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Madison, Wisconsin: Wisconsin Dept. of Natural Resources, Bureau of Integrated Science Services, [2001]

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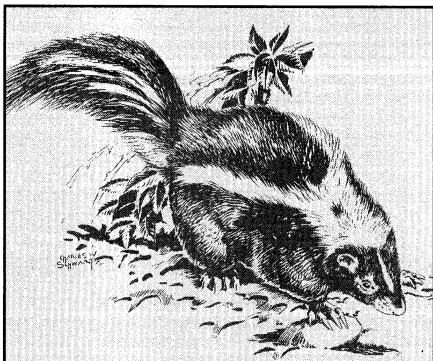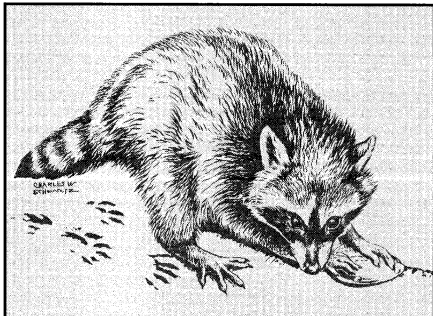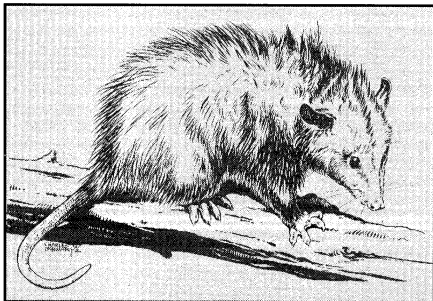
Evaluation of Abundance Indices for Striped Skunks, Common Raccoons and Virginia Opossums in Southern Wisconsin

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Abstract

We compared mark-recapture estimates of predator population sizes to 5 commonly used abundance indices to gain insight into the usefulness of the indices for monitoring predator population changes. Striped skunks (*Mephitis mephitis*), common raccoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*) were trapped on 3 approximately 6-mile^2 areas in southern Wisconsin during March-May, 1984-86 to estimate population densities. Spotlight counts, modified scent stations, simulated nests, snow-track counts and road-kill surveys were conducted February-June, 1984-86 on the 3 study areas as indices to abundance. Data from snow-track counts and road-kill surveys were not sufficient for analysis. Low capture probabilities (usually less than 15%) made model selection difficult for all species and resulted in wide confidence intervals for raccoon population estimates. Minimum density of skunks, raccoons and opossums varied from 0.2-4.5, 5.3-13.9 and 2.3-7.1/mile^2, respectively. Correlations between population indices and population density estimates were not significant in many cases. Only the correlation of opossum spotlight counts with density and the correlation of simulated-nest destruction rate with skunk density were significant. However, the destruction rate of simulated nests was highly correlated with the capture rate of all mammalian predators, and the correlation between skunk visitations to scent-station lines and capture rate was significant. The lack of significant correlation does not invalidate the indices due to the low power of the tests and the low precision of the indices and raccoon population estimates. As we applied them, spotlight counts, scent-station surveys and simulated-nest surveys required extremely large sample sizes to reliably detect annual changes in population indices on the order of 20 to 50%. However, we did observe significant differences between years in the three indices with sample sizes of 15-30 (areas pooled), when changes in population indices were on the order of 2-5 fold. In this study, abundance indices would not have been useful in detecting annual or area changes of less than 75-100% between our 6-mile^2 study areas. These abundance indices may be useful for detecting 2-5 fold changes in predator abundance for larger regions or as a trend indicator over several years.

Contents

Dense nesting cover is planted to provide ducks with an attractive and potentially safe place to locate their nests and hatch their broods.

Introduction

Habitat loss and severe nest predation appear to limit local duck production in Wisconsin. Research shows that duck nest success in some regions of Wisconsin is generally less than 20 percent (Gatti 1987), and on the Horicon Marsh Wildlife Area, predators destroy over 98% of unsuccessful duck nests (Bartelt 1990). To increase duck nest success in Wisconsin, dense nest cover is planted to retard the movement of predators into nesting fields. Research evaluating this dense nesting cover program shows large annual variations that cannot be explained by changes in vegetation alone (Bartelt 1990). Information on predator abundance is needed to help explain these annual changes in nest success and help interpret the results of the dense nest cover program. The relationship between predator numbers, vegetative cover and nest success should be known to guide future management decisions.

Indices to predator abundance are widely used in wildlife management and research, often without validation against true abundance (Rotella and Ratti 1986). Determining true abundance is difficult under field conditions, and White (1992) warns of the difficulty in interpreting the validity of indices without knowing the true population size. Only under special conditions can the true population size be known.

Less than 20% of duck nests hatch in Wisconsin because of mammalian depredation.

Because of the potential for predator populations to severely affect duck nesting success, we used a mark-recapture program to estimate predator population sizes and compared results from this technique to 5 commonly used indices of abundance. We did not expect to prove or disprove the validity of these indices but strove to gain insight into their usefulness.
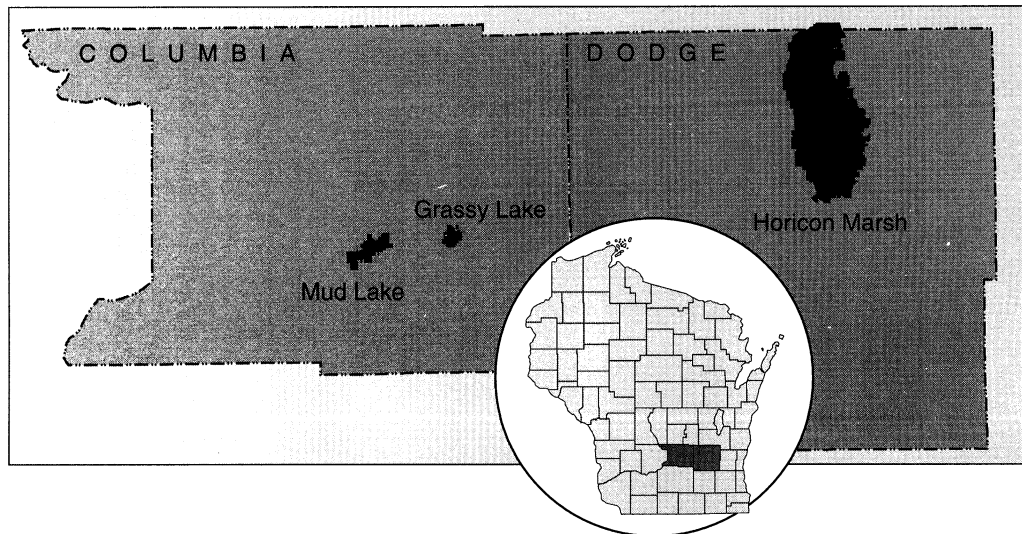
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Figure 1. Location of Horicon National Wildlife Refuge, Grassy Lake Wildlife Management Area and Mud Lake Wildlife Management Area.

Methods

Population and Density Estimates

We live-trapped striped skunks (*Mephitis mephitis*), common raccoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*) on 3 south-central Wisconsin study areas during March-May, 1984-86. Study areas included 2 state wildlife management areas, the Grassy Lake Wildlife Management Area (7.5 mile^2, including open water) and the Mud Lake Wildlife Management Area (6.0 mile^2), and the Horicon National Wildlife Refuge (6.5 mile^2). A border of private lands (~0.5-1.5 mile wide) surrounding each area was included in each study area. The 3 areas are located in Dodge and Columbia counties (Fig. 1) and are managed as waterfowl production areas.

Sixteen trap sites in suspected predator travel corridors were identified within each mile^2. Four traps were randomly placed at 4 of the 16 trap sites every 4 days. Traps were randomly moved every 4 days to insure all animals had an equal probability of capture. Traps were baited with sardines for 10 weeks during March and April and with marshmallows and strawberry jam in May in an effort to recapture raccoons. Traps were open and baited 4 nights per week.

