal waterway isolates most of the refuge from the mainland. This study was conducted throughout the intertidal salt marshes in the upper region of refuge, northeast of Bulls Bay.

The refuge also includes 12,545 ha of open water and 14,272 ha of fresh and brackish water impoundments, salt marshes, tidal creeks, sand dunes, beaches, and maritime forests (USFWS 2010). Elevations range from 0 to 3 meters above sea level, with tidal variations from 1 to 2 meters depending upon season and lunar cycle. The lower elevation salt marshes are dominated by smooth cord grass (*Spartina alterniflora*) with dense stands of black needle rush (*Juncus roemerianus*) in the higher elevation areas of the salt marsh, usually near uplands (USFWS 2010). Small hammocks of salt-shrub thicket, consisting of sea ox-eye (*Borrichia frutescens*) and saltwort (*Batis maritime*), occur at the interface of high salt marsh and uplands. The higher elevation islands consist of pine-hardwood forests dominated by loblolly pine (*Pinus taeda*), live oak (*Quercus virginiana*) and laurel oak (*Quercus laurifolia*) (USFWS 2010).
Originally established as a refuge for migratory birds, CRNWR provides habitat for over 270 species of waterfowl, shorebirds, wading birds, and raptors (USFWS 2010). The refuge offers a sanctuary for the largest nesting rookery for brown pelicans (*Pelecanus occidentalis* L.), terns and gulls on the South Carolina coast, as well as the largest wintering population of American oystercatchers (*Haematopus palliatus*), on the East coast (USFWS 2010). American alligator (*Alligator mississippiensis*), raccoon (*Procyon lotor*), American mink, marsh rice rats (*Oryzomys palustris*), and river otter (*Lutra canadensis*) also inhabit the refuge. The higher elevation barrier islands provide habitat for white-tailed deer (*Odocoileus virginianus*) as well as nesting sites for loggerhead sea turtles (*Caretta caretta*) (USFWS 2010).
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Figure 1.1 Study area in the northern section of the Cape Romain National Wildlife Refuge, Charleston County, South Carolina.
CHAPTER TWO

INFLUENCE OF ENVIRONMENTAL VARIABLES ON SPOTLIGHT SURVEY COUNTS OF

AMERICAN MINK IN COASTAL MARSHES

INTRODUCTION

Counts of animals through visual surveys, such as spotlight surveys, are widely used to monitor wildlife populations. The accuracy and efficiency of the survey technique is improved by increasing the probability of detection and decreasing variability among surveys (Steidl et al. 1997, Blackwell et al. 2006). Species detectability may be influenced by numerous factors, including environmental variables and observer bias (Buckland et al. 1993, Blackwell et al. 2006). Sources of variability should be considered since population monitoring plays a critical role in managing wildlife populations (Gibbs 2000, Ferraz et al. 2010).

Environmental variables, including weather conditions and physical habitat components, can influence the movement and behavior of wildlife species, which may subsequently alter their detectability (Gese 2004, Rush et al. 2009). Woodward and Marion (1978) showed that American alligator (Alligator mississippiensis) counts were positively correlated with water temperature during cool weather and negatively correlated with water level during warm weather. Similarly, crocodilian (Melanosuchus niger and Caiman crocodilus) counts had a positive relationship with temperature and negative relationship with water level, cloud cover, and wind speed (Pacheco 1996, Silveira et al. 2008). Although anecdotal, Baker (1999) noted that American mink
(Mustela vison) in coastal South Carolina were observed more often during spotlight counts when surveyed on extreme high tides, which occur throughout the summer and fall and occasionally in the spring.

The American mink is considered a species of high conservation priority throughout the coastal zone of South Carolina (Kohlsaat et al. 2005). Although current information is lacking on the population status of mink throughout much of South Carolina, particularly parts of the northern coastal zone, populations are considered to be in decline statewide (Baker 1999, Butfiloski and Baker 2005). Mink are nocturnal and elusive species and indirect survey methods have mostly been used to monitor populations in many areas (Bonesi and Macdonald 2004, Harrington et al. 2008). Spotlight surveys conducted during nocturnal high tides have been used in the coastal tidal marshes of South Carolina to survey mink (Baker 1999, Peeples 2001). Although spotlight surveys have been used in the past, the influence of environmental variables on the number of mink observed during surveys has, to the best of our knowledge, yet to be examined. This study may offer insights on how environmental conditions affect spotlight surveys for mink; therefore, allowing managers to standardize survey methods by incorporating those variables into survey plans.

The goal of this study was to examine the influence of various environmental variables on mink sightings during spotlight surveys from May to August of 2008 and 2009. The primary objective of this study was to evaluate the effects of environmental variables on spotlight counts for mink. Secondary objectives were to 1) validate
regression models by estimating mink counts for spotlight surveys conducted during 2009, and 2) determine the optimal tide height for conducting spotlight surveys for mink in coastal tidal marshes. The null hypothesis examined during this study was that environmental variables did not affect the detection of mink during spotlight surveys.

**METHODS**

**Spotlight Surveys**

Twenty-nine high tide spotlight surveys were conducted in the coastal marsh of Cape Romain National Wildlife Refuge from May to August of 2008 and 2009 (Table 2.1). The study area was divided into two sections, each containing a survey transect running approximately 22 km throughout the marsh. Surveys were conducted by boat to detect mink on Spartina rafts (dead vegetative parts of floating *Spartina alterniflora*) or other floating debris. Surveys began approximately 45 minutes before the predicted high tide and ran the full length of the selected survey transect. A boat was piloted at 19-22 km/hr, staying approximately 9-14 m off the marsh grass line. Brinkmann Q-Beam spotlights (three million candlepower) were used to scan the marsh on one side of the boat. Mink were detected by their eye shine (golden yellow-green) and positively identified with binoculurs. A spotter was positioned in the seat above the boat console to gain elevation advantage. A GPS location was taken at each confirmed sighting.

