A Comparison of Survey Techniques for Medium- to Large-sized Mammals in Forested Wetlands

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Abstract - Monitoring mammals is becoming increasingly important as state and federal agencies develop wildlife action plans addressing increased urbanization and climate-change impacts on plant and animal populations. We designed and implemented surveys applicable to forested wetlands to assess detection rates, estimate species richness, compare species distributions, and assess relative cost versus success among techniques. The survey techniques implemented included opportunistic observations, predator calling, spotlighting, scent stations, camera survey, and foothold trapping. Opportunistic observations produced the highest species-richness estimate (14), and were the least expensive ($0) because they were conducted while implementing other survey techniques. Trapping was the most expensive technique with a cost of $61 per animal detected but provided age structure and population estimates through mark–recapture analysis. Camera survey was relatively expensive with a cost of $1865 for the entire study period but recorded the most detections (n = 673), which resulted in a low per detection cost ($3). Opportunistic observations and camera surveys documented 2 species not detected by any other method. Our results indicate that, although camera survey was a cost-effective way to detect mammals, richness and distribution estimates could be improved by incorporating a variety of monitoring techniques specific to forested wetlands.

Introduction

Monitoring mammals is becoming increasingly important as increased urbanization affects their populations (Bradley and Altizer 2007, Lawler et al. 2009). Many medium- to large-sized mammals (e.g., *Ursus americanus* Pallas [American Black Bear], *Lynx rufus* Schreber [Bobcat], *Odocoileus virginianus* Zimmermann [White-Tailed Deer], *Procyon lotor* L. [Raccoon], etc.; hereafter "mammals") can serve as indicators of ecosystem health, regulators of prey populations, prey for other mammals and raptors, and fulfill important roles in the ecosystem such as seed dispersal (Boddicker et al. 2002, Gaidet-Drapier et al. 2006, Sanderson and Trolle 2005). Further, research has demonstrated the abilities of mammals to dramatically alter vegetation composition, nutrient cycling, and plant productivity (Augustine and McNaughton 1998, Boddicker et al. 2002, Hobbs 1996, Nowak 1991). Some mammals are difficult to monitor due to their cryptic habits or low population densities, resulting in few long-term monitoring efforts. Lack of information on many animal

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assemblages and lack of reliable estimates of population sizes restrict managers from implementing and evaluating land-management strategies (Caughley and Sinclair 1994, Desbiez et al. 2010, Sutherland 2000). Hence, many state and federal agencies have recently developed wildlife action plans that focus on mammals as representatives for health of ecological communities (AFWA 2012, USFWS 1981). Even so, time and cost constraints may discourage managers and landowners from implementing mammal surveys (Sheil 2001). Therefore, landowners need information that allows them to weigh the costs and benefits of implementing surveys.

The Southeast region of the United States contains over 12,000 km^2 of unique, forested wetlands important for wildlife conservation (Dahl and Stedman 2009). However, over 650 km^2 of forested wetlands in the region were lost to development or converted to agricultural uses between 2004 and 2009 (Dahl and Stedman 2009). Forested wetlands in some parts the Southeast have been altered by systems of raised roads bordered by 5–10-m-wide canals. While road systems allow distinctly greater access than available in unaltered forested wetlands, access to tracts of land away from roads is difficult and time consuming. Further, seasonal flooding and changing water levels prohibits use of random survey locations. Hence, forested wetlands provide unique challenges for land managers who aim to develop long-term–monitoring techniques for mammals.