Animals captured were anesthetized with ketamine hydrochloride and rompun (10:1) and marked with numbered aluminum ear tags and with individually coded plastic ear tags. Tag numbers on recaptured animals were recorded and the animals were released without anesthesia. Recapture data were used to estimate the pre-birth population size and standard errors for each area, year and species using program CAPTURE (White et al. 1982). Model selection procedures in program CAPTURE were used to select the model that "best" explained the observed patterns of initial captures and recaptures and for which population size could be estimated.

Population estimates were converted to density estimates to account for size differences between study areas. White et al's. (1982) nested subgrid procedure was not used for density estimation because systematic placement of traps in a grid across the study areas would have resulted in many traps being located in sites seldom used by predators. This would have further reduced capture probabilities (Table 5) and increased the difficulty in making population estimates. Therefore, density was calculated using 2 other methods. First, population size was divided by the size of the study areas, assuming that the entire study area was suitable habitat. Second, we divided population size by the total area of the study area plus a 0.5 mile buffer area surrounding each study area (Dice 1938). Based on home range sizes reported in the literature for radio-marked skunks (Rosatte 1987), raccoons (Sanderson 1987) and opossums (Seidensticker et al. 1987), 0.5 mile seemed appropriate since these species generally had approximately a 1-mile^2 home range in the upper Midwest. This buffered area was assumed to be the effective area used by predators sampled by our trapping. Year and area differences in predator population densities were evaluated with Z-tests.

Abundance Indices

Five indices to predator abundance were conducted February-June, 1984-86 on the 3 study areas. Indices included: (1) spotlight counts (Rybarezyk et al. 1981), (2) modified scent stations (Linhart and Knowlton 1975, Roughton and Sweeny 1982), (3) simulated nests (Hammond 1966), (4) snow-track counts and (5) abundance of road kills.

Above: Live traps were used to estimate predator population sizes on the 3 south-central Wisconsin study areas.

Above right: Predators captured in live traps were anesthetized to allow marking and data collection.

Spotlight Counts. Spotlight counts (33-42 miles in length) were conducted during April prior to "green-up." Roads inside and within 1 mile of each study area were driven after dark. Two observers using high-powered spotlights scanned both road ditches and adjacent fields. Species, location and time were recorded for each animal observed. Other variables such as weather conditions were recorded. Spotlight counts were replicated on 10 different nights for each study area. The number of each species seen/100 miles driven was calculated for each study area each year. Data were tested by ANOVA for differences among study areas and years.

Scent Stations. Scent-station surveys were conducted in May 1984-86 on each study area. Five lines of 10 scent stations were placed in road ditches inside and within 1 mile of each study area. Each scent station was a 3-foot circle cleared of vegetation and covered with sifted dirt. A standard fatty acid scent capsule (Roughton and Sweeny 1982) was placed in the center of each station. Scent stations were located 0.3 miles apart on alternate sides of the road and were checked for predator tracks on 4 consecutive nights. The percent use of these stations by each species was calculated for each study area each year. Data were tested for area and year effects using Kruskal-Wallis tests (Conover 1980).

Ear tags were used to identify individual animals when recaptured.
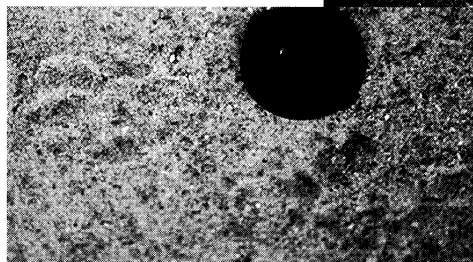
Scent stations were used as an index to predator numbers on the 3 south-central Wisconsin study areas.

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**Simulated Nests.** Simulated nests were constructed using 3 pheasant eggs for each nest during May-June, 1984-86. Simulated nests were placed on opposite sides of the road from scent stations and were also in 5 lines of 10 nests inside and within 1 mile of each study area. The simulated-nest survey was conducted 2 weeks after the end of the scent-station survey to increase the likelihood of independence. Simulated nests were checked weekly to determine the percent of nests destroyed by predators. Predator species cannot be reliably identified by patterns of nest destruction (Greenwood and Sargeant, unpubl. data cited in Greenwood 1986); therefore, nests were recorded as destroyed or not destroyed by a predator. Area and year effects were examined with Kruskal-Wallis tests.

Snow-Track Counts. Track counts were conducted on access roads, dikes and trails within each study area whenever snow conditions permitted during 1984-85. Care was taken not to count tracks of the same individual twice by following a track to make sure it did not cross the transect more than once. The number of tracks/mile for each species was calculated for each area.
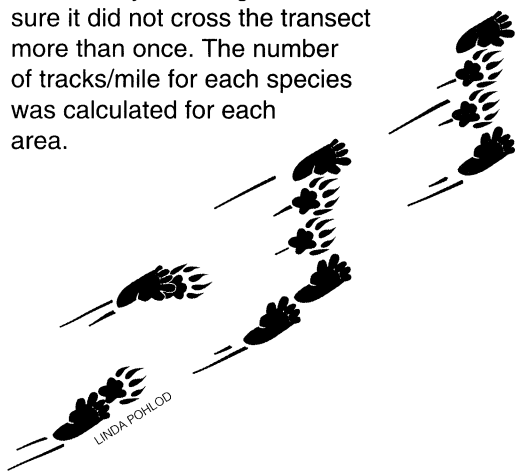
Roadkill Abundance. All road-killed predators encountered on the study area during 1984-85 were recorded and checked for eartags (Case 1978, Verts 1967). Since personnel were on most roads within the study areas 5 days per week during March-May, road kills were recorded incidental to live-trapping activities.

Statistical Analysis

Correlation analysis was used to compare the 9 population density estimates (3 areas × 3 years) for each species to each of the indices of abundance. In addition, abundance indices were compared to predator capture rates (captures/100 trap nights).

Minimum sample sizes required to be 80% certain of detecting 20% and 50% changes in population indices with a 5% level of significance were determined for spotlight, scent-station and simulated-nest surveys (Sokal and Rohlf 1981). The mean of the 9 year- and area-specific estimates of the coefficient of variation was used to estimate within year and within area variability for each species.

Results

Closure

The number of newly caught skunks declined throughout the trapping season in all years and areas suggesting that new animals were not immigrating into the study areas. Generally 60-70% (Table 1) of all new skunks were caught in the first 4-week trapping period. At Horicon in 1984 and Grassy Lake in 1986, however, only half of the new skunks were captured in the first 4-week time period. These data suggest that the skunk population was closed and that most of the skunk population was being trapped and marked.

During all years at Horicon and Mud Lake, and in 1984 at Grassy Lake, the number of newly captured raccoons either remained fairly constant throughout the trapping periods or else increased during the latter periods (Table 1). Very few raccoon recaptures were recorded at any time. These data suggest that ingress of raccoons might have been occurring. Alternatively, we may have had difficulty in trapping and marking the majority of the raccoon population in these areas.

The pattern of newly captured opossums was variable but generally captures of new opossums declined throughout the trapping period (Table 1). However, almost half of the newly caught animals in a year were caught in the second and third 4-week periods. At Horicon in 1986 and Grassy Lake in 1985, 41% and 51%, respectively, of the new animals were captured in the second 4-week trapping period suggesting possible immigration of opossums into Horicon in 1986 and Grassy Lake in 1985.

Program CAPTURE performs a test for closure that is statistically valid only when Model M_o or M_h is true (White et al. 1982). Five of the 14 tests for closure when Model M_o or M_h was selected as the best model indicated violations of the closure assumption (i.e., opossums at Horicon in 1986 [$P = 0.04$] and Grassy Lake in 1984 [$P = 0.03$] and 1986 [$P = 0.01$], and striped skunks at Mud Lake in 1984 [$P = 0.01$] and 1986 [$P = 0.03$]).

