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Estimating porcupine (*Erethizon dorsatum* Linnaeus, 1758) density using radiotelemetry and replicated mark-resight techniques

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Abstract

Quantitative estimates of the density of North American porcupines (*Erethizon dorsatum* Linnaeus, 1758) were obtained in two adjacent study areas in central Massachusetts (northeastern U.S.). Using mark-resight (with radio-marked porcupines) estimators with data collected on one single and four replicated surveys, none of the estimates (range = 10–42 porcupines/km^2) provided the relative precision needed to detect area-specific differences in density. This was because of the small samples of marked individuals (range= 5–12/survey; 4–6/km^2), low observability of porcupines during surveys ($\bar{x}$ = 15% of marked animals seen; range = 0–40%), and low numbers of surveys. Porcupines are more reclusive than we previously thought, and intensive survey efforts are needed to obtain reasonably precise density estimates in forested habitats.

Key words: *Erethizon dorsatum*, porcupine, mark-recapture, density estimation

Introduction

Despite the apparent abundance and wide geographic distribution of the porcupine in North America, there exist few quantitative estimates of population density for this species. In addition to helping make sense of demographic data, such estimates are useful for interpreting the role of porcupines in a forest ecosystem (e.g. Krefting et al. 1962; Keith and Cary 1991) or gauging the effectiveness of an eradication program (e.g., Dodge 1959; Brander and Books 1973).

We wanted estimates of porcupine population density for use in demographic (Hale and Fuller 1996) and habitat (Griesemer et al. 1995, 1996, 1998) studies we were conducting in central Massachusetts. Censuses using tracks in snow have been used in a number of studies (e.g., Curtis 1944; Brander 1973; Powell and Brander 1977; Smith 1977; Roze 1984), but when we followed tracks in snow we often encountered networks of intersecting and overlapping porcupine trails in concentrated denning areas where porcupines shared feeding trees and/or dens (Griesemer et al. 1996). This precluded our successful use of this technique.

Other methods besides censuses have been employed to estimate porcupine numbers, but most reports seemed unsatisfactory or incomplete. Several researchers (Taylor 1935; Reeks 1942; Golley 1957; Krefting et al. 1962; Dodge 1967) based population estimates on the number of porcupines seen or shot over a time period. These counts may have provided minimum numbers, but did not account for missed animals or immigrants. Shapiro (1949) used line strip techniques but did not detail his methods, did not account for

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potential bias due to low sighting probability, and did not provide an estimate of standard error. Brander (1973) used mark-recapture methods to estimate porcupine numbers and to generate an estimate of standard error. His study, however, lacked evidence that assumptions of mark-recapture methods (e.g., a closed population, equal catchability, and no loss of marks) were not violated.

The mark-resight method (Otis et al. 1978) described in this study was used in association with radio-marked animals (cf. Miller et al. 1997) in an attempt to assess its relative precision and feasibility as applied to the study of porcupines. We present our results, discuss the shortcomings of our efforts, and suggest means by which porcupines might be more rigorously counted.

Study area

We sampled 2 survey areas on the Prescott Peninsula at the Quabbin Reservoir in central Massachusetts, an area covered by Transition Hardwoods-White Pine-Hemlock forest (Westveld et al. 1956). Elevation on the study areas ranged from 162 to 351 m and the terrain was hilly, including some areas with steep rocky slopes.

The East and Central survey areas covered 2.2–2.6 km^2 and 2.2–3.1 km^2 respectively, and were located about 1 km apart. The East area included a very steep rocky ridge where numerous porcupine dens were concentrated, and had significantly fewer white pines (*Pinus strobus*) than the Central area (Griesemer et al. 1996, 1998). The Central area was only moderately hilly and lacked rocky slopes. There were fewer den sites and usually they were hollow trees or logs. We established these survey areas to encompass porcupine winter and summer home ranges as determined from radio-tracking 50 different individuals from July 1991 to September 1993 (Hale and Fuller 1996); this allowed us to maximize the number of radio-marked porcupines in the areas at the time of the surveys.

Material and methods

Porcupines were captured by hand or in live traps by focusing efforts in two portions of the Prescott Peninsula that eventually became our study sites. Captured individuals were marked with 40-g radio-collars and small (3 mm × 10 mm) yellow plastic eartags (Hale et al. 1994; Hale and Fuller 1996). Some individuals also had one to three 1.5 × 1.5 cm pieces of colored vinyl taped affixed to the end of their 20-cm radio antennas, but we assumed that none of the marking devices were so conspicuous as to cause the initial sightability of marked animals to differ from that of unmarked ones (in fact, at least 4 marked porcupines were initially classified as unmarked by survey observers and only subsequently verified as marked by an independent observer with a telemetry receiver).