Standardizing large-scale, multi-species monitoring efforts is necessary to effectively assess mammal communities (Zielinski and Kucera 1995). Reviews of survey techniques demonstrate the need for using more than one survey type to detect diverse species (Gompper et al. 2006, Harrison 2002, Hutchens and DePerno 2009, Lyra-Jorge et al. 2008). Further, different techniques allow for collection of different data, and the use of 1 technique alone may limit inference about populations of interest. For example, spotlight surveys can be used for abundance indices or density estimates where distance sampling is possible (Edwards et al. 2000, McCullough 1982, Naugle et al. 1996, Ruette et al. 2003), whereas automatic cameras can provide data for calculating abundance estimates when animals are individually marked (Carbone et al. 2001, Heilbrun et al. 2006, Karanth 1995, Karanth and Nichols 1998, Maffei et al. 2011, Silver et al. 2004).

Land managers need a cost-effective, long-term, spatially explicit protocol for monitoring mammal populations in forested wetlands to assess the impacts of harvest and habitat manipulation and to ensure stable populations. Therefore, our objectives were to assess detection rates, determine species-richness estimates, compare species distributions , and assess cost versus success among techniques. The survey techniques implemented were opportunistic observations, predator calling, spotlighting, scent stations, camera surveys, and foothold trapping.

Field-site Description

From 2007 to 2010, we conducted surveys at Bull Neck Swamp Research Forest (hereafter "Bull Neck"; Fig. 1), a 25-km^2 wetland located on the south side of Albemarle Sound in eastern North Carolina (35°56´–35°59´S, 76°23´–76°28´E). Bull Neck is an economically self-sustaining, working forest with active, smallscale timber harvests, prescribed burning, and hunting. It is owned by North Carolina State University and managed by the Fisheries, Wildlife, and Conservation Biology Program. Access to Bull Neck is restricted. The property is a forested wetland with secondary and tertiary dirt roads bordered by canals and has 5 land-cover types: non-riverine swamp forest, peatland *Chamaecyparis thyoides* L. (Atlantic White-cedar) forest, mesic mixed-hardwood forest, tidal cypress–gum swamp, and tidal freshwater marsh. Based on 50-year climate records, monthly mean temperatures ranged from 10.4 °C to 21.7 °C and rainfall averaged 126.5 cm per year (NOAA 2009).

Methods

We followed survey design suggestions by Zielinski and Kucera (1995). We used Arc GIS to overlay a grid of 2.6-km^2 cells onto a map of the property (Fig. 2). We assigned to each cell (n = 9) 2 scent stations, 1 camera station, and 1 predator-calling station (Fig. 2). Live-trap locations ranged from 6 to16 traps per cell, based on areas with abundant mammal sign. We conducted spotlight surveys across the property on drivable roads and recorded and placed detections in the appropriate cell post-hoc (Fig. 2). To assess cost of surveys, we recorded personnel hours for each method, set labor cost at the then current federal minimum wage rate of \$7.25 per hour, and recorded costs of supplies and equipment in 2010 dollars.

We recorded opportunistic encounters of mammals on the property while conducting other surveys. To prevent double counting, we assigned detected animals to 1 survey technique and did not record sightings or captures as opportunistic during

