EFFECTS OF HABITAT TYPE AND STRUCTURE ON DETECTION PROBABILITIES OF AMERICAN ALLIGATORS (*Alligator mississippiensis*) DURING NIGHT-LIGHT COUNTS

By

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To my family, friends, and colleagues

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EFFECTS OF HABITAT TYPE AND STRUCTURE ON DETECTION PROBABILITIES OF AMERICAN ALLIGATORS (Alligator mississippiensis) DURING NIGHT-LIGHT COUNTS

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Obtaining reliable population estimates is one of the most challenging issues in wildlife ecology today. Population surveys are an attempt to obtain an index of population size but rarely achieve the total number of all individuals in the population. These estimations are affected by many variables that lead to bias and variability in counts, i.e. the probability of detecting an individual animal is <1 and this probability varies. One of the most important steps in increasing precision and accuracy in estimations is to design surveys so detection probabilities can be estimated. The objective of this thesis was to determine the effect of habitat type, vegetation height, visual obstruction, water depth, distance from transect, survey boat seat height, and survey speed on detection rates of American alligators (*Alligator mississippiensis*) during night light surveys. I quantified effects on detection due to habitat types by establishing transects in different alligator habitats with reflective markers to simulate alligators eye reflections and then conducted mock surveys with experienced observers to determine the proportion of markers detected. Results from these surveys were then modeled using PROGRAM MARK to determine which variables had the most influence on alligator detectability. Detectability was found to be 0.53 (SE = 0.0611), 0.63 (SE = 0.0498), and 0.51 (SE = 0.0483) in the habitats of sawgrass

marsh, slough, and wet prairie respectively. The variable that had the greatest effect on detection rates was visual obstruction, followed by distance from the transect, vegetation height, water depth, and seat height. Detectability functions for the various habitats were obtained and varied slightly for each habitat by the variables included in the optimum model. These functions can be used to make more reliable population estimates during alligator population monitoring in Florida. These methods could also be used as a model to determine the effect of habitat on detectability for crocodilian species worldwide. Increased precision of estimates will allow alligator researchers to increase response time to population changes and will provide a basis for making better management decisions.

CHAPTER 1
INTRODUCTION

Population Estimates

Obtaining population estimates is one of the most challenging obstacles in wildlife ecology. Population surveys are an attempt to obtain an index of population abundance but they rarely represent actual population size. Scientists conducting population surveys are interested in the total number of individuals, structure (sex ratios, age structure) and size of populations, and population distribution throughout landscapes or study areas (Samuel and Pollock 1981, Lancia et al. 2005). There are many factors to consider when designing surveys to obtain population estimates, such as species characteristics, size of the survey area, vegetation, terrain, and resources needed (Krebs 2002).

Population estimates can be developed in many ways. The first is a census of the population, or a complete count of the individuals in the population (Williams et al. 2002, Lancia et al. 2005). Second, there are population estimates, which are estimates of total abundance based on a sample survey of individuals, nests, or other indicators, and adjusted for detection probabilities (Williams et al. 2002, Lancia et al. 2005). Lastly, there are population indices which assume a known proportion of the population observed during surveys (Williams et al. 2002, Lancia et al. 2005). When attempting population counts it is very difficult to obtain complete counts due to uncertain detection rates, large survey areas and resource availability, so a sample of the population is normally used.

Population monitoring is essential for successful and effective management of wildlife populations. Population monitoring programs serve two management roles (Nichols et al. 1995). To provide periodic assessments of the relative population size and demographic characteristics (sex ratios, age distribution) at possible decision points in the management process, and to provide knowledge of system responses to possible management alternatives. Some components of a sound monitoring program include; established objectives and goals, established protocols, and determining the scale of the program. Failure to address any of the crucial factors upon initiating a monitoring program can lead to problems with analysis and interpretation of the data. For example, two large-scale, long-term monitoring studies in the United States, the Mourning Dove Survey (Dolton 1996) and the Breeding Bird Survey (Peterjohn et al. 1996) have major fundamental problems (Pollock et al. 2002, Rosenstock et al. 2002). The primary sources of error are nonrandom placement of sampling points or sampling variance, which can be controlled by randomly or systematically selecting sample units and establishing uniform survey protocols (Pollock et al. 2002), and visibility bias, which is related to detection probabilities of the species, habitat characteristics, and environmental variables (Caughley 1974, Cook and Martin 1974, Samuel and Pollock 1981, Steinhorst and Samuel 1989).

Detectability

Thompson (1992) defined detectability as the probability that an object in a selected unit is observed - whether seen, caught, heard, or detected by some other means. There are three types of detectability that are associated with wildlife surveys and population estimates:

1. **Complete detectability.** All individuals within the population are completely detected over time, space, and other dimensions of the survey unit (Williams et al. 2002). If complete detectability is achieved over an entire population, the survey count is identical to the actual population size, and error free comparisons can be made within the population. Complete detectability is rarely achieved in wildlife population surveys (MacKenzie et al. 2004).

2. **Less than complete but constant detectability.** This is a biased estimate of the population (Williams et al. 2002). However, the bias is constant over time and space and, if the detection probability can be estimated, the count can be adjusted to provide an unbiased estimate of the population (Thompson and Seber 1994, Williams et al. 2002).

3. **Variable detectability.** The survey count is a biased estimate of the population and the bias is not constant over time and space (Williams et al 2002). In some cases, detection probabilities can be influenced by treatments, management decisions, or environmental

> variables and, if not estimated, can lead to results that might not reflect the status of the actual population. Detection probabilities should be estimated for each survey, to account for variable detectability.

Surveys of wildlife populations typically have detectability problems (Thompson and Seber 1994, Rosenstock et al. 2002). Imperfect detectability, if not adjusted, will lead to underestimates of the population (Thompson and Seber 1994, Ramsey and Harrison 2004). Population estimates are affected by many variables that lead to variability and bias in counts. Factors that influence detectability can be classified as environmental, species related, or human induced factors (Rosenstock et al. 2002). Environmental factors that affect detection rates are associated with habitat, topography, and weather conditions for a given survey area (Nupp and Swihart 1996, Rosenstock et al. 2002). Species-related influences on detectability can be related to changes in activity levels, shifts in movement patterns, and other natural behaviors. Potential human-induced factors include wariness, survey techniques, and observer abilities (Rosenstock et al. 2002). One of the most important steps in increasing accuracy and precision in population estimations is to design surveys to account for detection probabilities and the most critical variables that cause bias and variability (Thompson and Seber 1994).

Alligator Night-Light Surveys

Night spotlight counts (night-light counts) are commonly used as an index of relative size of crocodilian populations (Magnusson 1982, Wood et al. 1985, Bayliss 1987, Hutton and Woolhouse 1989, King et al. 1990). Indices assume that a constant or known proportion of the population is counted during each survey over time. If counts change, the population is expected to change proportionally. However, this assumes that detection is constant or known across space and over time. Departure of detection probabilities from some mean can be categorized as either variability (fluctuation around the mean due to uncontrolled variation of environmental variables, observer effectiveness, or survey methods) or changing bias (the systematic change in detection probabilities in one direction due to changes in habitat, increased wariness, shifts in behavior, or observer bias). When conducting analysis of change in populations, variability affects uncertainty about estimates whereas changing bias can affect inferences about population changes.

Past studies have shown that only a small proportion of alligators are observed during a night-light survey (Murphy 1977, Brandt 1989, Woodward et al. 1996). As much as 91% of the total alligator population may go undetected during night-light counts (Woodward et al. 1996). The proportion of alligators detected during night light counts is dependent on habitat, wariness, natural behavior shifts, and observer efficacy (Graham and Bell 1969, Murphy 1977, Brandt 1989, Woodward and Linda 1993). Detection probabilities of alligators may also vary with changes in environmental variables such as, water temperature, wave action, and vegetation cover (Murphy 1977, Woodward et al. 1978). Another source of variability is alligator availability, the movement of individuals in and out of the survey area. Some of the factors affecting availability are water level, hydrilla (*Hydrilla verticicllata*) coverage, and seasonal movements (Woodward et al. 1978, Woodward and Moore 1990). Higher water levels increase the accessible habitat for alligators, but these areas may be inaccessible to surveyors, which leads to reduced counts.

FWC Alligator Surveys

In 1987, the Florida Fish and Wildlife Conservation Commission (FWC) established an alligator harvest program to manage alligator populations at preharvest levels; increase economic value of wild alligators; generate revenue for management, research, and conservation; and provide alligator hunting opportunities to the public (Hines and Abercrombie 1987, Woodward et al. 1987, Wiley and Jennings 1990). Population monitoring is conducted to ensure harvests on alligator management units (AMU) are sustainable and populations are not in decline

(Woodward et al. 1987). Surveys are conducted on 120 AMU's every year to monitor populations. Current population models have established harvest quota levels of adult (≥183 cm.) alligators depending on population estimates and trends. The harvest quotas are set at 15%, 12%, 6%, 3%, and 0%, depending on the change in population estimates from year 0 of hunt initiation. Alligator night-light surveys are a critical component to the success of this harvest program and ensure populations are harvested at sustainable levels.

Survey routes are standardized, and typically follow the perimeter of a lake along the open water-shoreline/marsh interface (Woodward and Marion 1978), or middle/centerline of a river section (depending on river width). Airboats and outboard-motored boats are used to conduct surveys, but an effort is made to use the same craft type for any given area to maintain consistency in survey methodologies (Woodward and Marion 1978). Spring surveys are conducted from May to mid-June when adult alligator activity is the greatest (Woodward and Marion 1978), whereas summer surveys are conducted from July to mid-August. Surveys are conducted at a speed of approximately 20-25 km/hr, unless the driver must slow to properly record dense concentrations of alligators, maintain safe operating speed, or for navigational constraints. Spotlights (200,000 c.p.) are used to locate alligator eye reflections by working the light in a 180 degree arc in front of the vessel. The size of an alligator is estimated to the nearest 1 ft. (30 cm), if possible. In cases where the exact size cannot be estimated, alligators are recorded in broader size categories 0-2 ft (0-60 cm), 2-4 ft (61-121 cm), 4-6 ft (122-182 cm), ≥4 ft (≥122 cm), ≥6 ft (≥183 cm), and ≥9 ft (≥274 cm) or recorded as unknown-sized. Data from these surveys are used to analyze trends on an area-by-area basis.

Everglades Alligator Surveys

A network of survey routes has been established throughout the Everglades ecosystem to monitor alligator population trends during Everglades restoration efforts. Survey routes include both marsh and canal habitats and were established based on accessibility, hydrological characteristics, and orientation around marsh and canal habitats. Surveys are conducted along established survey routes, and alligators observed out to 50-m from the route are recorded. At every alligator observed, a GPS location is recorded along with, estimated size, water depth, muck depth, and habitat/vegetation type. Other variables recorded for surveys are air temperature (C), water temperature (C), wind (mph), cloud cover (%), and visible moon. Size estimates are in 0.25-m size classes, and alligators unable to be placed into a size class are recorder in broader size categories hatchlings (<0.25 m), small (<1.25 m), medium (1.25 - <1.75 m), large (≥1.75 m) and unknown. This monitoring program was designed to assess the success of Everglades restoration. The American alligator has been chosen as an indicator species for the restoration of the Greater Everglades Ecosystem due to their sensitivity to hydrologic changes, ecological importance, and sensitivity to habitat and system productivity (Rice et al. 2005). Restoration efforts will be assessed through performance measures of alligator populations, including alligator abundance and distribution, nest production, body condition, and alligator hole occupancy (Rice et al. 2005). Long-term monitoring of alligator populations is part of the Monitoring and Assessment Plan (MAP) of the Restoration Coordination and Verification (RECOVER) team formed to provide assessment of the success of the Comprehensive Everglades Restoration Plan (CERP).

CHAPTER 2
EFFECTS OF HABITAT TYPE AND STRUCTURE ON DETECTION PROBABILITIES OF AMERICAN ALLIGATORS

Factors Affecting Alligator Night-light Surveys

Prior to 1978, night-light surveys in Florida followed the guidelines recommended by Charbreck (1966). He recommended surveys be conducted on low moonlight nights with minimal wind during the months of April and May. These guidelines were later updated by the Alligator Recovery Team (Chabreck 1976), which recommended beginning surveys at least one hour after sunset during May–October, with air temperatures above 21 C. Woodward and Marion (1978) examined the effect of different environmental variables and survey procedures on night-light counts, and found alligator counts were positively correlated with water temperatures but leveled off at higher temperatures (Woodward and Marion 1978). They also found wave height was negatively correlated with counts, and variability was related to increased wave heights (Woodward and Marion 1978). Contradictory results were found between Woodward and Marion (1978) and Chabreck (1966) in relation to moon light effects on counts. Precipitation, air temperature, and percent cloud cover showed minimal effects on counts (Woodward and Marion 1978). In more recent years, wariness, emergence behavior, and habitat characteristics have been identified as factors that should be examined as potentially affecting counts.