**Environmental Variables**
Nine variables were recorded for each mink sighting: actual tide height, channel width, moon phase, temperature, wind speed and direction, relative humidity, barometric pressure, and general weather conditions. Tide height data was obtained from the National Oceanic and Atmospheric Administration (NOAA) database. Verified tide height data was based on the mean lower low water lever (MLLW) datum from station 8665530 in Charleston, SC and adjusted for the study area. Creeks and waterways along each transect were classified into three order classes based on average width (Order 1 >200 meters, Order 2 = 100-200 meters, and Order 3 < 100 meters).

Precipitation was originally included, although surveys were not attempted when there was rainfall since it was usually associated with severe weather and unfavorable conditions.

For surveys during 2008, temperature, wind speed and direction, relative humidity, and barometric pressure were retrieved from the National Estuarine Research Reserve System (NERRS) meteorological site in Georgetown, SC. During 2009 spotlight surveys, the temperature, wind speed, barometric pressure, and relative humidity were monitored throughout each survey with a Kestrel 4000 weather meter. Wind direction was determined throughout each survey by compass. Moon phase was recorded in the following four categories: 1 (New Moon), 2 (First Quarter Moon), 3 (Full Moon), 4 (Third Quarter Moon). General weather conditions were recorded throughout each survey as clear, partly cloudy, overcast, or stormy.
Additionally, Julian date, month and fortnight were recorded to evaluate time period effect in survey numbers throughout the summer study periods. Fortnights were broken up into two week periods beginning with the highest predicted tide during the second extreme high tide cycle in May.

Analysis

Spotlight survey observations were pooled for each transect and each year’s data were evaluated separately. Family groups, typically consisting of a female with young, were recorded as a single sighting because the observation of a kit was dependent on the observation of the mother. Mink sightings basically followed a Bernoulli distribution and the parameter being modeling was the probability of a mink sighting. The analyses and modeling of the probability were performed with traditional multiple regression and logistic multiple regression. Both gave similar results, and the traditional multiple regression results were reported due to ease of interpretation. Multiple regression models were selected by adding and removing variables until a model was reached where the model standard deviation of error could no longer be significantly reduced by additional variables. To determine any multicollinearity among the variables, pair-wise correlation analyses were performed. High correlation between tide height and moon phase ($r = -0.6804, P<0.001$) and barometric pressure and relative humidity ($r = -0.7044, P<0.001$) during 2009 suggested possible multicollinearity. Only the best estimators (variables that were most closely related to mink sightings) were
retained for the model; therefore, moon phase and relative humidity were dropped from the model. We also used stepwise regression to build models to evaluate the relationship of environmental variables and survey numbers, and to verify the results from the original multiple regression model. Variables were considered significant at the 5% level and any variables that did not meet the standard were removed.

**Validation of Models**

Multiple linear regression models were developed using the data from the twelve high tide spotlight surveys in 2008. Equations were derived from these models to estimate survey counts in 2009. Actual tide height and channel width were used in the equations because they were determined to influence spotlight survey observations during both survey years. Predicted tide height was also substituted for actual tide height to estimate survey counts based on predicted tide heights. The relationship between estimated and observed survey counts was determined by simple linear regression analysis.

**Optimal Tide Height**

A method was developed to determine the tide height at which the probability of observing a mink is significantly greater than all lower tide heights, i.e. optimal tide height. Past spotlight survey data, collected by SCDNR in Cape Romain National Wildlife Refuge from 1996-2001, were pooled to include the two summers of data from this
study. The total number of mink observed was reclassified in terms of detection or no detection (1,0) for each survey. Tide height was reclassified as above or below (1,0) the cut-off height (i.e. the minimum tide height at which counts are included in the analysis). The cut-off height was varied from 1.78 to 1.9 m above MLLW in increments of 0.015 m. At each cut-off height, tide height and sighting were cross-classified in a contingency table. Pearson’s Chi-square was used to determine the highest correspondence value, which was chosen as the optimal tide height for spotlight survey.

RESULTS

Spotlight Surveys

During 2008 and 2009, a total of 169 individual mink sightings were recorded throughout twenty-nine high tide spotlight surveys in CRNWR (Table 2.1). In 2008, 94 individual mink sightings were recorded during twelve spotlight surveys, while 75 individual mink sightings were recorded during seventeen surveys in 2009.

Influence of Environmental Variables

Tide height (P< 0.001) and channel width (P< 0.001) were significant variables ($r^2= 0.291$) in spotlight surveys conducted during 2008 (Figure 2.2). Tide height had a positive relationship with individual mink observations. There was a difference in the mean number of mink observations in the different channel widths, with a significant shift from channel width 1 to 2, but no difference between 2 and 3 (Figure 2.3). There
was no relationship detected between mink counts and temperature, wind speed and direction, barometric pressure, Julian date, month, or fortnight (respective P-values are P = 0.060, P = 0.220, P = 0.146, P = 0.468, P = 0.128, P = 0.434, P = 0.396).

During 2009, the actual tide height (P = 0.026), channel width (P = 0.039), and Julian date (P < 0.001) were significant variables (r² = 0.225). The actual tide height had a positive relationship with mink observations, while Julian date had a negative relationship (Figure 2.4). There was a difference in the mean number of mink observations in the different channel widths, with a significant shift from channel width 1 to 2, but no difference between 2 and 3 (Figure 2.5). There was no relationship detected between mink counts and temperature, wind speed and direction, and barometric pressure during the 2009 surveys (respective P-values are P = 0.842, P = 0.466, P = 0.611, P = 0.430). Julian date, month and fortnight were all correlated during 2009; however, Julian date was retained for the model since it was the best predictor.