Table 1. *Percent (N) of total new animals captured per 4-week time period (March-May) on 3 south-central Wisconsin wildlife management areas, 1984-86.*

Species and Month	Horicon			Grassy Lake			Mud Lake		
	1984	1985	1986	1984	1985	1986	1984	1985	1986
Skunk									
March	51 (18)	75 (15)	70 (23)	73 (8)	50 (2)	55 (6)	61 (14)	100 (9)	67 (4)
April	49 (17)	25 (5)	27 (9)	9 (1)	25 (1)	45 (4)	35 (8)	0 (0)	33 (2)
May	0 (0)	0 (0)	3 (1)	18 (2)	25 (1)	9 (1)	4 (1)	0 (0)	0 (0)
Raccoon									
March	23 (9)	36 (14)	26 (10)	32 (22)	51 (22)	33 (17)	27 (14)	39 (12)	23 (3)
April	30 (12)	31 (12)	26 (10)	19 (13)	30 (14)	49 (25)	43 (22)	26 (8)	31 (4)
May	48 (19)	33 (13)	47 (18)	49 (34)	19 (9)	18 (9)	37 (15)	35 (11)	46 (6)
Opossum									
March	63 (22)	40 (21)	29 (5)	45 (21)	42 (20)	64 (16)	49 (21)	58 (21)	59 (13)
April	14 (5)	33 (17)	41 (7)	34 (16)	51 (24)	16 (4)	40 (17)	28 (10)	23 (5)
May	23 (8)	23 (14)	29 (5)	21 (10)	6 (3)	20 (5)	12 (5)	14 (5)	18 (4)

The number of newly captured striped skunks declined throughout the trapping seasons at all 3 study areas.

Top right: Common raccoons were rarely recaptured at the 3 study areas.

Lower right: Recapture of Virginia opossums was more frequent but still quite variable at the 3 study areas.

Table 2. *Model selection and population estimates (White et al. 1982) for striped skunks on 3 south-central Wisconsin wildlife management areas, 1984-86. Models are listed in descending order of appropriateness, based on model selection criteria.*

Area	1984				1985				1986			
	Model	Est.	CI[a]	P[b]	Model	Est.	CI	P	Model	Est.	CI	P
Horicon	M_{th}	—[c]			M_b	20	20-22	.31/.05	M_{th}	—		
	M_b	41	35-52	.15/.07[d]	M_{bh}	20	20-22	.31	M_t	37	33-42	.03-.36
	M_t	35	35-36	.00-.26[e]	M_{tb}	—			M_{tb}	—		
	M_{tbh}	—[c]			M_h	31	22-40	.08	M_b	34	33-38	.23/.14
	M_{tb}	—[c]			M_o	38	20-59	.07	M_{tbh}	—		
	M_o	54	36-72	.08	M_{thb}	—			M_o	37	33-43	.16
	M_{bh}	37	35-43	.05-.20	M_{th}	—			M_{bh}	33	33-35	.10-.38
	M_h	134	88-180	.03	M_t	20	20-21	.00-.30	M_h	48	37-59	.12
Grassy Lake	M_o	12	11-16	.15	*f				M_{tbh}	—		
	M_h	12	11-14	.15	*				M_h	36	15-58	.03
	M_{tbh}	—			*				M_o	56	11-154	.02
	M_{bh}	11	11-13	.09-.29	*				M_{bh}	11	11-14	.24
	M_{tb}	—			*				M_{tb}	—		
	M_b	11	11-13	.13	*				M_{th}	—		
	M_{th}	—			*				M_b	11	11-14	.24/.01
	M_t	11	11-12	.00-.45	*				M_t	11	11-12	.00-.27
Mud Lake	M_h	54	33-75	.05	M_b	9	9-10	.50/.04	M_h	6	6-7	.15
	M_o	44	23-68	.06	M_{tb}	—			M_o	7	6-11	.13
	M_{tbh}	—			M_{bh}	9	9-10	.50	M_{tb}	—		
	M_{tb}	—			M_h	23	9-38	.05	M_{tbh}	—		
	M_{bh}	24	23-27	.23	M_o	17	9-31	.07	M_{bh}	*g		
	M_b	24	23-27	.23/.04	M_{tbh}	—			M_b	6	6-8	.27/.09
	M_{th}	—			M_{th}	—			M_{th}	—		
	M_t	23	23-24	.00-.26	M_t	9	9-7	.00-.56	M_t	6	6-7	.00-.67

[a] Approximate 95% confidence interval of the population estimate.
[b] Estimated probability of capture.
[c] Population size cannot be estimated for this model.
[d] Estimated probability of initial capture/estimated probability of recapture.
[e] Probability of capture varies among trapping occasions, range presented.
[f] No skunks were recaptured, model selection and population estimation procedures failed.
[g] No skunks were captured on first trapping occasion, analysis could not be completed.

Model Selection

For the 3 predator species, in all area-year combinations, one or more of the goodness-of-fit tests employed in the model selection procedure of program CAPTURE could not be performed due to small expected values. Results of the model selection procedure were highly variable for the 3 species. Five different models were selected as most appropriate for skunks (Table 2); models M_h, M_b, and M_{th} were each selected twice and models M_o and M_{tbh} were selected once. For raccoons, 4 different models were selected as best (Table 3). Model M_o was selected 6 times; models M_t, M_{tb},

and M_{tbh} were each selected once. Similarly, 5 different models were selected for opossums (Table 4). Model M_o was selected 4 times; model M_t was selected twice; and models M_h, M_{th}, and M_{tb} were each selected once.

Estimates of capture probability varied depending on the model selected (Tables 2-4). In general, estimated capture probability was low, increasing the difficulty of model selection. Capture probability tended to be higher for skunks (range 0.03-0.50 for selected models), intermediate for opossums (range 0.01-0.19) and lowest for raccoons (range 0.01-0.06).

Table 3. *Model selection and population estimates (White et al. 1982) for common raccoons on 3 south-central Wisconsin wildlife management areas, 1984-86. Models are listed in descending order of appropriateness, based on model selection criteria.*

Area	1984 Model	Est.	CI[a]	P[b]	1985 Model	Est.	CI	P	1986 Model	Est.	CI	P
Horicon	M_{tbh}	—[c]			M_o	100	45-135	.04	M_o	186	38-352	.02
	M_h	82	59-105	.06	M_h	150	101-199	.03	M_h	137	89-185	.03
	M_o	72	46-98	.07	M_{tbh}	—			M_{tbh}	—		
	M_{th}	—[c]			M_{bh}	83	39-277	.03-.07	M_{bh}	*		
	M_{tb}	—[c]			M_{th}	—			M_{th}	—		
	M_{bh}	45	40-56	.03-.30[d]	M_b	*			M_{tb}	—		
	M_b	*[e]			M_{tb}	—			M_b	*		
	M_t	69	45-93	.01-.14	M_t	99	46-152	.03-.07	M_t	38	38-39	.00-.18
Grassy Lake	M_t	160	101-219	.01-.11	M_{tb}	—			M_o	225	61-389	.02
	M_{th}	—			M_{th}	—			M_h	177	123-232	.03
	M_{tbh}	—			M_t	133	61-205	.01-.11	M_{tbh}	—		
	M_{tb}	—			M_b	62	47-85	.12/.03[f]	M_{bh}	136	51-357	.04
	M_o	165	102-228	.04	M_{tbh}	—			M_{th}	—		
	M_h	173	129-217	.04	M_o	140	62-218	.04	M_{tb}	—		
	M_{bh}	*			M_{bh}	48	47-52	.04-.51	M_b	136	51-357	.04/.02
	M_b	*			M_h	121	85-156	.04	M_t	226	60-392	.01-.04
Mud Lake	M_o	140	70-210	.04	M_o	161	31-327	.02	M_o	78	13-217	.02
	M_h	140	98-182	.04	M_h	112	70-155	.03	M_h	48	21-74	.03
	M_{tbh}	—			M_{tbh}	—			M_{tbh}	—		
	M_{bh}	297	51-1670	.02	M_{bh}	154	31-904	.02	M_{bh}	*		
	M_{tb}	—			M_{th}	—			M_{tb}	—		
	M_{th}	—			M_{tb}	—			M_b	*		
	M_b	297	51-1674	.02/.04	M_b	154	31-913	.02/.02	M_{th}	—		
	M_t	51	51-52	.00-.18	M_t	158	31-321	.01-.04	M_t	13	13-14	.00-.23