Wariness

Changes in detection rates of crocodilians due to natural avoidance behavior from previous contact with boats and or surveyors, can affect survey results (Webb and Messel 1979). Increased wariness was observed in the Black caiman (*Melanosuchus niger*) and the Yacare caiman (*Caiman yacare*) following human interactions (Pacheco 1996). Preliminary investigations by Spratt (1997), however, found little effect of harvest on alligator wariness in central Florida lakes. Wariness can influence night-light counts by increasing the distance at which an alligator submerges when a boat is approaching. This will, reduce the probability that the alligator is counted and increase bias of counts.

Emergence Dynamics

It is thought that alligators typically hunt for prey below the water surface at night and surface to move around, breathe, and conduct courtship activities. The proportion of time they spend at the surface, and are therefore visible during night-light surveys are thought to depend on feeding behavior, courtship activities, water temperature, and surface disturbance such as waves. Natural emergence behavior can be altered by human disturbance (Pacheco 1996). Ambient air temperature has been shown to influence submergence behavior in alligators (Murphy 1977, Brandt 1989). Bugbee (2008) found that adult alligators in the Everglades spend about 2/3 of the day submerged. Variables found to affect emergence behavior were hour of night, season, moon phase, water depth, water temperature, air temperature, rain, and wind (Bugbee 2008). Understanding alligator emergence behavior will help to determine what percentage of the population is actually available for detection during night-light surveys.

Habitat Characteristics

Habitat type, composition, and structure can influence detection probabilities of alligators during night light surveys. Detectability of crocodilian species has been found to vary with habitat conditions, such as presence and density of vegetation, as well as complexity, shape, and size of the survey area (Wood et al. 1985, Thorbjarnarson 1988). Crocodilian detection probabilities have been suggested to decrease in areas with vegetation cover (Bayliss 1987, Woodward et al. 1996, Da Silvera et al. 1997, Cherkiss et al. 2006). Although vegetation characteristics are thought to affect detection probabilities for alligator surveys, few studies have quantified the effects.

Objectives

My objectives were to determine the effect of habitat type and structure (as defined by vegetation height and density, and water depth) and survey procedure (as defined by survey speed, observer height, and distance from transect) on detection rates of alligators. The three habitats examined were sawgrass, slough, and wet prairie.

Habitat-Related Detection Probabilities

I hypothesized that habitat type influences detection rates of the American alligators during night-light surveys, with slough having the highest detectability followed by wet prairie then sawgrass. I hypothesized that with increasing vegetation height, distance from transect, visual obstruction, and survey speed will result in a decrease in detection probabilities. I also hypothesized that increased water depths and seat height will result in an increase in detection probabilities. The alternative hypothesis was that alligator detection is constant in all habitat types.

Anticipated Results and Benefits

Information gained from this study will increase the ability of alligator researchers to detect changes in FWC and Everglades alligator populations. Determining detection rates for habitat variables critical to alligator population surveys is essential for increasing the reliability of population estimates. Accounting for sources of variation in detection rates will improve precision, which will allow population trends to be detected sooner than current population analysis methods, thus lead to enhanced response time for research to observe population changes. As with all harvested species it is vital to have reliable population estimates in order to harvest in a sustainable manner. This project could be a model for assessing effects of habitat characteristics on night-light surveys of crocodilian species worldwide.

Materials/Methods

Study Area

I used three habitats to assess effects of vegetation characteristics on alligator detectability: sawgrass marsh, open slough, and wet prairie. The sawgrass and slough habitats were located within Water Conservation Area 2A in the Everglades Ecosystem, whereas the wet prairie transect was located on Lake Kissimmee (Fig. 1-1). The sawgrass marsh and open slough habitats were selected for habitat detectability models because they are the most abundant habitats within the Everglades Ecosystem and comprise the majority of Everglades alligator survey routes. The wet prairie habitat was selected on Lake Kissimmee because there were larger contiguous tracts of wet prairie habitat, which is similar in structure to Everglades wet prairie (Kushlan 1990).

Sawgrass Marsh

Sawgrass marsh is the most abundant marsh habitat in the Everglades, accounting for about 65-70% of the remaining wetlands habitat in that ecosystem (Loveless 1959, Kushlan 1990). Sawgrass marshes are considered an emergent marsh dominated by sawgrass (*Cladium jamaicense*), which accounts for (93%) of the plant biomass (Jordan et al. 1997). Vegetation species diversity is considered very low but other species occurring in sawgrass marsh habitats include maidencane (*Panicum hemitomon*), arrowhead (*Sagittaria spp.)*, spikerush (*Eleocharis spp.)*, and various floating-leave species [e.g. spatterdock (*Nuphar luteum*) and fragrant waterlily (*Nymphaea ordata*)] in open areas. Sawgrass marshes usually occur on slightly higher elevations or areas that have shallower water depth than open slough or wet prairie habitats. Vertical structure of sawgrass marshes can reach heights as great as 3 m. The mean vegetation height for a sawgrass marsh is around 140 cm (Jordan et al. 1997). Sawgrass marshes are usually categorized into either very dense stands of tall plants or sparse stands of short plants (Loveless

1959, Kushlan 1990, Wood and Tanner 1990, Gunderson 1994). Habitat structure is greatly influenced by hydroperiod and related water depths. Longer hydroperiods with greater water depths tend to produce taller and denser stands of sawgrass (Kushlan 1990). Conversely, shorter hydroperiods and shallower water depths tend to limit growth and favor less dense and shorter stands of sawgrass (Kushlan 1990, Newman et al. 1996). Alligator detection rates in sawgrass habitats may be influenced by vertical structure and density of the stands and fluctuations in hydroperiods.

Slough

Slough habitats in the Everglades occur in areas that have the greatest water depths. Many sloughs in the Everglades occur in the main water passages, such as Shark River slough to the west and Taylor slough to the east. Because sloughs are in the deepest water of the Everglades, they remain inundated for the longest periods and have a higher diversity of plants species than sawgrass. Slough habitats are dominated (88%) by floating macrophytes and submerged vegetation, and have a mean vegetation height of less than 30 cm (Loveless 1959, Gunderson 1994, Jordan et al. 1997). Some of the major species of slough habitats are fragrant water lily, spatterdock, and floating hearts (*Nymphoides aquaticaum*). Alligator detection rates in slough habitats are expected to be greater than in other habitats as a result of less vertical structure and a greater proportion of open water.

Wet Prairie

Wet prairie habitats occur in the intermediate water depths between the deeper slough habitat and the shallower sawgrass habitats within the Everglades. Wet prairies also occur on the fringe of lakes and in flatwoods of central Florida (Kushlan 1990). Wet prairies include a collection of graminoid (grasslike) plants of low-stature (Kushlan 1990, Gunderson 1994). Wet prairies have a mean vegetation height of about 70 cm (Jordan et al. 1997). Wet prairies have a shorter hydroperiod, but greater plant diversity then the slough or sawgrass habitats (Kushlan 1990). Some of the major species that occur in wet prairies are beakrush (*Rhynchospora tracyi*), maidencane, spikerush, and maidencane (Loveless 1959, Kushlan 1990, Wood and Tanner 1990, Gunderson 1994). The vegetative structure of wet prairie undergoes significant changes as water depths vary, beakrush and spikerush both exhibited taller canopy heights with greater water depths (Busch et al. 2004). Wet prairies within the Everglades and Lake Kissimmee are similar in structure but have differences in the dominate grass species (Kushlan 1990). Lake Kissimmee is dominated by maidencane and beakrush, whereas, the Everglades is dominated by beakrush and spikerush (Kushlan 1990). Changes in structure and density of vegetation in wet prairie habitat with varying in water depths may lead to lower alligator detection rates.

Air Cannon

An air cannon was built to distribute reflective markers throughout study areas without leaving an airboat trail to attract the attention of surveyors. The cannon was constructed of schedule 40 PVC pipe, and a sprinkler valve was used for the firing mechanism. The cannon was equipped with a pressure gauge and firing angles ranging from 0 to 85 degrees (Fig. 1-2). Air pressure was added using a portable air compressor that charged the cannon to the desired pressure. Prior to employing the cannon to distribute markers for the study, I fired it at different air pressures and angles to calibrate the horizontal distances of the reflective markers in respect to pressure and firing angle.

Reflective Markers

Reflective markers were constructed of a 3.2 cm diameter wooden dowel, 0.9 cm diameter steel rod, monofilament fishing line, heavy duty washers, and white reflective tape. The dowel was cut to 18 cm with a hole drilled in the bottom, and a 7.5 cm section of steel rod was attached to the bottom of the dowel with epoxy adhesive, and with monofilament line attached to the washer. The steel rod acted as a keel and kept the reflective marker floating upright while a washer anchored it in place. The marker was painted black and the reflective tape was attached to the top of the dowel (Fig. 1-3). White reflective tape was used to help observers distinguish markers from actual alligators. Two observers used spotlights at 10 m intervals out to 50 m and there was no difference observed in detecting the white reflective tape versus an actual alligator eye shine at the various distances.

Mock Surveys

Survey transects were established through areas most characteristic of the habitat type. Random points (60) were generated to distribute reflective markers along transects. Two sets of random numbers were used to distribute reflective markers: 1) To determine distance (0-200 m.) between markers along the transect, and 2) to determine distance (0-50 m.) from transect and whether the marker should be deployed on the right or left side of the transect. Transect lengths ranged from 4.18 km in the wet prairie habitat to 6.38 km in the sawgrass marsh habitat. Transect lengths varied in length depending on the random distances between marker locations. Markers were launched perpendicular to transects by air cannon, and GPS waypoints were taken as well as direction (left or right) and distance from the transect for each reflective marker. Reflective markers less than 5 m from the transect were hand-thrown from the front of the airboat.

Observers were considered skilled if they had conducted alligator night-light surveys in the past year or according to established protocols. The protocols consisted of a training period of participating on surveys as a recorded and exhibiting proficiency at size estimations. Once reflective markers were randomly distributed throughout each habitat, surveys were conducted by observers according to methods established by Woodward and Marion (1978), except observers didn't slow down to estimate sizes. Survey replicates were conducted 5-8 times on each habitat. Only five surveys from the most experience observers were used for modeling effects of habitat type and survey procedures on alligator detectability, due to unequal replicates between habitats.

At each marker detected, observers recorded a GPS waypoint perpendicular to the reflective marker on the transect, indicated a direction (left or right), and estimated the distance from the transect to the reflective marker. When surveys were completed, all markers were collected, and markers not recovered or not detectable were removed from the survey sample. Examples of reflectors removed from the study included those cases where the marker was laying on its side or did not re-surface after being launched. Both instances above would have reduced the probability of observing markers and would have biased survey results. Retained survey samples for the sawgrass, slough, and wet prairie habitats were 49, 49, and 54.

Habitat Variables

After all surveys were completed, variables such as vegetation height (VE), visual obstruction (VO), water depth (W), and distance (D) from transect were recorded at each marker. Vegetation height (cm) at the marker was measured from the surface of the water to the top of the vegetation. Visual obstruction, an indication of vertical vegetation density, was measured by 1-dm classes using the Robel Pole method (Robel 1970). Water depth (cm) was measured from the top of the substrate layer to the surface of the water. Airboat seat height (cm) and survey speed (km\hr) were also recorded for each observer/boat combination. Waypoints were loaded into Garmin Map Source (Garmin International Incorporation, Olathe, Kansas) and were examined by estimated distance and direction (right or left) to see what proportion of markers were observed by surveyors. Known locations were compared with observed markers to develop a mark-recapture data set for modeling detection probabilities.

Modeling

Count data were analyzed using Program MARK (White and Burnham 1999) to determine the most suitable model for determining habitat-specific detection probabilities of alligators during night-light counts. The model used for detectability models was the Huggins Closed Capture Model (Huggins 1989). This model allowed estimation of a closed population size (N) from initial capture probabilities (p) and recapture probabilities (c) (Huggins 1989, Huggins 1991). One condition of the model was animals are captured or recaptured at least once during the study, and it allowed for individual covariates to be used to model p and c. The initial capture probability (p) for use in modeling detection probabilities was set to one. This represented the initial time markers were deployed and all markers are known to be available for detection within the study area. As discussed earlier, markers unavailable for detection were removed from the data set. Recapture probabilities (c) represented detection probabilities of reflective markers.

Models were created based on biological factors and other significant variables that influence night-light counts. I selected distance from transect, visual obstruction, vegetation height, water depth, survey speed, and airboat seat height as covariates to be included in model. Other considerations for model development were whether to group habitats together, or keep them separate and examine possible interactions among variables. Separating habitats would allow me to determine if the covariates affected habitats equally or independently. If the effect of covariates was equal among the habitats, there would be no difference that could not be explained by the individual covariates. Interaction effects were examined because some covariates could be dependent on others. For example, an increase in water depth may lead to a decrease in vegetation height. A one-way non-parametric analysis was conducted to determine differences in habitat detectability rates. Thirty-one models were examined based on biological variables or combinations of variables thought to affect alligator detection rates in the three habitats (Table 1-1).