**Validation of Regression Models**

Mink counts were estimated for the 2009 spotlight surveys using equations based on predicted tide height (PT), actual tide height (AT), and channel width (CW). These equations were (1) Estimated Count = -1.1215 + 0.2865 * PT + (CW Estimate) and (2) Estimated Count = -3.002 + 0.5759 * AT + (CW Estimate). The relationship between observed counts and predicted mink counts, base on actual tide heights and channel width (R² = 0.107, P < 0.001) and predicted tide heights and channel width (R² = 0.077, P =
0.002), were significant for 2009 spotlight surveys (Figure 2.6). In general, estimated mink counts overestimated survey counts when the actual count was 0 and underestimated survey counts when the actual count was greater than 1.

**Optimal Tide Height**

At a tide height of 1.85 meters (6.05 feet) above MLLW, the Chi-square value was the highest ($X^2 = 4.466, P = 0.035$). For tide heights greater than 1.85 meters, the Chi-square values decreased, suggesting that Chi-square values were underestimated because restricting survey efforts to heights above the optimal would neglect potentially good survey nights.

**DISCUSSION**

**Influence of Environmental Variables**

Models applied to spotlight counts for each year indicated that tide height, channel width, and Julian date (only significant during 2009) were related to the number of mink observed during spotlight survey counts. Although these variables were significant, the models accounted for little variation in mink counts during both survey years. This suggests that tide height, channel width, and Julian date only marginally explained the mink observations during spotlight surveys.

The number of mink observed during spotlight surveys was positively related to tide height during both survey years, indicating that more mink are observed on higher
tides. Rush et al. (2009) observed similar results with detections of clapper rails, which share the same tidal marsh habitat as mink. A reduction in stable ground and vegetative cover during periods of high tide may leave mink more exposed and thus easier to detect during spotlight surveys. At higher tides, mink were typically observed on or near floating Spartina rafts (dead vegetative parts of floating Spartina alterniflora) or other floating debris, which provided refuge due to the lack of dry ground (Baker 1999). It is important to note that tide was recorded at each sighting, rather than as a maximum or average for each survey. This may have underestimated the influence of extreme high tides as fewer points were taken at those heights due to the change in tide height while surveys were being conducted. Regardless, tide height is an important factor and high tides (at least 6.05 feet above MLLW) should be utilized when planning and conducting surveys for mink.

The relationship between channel width and mink observations shows that the number of mink observations during spotlight surveys increased when medium and small channels were surveyed. Similarly in river systems, mink have shown preference for habitats associated with small streams over those associated with large, broad rivers (Allen 1984, Davis 1960). The observed relationship with channel width is likely associated with selecting sites that offer mink greater protection from wave action and avian predators during high tides (Ben-David 1995, Larivière 1999, Bonesi and MacDonald 2004). Further investigation into habitat use of mink in tidal marshes and the availability of resources is needed to clarify this association.
Julian date, month and fortnight were all negatively correlated with mink observations during the 2009 spotlight surveys. Although each presents a different breakdown of time throughout the study period, they each suggest the same outcome; mink were less likely to be observed as the summer progressed. Throughout the 2008 survey season, mink counts remained fairly consistent with a slight increase in observations around the beginning of July. The reason that a significant relationship was observed only during 2009 is unknown. However, the observed decrease in mink survey counts throughout the second summer could be due to several factors, including acclimation to spotlights and the growth of kits. Mink were surveyed more often throughout the second summer surveys and may have become “spotlight shy”. During the later part of the summer (mid July to August), mink had a higher tendency to flee or dive when initially located with a spotlight, which reduced the number of positive observations. This suggests that future survey efforts may need to be conducted less frequently during the survey period to minimize avoidance of spotlights. Surveying an area once during each extreme high tide cycles (at least 1.85 meters above MLLW), which typically occur every four weeks around a new moon during the summer and fall, may be enough to limit spotlight avoidance. Additionally, the growth of kits throughout the summer may have decreased the number of mink observed during spotlight surveys. Emergence of kits around mid-May reduced movement of females, as the kits were unable to flee when detected. Yamaguchi et al. (2002) suggested that the best season to monitor populations of resident mink is during the kit-rearing season (May to August).
when females are less mobile. By the end of the summer, kits are mobile and capable of fleeing and finding cover on their own.

Environmental variables that may affect animal detectability, such as those evaluated in this study, should be incorporated when planning monitoring efforts (Ferraz et al. 2010). However, results from this study are based on two summers (May to August) of spotlight surveys from CRNWR; therefore, generalizations about the effects of environmental variables on mink surveys need to be made with caution, particularly when extrapolated beyond the study area and outside the time frame of the study period.

**Validation of Regression Models**

The positive relationship between estimated and actual mink counts in 2009 surveys indicates that the regression models containing channel width and tide height were best in accounting for the influence of environmental variables. Estimated counts based on actual tide heights predicted mink counts better than those based on predicted tide height, although they both consistently overestimated count when it was actually 0, and underestimated counts when it was over 1. Predicted tide height was included in the analysis to show the relationship between estimated mink counts based on actual and predicted tide heights, since it is not possible to use actual tide height when looking at future spotlight survey efforts. Prediction equations were used only to
validate environmental variable models, given that mink counts were estimated for each sighting and did not incorporate any adjustment for survey length.