Data for the mark-resight estimates were collected concurrently during nine surveys carried out during spring and autumn 1992, and spring 1993. To maximize the sightability of porcupines, each survey was conducted during these parts of the year when most porcupines were out of dens and the forest canopy was relatively open (Griesemer et al. 1998). Of the nine surveys, two surveys were made in the East area during each of the three seasons. The remaining surveys were conducted in the Central area, once in fall 1992 and twice in spring 1993.

In each study area, we mapped twelve 1.5- to 3-km long parallel transects 100-m apart; the first transect line was begun at a random point no nearer than 50 m, and no farther than 100 m, from the survey area boundary. Each transect was walked in approximately 2 hours by solitary persons experienced in looking for porcupines or by pairs of less experienced persons (e.g., at a rate of about 1 km/h). Transects walked in a single day comprised one survey.

When a porcupine was sighted it was classified as marked or unmarked, based on observation with binoculars: The location of each sighted porcupine was marked with flagging. Immediately after the transects were completed, all radio-marked porcupines in or near the survey area were tracked and visually located to verify those reported as being seen from the transect lines, and to identify those in the survey area but not seen.

Mark-resight density estimates were calculated using NOREMARK (White 1996) which calculated simple Lincoln-Petersen estimates for single surveys, and joint hypergeometric maximum-likelihood estimates (JHE) and 90% confidence intervals (CI) for user-specified alphas for replicated surveys (e.g., Miller et al. 1997). To investigate the actual effort needed to identify differences between mark-resight estimates of porcupines, we identified several combinations of observability, marked animals available, and number of repeated surveys for a hypothetical population, and then estimated the population density using NOREMARK.

Because our porcupines were marked with radio-collars, we could monitor deaths and emigration and determine how many marked individuals were present on the survey area on each survey day; thus, we assumed our population was closed. Because these marked animals were previously captured opportunistically within the study area and monitored for up to 2 years, we recognize that our marked sample may not have been representative of the population either at the time of capture or at the time of the survey. However, because there is no feasible way to make such an evaluation, we assumed the sample was representative for the purposes of these analyses. We also recognize that a commonly violated assumption of mark-reobservation studies is that of "equal catchability", resulting in a negative bias in the estimate. In this study porcupines sighted in trees and on the ground might have unequal sighting probabilities. Population densities for each such sub-population, as well as for different ages and sexes, should ideally have been estimated separately, but the small sample size in this study ruled out this possibility. However, the different methods used for initial captures and later resights should cause any bias produced by unequal catchability to be relatively small. We found that the sighting location (ground or tree) was, in fact, independent of the marked/unmarked status of porcupines ($X^2 = 0.03$, d. f. = 1, P = 0.86).

Results

During each of the nine surveys, 2–10 porcupines ($\bar{x} = 6.4$) were seen by observers (Tab. 1); this comprised 4–32% ($\bar{x} = 16\%$) of the estimated population. Although 5–12 marked porcupines were available to be seen during each of the surveys ($\bar{x} = 7.2$; this comprised 5–27%, $\bar{x} = 18\%$ of the estimated population), only 0–2 of these were seen ($\bar{x} = 1.0$; $\bar{x}$ proportion seen = 0.15, range = 0.00–0.40). During the five area-specific survey periods, the minimum number of porcupines known to be alive (MNA) varied from 9–16. Point estimates of density determined by mark-resight methods varied 4-fold (range = 10–42/km^2) in the East area and by 1.5-fold (range = 11–17/km^2) in the Central area, but significant differences among seasons or areas could not be detected (Tab. 1).

Our simulations, given hypothetical population of 100, indicated that increasing the proportion of the population seen from 0.10 to 0.30 resulted in a 57% reduction in confidence interval length (Tab. 2). Similarly, increasing the proportion of the population marked from 0.20 to 0.40, or increasing sighting occasions from 2 to 4, resulted in 40 and 38% reductions, respectively. Improving all three parameters simultaneously resulted in an 83% reduction.

Discussion

Even with the major effort we expended in trying to enumerate porcupines, our quantitative estimates using the mark-resight method were unsatisfactory. Though our mark-resight density estimates for both sites and all surveys (10–42/porcupines/km^2) are comparable to other relatively recent estimates (5–18/km^2; Powell and Brander 1977; Roze 1984) from mixed forests, unrealistic variation among survey estimates make us reluctant to say much about differences in porcupine density. At the time of our surveys, we had no good feel for porcupine abundance, much less the proportion of animals marked or the likelihood of seeing animals while slowly walking through the woods. This, combined with the unavailability of good computer models to augment our efforts, resulted in imprecise, though probably not inaccurate, population estimates.