Model Selection

The Akaike Information Criterion (AICc) was used to determine which variables or mixture of variables resulted in the best fit for modeling habitat effects on alligator detectability during night light counts (Burnham and Anderson 2002, Pollock et al. 2002). Anderson (2008) suggested using AICc over AIC, because AICc is adjusted for small sample size. AICc determines the most parsimonious of models by taking into account the number of parameters in the model (Anderson 2008). AICc penalizes additional parameters and, therefore, identifies the best fitting model with a minimal numbers of parameters. AICc weight represents the probability that the model is the best fit given the tested data and models (Anderson 2008). LOGIT link functions were used to estimate optimum models' beta parameters. Beta parameters were determined to be significant if the upper and lower 95% confidence intervals did not encompass zero. Detectability functions were derived from beta parameters resulting from the best fitting model, and were used to graphically represent the effects of the habitat and survey variables on alligator detectability in the three habitats.

Results

Covariates that had the most influence on habitat detectability were visual obstruction (VO), vegetation height (VE), distance from transect (D), water depth (W) and airboat seat height (Seat) (Table 1-2). Survey speed in the range we tested had minimal effect on alligator detectability. There was no evidence of interaction effects between model covariates. Differences were found in the detection probabilities between the three habitat types, and I found it more appropriate to model them separately as opposed to combining habitat types for a universal detectability function. The best model (Model 3; AICc Weight = 0.54), included distance from transect, visual obstruction, vegetation height, water depth, and airboat seat height (Table 1-2). Models 4 and 5 showed some evidence for support with AICc weights of 0.13 and 0.10. I considered model averaging, but due to the clear separation in AICc weights between the top competing models (0.54 to 0.13), and the fact beta parameters for models ranked 2-4 were not significant, I decided against model averaging. The optimum model estimated detection probabilities for available alligators (alligators that are on the surface available for detection) in sawgrass marsh, slough, and wet prairie habitats as 0.53, 0.63, and 0.51. The only significant difference in detection rates was found between the wet prairie and slough habitats ($P = 0.0274$). All beta parameters for habitat variables for the optimum model were significant (Table 1-3).

Alligator Detectability Functions for each habitat type:

$$P_{\text{Sawgrass}} = 1/(1+e\text{^}-((1.0518)-(0.0400\times D)-(0.5599\times VO)-(0.0136\times VE)+(0.0131\times Seat))$$

$$P_{\text{Slough}} = 1/(1+e\text{^}-((-3.0797)-(0.0637\times D)-(0.5599\times VO)+(0.0577\times W)+(0.0131\times Seat))$$

$$P_{\text{Wet Prairie}} = 1/(1+e\text{^}-((-0.2896)+(0.0372\times D)-(0.5989\times VO)-(0.0144\times W)+(0.0131\times Seat))$$

Detection probabilities from the above functions can be obtained by simply inserting various covariate values (D = m, VO = dm, VE = cm, W = cm, and Seat = cm) for the habitat of interest.

Visual obstruction ($\beta = -0.5599$) had the greatest negative effect on alligator detectability, and affected all habitats equally (Fig. 1-4). Although visual obstruction exhibited the same effect on all habitats, detectability curves behaved differently due to other variables in the habitat-specific models. Distance from transect had a negative effect in sawgrass ($\beta = -0.0400$) and slough habitats ($\beta = -0.0637$), but had a positive effect in the wet prairie habitat ($\beta = 0.0372$) (Fig. 1-5). Vegetation height was important only for the sawgrass habitat, and water depth was important only for slough and wet prairie habitats. Vegetation height had a negative effect on detectability in sawgrass ($\beta = -0.0136$) (Fig. 1-6), and water depth had a positive effect in slough habitat (β = 0.0577) and a negative effect in wet prairie habitat (β = -0.0144) (Fig. 1-7). Airboat seat height (β = 0.0131) had a positive effect and affected all habitats equally (Fig. 1-8). Cumulative graphs for the sawgrass (Fig. 1-9), slough (Fig. 1-10), and wet prairie (Fig. 1-11) show the relationship of all models variables with the other variables set to minimum values.

Discussion

I found differences in alligator detection rates among the three habitat types (sawgrass, slough, wet prairie) tested. Detection probabilities varied from $p = 0.51$ in the wet prairie habitat to $p = 0.63$ in the slough habitat. The sawgrass habitat had a slightly higher detection probability than the wet prairie with a $p = 0.53$. The only difference ($P = 0.0274$) was between wet prairie and slough habitat. This could possibly be due to a location effect and suggest more replicates in different geographic regions should be conducted within habitat types. Although the other habitat combinations did not show significant differences in alligator detection rates, the final model variables were discernibly different among habitats and, therefore, they were modeled independently.

The slough habitat was expected to have the highest detection rate because they generally had greater water depths, lower vegetation height, and the greatest amount of open water (Loveless 1959, Kushlan 1990, Jordan et al. 1997). Factors affecting detection probabilities in the slough habitat in order of greatest positive to negative effect were water depth (+), seat height (+), distance from transect (-), and visual obstruction (-).

Generally, sawgrass marshes consisted of dense stands of sawgrass with a substantial amount of vertical structure (Loveless 1959, Kushlan 1990), which was also true for the study area. Sawgrass marshes had the lowest water depths, highest vegetation height, and the greatest plant biomass of habitats tested (Kushlan 1990, Jordan et al. 1997). Factors affecting detection probabilities on sawgrass habitat from greatest positive to negative effect were; seat height (+), vegetation height (-), distance from transect (-), and visual obstruction (-). Sawgrass habitat had only one positive relationship, which was seat height.

Wet prairie habitats include intermediate characteristics between the slough and sawgrass habitat in relation to water depth, vegetation height, and plant biomass (Jordan et al. 1997). Factors affecting detection probabilities on the wet prairie habitat in order from greatest positive to negative effect were distance from transect (+), seat height (+), water depth (-), and visual obstruction (-). Based on habitat characteristics, vegetation height and visual obstruction, I expected the sawgrass marsh to have the lowest alligator detectability, but this was not the case. The lowest detectability was observed in the wet prairie habitat, which could be caused by other confounding factors that will be discussed later.

When examining composite graphs (Fig. 1-9 – 1-11), the relationships between positive and negative variable effects of models were more evident. For example, in sawgrass habitat, when all covariates were set to minimum values, the detectability function yielded a detection probability of $p = 0.93$. The probability is very high at the minimum values because most of the sawgrass covariates had negative effects except for seat height, which had a small positive effect. Conversely, when all covariates of slough habitat were set to minimum values, the detection probability was only $p = 0.42$. This probability starts out fairly low because water depth and seat height in slough habitat had positive effects on detectability. For the detectability functions to be useful to alligator researchers and behave correctly, all critical variables in habitat models must be measured and incorporated into the model. Although visual obstruction and seat height had the same effect on all three habitats, distance from transect, vegetation height, and water depth differed greatly in their influence on alligator detectability.

Visual Obstruction

Visual Obstruction had the greatest influence on detection rates, and affected all habitats equally. This was expected because, as vertical vegetation density increases, detectability decreases regardless of other habitat characteristics. If vegetation is obstructing an observer's view and an observer cannot see the surface of the water, he is unlikely to see an alligator eye reflection. Detection probability declined quickly as visual obstruction increased (Fig. 1-4).

Distance from Transect

I expected distance from transect to be negatively correlated with detectability for all habitats, but I found mixed results. Distance had a negative effect on alligator detectability in sawgrass and slough habitats but a positive effect on detectability in the wet prairie (Fig. 1-5). In the slough habitat, distance had a greater negative effect on detectability than in the sawgrass habitat. However, the positive effect of distance on detectability in the wet prairie habitat goes against the basic principle of distance sampling. One of the major assumptions of distance sampling is that all animals on the line should be completely detected ($p = 1$) (Buckland et al. 1993). However, I believe that vegetation type can explain this counterintuitive finding. In wet prairies, the primary vegetation consisted of maidencane and various other grass species, which was relatively dense. The light beam reflecting off wet grass may sometime obscure alligator eye shines in denser grass. I frequently observed alligator eye refelections to be more difficult to detect at close range in the dew covered vegetation on wet prairies. Frequently, alligators are observed from far distances in wet prairies but disappear when trying to approach the alligator.

Vegetation Height

Vegetation height affected detectability only in sawgrass habitat (Fig. 1-6). This is probably because the sawgrass habitat had a greater vertical vegetation structure when compared to slough and wet prairie habitats. Sawgrass stands can have mean canopy heights of 1.4 m

(Jordan et al. 1997) and maximum heights of 3 m (Kushlan 1990), whereas vegetation in other habitats is generally shorter. An interaction between vegetation height and water depth was expected but did not emerge as a significant effect in model sets.

Water Depth

Water depth affected alligator detectability in slough and wet prairie habitats but did not have a significant effect in sawgrass habitat (Fig. 1-7). Detectability was positively associated with water depth within the slough habitat and negatively associated with water depth in the wet prairie habitat. The positive effect of water depth on detectability in slough habitat was expected. With higher water levels, slough habitat would have more open areas with less and shorter emergent vegetation, which should increase the chances of detecting an eye reflection. On the other hand, the negative effect of water depth on detectability in the wet prairie habitat is a little harder to understand, and was unexpected. One possible alternative could be that vegetation structure in wet prairies changes dramatically with differing water depths, thus leading to decreased detectability. Busch et al. (2004), found two wet prairie species, spikerush and beakrush, had significant differences in vegetation height between flooded and drained conditions. Spikerush height was greater in flooded treatments (83 cm) compared to (59 and 61 cm) in drained treatments (Busch et al. 2004). Beakrush also had greater height in flooded treatment (67 cm) compared to the drained treatment (59 cm) (Busch et al. 2004). I collected vegetation data along survey transects but data derived from this was insufficient to assess changes in vegetation structure with varying water depths. Another alternative hypothesis is that greater water depths could have confounded the problem of spot-light glare on the taller grass species.

Seat Height

Airboat seat height was positively correlated with detection probabilities on all habitat types (Fig. 1-8). This seems intuitive, because the higher the observer is, the less obstructions encountered along the vision line and the greater the chances of detecting an eye reflection. Higher seat height gives observers a better line of sight angle to detect alligators behind taller vegetation. This would suggest that in order to increase detection rates on alligator surveys, alligator researchers should use an airboat with the highest observer seat as safely possible. At a minimum, standardization of seat height among survey crafts would reduce variability due to that variable.

Management Implications

Habitat detectability functions can be applied to future alligator nightlight surveys in the Everglades to obtain an improved estimate of the alligator population. For the three habitats, the various covariates could be measured and used in the detectability functions to obtain a detection probability of available (on the surface) alligators for a given survey. Distance from transect, could be set to a constant 25 m, since Everglades alligator surveys only count alligators detected < 50 m from either side of the survey transect. One assumption associated with setting the distance from transect to a constant 25 m would be that alligators are equally distributed throughout the 50 m wide swath on both sides of the survey route. By setting the distance from transect to 25 m the model will be estimating the mean detection probability. Random points should be sampled out to 50 m along the survey route to obtain mean vegetation height, water depth, and visual obstruction measurements. Due to variation that can occur within habitat variables over time such as, dry season vs. wet season, vegetation composition shifts, and other processes that could alter the habitat characteristics, it is helpful to obtain habitat measurements for each survey. If variability is small, mean water depth for a given survey route may be able to be correlated with an established water gauge within the Everglades Depth Estimation Network (EDEN) in close proximity. One problem associated with using existing water gauges is that in extreme dry seasons, the marsh water levels may lose connectivity with the gauge and would be considered an unreliable measurement for the survey route. It is strongly suggested that since vegetation height and visual obstruction measurements should be taken for each survey, water depth measurements should also be recorded. I recommend obtaining habitat measurements for each survey for the first several years. After several years of collecting habitat data, variability of the habitat measurements could be analyzed, and if variability is small, frequency of collection of habitat data could be reduced. If variability is great within the habitat characteristics, I recommend calculating detection probabilities for each random sampling point, and then taking the average of the individual detection probabilities to obtain the detection probability for the survey route. On the other hand, if variability is small among the random sampling points, the mean of habitat characteristics could be used to obtain the detection probability for the survey route.