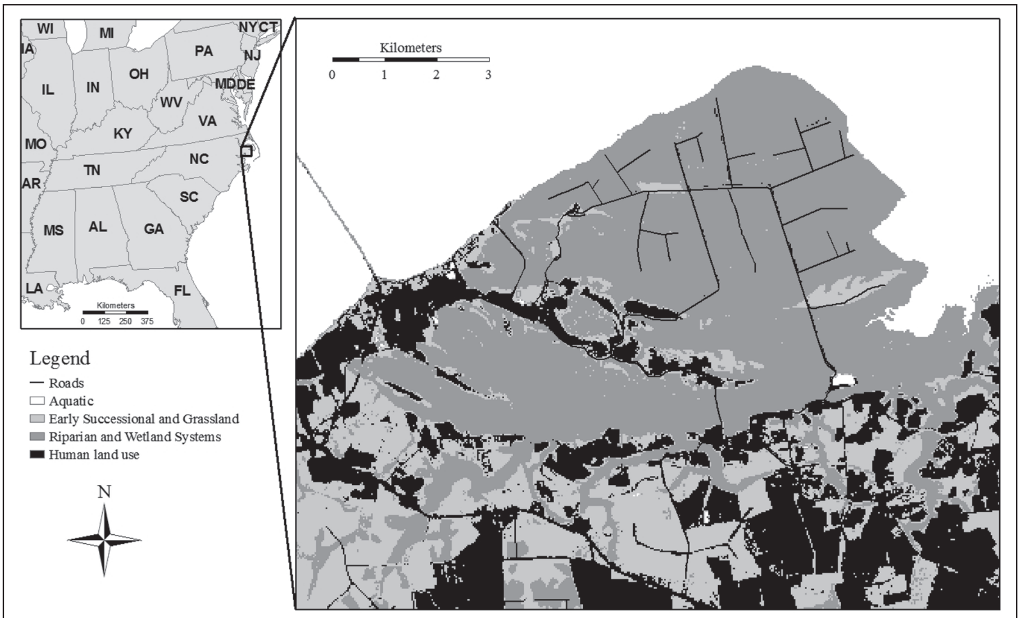

Figure 1. Land-cover types on Bull Neck Swamp Research Forest and surrounding areas in North Carolina, 2007.

spotlighting, predator-calling, and trapping surveys when they were included as detections for that survey. At each opportunistic encounter, we recorded the species, date, time, location, and number of individuals. We did not quantify equipment and labor costs for the opportunistic technique because we recorded observations while researchers performed other survey techniques, which required no additional cost. We made the assumption that a majority of land managers spend a considerable amount of time on their property and could record opportunistic observations at no additional cost.

We conducted predator-calling surveys at dawn and dusk in 1 location per cell twice per month (Fig. 2) in June, July, and August of 2007. We concealed observers in a portable blind and used a rabbit distress call (Primos Ki-Yi™, Flora, MS) at 5-minute intervals as a lure, monitoring the area with binoculars for 45 minutes. Predator calling equipment included a blind, binoculars, distress caller, and ATV fuel and mileage. Labor costs included 2 technicians working 10 hours per month.

We conducted spotlight surveys on a fixed 19.3-km route every 2 weeks for 2 consecutive nights from June to September 2007. If rain was forecasted, we performed the survey on the next rain-free night. We repeated counts to reduce estimate variability (McAninch 1995) and randomized the start time between 20:30