[a] Approximate 95% confidence interval of the population estimate.
[b] Estimated probability of capture.
[c] Population size cannot be estimated for this model.
[d] Probability of capture varies among trapping occasions, range presented.
[e] Population size could not be estimated because the number of new animals caught on successive occasions did not decline.
[f] Estimated probability of initial capture/estimated probability of recapture.
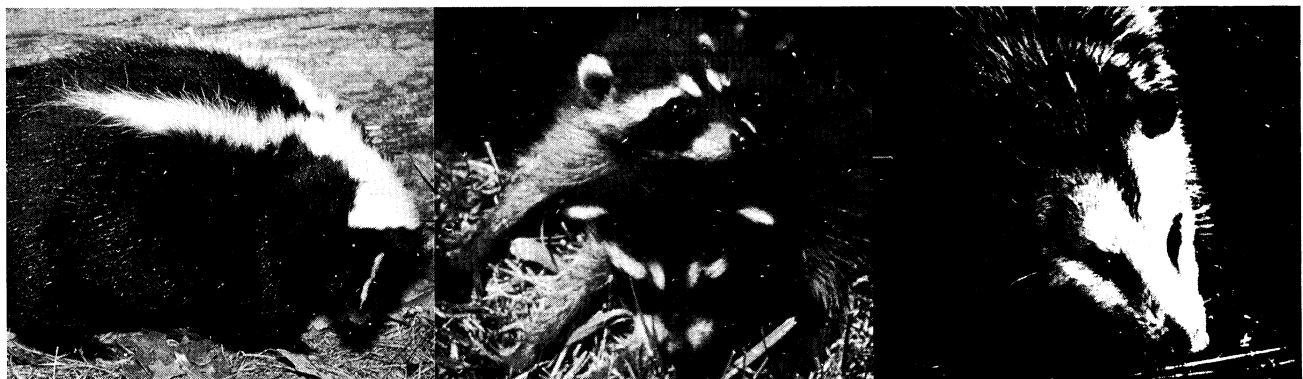
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Table 4. *Model selection and population estimates (White et al. 1982) for Virginia opossums on 3 south-central Wisconsin wildlife management areas, 1984-86. Models are listed in descending order of appropriateness, based on model selection criteria.*

Area	1984 Model	Est.	CI[a]	P[b]	1985 Model	Est.	CI	P	1986 Model	Est.	CI	P
Horicon	M_{th}	—[c]			M_t	85	61-109	.01-.20	M_o	36	17-61	.05
	M_{tbh}	—[c]			M_{th}	—			M_h	37	22-53	.05
	M_{bh}	38	35-44	.19	M_{tbh}	—			M_{tbh}	—		
	M_b	38	35-44	.19/.08[d]	M_{tb}	—			M_{bh}	*[f]		
	M_o	50	36-64	.09	M_o	88	62-114	.08	M_{tb}	—		
	M_h	103	62-144	.05	M_b	99	52-189	.06/.08	M_b	*		
	M_{tb}	—[c]			M_{bh}	52	52-53	.07-.78	M_{th}	—		
	M_t	49	36-62	.02-.16[e]	M_h	129	92-167	.05	M_t	17	17-18	.00-.35
Grassy Lake	M_o	69	51-87	.09	M_{tb}	—			M_o	35	25-47	.10
	M_h	88	65-111	.07	M_{th}	—			M_h	37	27-47	.10
	M_{tbh}	—			M_{tbh}	—			M_{th}	—		
	M_{bh}	71	47-110	.09	M_t	124	61-187	.01-.09	M_{bh}	30	25-41	.15
	M_{th}	—			M_b	56	47-70	.15/.03	M_{tbh}	—		
	M_{tb}	—			M_o	129	61-197	.04	M_{tb}	—		
	M_b	71	47-110	.09/.09	M_{bh}	47	45-49	.04-.48	M_b	30	25-41	.15/.10
	M_t	69	52-86	.03-.12	M_h	162	111-214	.03	M_t	25	25-26	.00-.28
Mud Lake	M_t	58	45-71	.02-.21	M_h	68	49-88	.08	M_o	31	22-42	.10
	M_{th}	—			M_o	52	37-67	.10	M_h	31	23-39	.10
	M_{tb}	—			M_{tbh}	—			M_{tbh}	—		
	M_{tbh}	—			M_{bh}	38	36-44	.05-.23	M_{bh}	27	22-39	.13
	M_{bh}	50	43-61	.15	M_{tb}	—			M_{th}	—		
	M_o	60	46-74	.10	M_{th}	—			M_{tb}	—		
	M_b	50	39-61	.15/.09	M_b	42	36-53	.16/.09	M_b	27	22-39	.13/.10
	M_h	67	52-82	.09	M_t	36	36-37	.00-.28	M_t	31	22-41	.03-.20

[a] Approximate 95% confidence interval of the population estimate.
[b] Estimated probability of capture.
[c] Population size cannot be estimated for this model.
[d] Estimated probability of initial capture/estimated probability of recapture.
[e] Probability of capture varies among trapping occasions, range presented.
[f] Population size could not be estimated because the number of new animals caught on successive occasions did not decline.

Population and Density Estimates

Skunks. Population estimates for skunks were usually very close to the actual number of skunks captured and marked suggesting that most of the skunks in the population were caught and marked (Table 5). In almost all cases, the number of new captures declined to low levels by the end of the trapping period. Estimated density of skunks (based on buffered areas) varied from 4.5 per square mile at Mud Lake in 1984 to 0.2 skunks per square mile at Grassy Lake in 1985 (Table 6). Population estimates were fairly precise ($\bar{x}$ C.V. = 12%, range 0.8-30%).

Population estimates suggest that most striped skunks in the 3 study areas were caught and marked.

WILLIAM WHEELER

Table 5. *Population estimates of striped skunks, common raccoons and Virginia opossums on 3 south-central Wisconsin wildlife management areas, 1984-86.*

Area and Parameter	Skunk			Raccoon			Opossum			All Species		
	1984	1985	1986	1984	1985	1986	1984	1985	1986	1984	1985	1986
Horicon												
No. caught	35	20	33	40	39	38	35	52	17	110	111	88
No. recaptured	18	7	38	16	9	4	21	23	5	55	39	47
Population Est.	41	20	37	82	100	186	38	85	36	161	205	259
Conf. Interval	35-52	20-22	33-42	59-105	45-135	38-352	35-44	61-109	17-61	135-187	163-247	91-427
Model Selected	M_b	M_b	M_t	M_h	M_o	M_o	M_{bh}	M_t	M_o			
Grassy Lake												
No. caught	11	4	11	69	47	51	47	47	25	127	98	87
No. recaptured	11	0	1	18	9	6	27	10	15	56	19	22
Population Est.	12	4	36	160	133	225	69	124	35	241	261	296
Conf. Interval	11-16		15-58	101-219	61-205	61-389	51-87	61-187	25-47	179-303	165-357	130-462
Model Selected	M_o		M_h	M_t	M_t	M_o	M_o	M_t	M_o			
Mud Lake												
No. caught	23	9	6	51	31	13	43	36	22	117	76	41
No. recaptured	8	3	4	11	3	1	28	21	13	47	27	18
Population Est.	54	9	6	140	161	78	58	68	31	252	238	115
Conf. Interval	33-75	9-10	6-7	70-210	31-327	13-217	45-71	49-88	22-42	178-326	76-405	41-254
Model Selected	M_h	M_b	M_h	M_o	M_o	M_o	M_t	M_h	M_o			

Table 6. *Population density (N/mi^2) estimates of striped skunks, common raccoons and Virginia opossums on 3 south-central Wisconsin wildlife management areas, 1984-86.*

Area and Parameter	Skunk			Raccoon			Opossum			All Species		
	1984	1985	1986	1984	1985	1986	1984	1985	1986	1984	1985	1986
Horicon												
Population estimate[a]	41	20	37	82	100	186	38	85	36	161	205	259
Density[b]	6.3	3.1	5.7	12.6	15.4	28.6	5.8	13.1	5.5	24.8	31.5	39.8
Density - Buffered Area[c]	2.6	1.3	2.4	5.3	6.5	12.0	2.5	5.5	2.3	10.4	13.2	16.7
Grassy Lake												
Population estimate	12	4	36	160	133	225	69	124	35	241	261	296
Density	1.6	0.5	4.8	21.3	17.7	30.0	9.2	16.5	4.7	32.1	34.8	39.5
Density - Buffered Area	0.7	0.2	2.1	9.1	7.6	12.9	3.9	7.1	2.0	13.8	14.9	16.9
Mud Lake												
Population estimate	54	9	6	140	161	78	58	68	31	252	238	115
Density	9.0	1.5	1.0	23.3	26.8	13.0	9.7	11.3	5.2	42.0	39.7	19.2
Density - Buffered Area	4.5	0.8	0.5	11.7	13.4	6.5	4.8	5.7	2.6	21.0	19.8	9.6

[a] Population estimates calculated from White et. al. (1982).
[b] Horicon = 6.5 mi^2, Grassy Lake = 7.5 mi^2, Mud Lake = 6 mi^2.
[c] Horicon buffered = 15.5 mi^2, Grassy Lake buffered = 17.5 mi^2, Mud Lake buffered = 12 mi^2.