**Optimal Survey Tide Height**

The optimal tide height to conduct spotlight surveys for mink in CRNWR occurs at 1.85 meters (6.05 feet) above MLLW, at which point the chance of observing mink is significantly greater (P= .035) than if surveyed at a lower tide height. Similarly, although anecdotal, Baker (1999) suggested that tide height was a significant factor in mink sighting and that surveys should only be conducted on tides above 2.2 meters above MLW. The underestimation of correspondence values for tide heights beyond the optimal height indicates that mink survey efforts restricted to heights above the optimal would neglect potentially good survey nights.
LITERATURE CITED


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Table 2.1 Spotlight surveys for mink conducted during May to August of 2008 and 2009 in the Cape Romain National Wildlife Refuge, Charleston County, South Carolina.
Fig. 2.1 Mink sightings along survey transects during high tide spotlight surveys from May to August or 2008 and 2009 in Cape Romain National Wildlife Refuge, Charleston County, South Carolina. The colored lines indicate the two spotlight survey transects (CR-A and CR-B) and the green dots indicate locations of mink observations.
Fig. 2.2 Relationship between the number of mink sightings and actual tide height during spotlight surveys in Cape Romain National Wildlife Refuge, South Carolina, from May to August of 2008.
Fig. 2.3 Change in the mean number of mink sightings from channel width order 1 (>200 m) to 2 (100-200 m) to 3 (<100 m) during spotlight surveys in Cape Romain National Wildlife Refuge, South Carolina, from May to August of 2008. The blue line represents the mean number of mink sighted at each creek order. The dots represent individual mink sightings at each creek order. The points are scattered to show the sample size at each creek order.
Fig. 2.4 Relationship between the number of mink sightings and (A) actual tide height and (B) Julian date during high tide spotlight surveys in Cape Romain National Wildlife Refuge, South Carolina, from May to August of 2009.
Fig. 2.5 Change in the mean number of mink sightings from channel width order 1 (>200 m) to 2 (100-200 m) to 3 (<100 m) during spotlight surveys in Cape Romain National Wildlife Refuge, South Carolina, from May to August of 2009. The blue line represents the mean number of mink sighted at each creek order. The dots represent individual mink sightings at each creek order. The points are scattered to show the sample size at each creek order.
Fig. 2.6 Relationship between predicted survey counts using (A) actual tide heights and channel width and (B) predicted tide height and channel width, based on equations derived from spotlight surveys in the Cape Romain National Wildlife Refuge, South Carolina from May-June of 2008 (Equations 1 and 2 in Results), and the observed counts in spotlight surveys.
CHAPTER THREE

PROBABILITY OF DETECTING TRENDS IN SURVEY COUNTS OF AMERICAN MINK

INTRODUCTION

The American mink (Mustela vison) is a species of high conservation priority throughout the coastal zone of South Carolina (Kohlsaat et al. 2005). Although current information is lacking on the population status of mink throughout much of South Carolina, particularly in parts of the northern coastal zone, populations are considered to be in decline statewide (Baker 1999, Butfiloski and Baker 2005). Several factors, including habitat loss and environmental pollutants, may have contributed to the decline in mink populations throughout the state. Since mink are highly susceptible to environmental contaminants, they are considered an important bio-indicator of ecosystem health (Carmichael and Brewer 1989). Restoration efforts in several areas of the northern coastal marshes of South Carolina have involved the relocation of over 200 mink to four locations, including the Cape Romain National Wildlife Refuge (Butfiloski and Baker 2005). However, budget and manpower constraints have limited efforts to monitor mink in these areas since relocation. Therefore, it is important to develop and implement an efficient and cost-effective monitoring program to evaluate the success of reintroduction efforts, as well as determine the status of mink populations in coastal South Carolina.

A major component of any population monitoring program is the ability to detect significant changes in abundance (Gerrodette 1997). The probability that a
monitoring program detects a trend in survey counts when the trend is occurring represents its statistical power, i.e. correctly rejecting the null hypothesis when the alternative hypothesis is true (Zielinski and Stauffer 1996). Sample size, sample variability, and the extent of real differences in counts all affect a monitoring program’s ability to detect change (Cohen 1988, Zielinski and Stauffer 1996). Power analysis is typically used to detect a decrease in abundance or counts, although the ability to detect an increase could be particularly useful in conjunction with mink restoration or conservation efforts where an increasing population trend is anticipated.

Past monitoring efforts to assess the abundance of mink along the coast of South Carolina have included the use of high tide spotlight and track-board surveys. Both techniques have shown varying degrees of success (Peeples 2001, Butfiloski and Baker 2005). High tide spotlight surveys, however, have been the primary means of mink monitoring efforts. Indices from spotlight surveys may not accurately represent actual population size, since there is an unknown association between the number of individuals counted and the actual number of mink present in tidal marshes during surveys (Jodice et al. 2001, Ruette et al. 2003). Therefore, large samples with replications may be needed to detect changes in mink population size with any statistical power (Gese 2004).

Successful management of mink populations in the future will require monitoring programs that provide accurate estimates of population trends to direct future management and aid in the recovery of this mustelid. However, monitoring
efforts may be limited by a lack of resources and time to cover the number of surveys
needed to effectively monitor or detect a change in mink populations. Therefore, it is
important to determine if data collected from mink spotlight surveys can be used to
accurately detect trends in mink abundance in coastal tidal marshes with minimal
efforts. The goal of this study was to develop a monitoring program that would allow
managers to minimize sampling effort, while maintaining a high probability of detecting
a given trend in mink abundance. The specific objective was to evaluate the effects of
annual survey effort, survey frequency, variability among surveys, and acceptable alpha
levels on the probability that spotlight surveys would detect annual trends in mink
survey counts. The null hypothesis tested in this study was that the change in these
parameters would have no effect on the power of detecting a trend in mink survey
counts.