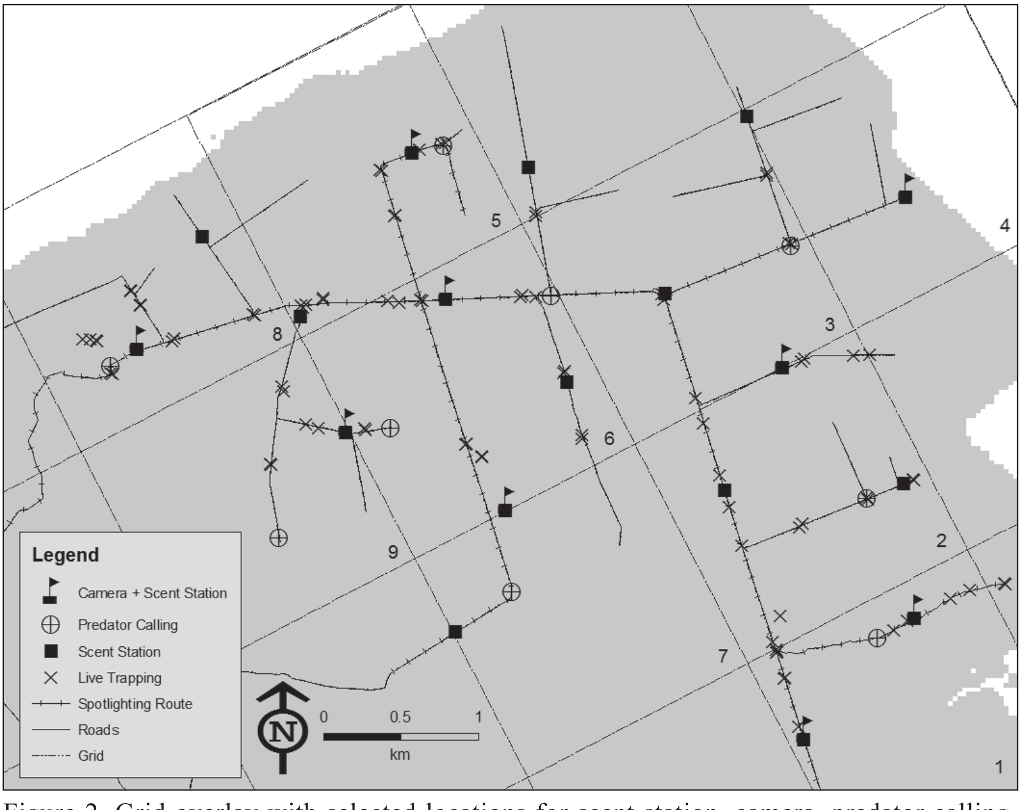

Figure 2. Grid overlay with selected locations for scent station, camera, predator calling, trapping, and spotlight surveys at Bull Neck Swamp Research Forest, NC, 2007. The assigned cell number is marked in the bottom right corner of each cell.

and 02:30 hrs to ensure independence. We surveyed all secondary roads (Fig. 2) by driving 8 km/h with 2 observers in the back of the vehicle with a 2,000,000-candlepower spotlight. We used binoculars as needed to assist in identifying mammals observed and recorded observer names, species observed, date, time, location, overnight temperature, visibility, precipitation, and comments (e.g., eyeshine color, number of individuals). Presence of canals along roads prevented measuring distances for sightings. Equipment costs included fuel, mileage, and spotlights. Labor costs included 3 technicians working 4 hours per night, 4 nights per month.

We trapped mammals with #1.5 Victor® Soft Catch® foothold traps (Oneida Victor, Euclid, OH), set with a 0.91-kg pan-tension from 01 March to 09 March 2008. Trap size was selected to target medium-sized mammals (e.g., *Urocyon cinereoargenteus* Schreber [Gray Fox]). We set up to 85 traps per night in locations with animal sign (e.g., trails through vegetation, latrines) and activity based on preliminary data from camera and scent-station surveys (Fig. 2). Costs included foothold traps, lures, trowels, sifters, shovels, catch poles, and hatchets. In addition, we included fuel and mileage for 2 trucks and 3 ATVs as equipment costs and 3 technicians working 8 hour days for 10 days as labor costs. Trapped Bobcats were radio-collared (Rockhill et al. 2011, 2013) and ear-tagged as part of a concurrent study; all animals were released at the capture location immediately following processing.

We monitored scent stations in June, July, and August of 2007. To minimize misdetections and to maximize visitations, we used a 0.6-m-wide scent-station strip to connect two 1 m x 1 m scent stations placed 3 m apart on opposite sides of secondary and tertiary roads. We cleared the stations and connecting strip of all vegetation and used a mixture of play sand and mineral oil to preserve tracks. A visual attractant (i.e., fake feathers, silver tassels) was stapled approximately 0.1 m from the top of an 0.8-m wooden stake placed in the center of each station and a cotton ball was stapled to the top of each stake. Gray Fox urine was placed on the cotton ball on one station and sardine oil on the cotton ball on the opposite station. Stations were set and checked for 4 consecutive days each month. When not in use, we removed stakes and scent lures from the stations. We determined if lures used affected detections at scent stations and if species were detected more or less than expected using contingency table analysis (SPSS Statistics for Windows; IBM Corp. 2013) with alpha set at $P < 0.05$. To be consistent with standard methodologies, we randomly selected results from one of each paired scent stations to estimate a density index for comparison with other survey techniques. Scent-station equipment costs included sand, mineral oil, scent, lures, stakes, cotton balls, rulers, camera, and ATV fuel and mileage. For labor costs, we included 2 technicians working an average of 8 hours per day for 4 days per month.