Skunk populations apparently declined on all study areas from 1984 to 1985 (Horicon: $Z = 3.66$, $P < 0.001$; Mud Lake: $Z = 4.20$, $P < 0.001$; Grassy Lake: test could not be performed because no skunks were recaptured in 1985 and standard error of density could not be estimated). The Horicon skunk population increased from 1985 to 1986 ($Z = 6.44$, $P < 0.001$) and the Grassy Lake population appeared to increase (no test possible). In contrast, skunk numbers at Mud Lake declined even further in 1986 ($Z = 5.30$, $P < 0.001$). No explanation is readily apparent for the decline in skunk number from 1984 to 1985.

In 1984, skunk density was lowest at Grassy Lake, intermediate at Horicon and highest at Mud Lake (Grassy Lake vs. Horicon: $Z = 5.18$, $P < 0.001$; Horicon vs. Mud Lake: $Z = 2.01$, $P = 0.04$). Conversely, skunk density at Mud Lake was lower than at Horicon in 1985 ($Z = 6.93$, $P < 0.001$). During 1986, skunk densities were similar at Horicon and Grassy Lake ($P = 0.64$), but markedly lower at Mud Lake (Mud Lake vs. Horicon, $Z = 11.5$, $P < 0.001$; Mud Lake vs. Grassy Lake, $Z = 2.53$, $P = 0.01$).

Raccoons. Due to the very low capture probabilities, the precision of raccoon population estimates was low ($\overline{x}$ C.V. = 38%, range 14-91%). Therefore, despite a doubling of the estimated population at Horicon from 1984 to 1986 and a 70% increase at Grassy Lake from 1985 to 1986 (Table 6), these between year differences were not significant (Horicon 1984 vs. 1986: $Z = 1.24$, $P = 0.21$; Grassy Lake 1985 vs. 1986: $Z = 1.03$, $P = 0.30$). Similarly, the 51% decline in estimated raccoon density on Mud Lake from 1985 to 1986 was not significant ($Z = 0.76$, $P = 0.44$). Raccoon density was lower at Horicon than at Grassy Lake ($Z = 2.06$, $P = 0.04$) or Mud Lake ($Z = 2.12$, $P = 0.03$) during 1984, but densities did not differ significantly among area in 1985 or 1986 ($P > 0.32$).

Low capture probabilities limited the precision of common raccoon population estimates in this study.

Opossums. Precision of opossum population estimates was moderate ($\overline{x}$ C.V. = 17%, range 8-35%). Opossum populations apparently increased from 1984 to 1985 on all study areas (Table 6). This change was significant at Horicon ($Z = 3.78$, $P < 0.001$), but not at Grassy Lake ($Z = 1.71$, $P = 0.09$) or Mud Lake ($Z = 0.91$, $P = 0.36$). Following the severe winter of 1985-86, opossum populations declined by more then 50% on all study areas ($Z = 2.78$-3.27, $P = 0.004$-0.001). During 1984, opossum density was lower at Horicon than at Grassy Lake ($Z = 2.57$, $P = 0.01$) or Mud Lake ($Z = 4.02$, $P < 0.001$). Opossum densities did not differ significantly among areas in 1985 or 1986 ($P > 0.29$).

All Species. Due to the large influence of raccoon density on the combined predator density estimates (Table 6) and the low precision of raccoon density estimates, none of the between year changes in combined predator density were significant ($Z = 0.16$-1.73, $P = 0.08$-0.50). During 1984, density of mammalian predators was higher at Mud Lake than at Horicon ($Z = 3.31$, $P < 0.001$) or Grassy Lake ($Z = 2.01$, $P = 0.04$). Among area differences during 1985 and 1986 were not significant ($Z = 0.03$-0.98, $P = 0.33$-0.98).

Abundance Indices

Spotlight Counts. Spotlight counts of skunks (Table 7) varied among years ($F = 9.05$; 2, 81 df; $P < 0.001$) and areas ($F = 4.95$; 2, 81 df; $P = 0.009$); the year x area interaction was not significant ($F = 1.23$; 4, 81 df; $P = 0.31$). Mean spotlight counts of skunks, pooling among years, were higher at Horicon than at Mud Lake or Grassy Lake. Pooled spotlight counts of skunks in the 3 areas were highest in 1986. Within years and within areas, counts of skunks were highly variable ($\overline{x}$ C.V. = 114.8).

The interaction of year and area effects on spotlight counts of raccoons was not significant ($F = 1.68$; 4, 81 df; $P = 0.16$). Pooling across years, counts of raccoons differed significantly among areas ($F = 5.15$; 2, 81 df; $P = 0.008$), higher at Grassy Lake than at Horicon or Mud Lake. Raccoon counts differed among years ($F = 13.65$; 2, 81 df; $P < 0.001$). Spotlight counts of raccoons were higher in 1986 than in the other years in all 3 areas (Table 7). The within year and within area variability of raccoon spotlight counts was lower than for skunks ($\overline{x}$ C.V. = 48.1).

Spotlight counts of opossums (Table 7) varied significantly among years ($F = 8.37$; 2, 81 df; $P < 0.001$). In all 3 areas, the mean spotlight index for opossums increased from 1984 to 1985, but then decreased in 1986. Spotlight counts varied

Table 7. *Summary statistics for the number of individual striped skunks, common raccoons and Virginia opossums seen/100 miles on 10 spotlight counts conducted at 3 south-central Wisconsin wildlife management areas, 1984-86.*

Species	Area	Year	$\bar{x}$	S.E.	Min.	Max.	C.V.
Skunk	Horicon	84	2.0	0.9	0.0	9.0	147.2
		85	4.4	1.2	0.0	12.0	87.8
		86	7.5	1.6	2.0	17.0	67.5
	Grassy Lake	84	1.8	0.7	0.0	5.0	116.5
		85	1.0	0.7	0.0	6.0	216.0
		86	3.9	1.2	0.0	9.0	96.3
	Mud Lake	84	2.2	0.9	0.0	8.0	124.6
		85	1.5	0.5	0.0	3.0	105.4
		86	4.1	0.9	0.0	11.0	72.2
Raccoon	Horicon	84	6.5	1.1	2.0	14.0	53.4
		85	16.0	2.5	7.0	26.0	49.9
		86	23.9	3.8	3.1	38.0	50.7
	Grassy Lake	84	18.6	2.1	3.0	24.0	34.9
		85	17.3	2.3	9.0	31.0	41.1
		86	25.3	3.4	12.0	46.0	42.5
	Mud Lake	84	11.5	2.4	3.0	25.0	66.3
		85	12.0	2.4	0.0	26.0	62.7
		86	19.3	2.0	11.0	30.0	33.3
Opossum	Horicon	84	1.7	0.7	0.0	7.0	124.2
		85	2.7	0.7	0.0	7.0	83.8
		86	1.3	0.7	0.0	7.0	170.3
	Grassy Lake	84	1.8	0.8	0.0	7.0	135.6
		85	4.9	1.2	0.0	12.0	74.7
		86	0.9	0.5	0.0	3.0	161.0
	Mud Lake	84	0.6	0.4	0.0	3.0	210.8
		85	1.8	0.9	0.0	9.0	161.0
		86	0.3	0.3	0.0	3.0	316.2
All	Horicon	84	10.2	1.3	5.0	18.0	39.7
		85	23.1	2.3	14.0	35.0	31.6
		86	32.0	4.3	8.1	52.0	42.1
	Grassy Lake	84	22.2	2.3	6.0	29.0	33.2
		85	23.2	2.7	15.0	41.0	36.5
		86	30.1	4.2	12.0	55.0	44.0
	Mud Lake	84	14.3	2.8	5.0	33.0	62.2
		85	15.3	2.7	0.0	32.0	55.3
		86	23.7	2.0	17.0	36.0	26.6

among areas ($F = 3.92$; 2, 81 df; $P = 0.024$), higher at Grassy Lake than at Mud Lake. Counts at Horicon were intermediate. The effect of area on opossum counts did not differ significantly among years ($F = 1.17$; 4, 81 df; $P = 0.332$). Counts of opossums exhibited extreme variability within years and within areas ($\bar{x}$ C.V. = 159.7).