Although, habitat detectability models are useful for determining detection probabilities of alligators on the surface, they do not take into account the proportion of alligators that are submerged or unavailable for detection. Bugbee (2008) conducted a study looking into the effects of various environmental variables and their effect on emergence behavior of adult alligators. The product from Bugbee (2008) was an adult alligator emergence model, which incorporated various environmental variables to estimate the proportion of alligators emerged, or the proportion of alligators available for detection. Variables included in the adult alligator emergence model were: hour of night, season, moon phase, water depth, water temperature, air temperature, rain, and wind, which have all been documented to affect crocodilian night-light counts (Murphy 1977, Woodward and Marion 1978, Montague 1983, Bayliss 1987, Mazzotti 1989, Pacheco 1996). To further improve alligator population estimates, the combination of habitat detectability models and the adult alligator emergence model (Bugbee 2008), could be used to adjust night-light counts to gain more reliable alligator population estimates in the Everglades (Appendix A). Although, habitat detectability models and the adult alligator emergence model account for the majority of variability in alligator detection rates, there are still some gaps in the information.

Applying detectability functions to alligator surveys on alligator management units (AMU) administered by the FWC would be an expensive and time consuming task. AMUs do not have rigid survey transects but, rather, have survey routes that cover the majority of occupied habitat within an AMU. Changes in water levels and vegetation types and densities would require annual assessments of habitat characteristics. The FWC alligator surveys also include many more habitats than were examined in the study, and FWC alligator surveys do not record locations for each alligator observed. Another reason it would be difficult would be the amount of survey areas (approximately 120) that are surveyed yearly. In order to apply habitat detectability functions to FWC alligator surveys more research would need to be conducted and replicated for more habitats and areas across the state. If detectability functions are obtained for the multiple habitats statewide, a combination of the use of Geographic Information Systems (GIS) and changes to night-light survey recording procedures (obtaining locations for alligators encountered) could result in feasible application of the habitat detectability models statewide.

Previous estimate have indicated detectability of alligators ≥122 cm in North Central Florida lakes during night-light counts to average 0.09 on Lake Woodruff and 0.19 on Orange Lake (Woodward et al. 1996). Other estimates from Par Pond, South Carolina indicated detectability range of 0.30-0.35 for all sizes (Murphy 1977, Brandt 1989) and detectability of 0.09 for $\geq$183 cm alligators in impounded wetlands in South Carolina (Rhodes and Wilkinson 1994). With the combination of the Bugbee (2008) emergence model and the habitat detectability functions, detectability ranged from 0.15 to 0.21 for adult alligators (Appendix A), but this estimate does not account for wariness. This gives some support for the current universal correction factor of 0.14 being used by the FWC when adjusting night-light counts.

CHAPTER 3
CONCLUSIONS

Improving reliability and reducing uncertainty in population estimates can enhance management capabilities for wildlife populations. In recent years, researchers have improved the capability and implemented techniques to account for detectability during wildlife population surveys. Incorporating detectability into population estimates will enable researchers to obtain a better understanding of trends or changes occurring within populations. There are many methods that can be used to account for varying detectability rates such as double sampling, removal methods, capture-recapture, and distance sampling (Pollock et al. 2002). However, many of these approaches are very expensive when compared to using traditional indices (Pollock et al. 2002).

Simulated surveys are another method to assess detectability under varying conditions and treatments. Some studies on other species have constructed replicas or plaster models of animals then conducted surveys to obtain detection rates (Gardner et al. 1999, Cherkiss et al. 2006, Pearse et al. 2007). The use of simulated surveys has proven to be a valid technique to account for and quantify the effects of different habitat variables on alligator detection probabilities during night-light counts. Although the habitat detectability models in this study accounted for the majority of habitat variables, additional variables might improve and enhance modeling abilities for different habitats. Vegetation composition, horizontal structure, and species of vegetation could be included in future model sets to determine effects and enhance estimations of detectability.

One issue that was not addressed in this study is the spatial relationship between reflective markers. In areas with higher densities of markers, observers may tend to fixate on an observed marker and reduce or eliminate scanning for other markers, which could lead to missed markers that should otherwise be detected. This also occurs in actual alligator surveys, particularly in areas where alligator density is high. The problem can also exist in areas with difficult terrain to navigate during surveys, where observers are concentrating on avoiding obstacles rather than scanning for eye reflections. This problem could be minimal for some observers but could be higher for other observers, depending on survey experience, survey techniques, and driving ability. At the very least, this adds variability to detection rates with associated uncertainty. This problem supports the need to establish strict protocols for how surveys are conducted and ensure all observers are conducting surveys by the same methodology. There should be standard methods on how to handle situations that occur during surveys, such as encountering high alligator densities, new stands of vegetation cover that reduce visibility, and other cases. Addressing these problems can result in a reduction in observer associated variability in survey counts.

Another problem not addressed in the study was replication of habitat types statewide and under varying hydrologic conditions. Surveys were replicated by observers but habitats were not replicated. Without replication, inferences should not be made for habitats statewide but rather made by area. Future work could be conducted on habitats in different areas to test detection models and determine if these findings are consistent for all areas within these habitat types. It would be instructive to examine other common alligator habitats should throughout the state, such as shrub swamp, spatterdock, and other types of emergent marshes. During the study period, hydrologic conditions were relatively stable, and the models may not account for influence that could appear during varying hydrologic conditions. Future work should examine and analyze model predicted detection probabilities under varying hydrologic conditions, to determine the effect of hydrology and assess whether the current model variables account for fluctuations.

Determining the effect of human induced wariness on alligator night light counts needs to be explored further. Preliminary data examining effects of hunting on alligator wariness, determined there was no significant difference between harvested and unharvested areas; however results were confounded by water levels and temperatures (Spratt 1997). In more recent years, more data have been added and another analysis conducted. The recent analysis of harvested and unharvested areas has shown a significant difference for alligators >1.8 m, but only at or below median water levels. The average depressive effect of wariness on nightlight counts was estimate to be -42% (-60% to -16% $CI_{95\%}$) at median water level, and -76% (-88% to -50% $CI_{95\%}$) at 0.6 m below the median (R. A. Kiltie, Florida Fish and Wildlife Conservation Commission, unpublished report). Future research is needed to examine the effect of changing wariness on detection rates and a practical way of applying wariness detectability coefficient to alligator surveys.

Alligator night-light surveys will continue to be the most viable and efficient method for monitoring alligator populations, and a better understanding of factors that influence detectability during night-light counts will lead to better estimates of the population. Reducing variation in population estimates will allow researchers to detect changes in alligator populations over a shorter period of time and provide more reliable information for setting harvest quotas. Improved population estimates also will allow researchers to better determine the effects of Everglades restoration activities on alligator populations.

Table 2-1. Model set used to model American alligator detectability as a function of distance (D), visual obstruction (VO), vegetation height (VE), water depth (W), seat height (Seat), and survey speed (Speed).

Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
D	D	D	D	D	D	D	D
VO	**VO**	**VO**	**VO**	**VO**	VO	**VO**	**VO**
VE	VE	VE (SG)	VE	VE	VE	VE	VE(SL,WP)
W	W	W (SL,WP)	W	W	W	W(SL,WP)	W (SG)
Speed	Seat	**Seat**	**Seat**	**Seat**	**Seat**	**Seat**	**Seat**
Seat		Habitat		Habitat	Habitat	Habitat	Habitat
Habitat							

Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
D	D	D	D	**D**	D	**D**	**D**
VO	**VO**	**VO**	**VO**	**VE**	**VO**	**VO**	**VO**
VE	W	VE	VE	**W**	VE	**VE**	**VE**
W	**Seat**	**Seat**	W	Habitat	W(SG,WP)	**Speed**	**Seat**
Seat	Habitat	Habitat	Seat		**Seat**	**Seat**	
			Habitat		Habitat	Habitat	

Model 17	Model 18	Model 19	Model 20	Model 21	Model 22	Model 23	Model 24
D	**D**	**D**	**D**	**D**	**D**	**D**	**VO**
VO	**VO**	**VO**	**VO**	**VO**	**VO**	**VO**	**VE**
VE	**VE**	**VE*W**	**VE**	**VE**	**VE**	**VE**	**W**
Speed	**W**		**Seat**	**W**	Habitat	Individual	Habitat
Habitat	**Seat**		Habitat	Habitat			
	Habitat						

Model 25	Model 26	Model 27	Model 28	Model 29	Model 30	Model 31
D	**D**	**D**	**D**	**D**	**D**	**D**
VO	**VO**	**VO**	**VO**	**VO**	**VE**	**VE**
Habitat	**VE**	**VE**	**VO*W**	**W**	**VO*VE**	**W**
	W	**W**	Individual	**VO*W**	Habitat	Habitat
	Speed	Individual		Individual		
	Seat					
	Individual					

Note: SG, SL, and WP next to a variable indicates that it only applies to those specific habitats. Variables in **BOLD** indicates that the variable applies to the all habitats.

Table 2-2. Δ AICc and AICc weights for the models used to describe detectability of alligators in sawgrass, slough and wet prairie habitats.

Model	AICc	ΔAICc	ŵ	Model Likelihood	# Par	Deviance
3	622.61	0.00	0.54	1.00	11	600.32
4	625.39	2.78	0.13	0.25	12	601.04
5	626.02	3.41	0.10	0.18	14	597.55
6	627.17	4.56	0.06	0.10	16	594.56
7	627.37	4.76	0.05	0.09	11	605.08
9	627.76	5.15	0.04	0.08	14	599.29
2	628.26	5.65	0.03	0.06	14	599.79
1	628.51	5.90	0.03	0.05	17	593.82
12	629.70	7.09	0.02	0.03	16	597.09
10	632.36	9.75	0.00	0.01	11	610.06
14	634.29	11.68	0.00	0.00	13	607.89
11	635.54	12.93	0.00	0.00	11	613.25
8	645.25	22.64	0.00	0.00	11	622.96
20	654.33	31.72	0.00	0.00	7	640.21
15	654.91	32.30	0.00	0.00	8	638.75
18	656.37	33.76	0.00	0.00	8	640.21
16	660.66	38.05	0.00	0.00	5	650.59
22	661.44	38.83	0.00	0.00	6	649.35
17	661.73	39.12	0.00	0.00	7	647.61
21	663.47	40.86	0.00	0.00	7	649.34
24	666.55	43.94	0.00	0.00	6	654.46
25	666.76	44.15	0.00	0.00	5	656.69
19	668.23	45.62	0.00	0.00	4	660.19
23	668.36	45.75	0.00	0.00	15	637.82
27	670.43	47.82	0.00	0.00	16	637.82
26	671.04	48.43	0.00	0.00	18	634.28
28	674.81	52.20	0.00	0.00	15	644.28
29	676.77	54.15	0.00	0.00	16	644.16
30	797.18	174.58	0.00	0.00	6	785.10
13	844.76	222.15	0.00	0.00	6	832.66

Note:Δ AICc values < 2 indicate substantial evidence for the model. AICc weights are the probability that the models is the most parsimonious out of the set.

Table 2-3. Beta parameters for optimum alligator detectability models for sawgrass (SG), slough (SL), and wet prairie (WP) habitat. Beta is represented by LOGIT link function parameters.