We placed 1 digital camera (Capture 3.0; Cuddeback Digital, DePere, WI) equipped with an infrared sensor triggered by temperature and movement at 9 of the 18 scent stations (Fig. 2). Cameras were mounted to trees at a height that placed the sensor 0.2–0.3 m above the ground. Initial angle placement was parallel to the road, after which we conducted walk tests from 1 m to the opposite side of the road (~10 m) and adjusted the camera angle to maximize detections. Although cameras were monitored continuously for 3 years, data presented are from June, July, and August of 2007. We programmed cameras to run 24 hours per day, taking pictures once per minute when activity was detected. When batteries failed, we reduced the number of camera days accordingly. Equipment costs for this survey included cameras, USB cards, replacement batteries, download accessories, and ATV fuel and mileage. Labor costs included 1 technician to check all cameras, download, and record images, with all activities combined estimated to total 7 hours per month.

For all techniques, we assessed detection rate (total number of detections per species), species richness (number of species detected per survey method), and the cost and effort of performing each technique in relation to detection of species. Species distribution (percent of cells, $n = 9$, where each species was detected) was quantified for camera surveys, scent stations, trapping, camera surveys + opportunistic observations, scent stations + opportunistic observations, and all techniques combined. We were unable to estimate species distribution from spotlight surveys, predator calling, and opportunistic encounters due to small numbers of detections. To assess cost versus success of each technique, we quantified total equipment and labor costs, calculated a total monthly cost, and determined the number of monthly detections as well as hours of labor per detection.

All animal-handling techniques were approved by the Institutional Animal Care and Use Committee at North Carolina State University (08-012-O) and followed guidelines provided by the American Society of Mammalogists (Gannon and Sikes 2007) and ASAB/ABS Guidelines for the Use of Animals in Research.

Results

We recorded a total of 1010 mammal detections representing 15 species across all surveys (Table 1). Opportunistic observations accounted for the highest number of species ($n = 14$), and predator calling detected the lowest number of species ($n = 2$). Cameras recorded the second highest number of species ($n = 12$) and had the highest number of detections ($n = 653$), although 63% of the detections were of American Black Bear. No single technique detected all species identified by all survey techniques combined (Table 1). *Mustela vison* Schreber (American Mink) was only detected by opportunistic observations and *Sus scrofa* L.(Feral Hog) was only detected with the camera survey. Gray Fox was the only species detected by all surveys. *Castor canadensis* Kuhl (American Beaver) was detected infrequently regardless of technique.

Trapping was successful in capturing 5 species. We had 10 total captures of 7 individual Bobcat; 2 males (1 adult, 1 juvenile) and 5 females (1 adult, 4 juvenile). We captured Gray Fox (7 male, 10 female), Raccoon (14 male, 3 female, 4 unknown), *Didelphis virginiana* Kerr (Virginia Opossum) (7 male, 4 female, 6 unknown) and a *Canis lupus familiaris* L. (Domestic Dog).

Lures used did not affect detections at scent stations ($\chi^2 = 10.14$, df = 8, $P = 0.2553$). We detected American Black Bear more than any other species, and over half of the detections were in the center strip only (Fig. 3). Center-strip only detections were observed 32.3% more than expected and would have been missed with a standard scent-station design (Table 2). American Black Bear was the only species detected less than expected (-36.1%) at the urine stations while Bobcat had the highest deviation from expected values (+50.9%) at urine stations (Table 2). Gray Fox, Virginia Opossum, and Raccoon tended to investigate urine stations at higher rates than expected, but their presence at one of the sections often resulted in presence at all 3 sections of the station (Table 2, Fig. 3).