When the 3 predator species were combined, spotlight indices differed significantly among years ($F = 15.73$; 2, 81 df; $P < 0.001$) and areas ($F = 4.99$; 2, 81 df; $P = 0.009$). Mean spotlight indices, pooled across areas, increased from 1984 to 1985 and again from 1985 to 1986 (Table 7). Predator spotlight indices at Grassy Lake were significantly higher than at Mud Lake, while those at Horicon were intermediate.

Table 8. *Summary statistics for the number of visits/100 station-nights on 5 scent-station lines at 3 south-central Wisconsin wildlife management areas, 1984-86.*

Species	Area	Year	$\bar{x}$	S.E.	Min.	Max.	C.V.
Skunk	Horicon	84	5.8	1.9	3.0	13.0	71.5
		85	8.3	3.0	0.0	18.0	80.8
		86	5.0	2.2	0.0	12.5	99.4
	Grassy Lake	84	5.6	1.5	0.0	8.0	58.7
		85	0.5	0.5	0.0	2.5	223.6
		86	2.5	1.4	0.0	7.7	123.8
	Mud Lake	84	4.2	1.2	0.0	6.0	63.9
		85	0.5	0.5	0.0	2.5	223.6
		86	1.0	0.6	0.0	2.5	136.9
Raccoon	Horicon	84	2.0	1.2	0.0	5.0	136.9
		85	4.6	2.1	0.0	10.2	99.6
		86	2.5	1.4	0.0	7.5	122.5
	Grassy Lake	84	2.4	1.1	0.0	6.0	104.6
		85	3.5	1.0	0.0	5.0	63.9
		86	6.1	1.0	2.6	7.7	36.8
	Mud Lake	84	3.0	1.3	0.0	6.0	100.0
		85	4.0	1.7	0.0	10.0	94.8
		86	3.5	2.3	0.0	12.5	148.1
Opossum	Horicon	84	2.8	0.8	0.0	5.0	63.9
		85	7.4	3.6	0.0	21.0	110.0
		86	3.5	1.9	0.0	10.0	119.5
	Grassy Lake	84	0.6	0.6	0.0	3.0	223.6
		85	2.0	0.5	0.0	2.5	55.9
		86	1.0	0.6	0.0	2.6	137.0
	Mud Lake	84	0.6	0.6	0.0	3.0	223.6
		85	3.5	1.3	0.0	7.5	81.4
		86	2.5	1.4	0.0	7.5	122.5
All	Horicon	84	10.6	3.3	3.0	21.0	68.9
		85	20.3	6.9	5.0	44.0	76.2
		86	11.0	5.3	0.0	30.0	107.0
	Grassy Lake	84	8.6	2.5	0.0	14.0	65.6
		85	6.0	1.0	2.5	7.5	37.3
		86	9.6	0.5	7.5	10.3	12.4
	Mud Lake	84	7.8	2.6	0.0	15.0	75.0
		85	8.0	2.5	2.5	15.0	71.3
		86	7.0	2.0	2.5	12.5	63.9

Table 9. Summary statistics for the percent of nests destroyed on 5 lines of simulated nests at 3 south-central Wisconsin wildlife management areas, 1984-86.

Area	Year	$\bar{x}$	S.E.	Min.	Max.	C.V.
Horicon	84	50.4	7.1	25.0	67.0	31.6
	85	32.6	7.6	17.0	60.0	52.1
	86	28.8	9.1	0.0	57.0	70.7
Grassy Lake	84	36.4	7.1	25.0	57.0	43.4
	85	30.0	5.5	20.0	50.0	40.8
	86	19.4	4.1	11.0	33.0	47.0
Mud Lake	84	64.8	6.8	43.0	80.0	23.3
	85	28.4	5.7	20.0	50.0	44.9
	86	10.6	6.0	0.0	33.0	127.2

Scent-Station Surveys. Visitation rates to scent stations were low for all 3 species (Table 8) . Overall mean rates for skunks, raccoons and opossums were 3.7%, 3.5% and 2.7%, respectively. Skunk visitation rates varied among years (χ^2 = 7.29, 2 df, P = 0.026) and areas (χ^2 = 8.48, 2 df, P = 0.014). At Grassy Lake and Mud Lake, skunk visitations were highest in 1984, while at Horicon, the skunk visitation rate was highest in 1985. Visitation rates were highest at Horicon in all 3 years. Raccoon visitations to scent stations were similar among years (χ^2 = 1.24, 2 df, P = 0.538) and areas (χ^2 = 1.49, 2 df, P = 0.475). Opossum visitation rates differed among areas (χ^2 = 7.18, 2 df, P = 0.028), but not among years (χ^2 = 3.44, 2 df, P = 0.179). Combining all species, visitation rates did not differ among years (χ^2 = 0.02, 2 df, P = 0.992) or areas (χ^2 = 2.52, 2 df, P = 0.284). As with spotlight counts, variability of scent-station indices within years and areas was very high ($\bar{x}$ C.V. = 120.2, 100.8 and 126.4 for skunks, raccoons and opossums, respectively).

Simulated Nests. Mammalian predators destroyed an overall mean 33.5% of simulated nests (Table 9). Nest destruction rates differed among years (χ^2 = 15.98, 2 df, P < 0.001), but not among areas (χ^2 = 1.78, 2 df, P = 0.41). Destruction rates decreased from 1984 through 1986 in all 3 areas. Compared to spotlight counts and scent-station surveys, the within year and within area variability of the simulated-nest survey was lower ($\bar{x}$ C.V. = 53.4).

Snow-Track Counts. Snow conditions were suitable for only 1 snow-track survey in 1984 and none in 1985. Snow-track surveys were not attempted in 1986. On the 1 survey conducted in 1984, no tracks were found at Mud Lake, only raccoon tracks were observed at Horicon (0.25 tracks/mile), and few tracks were noted at Grassy Lake

Mammalian predators rarely visited scent stations during this study.
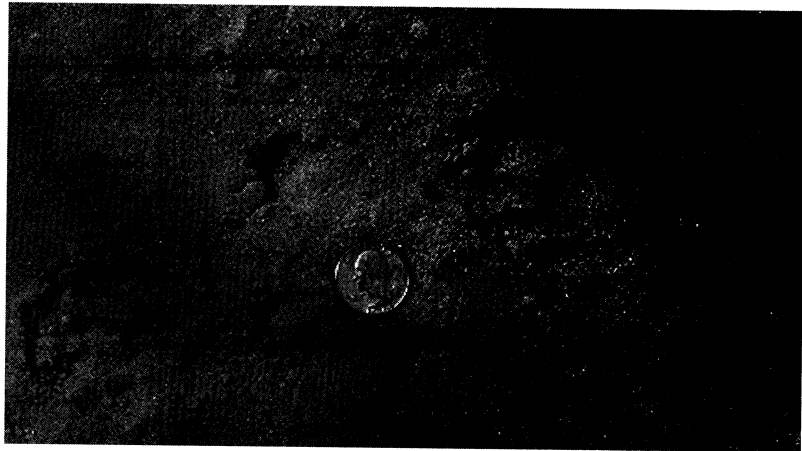
(0.32 tracks/mile for skunks and opossums and 0.64 tracks/mile for raccoons).