Table 1. Porcupine survey data and the resulting population density estimates in two study areas on the Prescott Peninsula in central Massachusetts as determined by using mark-resight estimators (and computer program NOREMARK; WHITE 1996).

Area	Date of survey	No. of marked porcupines available	No. of marked porcupines seen	Proportion of marked porcupines seen	No. of unmarked porcupines seen	Minimum no. known alive (MNA)	Popultion estimate	Size of survey area (km^2)	Density estimate: No./km^2 (90% CI)	Density estimate: MNA
East	29 Apr 92	5	1	0.20	4		17.0[a]			
	13 May 92	6	2	0.33	5		17.7			
						Total 11	22[b]	2.2	10 (6–25)	5
	17 Oct 92	6	0	0.00	10		76.0			
	31 Oct 92	9	1	0.11	6		39.0			
						Total 16	123	3.1	42 (13–354)	5
	28 Apr 93	5	2	0.40	6		17.0			
	5 May 93	5	0	0.00	9		59.0			
						Total 14	43	3.1	14 (7–52)	5
Central	24 Oct 92	6	1	0.17	3		16.5			
						Total 9	24	2.2	11 (5–84)	4
	1 May 93	12	1	0.08	1		18.5			
	8 May 93	11	1	0.09	5		41.0			
						Total 16	45	2.6	17 (9–64)	6

[a] Lincoln-Petersen estimate.
[b] Mark-resight population estimate for a closed population using joint-hypergeometric maximum-likelihood estimator.

Table 2. Variation in precision of mark-resight porcupine population estimates given a) different sightability, b) proportion of animals marked, c) number of repeated surveys, or a combination of all three. All estimated are based on a hypothetical population of 100 porcupines, and use joint hypergeometric maximum likelihood estimates (JHE) as calculated by the computer program NOREMARK (White 1996).

	Sightability	Proportion of porcupines marked	Number of porcupines seen: Total	Marked	Unmarked	No. of repeated surveys	Total (90%CI)
a)	0.10	0.20	10	2	8	2	99 (57–235)
	0.30	0.20	30	6	24	2	99 (74–150)
b)	0.10	0.20	10	2	8	2	99 (57–235)
	0.10	0.40	10	4	6	2	99 (70–176)
c)	0.10	0.20	10	2	8	2	99 (57–235)
	0.10	0.20	10	2	8	4	99 (65–176)
all)	0.30	0.40	30	12	18	4	100 (87–117)

Our simulation modeling that incorporated realistic data supported the notion that the precision of mark-resight estimates can be improved by increasing the number of surveys, the number of marked porcupines, and/or the number of porcupines seen per survey (e.g., Robson and Regier 1964; Rice and Harder 1977; Pollock et al. 1990). From a practical point of view, increasing the number of sighting occasions and increasing the number of marked porcupines might be the best way to increase precision of estimates. Increased search effort might help, but we have no data to test this potential improvement.

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Zusammenfassung

Dichteschätzungen von Baumstachlern (Erethizon dorsatum Linnaeus, 1758) mittels Radiotelemetrie und Sichtungen markierter Individuen

Quantitative Schätzungen der Dichte von nordamerikanischen Baumstachlern (*Erethizon dorsatum* Linnaeus, 1758) wurden in zwei benachbarten Untersuchungsgebieten von Zentral-Massachusetts (nordöstl. USA) durchgeführt. Die Daten wurden hauptsächlich an markierten Tieren über Telemetrie und Sichtungen während einmaliger und wiederholter Kontrollgänge erhoben. Keine der Abschätzungen (10–42 Ind./km^2) lieferte eine hinreichende Genauigkeit, um Regionen-spezifische Unterschiede in der Dichte zu ermitteln. Gründe dafür könnten in der geringen Anzahl markierter Individuen liegen (5–12 Ind./Kontr.; 4–6 Ind./km^2), in der geringen Sichtung von Baumstachlern während der Kontrollgänge ($\bar{x}$ = 15% der markierten Individuen; Schwankung = 0–40%) und in der geringen Anzahl von Kontrollgängen. Baumstachler leben offenbar stärker zurückgezogen als angenommen. Intensivere Kontrollen sind notwendig, um präzise Daten über Dichteschätzungen in Waldhabitaten zu erhalten.

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