Scent stations were successful at detecting Raccoon across the entire property. Further, distribution of species was documented more thoroughly (i.e., recorded in more cells) with scent stations. Otherwise, detection of species across the entire property was only possible by combining techniques (Table 3). For example, Virginia Opossum were detected in 4 of the 9 cells with camera surveys, but a combination of all survey techniques was required to detect them across all 9 cells. Combining data from scent stations, cameras and live traps resulted in detection in all cells for Black Bear, Gray Fox, Virginia Opossum, and Raccoon.

Table 1. Detection rate (total number of detections per species) by survey technique at Bull Neck Swamp Research Forest, NC, 2007. Opport. observ. = opportunistic observations. Total number of techniques successful at detecting each species is denoted in the far right column.

Species	Camera survey	Predator call	Scent station	Spotlighting	Trapping	Opport. observ.	Total techniques
American Beaver	-	-	1	-	-	1	2
American Black Bear	408	-	35	12	-	13	4
Bobcat	17	1	8	-	10	1	5
Domestic Cat	1	-	3	-	-	1	3
Domestic Dog	15	-	1	-	1	3	4
Feral Hog	1	-	-	-	-	-	1
Gray Fox	122	1	29	3	19	4	6
American Mink	-	-	-	-	-	1	1
Muskrat	-	-	4	-	-	3	2
Nutria	5	-	-	4	-	4	3
Rabbit	1	-	1	1	-	1	4
Raccoon	25	-	33	1	19	9	5
River otter	1	-	-	-	-	3	2
Virginia Opossum	14	-	26	4	17	1	5
White-Tailed Deer	43	-	1	34	-	43	4
Total captures	653	2	142	59	66	88	1010
Species richness	12	2	11	7	5	14	15

Table 2. Percent deviations between sardine, center-strip, and urine scent stations for each mammal species estimated from contingency-table analysis based on scent-station surveys conducted at Bull Neck Swamp Research Forest, NC, 2007–2008. Standard residuals are presented in parentheses.

Species	Sardine	Center-strip	Urine
Black Bear	+6.5 (+0.28)	+32.3 (+1.59)	-36.1 (-1.81)
Bobcat	-19.5 (-0.31)	-37.5 (-0.67)	+50.9 (+0.93)
Gray Fox	-17.4 (-0.69)	-1.3 (-0.06)	+14.4 (+0.66)
Opossum	-0.6 (-0.02)	-11.8 (-0.5)	+11.8 (+0.51)
Raccoon	+19.6 (+0.54)	-16.3 (-0.96)	+16.2 (+0.47)

Trapping had the highest overall cost ($4024) and highest cost per species ($805; Table 4). Due to high equipment and labor costs, total cost per capture was $61. Trapping targeted specific mammals, which resulted in low species richness (n = 5), and was labor intensive, requiring a high number of hours (1.21) per species. Scent-station surveys were relatively inexpensive ($369/month), had the second lowest cost per species detected ($34; Table 4), and the second lowest total cost per detection ($8) and hours of labor needed per species observed (0.68). Of all techniques that allowed calculation of detection rates, camera survey had