Roadkill Abundance.
Relatively few vehicle-killed predators were observed on the 3 study areas during 1984 and 1985. No effort was made to record roadkills in 1986. At Horicon, no skunk, 1 raccoon and no opossum road-kills were recorded in 1984, com-pared to 2 skunk, no raccoon and 4 opossum roadkills in 1985. At Grassy Lake, no skunk or rac-coon roadkills were found in 1984 and only 1 roadkill of each of these species was found in 1985. One and 4 opossum road-kills were observed in 1984 and 1985, respectively, on Grassy Lake. At Mud Lake, 1 skunk, no raccoon and 1 opossum roadkills were recorded in 1984, while 1 skunk, 1 raccoon and 3 opossum roadkills were noted in 1985.

Comparison of Population Estimates to Abundance Indices

Because of the poor performance of snow-track counts and roadkill sur-veys on our study areas, we limited our comparison of population esti-mates and indices to the spotlight, scent-station and simulated-nest sur-veys. Correlations between popula-tion indices and population density

Table 10. *Correlation coefficients, significance levels for 1-tailed tests and esti-mates of power ($1-\beta$) for correlations between predator population indices and captures/100 trap nights and population density estimates from 3 south-central Wisconsin wildlife management areas, 1984-86. Estimates of power assumed that true rho equals observed r. Significant values shown in* **boldface** *type.*

Species Statistic	Spotlight Survey Capture Rate	Density	Scent Station Survey Capture Rate	Density	Simulated Nest Survey Capture Rate	Density
Skunk						
r	0.452	0.177	0.661	0.366	0.569	0.741
P	0.111	0.324	**0.026**	0.166	0.055	**0.011**
$1-\beta$	0.331	0.117	0.624	0.245	0.481	0.759
Raccoon						
r	0.015	0.346	0.007	0.331	0.576	-0.013
P	0.485	0.181	0.493	0.192	0.052	0.513
$1-\beta$	0.055	0.228	0.053	0.215	0.491	0.048
Opossum						
r	0.573	0.741	0.265	0.219	0.480	0.204
P	0.053	**0.011**	0.245	0.286	0.095	0.299
$1-\beta$	0.487	0.759	0.167	0.139	0.364	0.131
All						
r	-0.358	-0.011	0.362	-0.186	0.839	0.346
P	0.828	0.511	0.169	0.684	**0.002**	0.181
$1-\beta$	0.005	0.049	0.242	0.018	0.912	0.228

estimates were not significant in a majority (10/12) of cases (Table 10). Spotlight counts of opossums were positively correlated with population densities and simulated-nest destruction rate was posi-tively correlated with skunk density. Both the correlation of simulated-nest destruction rate with the capture rate of all mammalian predators and the correlation of skunk scent-station visitations with the skunk capture rate were significant. Additionally, the correlation of spotlight counts and capture rate of opossums approached statistical signifi-cance, as did the correlations of simulated-nest destruction and cap-ture rates of skunks, raccoons and opossums (Table 10).

Sample Size Requirements

Given the high within year and within area variability observed with spotlight counts, detecting a 20% change in the index for raccoons with an 80% certainty would require 93 spotlight counts. Detecting a 20% change in the index for skunks would require 528 counts, while 1,020 counts would be required to detect the same change in the index for opossums. Detecting a 50% change in the abundance index using this method would require 15, 84 and 163 counts for raccoons, skunks and opossums, respectively.

Four hundred six scent-station lines would be needed to be 80% certain of detecting a 20% change in the index for raccoons, 578 lines would be required for skunks and 639 for opossums. A 50% change in the visitation rate of raccoons could reliably be detected with 65 scent-station lines, while 93 and 102 lines would be needed for skunks and opossums.

Detecting a 20% change in destruction rate of simulated nests with 80% certainty would require 114 lines. A 50% change in destruction rate could be detected with 18 lines.

DNR PHOTOS

Discussion

An important assumption of the population estimation procedures used in program CAPTURE is demographic closure, i.e., no births, deaths, ingress or egress occurred during the trapping period. A further assumption required for estimation of population density is geographic closure, i.e., the animals occur within a defined geographic area. The trapping period in this study was conducted before young predators were large enough to move out of the den; therefore, there was no recruitment into the population. Also, mortality of adult predators was likely low during this time. Greenwood et al. (1985) using radio telemetry found that a population of skunks he was trapping in North Dakota was essentially closed demographically during mid-late April; no births nor deaths, and only 1 suspected dispersal occurred during the trapping period. Bjorge et al. (1981) noted that dispersal of juvenile striped skunks in Alberta occurred primarily in July and August.

In contrast, at northern latitudes, juvenile raccoons typically do not disperse during their first summer or fall but remain with their mother and siblings during the winter denning period and disperse the following spring (Fritzell 1977, Fritzell 1978, Schneider et al. 1971).

Gardner (1982) characterized opossums as solitary wanders without easily definable home ranges. Gillette (1980), studying radio-tagged opossums in southeastern Wisconsin, noted home range shifts by some adult male opossums and frequent dispersal movements by adult females during April-July. Opossums in southern Wisconsin produce 2 litters per year. Dispersal of first litter young occurred in late summer and fall, while second litter young did not disperse until the following spring (Gillette 1980). Similar movement patterns were observed for opossums in Virginia (Seidensticker et al. 1987).

White et al. (1982) concluded that a valid statistical test for demographic closure cannot be devised because of behavioral responses, and time trends in capture probabilities could not be distinguished from failure of closure. They recommend that the closure test performed by program CAPTURE be consulted only when models M_o or M_h are selected. They further warn that the closure test may not be valid in these cases if a different model is really the true model. Both behavioral and time effects were suggested in our results for all species in some year-area combinations (Tables 2-4). Models M_o or M_h best fit the patterns of skunk captures for 3 area-year combinations. The closure test was significant at Mud Lake in 1984 and 1986, rejecting the hypothesis of closure. Model M_o was selected 6 times for raccoons, with none of the closure tests being significant. For opossums, model M_o was selected 4 times and model M_h was selected once. Closure was rejected in 3 of these 5 tests.

Because of the difficulty in interpretation of closure tests, the pattern of newly caught skunks during the trapping period and predator movement patterns described in the literature, we believe that the assumption of demographic closure was approximated for skunks but probably not for opossums in some cases. The constant to increasing pattern of newly caught raccoons, the low number of recaptures, the lack of significant closure tests, and the possibility of juvenile dispersal occurring during the trapping period made it difficult to conclude whether raccoon populations were demographically closed.

For all 3 species, no 1 model type did well in all years and areas. Smith and Brisbin (1984) also noted inconsistent model selection by program CAPTURE for opossums and raccoons. We believe it is unlikely that skunks, raccoons and opossums exhibited different behaviors in different years or areas (i.e., trap shyness or trap "happiness," changes of trapability over time or heterogeneity among individuals). Instead, we believe that the low capture probabilities made it difficult to select the appropriate models. In all cases, at least 1 of the model selection tests could not be performed because of small expected values. Movement of some new animals into the study area may have further complicated model selection. White et al. (1982) cautioned that studies with low capture probabilities (< 0.10) will generate unreliable results. The frequent selection of model M_o was likely due to insufficient data to conclude that more complicated models were more appropriate. This was especially true for raccoons (capture probabilities were usually < 0.05), which we believe were trap-shy on our study areas because of the low number of recaptures. Yet, the simplest model, M_o, was most often selected.

Although model selection was inconsistent, the best 2 or 3 models for which population size could be estimated usually led to similar population estimates and confidence intervals. This was especially true for skunks (Table 2). For opossums, an exception was Grassy Lake in 1985 where the best 2 models (for which there was an estimate) lead to population estimates of 124 or 56. However, for raccoons the population estimates resulting from the top 2 models often differed by more than 30%. Failure to select the most appropriate model for raccoons may have lead to seriously biased estimates of population size and variance (Conner and Labisky 1985, Greenwood et al. 1985, Moore and Kennedy 1985).

The 3 study areas were not geographically closed, i.e., they were not fenced, small islands or surrounded by unsuitable habitat. Animals on the periphery of the study area with a small portion of their home range extending into the trapped area may have been captured and included in the population estimate. Therefore, the density estimates calculated by dividing the population estimate by the study area size are likely an overestimate of the true density. Conversely, the density estimates based on the 0.5-mile buffers around the study areas may underestimate true density if animals had home ranges in the buffer zones but not in the trapped areas.