			95% Confidence Interval	
Parameter	Beta	Standard Error	Lower	Upper
Sawgrass (SG)	1.0518	0.9365	-0.7837	2.8873
Slough (SL)	-3.0796	1.5991	-6.2139	0.0545
Wet Prairie (WP)	-0.2896	0.8182	-1.8932	1.3141
SG Distance (D)	-0.0400	0.0152	-0.0698	-0.0103
SL Distance (D)	-0.0637	0.0182	-0.0993	-0.0281
WP Distance (D)	0.0372	0.0141	0.0096	0.0648
AH Visual Ob. (VO)	-0.5599	0.0470	-0.6519	-0.4679
SG Vegetation (VE)	-0.0136	0.0042	-0.0218	-0.0054
SL Water Depth (W)	0.0577	0.0200	0.0185	0.0970
WP Water Depth (W)	-0.0144	0.0069	-0.0280	-0.0009
AH Seat Height (Seat)	0.0131	0.0043	0.0047	0.0216

Note: AH represents the variable applies to all three habitat types equally

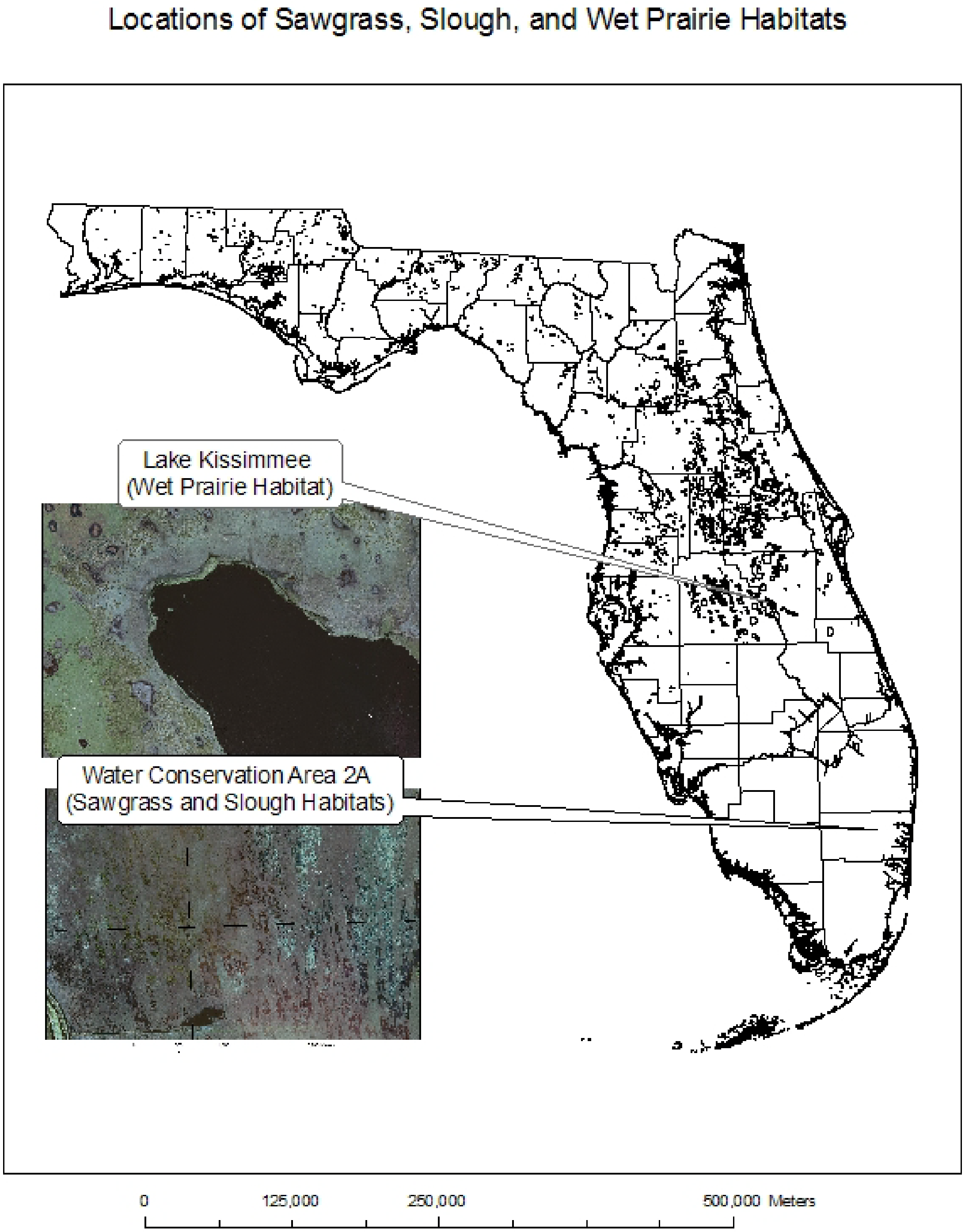

Figure 2-1. Locations of sawgrass, slough, and wet prairie habitats used for alligator detection surveys in Florida.

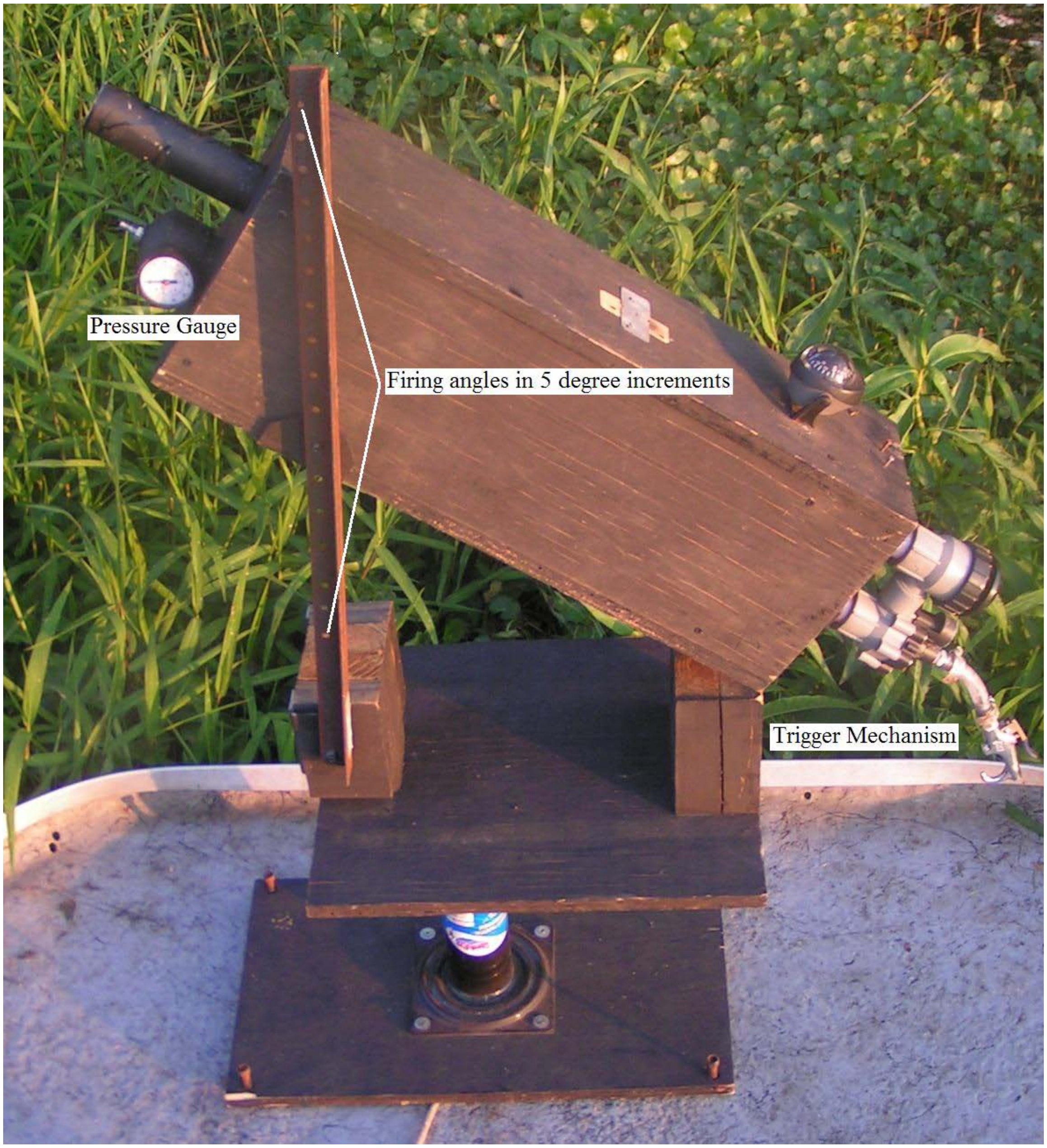

Figure 2-2. The air cannon, which was constructed to distribute reflective markers in selected habitats in Florida wetlands. The pressure gauge and firing angles were used to obtain the desired distance from the transect.

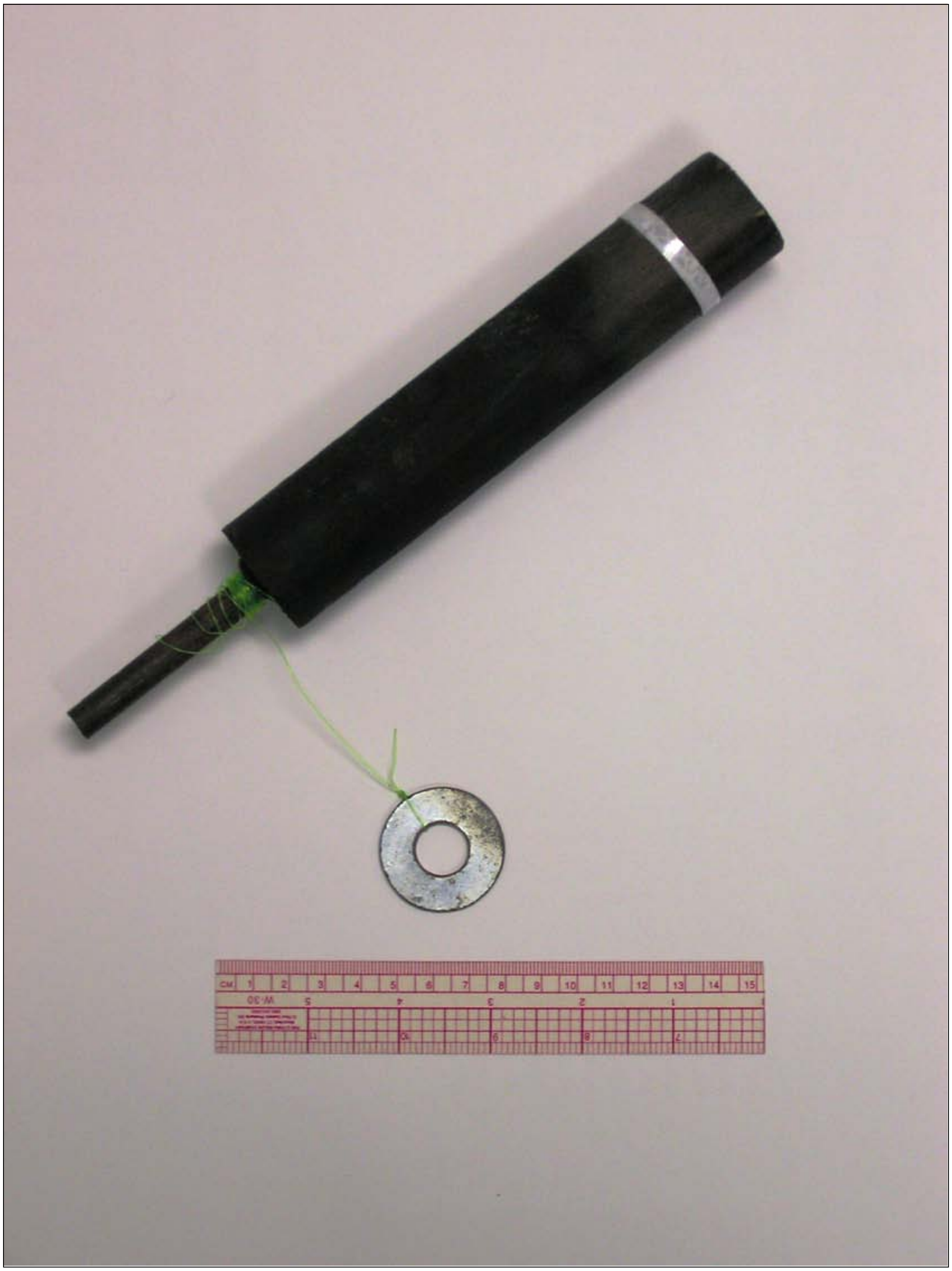

Figure 2-3. Reflective markers used to simulate alligator eye reflections during night-light counts.