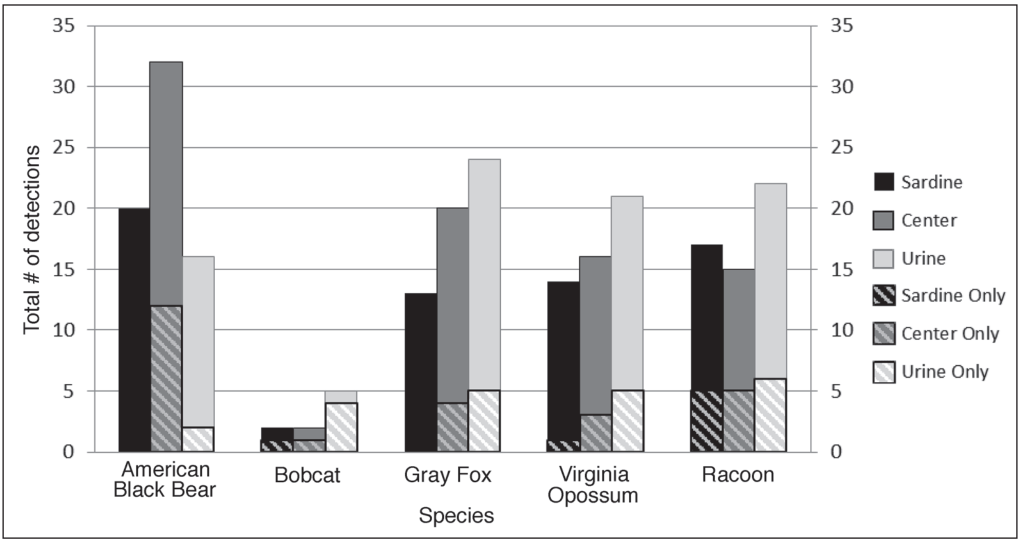

Figure 3. Total number of detections at sardine oil, center, and Gray Fox-urine scent stations at Bull Neck Swamp Research Forest, NC, 2007. The dashed portion of each bar represents the number of detections that were exclusively recorded at that section of the scent station.

Table 3. Distribution of mammal species detections by the most successful of the survey techniques and combinations of techniques used at Bull Neck Swamp Research Forest, NC, 2007.

Species	Trapping	Camera surveys	Scent stations	Opport. observ.	Camera surveys + opport. observ.	Scent stations + opport. observ.	All techniques combined
American Beaver	0	0	11	11	11	22	11
Black Bear	0	89	89	56	100	100	100
Bobcat	44	56	56	11	56	56	78
Domestic Cat	0	0	22	11	11	33	22
Domestic Dog	11	33	11	22	33	33	44
Gray Fox	78	78	78	78	78	78	88
Muskrat	0	0	33	22	22	44	33
Nutria	0	22	0	11	22	11	22
Rabbit	0	11	11	11	11	22	22
Raccoon	67	67	100	56	67	100	100
Virginia Opossum	67	44	89	11	56	89	100
White-Tailed Deer	0	67	0	89	100	100	67

the lowest cost per detection ($3; Table 4), and most of the cost accrued was for equipment and initial setup ($1865), resulting in a cost per species observed of $56. Monthly maintenance and data processing was inexpensive ($51) compared to other techniques and required only 0.01 hours of labor per detection. Opportunistic observations had no costs and documented 1 species (Mink) not detected with any other technique (Table 1).

Opportunistic observations, which add no extra cost, combined with cameras detected all species and together resulted in the most total detections (Tables 1, 3, 4). Opportunistic observations combined with scent stations detected all but Feral Hog and had the second most total detections, again without adding cost. While camera surveys combined with opportunistic observations constituted the best detection rate, scent stations combined with opportunistic observations was the most cost effective (Tables 1, 3, 4).

Discussion

Through this study, we compared various survey techniques and assessed each technique for performance in terms of estimates of detection rates, species richness, and species distribution, and for cost-effectiveness. Further, we provided additional species-specific information on the study property, Bull Neck. Nine mammal species had been documented on the property prior to our survey, and this study documented 6 additional species (Bobcat, Feral Hog, American Mink, *Myocastor coypus* (Molina) [Nutria], *Felis catus* (L.) [Domestic Cat], and Domestic Dog). Although we could not compare detection rates for any single species across all survey techniques, we could compare detection rates across an area within a survey technique, assuming no spatial variation in detection probability. Interestingly, no techniques produced consistently high or low estimates for all species in the same cells, indicating that spatial detection varied by technique and a combination of techniques would be necessary to accurately record presence and distribution of species on a property (Table 3).