Both our minimum (0.2-4.5 skunks/mile^2) and maximum (0.5-9.0/mile^2) spring skunk density estimates are among the lowest reported in the literature. Rosatte (1987), in a review of published density estimates, described a range of skunk including 1.3-6.2/mile^2 in Alberta, 9-37/mile^2 in Illinois, 12/mile^2 in Ohio and 33-67/mile^2 in Illinois, although the seasons in which these estimates were made were not reported. Skunk populations are generally at the lowest point of their annual cycle during spring. Published density estimates of raccoons, reviewed by Kaufmann (1982) and Sanderson (1987), ranged from lows of 1.3-2.6/mile^2 in North Dakota and 3.9-8.3/mile^2 in Manitoba to 40-50/mile^2 in Illinois, Ohio, and Virginia to highs of 80/mile^2 in Mississippi and 127/mile^2 in Alabama. Our raccoon density estimates (min. 5.3-12.9/mile^2, max. 13-30/mile^2) were intermediate to those previously published. Spring opossum densities on waterfowl management areas in southern Wisconsin (min. 2.3-7.1/mile^2, max. 5.2-16.5/mile^2) were similar to estimates from Iowa (6.0/mile^2), Illinois (10.1/mile^2) and Virginia (1.3-20.2/mile^2 and 12.7/mile^2), but much lower than the fall density of 259/mile^2 estimated for a waterfowl marsh in New York (reviews by Gardner [1982] and Seidensticker et al. [1987]).

Snow-track counts in northern Wisconsin closely tracked the expansion of fisher populations following

their reintroduction to the state (Kohn et al. 1993); however, suitable snow conditions in southern Wisconsin are too unpredictable for this survey technique to be useful for monitoring predator populations in that portion of the state. Additionally, reduced activity by opossums (Gillette 1980), raccoons (Kaufmann 1982) and skunks (Godin 1982) during winter would further limit the effectiveness of snow-track surveys for monitoring northern populations of these species.

Case (1978) concluded that road-kill surveys could potentially be used for monitoring long-term population trends. Rolley and Lehman (1992) observed negative correlations between regional raccoon harvests and subsequent road-kill surveys and felt that road-kill surveys may be able to detect long-term (5- to 10-year) trends in raccoon populations over broad geographic areas. Because of the limited number of roadkills observed on our 3 study areas, we believe that road-kill surveys have limited potential for monitoring changes in local predator populations.

Spotlight counts of opossums were positively correlated with estimates of opossum density and simulated-nest destruction rates were correlated with skunk density. The lack of significant correlation between population estimates and indices in the other comparisons does not invalidate the indices (White 1992). Although we failed to reject the null hypothesis of $\rho = 0$, we have insufficient evidence to accept the null hypothesis and conclude that there is no correlation between the population indices and population density. Because of the low number of data points (n = 9), the probability of significantly detecting true positive correlations was low (1-β < 0.38) if the true ρ is small (< 0.50). In addition, the small range of density estimates for raccoons and opossums together with the low precision of the raccoon population estimates further reduced the ability to detect possible correlations. Even if there were strong linear relationships between population density and the indices, by combining data from 3 study areas we may have masked these relationships if the slopes of the relationships differed substantially among the study areas (Roughton and Sweeny 1982). This could occur if the study areas differed in habitat composition with resulting differences in movement rates and/or activity patterns.

Conner et al. (1983) believed that scent-station indices reflected changes in raccoon, bobcat (*Lynx rufus*) and common gray fox (*Urocyon cinereoargenteus*) abundance; however, Minser (1984) criticized Conner's study design because it lacked multiple estimates of density. Linscombe et al. (1983) observed that regional and habitat differences in visitation rates by furbearers in Louisiana were consistent with regional harvest patterns and habitat preferences and

concluded that scent-station surveys provided useful information on furbearer population size. Leberg and Kennedy (1987) compared raccoon scent-station visits to density estimates from 9 study areas with 4 different habitat types. Density estimates among the study areas varied over a 23-fold range. Visitation rates were positively correlated to density in most months. Fuller and Kuehn (1985) observed a strong correlation between skunk scent-station indices and incidental captures of skunks during gray wolf (*Canis lupus*) trapping. Diefenbach et al. (1994) reintroduced bobcats onto a barrier island of the coast of Georgia and compared scent-station indices to essentially known and controlled population sizes. They found a significant positive relationship between scent-station indices and population size.

Roughton and Sweeny (1982) recommended visitation rates of 40-60% as optimum for detecting changes in predator abundance when using scent-station surveys. Our visitation rates were largely less than 10%. Substantially higher visitation rates have been obtained in surveys specifically designed to monitor raccoon abundance when stations were subjectively placed in sites likely to be visited by raccoons (Leberg and Kennedy 1987). Different scents and tracking surfaces have been found to affect visitation rates by some species (Morrison et al. 1981). Changes in survey methods that yielded higher visitation rates would likely improve the usefulness of scent stations for detecting population changes of a target species. However, species-specific modification of survey procedures could lower visitation rates for other predator species, adversely affecting the survey's ability to monitor changes in the community of mammalian predators on nesting waterfowl.

Validation of spotlight counts and simulated-nest surveys have received much less research. Rybarczyk et at. (1981) noted that variation in weather, i.e., temperature, relative humidity and barometric pressure, contributed substantially to the variation in spotlight counts of raccoons. April spotlight counts did decline following record levels of harvest but may have been affected by below normal relative humidity that spring.

The strong correlation between the simulated-nest index and capture rate of all species together with the nearly significant correlations of the simulated-nest index with individual species capture rates and lack of correlation of the index with density estimates of opossums and raccoons suggests 2 possible explanations. First, if inappropriate models were selected then capture rate may have better reflected variation in population size then the density estimates and the simulated-nest index closely tracked changes in the combined mammalian predator community. Alternatively, both capture rate and the

simulated-nest index may have been affected by factors independent of population size. Variation in prey availability may have influenced predator response to bait and therefore their trapability as well as their destruction of simulated nests. We cannot distinguish between these possibilities with our data, but Smith and Brisbin (1984) concluded that capture probability of raccoon, opossum and gray fox differed greatly among years and that total captures did not reflect population changes.

Management Implications

As applied in this study, spotlight counts, scent-station surveys and simulated-nest surveys were imprecise, i.e., there was large within year and within area variation. Spotlight counts of skunks and opossums had coefficients of variation similar to those of scent-station indices. Coefficients of variation for the simulated-nest index and raccoon spotlight counts were approximately 50% smaller than scent-station indices, but were still relatively large. Because of the variability of the 3 survey techniques, extremely large sample sizes are required to reliably detect changes in population indices on the order of 20-50%. However, we did observe significant differences between years in the three indices with sample sizes of 15-30 (areas pooled), when changes in population indices were on the order of 2-5 fold. Fluctuations of this magnitude have been frequently reported for populations of striped skunks (Allen and Shapton 1942, Bjorge et al. 1981, Fuller and Kuehn 1985, Verts 1967). Seidensticker et al. (1987) described a doubling in opossum density in 1 year followed by a decline of equal magnitude. Population eruptions have been inferred from Hudson's Bay Company records of raccoon fur sales (Sanderson 1951), but Fritzell (1982) attributed the eruptions in fur sales to changes in the market process. He presented raccoon fur sales records from other companies that exhibited 2 fold changes over 2-3 years and suggested that these reflected normal fluctuations. Despite their imprecision, scent-station surveys, spotlight counts and simulated-nest surveys appear to be capable of detecting large population changes with a moderate level of effort.

Many managers consider scent-station surveys useful due to their uniformity, repeatability and cost-effectiveness (Brady 1979). An additional advantage is the ability to obtain data for a number of species with a single survey (Linscombe et al. 1983). Spotlight surveys for furbearers would be more cost-effective if they could be incorporated into surveys conducted for other species such as deer (Rybarczyk et at. 1981).

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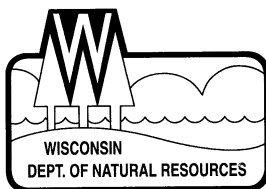
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