METHODS

Spotlight Surveys

Eleven high tide spotlight surveys were conducted in the coastal marsh of Cape
Romain National Wildlife Refuge from May to August of 2008 and 2009 (Table 3.1).
Surveys were conducted by boat to detect mink on Spartina rafts (accumulation of dead
vegetative parts of *Spartina alterniflora*) or other floating debris. Surveys began
approximately 45 minutes before predicted high tide and ran along a 22 km transect. A
boat was driven at 20 kilometers per hour, staying approximately 15 meters off the
grass line. Brinkmann Q-Beam (three million candlepower) spotlights were used to scan the marsh on one side of the boat. Mink were detected by their eye shine and positively identified with binoculars. The spotter was positioned in the seat above the boat console to gain elevation advantage. At each sighting, the number of mink observed was recorded along with a GPS location.

**Power Analysis**

Power analysis was used to estimate the probability of detecting annual trends in spotlight survey counts of mink. The power of various monitoring scenarios was estimated using the program MONITOR (Gibbs and Ere 2010). Program MONITOR uses Monte Carlo simulations to generate simulated sets of survey counts based on a user defined sampling program and then generates detection rates derived from simple linear regression analyses (Geissler and Sauer 1990; Gibbs and Melvin 1997). To estimate power, we supplied MONITOR with an initial estimate of mean mink survey counts and a standard deviation ($\mu = 12.18$, $\sigma = 5.93$), based on surveys conducted on a minimum tide height of a 6.05 feet (1.85 meters) above mean lower low water level (MLLW). Two-tailed hypothesis tests were used to test the probability of detecting an increase or decrease in trend counts. Models investigated in this study include the assumptions that changes in mink abundance occur in constant increments (linear model) and that the standard deviation is constant.
MONITOR also required several parameters which included survey effort, survey frequency, length of survey effort, and alpha levels. Survey effort was specified as the number of surveys per year and evaluated at 1, 3, 5, 8, 10, 12, and 15 surveys annually. Survey frequency, or period between successive surveys, was evaluated with annual and biennial surveys. Length of survey effort, or essentially monitoring program length, was evaluated for five and ten years, with biennial surveys evaluated only for ten year periods. Variability among surveys was evaluated at the standard deviation of survey data from this study ($\sigma = 5.93$), and at a lower ($\sigma = 3$) and higher value ($\sigma = 9$). Simulated trends (i.e. change in survey count per year) were estimated at twelve annual rates of change including, $\pm 1\%$, $\pm 3\%$, $\pm 5\%$, $\pm 8\%$, $\pm 10\%$, and $\pm 15\%$ per year. Analyses were also run at significance levels, or type I error, of 0.05 and 0.10.

Analyses for each monitoring scenario were completed, consisting of combinations of annual rates of increase, survey frequency, annual survey intensity, variability in detections, and alpha levels. The combinations of variables resulted in 1008 probabilities of detecting a trend in survey counts. For each scenario, one value of statistical power after 1,000 replications was estimated. A table was created which could be used to determine the probability that spotlight surveys would detect a trend in survey counts for mink, given the information on spotlight surveys from this study. Scenarios considered suitable for the design of a mink monitoring program were selected with a minimum acceptable power of $(1- \beta) = 0.90$, i.e. the highest probability of failing to detect a specified trend was 0.10.
RESULTS

Spotlight Surveys

Eleven spotlight surveys were conducted throughout the marshes of Cape Romain National Wildlife Refuge (CRNWR) at optimal tide heights (1.85 meters above mean lowest low water level (MLLW)), from May to August of 2008 and 2009 (Table 3.1). Surveys resulted in 134 mink observations with an observation rate of 6.18 mink per survey (σ=5.93).

Probability of Detecting Trends

Results show that detection of annual trends in mink populations were strongly influenced by annual survey effort, length of survey effort, alpha level, and standard deviation. Increasing the number of annual surveys significantly increased the power of detecting trends in mink population, thus improving the rate (increase or decrease) that a particular number of annual surveys can detect (Figure 3.1). For example, if eight surveys (α=0.10, σ=5.93) were conducted each year for five years, there would only be an 81% probability of detecting an annual 10% increase in mink counts. If two additional spotlight surveys were conducted each year, the probability of detecting the same 10% increase in counts improves to the desired power of 90%.

An increase in length (number of years) of survey effort significantly decreased the number of surveys required to detect a significant annual trend in mink counts (Figure 3.2). When survey effort is extend to ten years, three surveys per year (α=0.10,
σ=5.93) would detect an annual decrease of 15% in mink counts with at least 90% power, compared to the ten annual surveys required with only five years of survey effort. The increase in length of monitoring effort also decreases the rate of change that may be detected with sufficient power (Figure 3.2). The same three surveys per year for ten years (α=0.10, σ=5.93) would be able to detect an annual decline of 10% with a power of 89%.

A reduction in the frequency of survey effort from each year to every other year decreased the power of detecting a particular trend and increased the minimum rate of change that may be detected with 90% power. However, the use of biennial surveys resulted in power estimates comparable to annual surveys with similar total survey effort (Table 3.1). If mink were surveyed every other year for ten years (α=0.10, σ=5.93), the overall number of surveys required to detect a 10% change could be reduced by surveying five times every other year (25 surveys total) rather than three times per year (30 surveys total).

A decrease in variability among surveys also decreased the effort required to detect a trend in mink counts with significant power (Fig 3.3). At a standard deviation of 5.93, it would take ten surveys per year for five years (α = 0.10) to reach a 92% probability of detecting an annual decrease of 15%. If the variability was reduced to a standard deviation of 3, the probability of detecting the same 15% annual decrease in counts would increase to around 100%. Alternatively, when the variation in counts increased, the probability of detecting a trend decreased (Fig. 3.3). With a standard
deviation of 9, it would take an additional five spotlight surveys per year to reach a 92% probability of detecting a 15% decrease in counts.