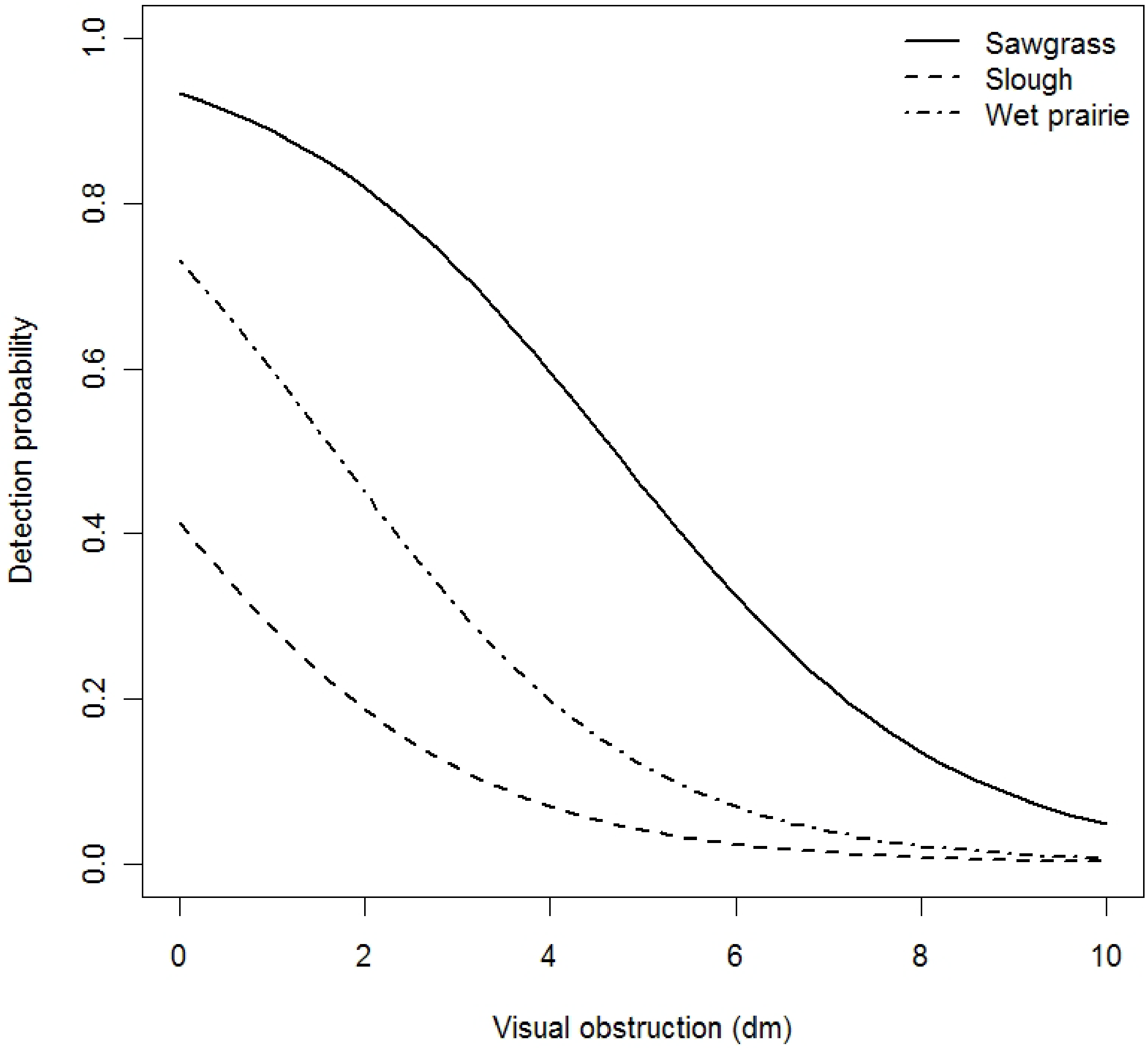

Figure 2-4. Relationship of visual obstruction (VO, dm) on alligator detection probabilities in sawgrass, slough, and wet prairie habitats during night-light counts. All other variables set at minimum values; distance (D = 0 m), vegetation height (VE = 0 cm), water depth (W = 20 cm) and seat height (Seat = 120 cm)

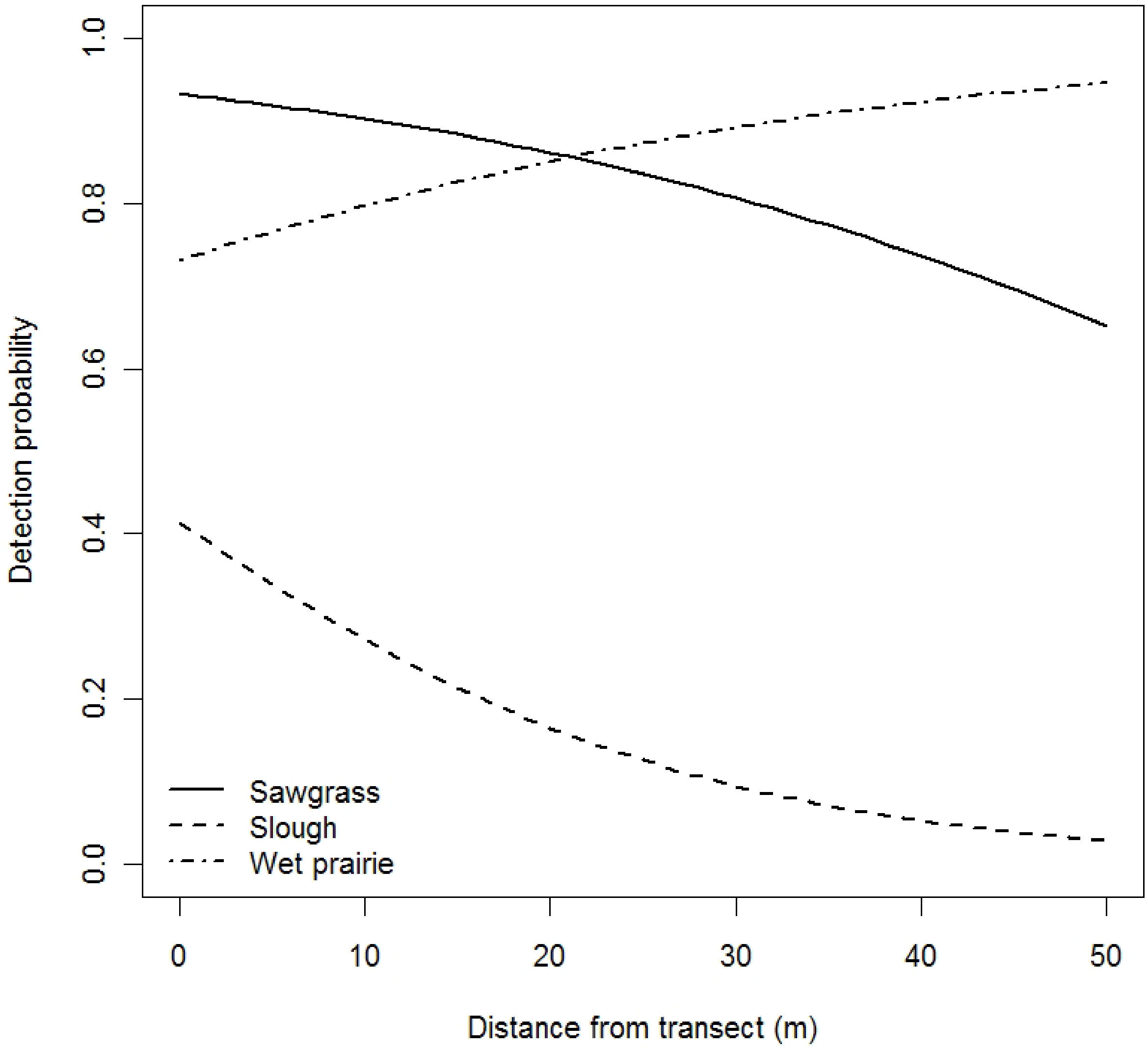

Figure 2-5. Relationship of distance from transect (D, m) on alligator detection probabilities in sawgrass, slough, and wet prairie habitats during night-light counts. All other variables set at minimum values; visual obstruction (VO = 0 dm), vegetation height (VE = 0 cm), water depth (W = 20 cm) and seat height (Seat = 120 cm)

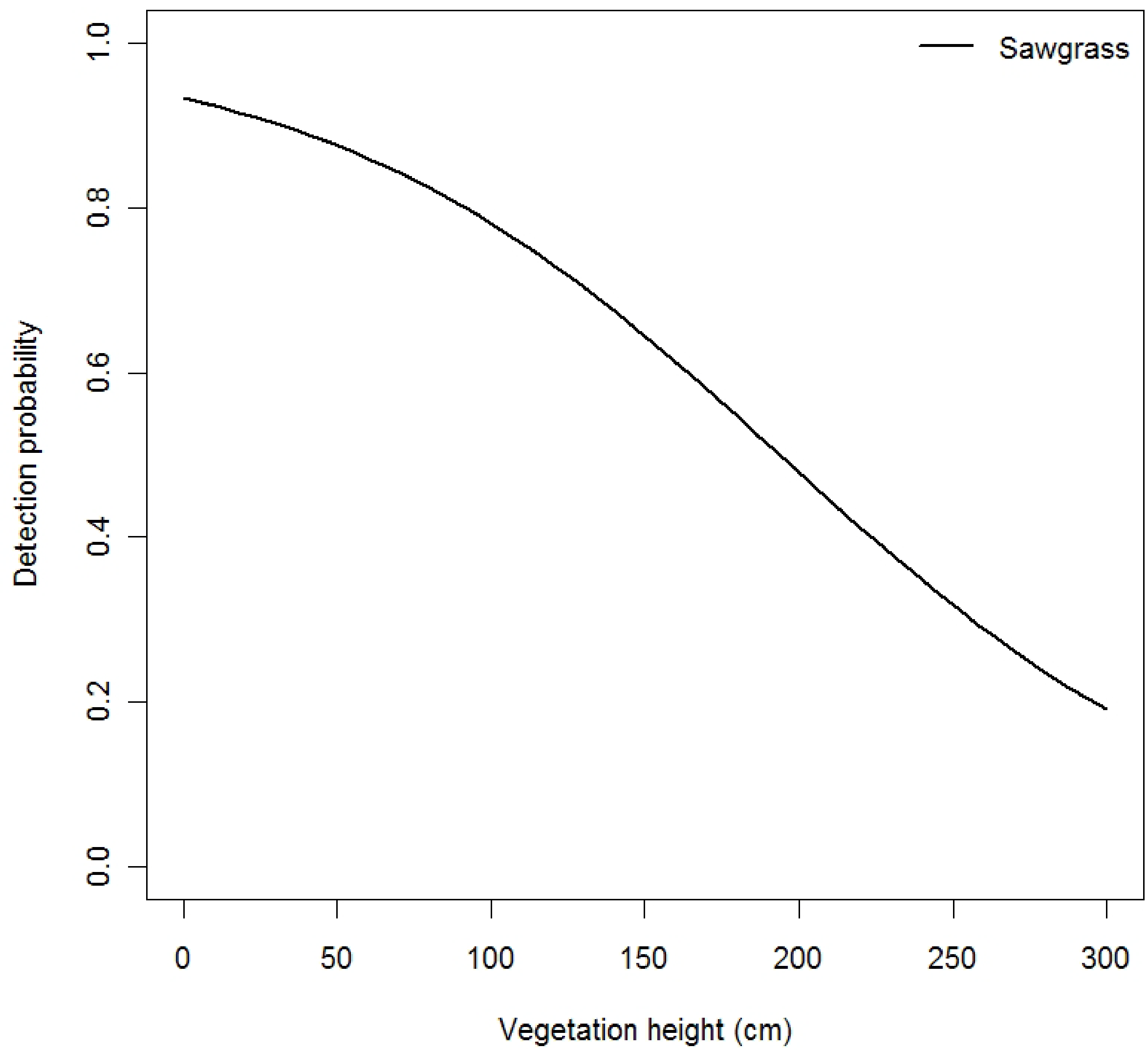

Figure 2-6. Relationship of vegetation height (VE, cm) on alligator detection probabilities in sawgrass habitats during night-light counts. All other variables set at minimum values; visual obstruction (VO = 0 dm), distance (D = 0 m) and seat height (Seat = 120 cm)

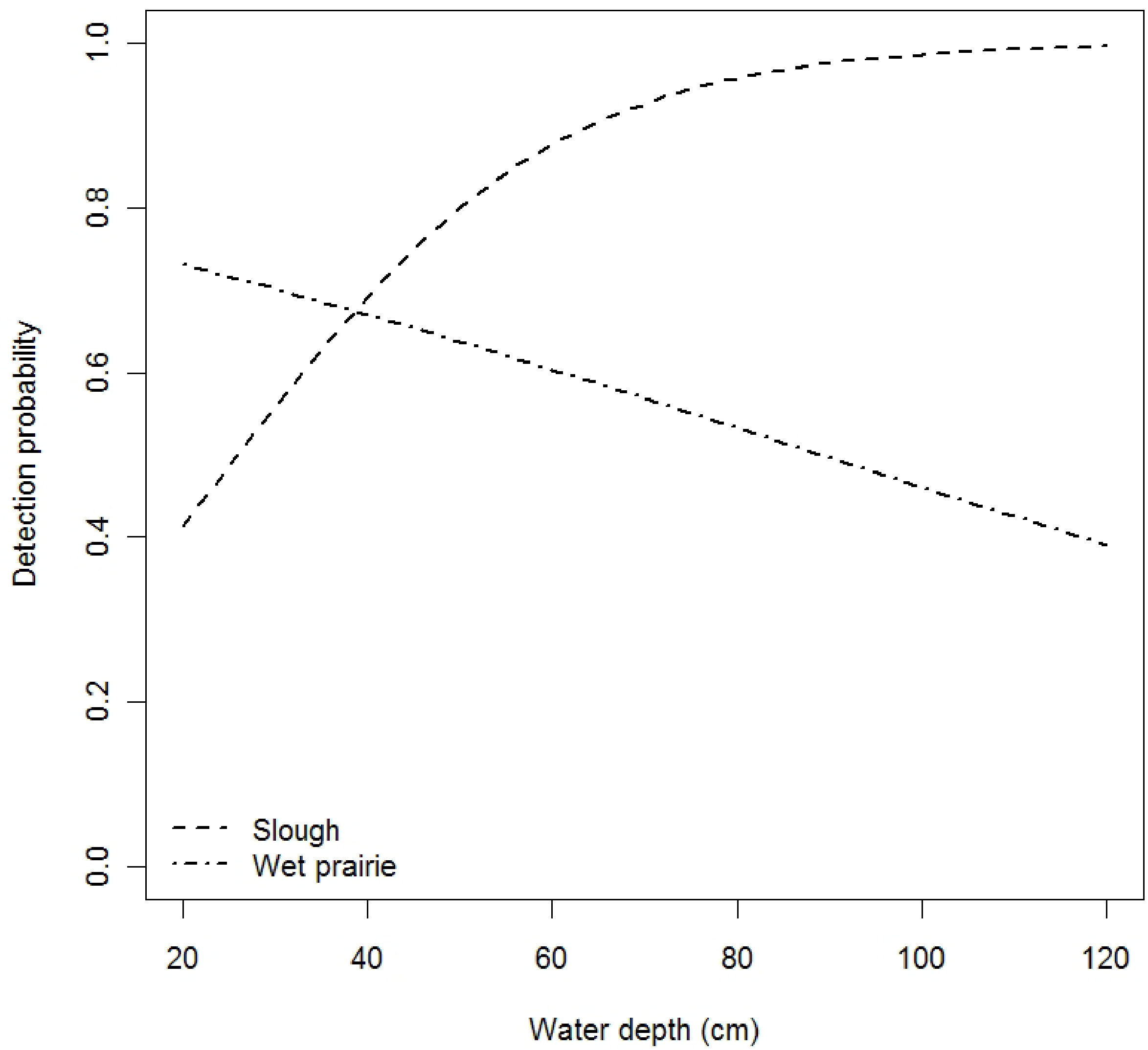

Figure 2-7. Relationship of water depth (W, cm) on alligator detection probabilities in slough, and wet prairie habitats during night-light counts. All other variables set at minimum values; visual obstruction (VO = 0 dm), distance (D = 0 m) and seat height (Seat = 120 cm)