Camera and scent-station surveys were the most effective techniques for surveying mammals in forested wetlands; both techniques recorded the majority of species and when used together detected all but one species (i.e., Mink). Scent stations were relatively economical and required minimal implementation efforts

Table 4. Labor hours and monthly costs for each survey technique used to detect mammal species at Bull Neck Swamp Research Forest, NC, 2007–2008. All costs are in U.S. dollars ($).

	Total cost			# of	# of	Hours of
Survey technique	Equipment	Labor	Monthly	species observed	detections per month	labor per detection
Opportunistic observations	0	0	0	14	29	0.00
Spotlighting	166	1044	403	7	20	0.81
Trapping	2284	1740	4024	5	66	1.21
Scent station	411	696	369	11	47	0.68
Camera survey	1865	152	672	12	224	0.01
Predator calling	268	435	234	2	1	15.00

for establishment and monthly monitoring (Conover and Linder 2009); nonetheless, that technique may produce low detection rates for some species (i.e., Bobcats; Harrison 2002). Cameras had high upfront cost, though the relatively low operational expenses result in relatively economical costs for long-term monitoring efforts (Dajun et al. 2006, Lyra-Jorge et al. 2008, Nichols et al. 2011, O'Connell et al. 2011, Silveira et al. 2003). We detected few aquatic mammals with these 2 techniques, and surveys designed specifically for their detection would be an ideal inclusion to mammal-monitoring protocols (O'Connell et al. 2011).

Although not as effective as camera and scent-station surveys, other methods provided useful data that were either species specific or expanded distributional data. Spotlight surveys were effective for detecting White-Tailed Deer but were not a realistic option for density estimates due to low detection rates and extensive canals posing logistic difficulties (Focardi et al. 2001, McCullough 1982, Naugle et al. 1996). Because distance sampling is a benefit of spotlight surveys and roads bordered by canals are characteristic of managed coastal wetlands, this survey technique is not recommended in forested wetlands. Although predator calling allowed us to detect elusive carnivores, the low numbers of individuals and species observed prevented us from estimating species richness, distribution, and detection rates. While implementing trapping may be too expensive for annual use, it increased our knowledge of the abundance and distribution of furbearers. We, therefore, recommend including trapping surveys when feasible, or obtaining data from trappers. Opportunistic encounters resulted in the highest species richness estimates at the lowest cost.

Managers have come to rely nearly exclusively on camera surveys for monitoring species abundance and distribution (Ahumada et al. 2011, O'Connell et al. 2011). Our results are consistent with previous studies that report the need to employ multiple survey techniques to monitor species richness and composition accurately (Gompper et al. 2006, Harrison 2002, Hutchens and DePerno 2009, Lyra-Jorge et al. 2008). No single technique is ideal for surveying medium- to large-sized mammals (Gompper et al. 2006). For example, scent stations had a high rate of missed detections, as shown through the center-strip data, whereas cameras were less efficient at detecting smaller mammals (e.g., American Mink, *Ondatra zibethicus* (L.) [Muskrat]). While cameras may be appropriate for monitoring the distribution or populations of some species, we caution against depending solely on camera surveys to make inferences on mammal presence or absence, distribution, and richness; we suggest that a number of techniques be used for maximum accuracy.

A lack of information on the time and cost constraints associated with monitoring mammals in forested wetlands has limited land managers from implementing surveys (Sheil 2001). We urge land managers to implement a combination of survey techniques to provide the greatest amount of information at the lowest cost. If sufficient funds and resources exist, we recommend a combination of all survey techniques to produce the greatest amount of information. Realistically, budget and time constraints limit land managers from implementing all survey techniques reported. If budget limited, scent stations are sufficient in providing baseline data on species distribution and diversity (Conover and Linder 2009). If adequate upfront funds exist, we suggest combining camera surveys with recorded opportunistic observations; assuming managers spend adequate time on the property in addition to monthly camera checks. In general, managers will need to decide which techniques best meet their objectives while understanding the limitations of each technique.

Acknowledgments

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