If the probability of making a Type I error was decreased by lowering the alpha level to 0.05, the number of surveys required to detect a trend with significant power would increase (Fig. 3.4). For example, if five spotlight surveys were conducted each year for ten years (σ=5.93, α=0.10), there would be a 90% probability of detecting a 5% increase in counts each year. When the probability of making a Type I error is reduced to 0.05, the probability of detecting the same increase in counts decreases to 84% and would require an additional three surveys to meet the desired power of 90%.

DISCUSSION

Results show that the detection of annual trends in mink counts was strongly influenced by the number and precision of surveys, survey frequency, and acceptable Type I error. It was not possible to achieve the desired power (1-β =0.90) with most sampling scenarios. Annual rates of increase in mink counts of less than 3% per year would be very difficult to detect, at least within realistic efforts and manpower, using high tide spotlight surveys.

The number of annual surveys required to detect a trend with significant power increases rapidly as the desired annual rate of change is reduced. However, manpower constraints may limit the effort that agencies can dedicate to multiple surveys conducted every year, thus limiting any trends the monitoring program could detect.
Additionally, testing for increasing and decreasing trends (two-tailed hypothesis test) may have increased the number of surveys required to detect a specified trend. Zielinski and Stauffer (1987) reported that required sample sizes were 20-50% higher when testing for a two-tailed alternative hypothesis compared to the one-tailed alternative. Gibbs and Ere (2010) suggested that a one-tailed hypothesis test should only be used when an increasing or decreasing trend is expected to occur in the population being monitored.

Length of monitoring program and survey frequency also had a significant impact on the probability of detecting annual mink trends. An increase in survey effort from five to ten years of monitoring sufficiently increased the power of detecting a trend so that substantially fewer surveys within each year were required (Jodice et al. 2001). Furthermore, if the same effort was extended from five to ten years the annual rate of change that the program could detect with sufficient power would decrease, allowing detection of smaller changes in mink counts. It may also be important to consider whether frequency of sampling is optimal using annual estimates. Gerrodette (1987) suggested that if change in counts is shifting slowly, it may be sufficient to conduct surveys every other year. Estimated power was similar when simulations were run with spotlight counts obtained either from annual or biennial surveys, although biennial surveys may be better suited for detecting large changes in counts with regards to available manpower and resources (Travaini et al. 2009). Even though annual survey effort increases, the total number of surveys required to detect a trend over the same
number of years is reduced with biennial surveys (Gerrodette 1987). Ideally, this survey scenario would allow for more flexibility in monitoring mink populations along the entire coast, and it would also allow surveys to be conducted every other year.

It was expected that more precise mink survey counts (decrease in survey count variability) would yield a higher power of detecting annual trends. To detect trends with sufficient power, given a reasonable number of samples (8 surveys per year), the rate of change must be sufficiently high or standard deviation must be low (Gerrodette 1987). As the standard deviation increases, the probability of detecting trends decreases considerably. The rate of change cannot be controlled, but the standard deviation can be controlled to a certain degree by reducing measurement error through increasing sample size and taking replicate measurements (Gerrodette 1987, Schwagmeyer and Mock 1997).

Relaxing the probability of making a Type I error reduces the survey effort required to detect a trend in mink counts with significant power ($1 - \beta = 0.90$). In ecological studies, it is standard practice to use $\alpha = 0.05$ as the significance level at which the null hypothesis is rejected (Gibbs and Ere 2010). In this study, the Type I error was relaxed up to $\alpha = 0.10$, although it has been argued that a Type I error rate of $\alpha = 0.20$ is sufficient in many cases (Zielinski and Stauffer 1996, Travaini et al. 2009, Gibbs and Ere 2010). If the cost is high of falsely reporting that a significant trend has occurred (e.g., an expensive management action is initiated when a false trend is detected) it may be better to lower the significance level to avoid a false alarm (Type I error) from occurring
too often (Gibbs and Ere 2010). However from a management perspective, a false alarm may be more tolerable than the repercussions of failing to detect a significant trend due to Type II error (Travaini et al. 2009). Balancing Type I and Type II error is challenging because of the associated costs of either failing to detect a trend or concluding there is a trend when there is actually not. Other studies have suggested using β=0.20 to decrease cost and survey efforts required to detect a trend in populations (Zielinski and Stauffer 1996). In this study, we set the minimum acceptable power to 1-β=0.90 to put priority on increasing the probability of detecting an actual trend in mink counts over mistakenly concluding a trend has occurred (Zielinski and Stauffer 1996).

Annual survey effort would be greatly reduced if wildlife biologists and managers only required knowledge of significant trends as great as 15% per year (Gerrodette 1987). However, monitoring programs designed to detect only catastrophic changes, especially declines, run the risk of overlooking changes that may require further management actions. Unfortunately, limited manpower and financial resources often inhibit the extent of effort that agencies can allocate toward a monitoring program. While annual trends in mink counts of less than 3% per year would be very difficult to detect, at least within realistic survey efforts, a monitoring program designed to detect at least an 8% annual decline with 90% confidence should be feasible to establish.

Results presented in this study should be interpreted conservatively, as the power of detecting a trend in mink counts would decrease with a year to year increase
in the standard deviation of survey counts (Jodice et al. 2001). The modeled scenarios are based on spotlight surveys conducted in the coastal marshes of CRNWR and may not accurately represent trend probabilities for other mink populations found across the coastal marshes or inland watersheds of South Carolina. Furthermore, these scenarios are based on surveys conducted during the summer (May to August) and are not applicable to surveys conducted outside of the study period. However, the power of detecting trends found during this study may provide a basis for establishing a monitoring program for coastal mink in other areas.
LITERATURE CITED