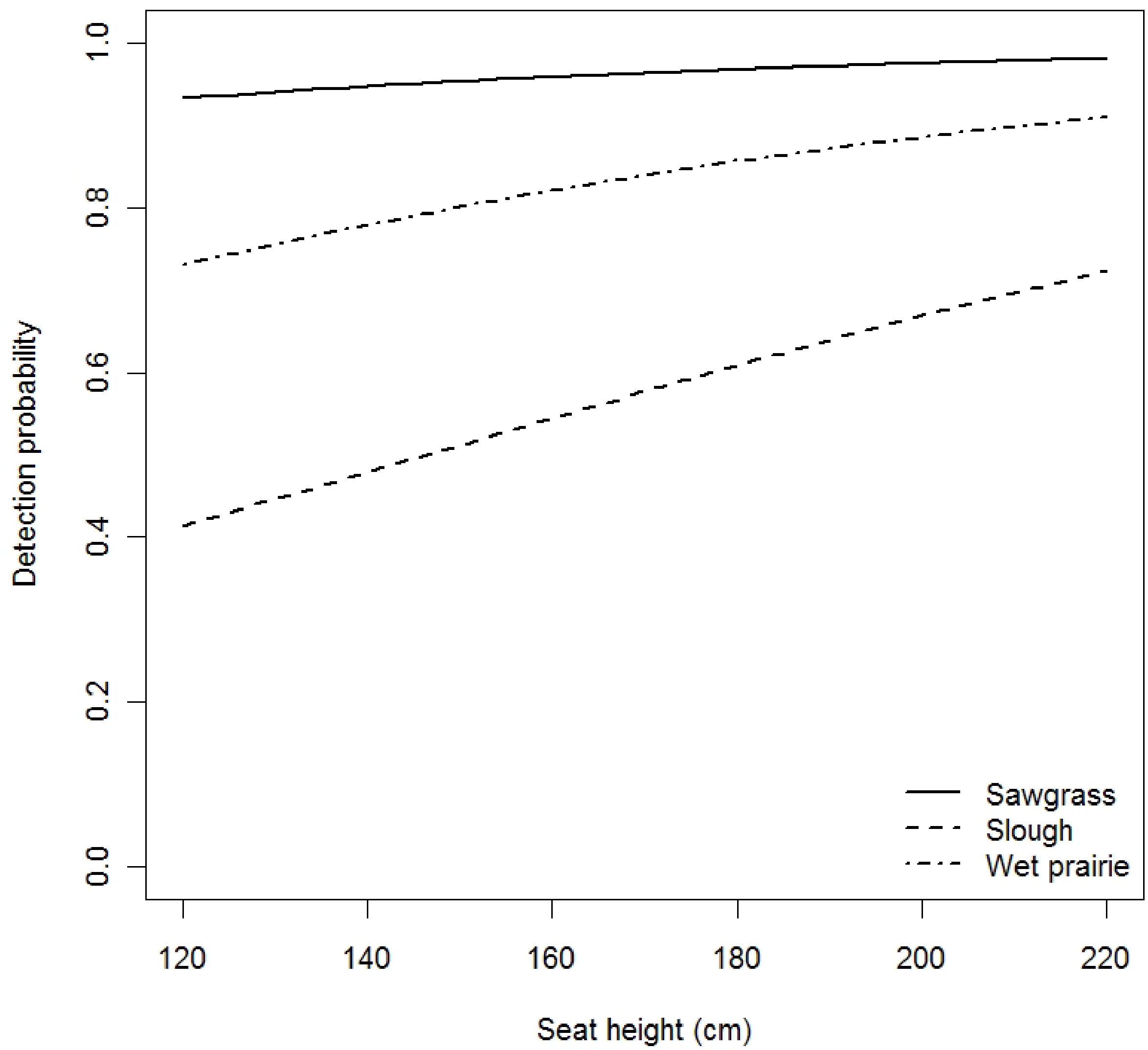

Figure 2-8. Relationship of seat height (Seat, cm) on alligator detection probabilities in sawgrass, slough, and wet prairie habitats during night-light counts. All other variables set at minimum values; visual obstruction (VO = 0 dm), distance (D = 0 m), vegetation height (VE = 0 cm), and water depth (W = 20 cm)

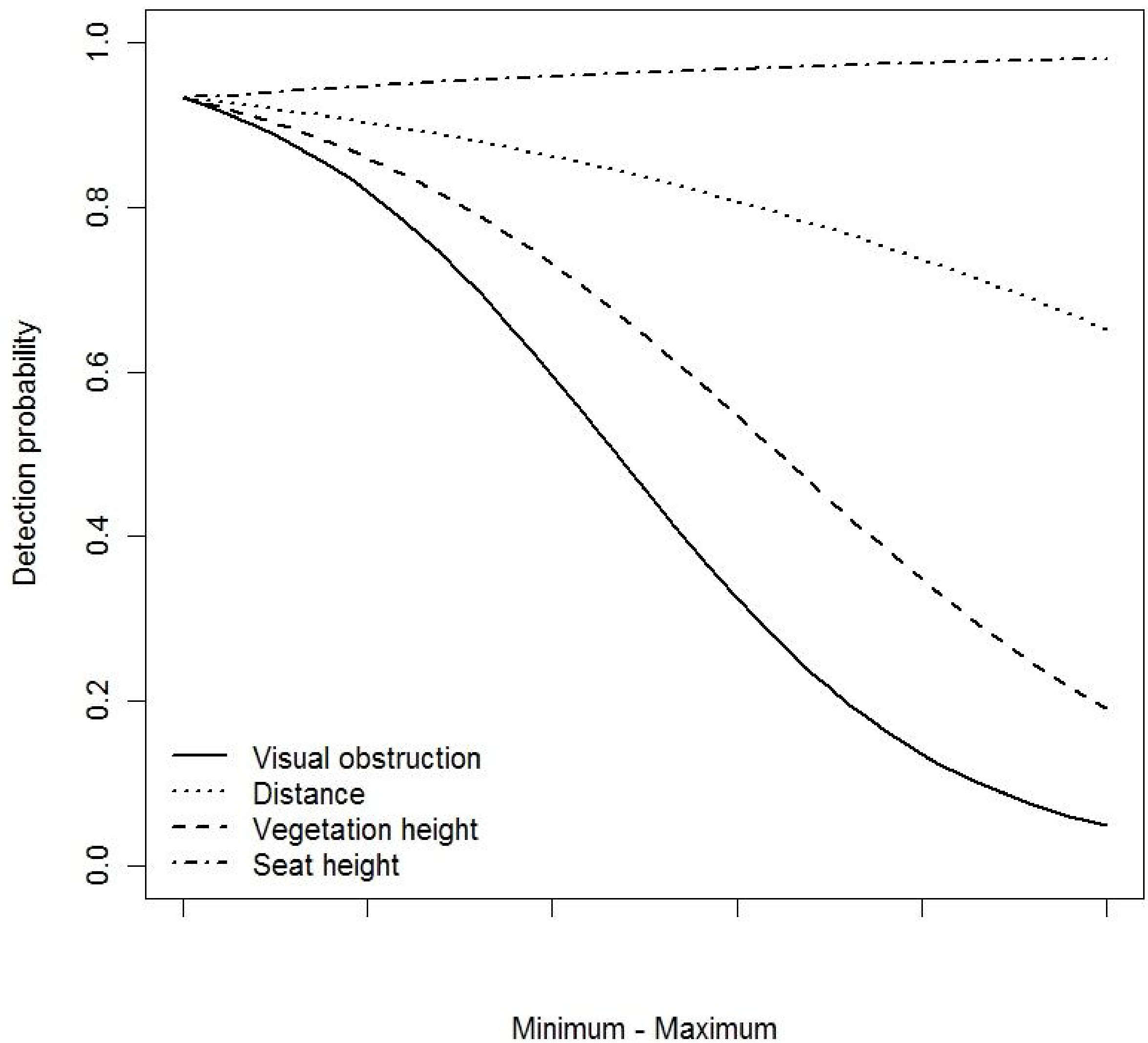

Figure 2-9. Factors affecting alligator detection probabilities during night-light counts in a sawgrass habitat. Mean alligator detection probability for a sawgrass habitat was estimated to be 0.5224. Detectability variables are from minimum to maximum values with others set at minimum values; visual obstruction (0 – 10 dm), distance (0 – 50 m), vegetation height (0 – 300 cm), and seat height (120 – 220 cm).

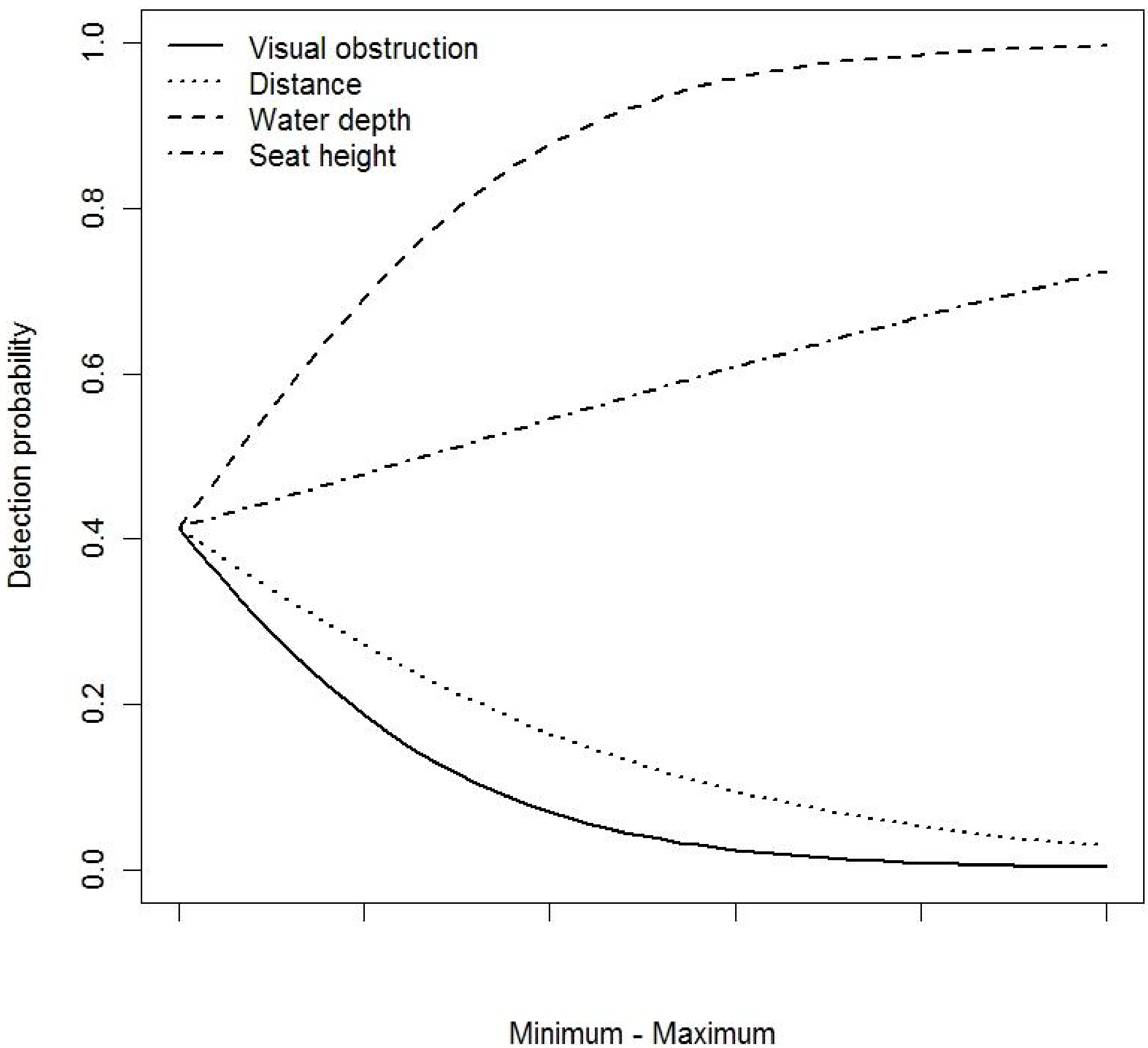

Figure 2-10. Factors affecting alligator detection probabilities during night-light counts in a slough habitat. Mean alligator detection probability for a slough habitat was estimated to be 0.6261. Detectability variables are from minimum to maximum values with others set at minimum values; visual obstruction (0 – 10 dm), distance (0 – 50 m), water depth (20 – 120 cm), and seat height (120 – 220 cm).