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Table 3.1 Spotlight surveys for mink conducted during optimal survey conditions in Cape Romain National Wildlife Refuge, Charleston County, South Carolina, from May to August of 2008 and 2009.
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Table 3.2 Power estimates for different scenarios of change in survey counts of American mink. Bold numbers indicate the power estimates that met the minimum acceptable power (1-β=0.90).
* Indicates a monitoring program with surveys conducted every other year.
Figure 3.1 Power curves for detecting various rates of annual (A) increase and (B) decrease in survey counts of American mink using high tide spotlight surveys ($\sigma = 5.93$, $\alpha = 0.10$, 5 years).
Fig 3.2 Power curves for detecting an annual 15% decrease in survey counts of American mink in using high tide spotlight surveys for 5 and 10 year monitoring programs ($\sigma = 5.93$, $\alpha = 0.10$).
Figure 3.3 Power curves for detecting an annual 15% decrease in survey counts of American mink using high tide spotlight surveys with various values of the standard deviation ($\alpha = 0.10$).
Figure 3.4 Power curves for detecting an annual 5% increase in survey counts of American mink using high tide spotlight surveys with the probability of making a type I error of $\alpha = 0.05$ and $0.10$ ($\sigma = 5.93$, 10 years of survey effort).
CHAPTER FOUR

MANAGEMENT RECOMMENDATIONS

INTRODUCTION

Monitoring animal populations is a necessary component of wildlife management and is particularly important when developing conservation policies and management protocols. Ideally monitoring programs should allow for survey techniques that require a minimum investment in manpower efforts and costs that yield reliable estimates. However, budget and manpower constraints have limited recent efforts to monitor mink populations in the northern coastal marshes of South Carolina. Therefore, it is important to develop and implement an efficient and cost-effective monitoring program for coastal mink populations. A standardized protocol is also needed to improved accuracy and precision of survey efforts to document mink population trends and assist with future management. Initial project goals were to improve survey techniques to incorporate into a monitoring program that is less manpower intensive, less dependent upon tidal influences, and able to be implemented as needed. The following are suggestions for monitoring coastal marsh mink populations based on survey techniques and the findings of this project, as well as from empirical observations.
SURVEY METHODS

High tide spotlight surveys are a cost-effective and efficient technique to monitor coastal mink populations. These surveys are conducted by watercraft and involve spotlighting the edge of creeks or waterways through coastal marshes. Cruising speed should be as slow as time permits, but consistent from survey to survey. Speeds during our surveys were just enough to get the boat on plane (18-22 kmph) which reduced waves thrown into the marsh. High powered spotlights, such as the three million candle power Brinkman Q-beam Max Million III, should be used to scan the edge of the marsh in order to detect mink by their eye shine. Mink are usually observed on Spartina racks (accumulation of dead vegetative parts of *Spartina alterniflora*) or other floating debris. When a possible mink is spotted ahead of the boat, observers should visually mark the location and remove the light from the mink until the boat is perpendicular to the initial sighting. This typically keeps the animal from immediately fleeing and allows observers to get a better look to make a positive identification. Reducing the intensity of the spotlight, either through a lower powered light or colored lenses, may also reduce movement after initial sighting. At each sighting, the number of mink observed, GPS location, and any observations that may aid in the management of the species need to be recorded.

Although an assessment of track-board surveys was not included in this study, this method is important to note because past survey efforts suggest that they have potential values as a population monitoring device for coastal mink, as well serve as a
platform for live trapping mink in relocation efforts (Peeples 2001, Reynolds et al. 2004, Butfiloski and Baker 2005). However, low visitation rates (2.2%) from track-board trials during this study, using the GCT mink raft (e.g. track-board design developed in England by The Game Conservancy Trust), indicate that track-boards may be an inefficient method of monitoring the relative abundance of coastal mink population during the summer in the marshes of Cape Romain National Wildlife Refuge (CRNWR). Therefore, it is not recommended that track-boards be used a primary monitoring method for mink due to the relative inefficiency compared to spotlight surveys, as well as the potentially high costs and manpower efforts required.

**SURVEY TIMING**

Timing of survey efforts should also be considered when developing and implementing a mink population monitoring program. This study focused on survey efforts during the summer months (May to August) when the highest nocturnal tides usually occur. Yamaguchi et al. (2002) suggested that the best season to assess populations of resident mink is during the kit-rearing season (May to August) when females are less mobile. Surveying during these periods will also help to determine recruitment in coastal mink populations. The slight disadvantage of surveying mink populations during the breeding (February to April) and kit dispersal season (August to September), however, is the tendency to inflate survey counts due to transient males or dispersing juveniles (Birks 1981, Ireland 1988, Yamaguchi et al. 2002). Regardless it is
suggested that mink spotlight surveys be conducted from May to August of each year. Surveys can be conducted as often as field personnel are available, although alternating areas when surveying consecutive nights is suggested to reduce the chances of mink becoming “spotlight shy”. Surveying areas during extreme high tide cycles (at least 6.05 feet above MLLW), which usually occur every four weeks around a new moon during the summer and fall, should be enough to limit spotlight avoidance.

Attempts to standardize timing of surveys relative to daily tidal activity can be difficult, as timing of tidal inundation varies considerably from day to day. In order to utilize the highest interval of the tide cycle, surveys should be centered on the predicted tide height, which progressively gets later between consecutive nights. When the tide begins to descend, it is often more difficult to detect eye-shine because of the increased grass height and water droplets that remain on Spartina and other marsh vegetation, which is often mistaken for the reflection of mink eyes. Mink surveys during this study typically began thirty to forty-five minutes before the predicted tide height.

**SURVEY CONDITIONS**

In order to increase the accuracy and precision of surveys, environmental variables that may influence mink observations during spotlight surveys should to be considered (Ferraz et al. 2010). Spotlight surveys for mink in coastal tidal marshes of South Carolina should be scheduled around tidal fluctuations. Surveys conducted during high tides allows for greater mink sighting distance because less vegetative cover is
available throughout the marsh. Results also suggest that spotlight surveys conducted on a tide of at least 1.85 meters above MLLW will optimize the probability of observing mink. There are a limited number of optimal high tides that occur each year, particularly during the time period of this study. Potential survey nights can be found using Tidelog or National Oceanic and Atmospheric Administration’s (NOAA) tides and currents website.

Channel width should also be considered when establishing survey transects for mink. The relationship between channel width and survey count shows that the number of mink sightings during spotlight surveys is highest in medium to small channels. Likewise, in other areas, mink have shown preference for habitats associated with small streams over those associated with large, broad rivers (Allen 1984, Davis 1960). Mink survey transects should cover as much area as feasible, although they should focus on medium to small navigable creeks (<200 meters average width).

**SURVEY EFFORT**

Surveys should be conducted yearly or every other year to document mink population changes and to identify areas that may warrant management action. Annual survey efforts would be greatly reduced if knowledge of significant trends, as great as 15% per year, were all that was required (Gerrodette 1987). However, monitoring programs designed to detect only catastrophic changes, especially declines, run the risk of overlooking changes that may require further management actions. While annual
trends in mink counts of less than 3% per year would be very difficult to detect, at least within realistic survey efforts, a long term monitoring program capable of detecting at least 10% annual change with 90% confidence may be feasible to establish.

MONITOR simulations in this study provided a number of possible scenarios for monitoring coastal mink populations in South Carolina. For example, if the objective is to minimize effort required to detect a large annual trend, conducting three surveys/season (30 total) or five surveys/every other season (25 total) for 10 years in each survey area would detect an annual decrease of 10% or increase of 8% with sufficient power ($\alpha=0.10$, $\sigma=5.93$). However, if the objective is to detect the lowest possible rate of change, conducting five surveys/season (50 total) or eight surveys/every other season (40 total) for 10 years in each survey area should be able to detect an annual decrease of 8% and increase of 5% with sufficient power ($\alpha=0.10$, $\sigma=5.93$).

Scenarios run during this study were based on 5 and 10 years of monitoring. The survey effort and mean number of mink sightings would need to increase and variability among surveys would need to be reduced to detect a significant trend with less than five years of survey data. Also, restricting surveys to a higher tide height than the optimum (> 1.85 m above MLLW) increased the mean number of observations as well as the variability among surveys. Based on these results, limiting surveys to a higher tide height did not decrease the survey effort required to detect an increasing or decreasing trend in survey counts.
Unfortunately, limited manpower and the number of optimal nocturnal high tides that occur throughout the summer may restrict efforts to survey mink in monitoring areas. During the summer and fall, extreme high tide cycles typically occur once a month around the new moon and occasionally around a full moon. Each cycle usually includes 3 to 4 days of optimal tide height, although each monitoring area may need to be limited to one survey per cycle to limit spotlight avoidance. During the study, there was a potential of 4 extreme high tide periods in 2008, from which only three were surveyed for each survey area. Due to the limited number of extreme high tide cycles at night during the period of this study, surveys may need to be expanded from April to September. However, caution should be taken when using the results of this study to make inferences about surveys conducted beyond the time frame of this study because modeled scenarios may not be applicable.

**EQUIPMENT**

Surveys should be conducted using spotlight with maximum range. High power spotlights, such as the three million candle power Brinkman Q-beam Max Million III, perform well for locating mink through eye shine, especially at further distances. The addition of a colored lens or lower power spotlight may be more suitable after initial sighting to reduce the chances of the mink fleeing. Red lenses were used during spotlight surveys outside of the study area and seemed to be less invasive, and served
to reduce glare from water droplets on marsh grass. However, the addition of the red lens reduced the visible distance nearly in half.

The type of boat used, or more importantly the position of the observer in the boat, is also important to consider as it may affect the number of mink observed during surveys. During this study, the observer was positioned in a seat above the boat console. A raised platform or seat may increase the probability of detecting mink because of the height advantage over surveying from the front deck of a boat.

It is also necessary to have an aerial map and a GPS unit with a detailed nautical map of the survey area. Tidal marshes can be confusing in the dark, especially during extreme high tides when much of the marsh (including the edge) is not visible and is submerged under the water. Additionally, a GPS unit will allow tracking of boat cruising speed, as well as the distance covered during the survey.

Surveys can be conducted with two people, although it is useful to have an extra person in the boat to watch for buoys. A one-night training session is suggested for inexperienced volunteers and SCDNR personnel to become acquainted with the environment and the ability to correctly locate mink along survey transects with spotlights. The success of a monitoring program depends on the observer’s ability to effectively locate mink through their eye shine (golden yellow-green) and correctly distinguish them from raccoons, otters, or other animals in the tidal marshes.
Further Investigation

There is limited information on the ecology of mink in tidal marshes, particularly in South Carolina. A better understanding of the ecology of this species in coastal tidal marshes, particularly habitat use, diets, and limiting factors (i.e. proximity to highly used recreational areas, development, etc.), would help in the management of current and re-introduced mink populations.

Information is also lacking to determine whether the monitoring approach described in this study represents true populations of coastal mink. It is assumed that the survey method used in this project reflects actual changes in mink populations. However, indices from spotlight surveys may not accurately represent actual population size, since there is an unknown association between the number of individuals counted and the actual number of mink present in the tidal marsh during the survey (Jodice et al. 2001, Ruette et al. 2003). A capture-mark-recapture study of coastal mink would provide important and comparable information to spotlight surveys when attempting to accurately estimate coastal mink population size.

Spotlight surveys need to be used in other areas throughout the northern coastal marshes to determine where additional relocation efforts need to focus. Survey transects should be established in North Inlet, Pawley Island/ Litchfield Beach, Murrells Inlet, and Little River. However, before any additional restoration efforts occur, the potential impact of mink on other species in the tidal marshes and surrounding habitat needs to be considered.