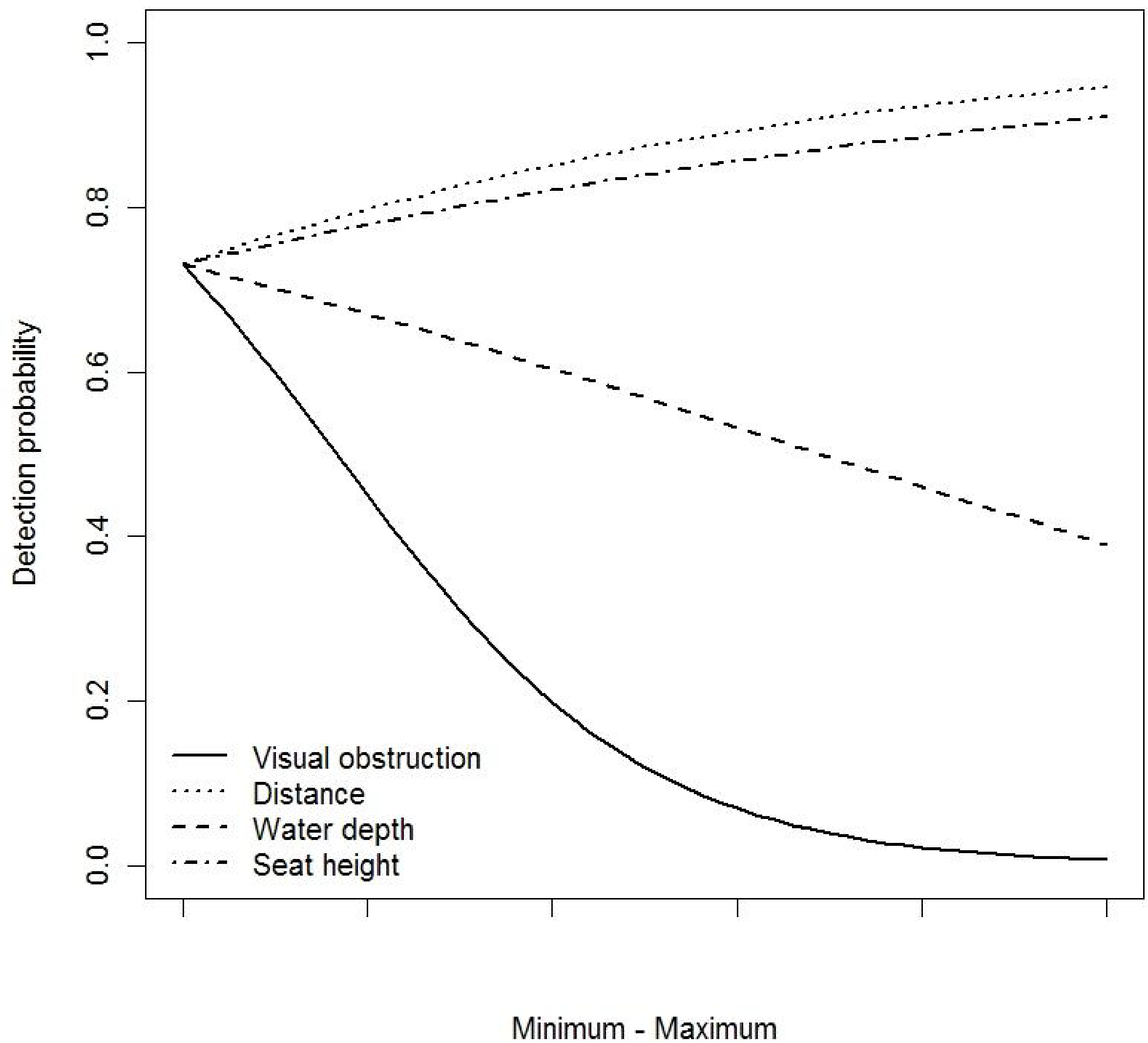

Figure 2-11. Factors affecting alligator detection detection probabilities during night-light counts in a wet prairie habitat. Mean alligator detection probability for a wet prairie habitat was estimated to be 0.5088. Detectability variables are from minimum to maximum values with others set at minimum values; visual obstruction (0 – 10 dm), distance (0 – 50 m), water depth (20 – 120 cm), and seat height (120 – 220 cm).

APPENDIX
APPLICATION OF ALLIGATOR DETECTABILITY MODELS

Alligator detectability

The probability of observing an alligator in a defined population during a night-light survey can be expressed as the product of alligator availability and the probability of detecting an available alligator.

$$P_{total} = P_{available} \times P_{detected} \times P_{other}$$

For this application $P_{available}$ is represented by whether an alligator is emerged (on the surface) or submerged (below the surface), and $P_{detected}$ is represented by the probability an available alligator will be detected in a given habitat (sawgrass, slough, or wet prairie). P_{other} represents factors that may influence detection rates such as environmental variables or observer ability, but have not been quantified, and are not included in the model.

$$P_{total} = P_{available} \times P_{detected} \times P_{other} = P_{emergence} \times P_{habitat} \times P_{other}$$

Alligator emergence model

Bugbee (2008) developed an emergence model to determine the availability of alligators during night-light surveys. The equation for the alligator emergence model is represented below:

$$P_{emergence} = 1 / (1+e\text{^}-((-0.1241) - (0.007 \times hr1) - (0.187 \times hr2) - (0.067 \times hr3) + (0.105 \times hr5) + (0.010 \times hr6) + (0.095 \times hr7) - (0.037 \times hr8) + (0.025 \times hr9) - (0.744 \times AU) + (0.419 \times SP) - (0.190 \times MQ) + (0.060 \times MH) - (0.0085 \times WD) - (0.012 \times WT) + (0.016 \times AT) - (0.003 \times R) - (0.026 \times WI))$$

where hour after sunset equals hr1 to hr9, season equals autumn (AU) and spring (SP), moon phase is quarter moon (MQ) and half moon (MH), water depth (WD) is surface of water to top of substrate, water temperature (WT) at the surface, air temperature (AT), rainfall (R) during survey, and wind speed (WI) during survey. Hr4, summer , and Moon (full) were considered reference values, were assigned values of 0, and were not included in the equation.

To apply the alligator emergence model to a given survey, one should input the values in the above equation. Inputs of 1 or 0 for hour after sunset, season, and moon phase indicate the variable applies (1) or does not apply (0) to a survey. For example if a survey was conducted in the first and second hour after sunset, hr1 and hr2 would get a 1 while hr3 – hr9 would get a 0.

Habitat detectability models

Habitat detectability models were developed for a sawgrass, slough, and wet prairie habitat. The equations for the habitat detectability models are represented below:

$P_{sawgrass} = 1 / (1+e$^-((1.0518) - (0.0400 × D) - (0.5599 × VO) - (0.0136 × VE) + (0.0131 × Seat))

$P_{slough} = 1 / (1+e$^-((-3.0797) - (0.0637 × D) - (0.5599 × VO) + (0.0577 × W) + (0.0131 × Seat))

$P_{wet\ prairie} = 1 / (1+e$^-((-0.2896) + (0.0372 × D) - (0.5989 × VO) - (0.0144 × W) + (0.0131 × Seat))

where distance from transect (D, visual obstruction (VO) or vegetation vertical density, vegetation height (VE), water depth (W) is surface to top of the substrate, and airboat seat height (Seat).

A practical example

Take for example an alligator night-light survey that was conducted in spring under a quarter moon and took three hours to complete. Hypothetical environmental measurements associated with the survey were; 70 cm water depth, 29 C water temperature, 30 C air temperature, 0 cm/hr rain, and a wind speed of 2 km/hr. According to the alligator emergence model, the estimated probability of an alligator emerged would be 0.34. The survey conditions for the sawgrass, slough, and wet prairie habitat, can be assumed the same for these examples.

$P_{emergence} = 1 / (1+e^{-((-0.1241) - (0.007 \times 1) - (0.187 \times 1) - (0.067 \times 1) + (0.105 \times 0) + (0.010 \times 0) + (0.095 \times 0) - (0.037 \times 0) + (0.025 \times 0) - (0.744 \times 0) + (0.419 \times 1) - (0.190 \times 1) + (0.060 \times 0) - (0.0085 \times 50) - (0.012 \times 29) + (0.016 \times 30) - (0.003 \times 0) - (0.026 \times 2))}) = 0.34$

Sawgrass habitat

Hypothetical mean habitat variables associated with the sawgrass habitat were; 22 m distance from transect, 2 dm visual obstruction, 75 cm vegetation height, and an airboat seat height of 160 cm. Therefore the probability of detecting an available alligator in the sawgrass habitat was

$P_{sawgrass} = 1 / (1 + e^{- ((1.0518) - (0.0400 \times 22) - (0.5599 \times 2) - (0.0136 \times 75) + (0.0131 \times 160))}) = 0.51$

The combined estimated detection probability for the alligator emergence model and the sawgrass habitat detectability model were

$P_{total} = P_{available} \times P_{detected} = P_{emergence} \times P_{sawgrass} = 0.34 \times 0.51 = 0.17$

Slough habitat

Hypothetical mean habitat variables associated with the slough habitat were; 22 m distance from transect, 2 dm visual obstruction, 70 cm water depth, and an airboat seat height of 160 cm. Therefore the probability of detecting an available alligator in the slough habitat was

$P_{slough} = 1 / (1 + e^{-((-3.0797) - (0.0637 \times 22) - (0.5599 \times 2) + (0.0577 \times 70) + (0.0131 \times 160))}) = 0.63$

The combined estimated detection probability for the alligator emergence model and the slough habitat detectability model were

$P_{total} = P_{available} \times P_{detected} = P_{emergence} \times P_{slough} = 0.34 \times 0.63 = 0.21$

Wet prairie habitat

The mean habitat variables associated with the wet prairie habitat were; 22 m distance from transect, 2 dm visual obstruction, 70 cm water depth, and an airboat seat height of 160 cm. Therefore the probability of detecting an available alligator in the wet prairie habitat was

$P_{\text{wet prairie}} = 1 / (1 + e\wedge -((-0.2896) + (0.0372\times22) - (0.5989\times2) - (0.0144\times70) + (0.0131\times160)) = 0.62$

The combined estimated detection probability for the alligator emergence model and the wet prairie habitat detectability model were

$P_{\text{total}} = P_{\text{available}} \times P_{\text{detected}} = P_{\text{emergence}} \times P_{\text{wet prairie}} = 0.34 \times 0.62 = 0.21$

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BIOGRAPHICAL SKETCH

Cameron Blair Carter was born on February 5, 1980 in Orlando, Florida. He grew up in Lake Mary, Florida, graduated from Lake Mary High School in 1998. He spent much of his free time, while growing up, exploring the lakes and rivers throughout Florida, where he developed an interest in wildlife. He earned a B.S. in natural resource conservation with a minor in wildlife ecology and forestry from the University of Florida in 2003. Upon graduation in 2003, Cameron began working with the Florida Fish and Wildlife Conservation Commission (FWC) in the Reptiles and Amphibian Research Subsection of the Fish and Wildlife Research Institute. He is currently a Biological Scientist with FWC and focuses on alligator research and management.