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Relative Effectiveness of Several Bait and Trap Types for Assessing Terrestrial Small Mammal Communities in Neotropical Rainforest

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Abstract

The relative effectiveness of five bait types (peanut butter, *yuca*, plantain, fresh beef, and dried, salted fish) and four trap types (Victor, Sherman, Tomahawk, and pitfall) for capturing small mammals in lowland Neotropical rainforests was evaluated. Peanut butter was the most effective bait and Victor rat traps the most effective trap. Each captured more species and individuals than any other bait or trap type. Nonetheless, other bait and trap types captured unique species that were not taken with peanut butter bait or Victor traps. This was particularly true for trap types. Pitfall and Tomahawk traps sampled different components of the small mammal community, mostly based on body size. Tomahawk traps captured more individuals of larger species (such as *Proechimys* spp.) than Victor traps. Pitfall traps captured smaller species that were rarely or never taken in any other trap type. It is recommended that a variety of traps and baits be used to maximize the number of species and individuals that are captured. In addition, it is recommended that trapping be conducted for a minimum of 11 consecutive nights to ensure that all species present on a grid have been recorded.

Key words: bait types, mammals, Neotropics, rainforest, trap types

Introduction

Habitats of the Neotropics represent the most diverse ecosystems in the world, with high species richness across many taxa. These habitats also are some of the most threatened by deforestation and subsequent loss of habitat (Skole and Tucker 1993; Kricher 1997). Therefore, it is important to have complete and unbiased census techniques, to the extent possible, to facilitate knowledgeable conservation recommendations.

Small mammal diversity peaks in the tropics, and the species present there vary greatly in body size (5 g to 1.5 kg), diet (frugivorous to carnivorous), and habit (semi-fossorial to arboreal), making them difficult to inventory completely (Voss and Emmons 1996; Patton et al. 2000; Voss et al. 2001; Hice and Velazco 2012). It is known that trap types, bait types, and trapping protocols (e.g., time) influence results of inventories. In North America, a vast literature examines the effectiveness of many different trap and bait types used in small mammal field studies (Edwards 1952; Sealander and James 1958; MacLeod and Lethiecq 1963; Beer 1964; Patric 1970; Wiener and Smith 1972; Duran and

Samz 1973; Nellis et al. 1974; Rose et al. 1977; Szaro et al. 1988; McComb et al. 1991; Kalko and Handley 1993). When estimating population abundance and community composition, significant differences have been found between snap traps and live traps (Pizzimenti 1979; Woodman et al. 1996), among types of live traps (Wiener and Smith 1972; Astúa et al. 2006; Santos-Filho et al. 2006; Umetsu et al. 2006; Caceres et al. 2011), among types of snap traps (Smith et al. 1971), among bucket sizes in pitfall traps (Ribeiro-Júnior et al. 2011), and between pitfall traps and all other trap types (Handley and Kalko 1993; Voss et al. 2001; Hice and Schmidly 2002; Santos-Filho et al. 2006; Umetsu et al. 2006; Caceres et al. 2011). The type of bait also can significantly alter capture rates (Beer 1964; Patric 1970; Buchalczyk and Olszewski 1971; Willan 1986). This may be even more pronounced in the tropics because of the greater variety of small mammals present. Nonetheless, few studies have addressed the impact of bait type on capture rate in the Neotropics (Cerqueira et al. 1990; Woodman et al. 1996; Astúa et al. 2006).

Trap and bait comparisons were performed during the course of a larger study designed to examine the effects of deforestation and habitat on small mammal community structure (Hice 2003; Hice and Velazco 2012). Four trap and five bait types were compared in different habitats of lowland Neotropical rainforest in northeastern Peru. In addition, the length of time necessary to monitor grids to thoroughly survey the small mammal community was examined. The purpose of this portion of the study was not to examine the efficacy of the trapping effort in total (those results are presented in Hice and Velazco 2012). Instead, goals were to identify the best combination of trap and bait types with which to capture small mammals in lowland Neotropical rainforest and to determine how long grids needed to be monitored to characterize the small mammal community structure.

STUDY AREA AND METHODS

This study was conducted at the Reserva Nacional Allpahuayo-Mishana (RNAM; 3°58'S; 73°25'W), a 57,667 hectare national reserve operated by the Instituto de Investigaciones de la Amazonía Peruana (IIAP), located 28 km southwest of Iquitos on the Iquitos-Nauta highway, Province of Maynas, Department of Loreto, northeastern Peru. The site is located in the Humid Tropical Forest Botanical Province of the Holdridge System (Tosi 1960), and comprises one major habitat type: low-terrace broadleaf tropical rainforest (López-Parodi and Freitas 1990), a type of non-flooded or *terra firme* forest. The climate is tropical, with a mean annual temperature of 26º C. The highest average monthly temperature (31º C) occurs in November and the lowest (22º C) in July (Salati 1985). Daily temperatures fluctuate approximately 10º C. Average annual rainfall is 2,945 mm, with a slightly drier season from June to September (Johnson 1976). The elevation of the site ranges from 110 to 180 m.

To compare the effectiveness of baits, three grids (numbered B1–B3) were established in primary rainforest, each with a 7 x 7 trap array and 15 m spacing between stations (1.1 ha of effective area - traps stations were considered to be in the center of each 15 m square, making the grid 105 m^2). This size trap array represents the largest that could be used because only 200 traps of each type were available. Each station comprised four traps of the same type arranged symmetrically around a central flag with their entrances facing outward. There were four sizes of Tomahawk mesh live-traps (40 x 14 x 14 cm, 48 x 17 x 17 cm, 51 x 19 x 19 cm, and 66 x 23 x 23 cm; three small and one of the larger sizes at each station) on grid B1, Victor snap-type rat traps on grid B2, and folding Sherman aluminum live-traps (22.9 x 7.6 x 8.9 cm) on grid B3 (see Voss and Emmons 1996, Fig. 4, for photographs of these trap types). Each trap at a station contained a different bait. On grid B1, traps were baited with 1) alternating *yuca* or plantain; 2) dried, salted fish (hereafter fish); 3) fresh beef, or 4) a peanut butter/pork fat mixture (2:1 ratio of peanut butter to pork fat with sufficient oatmeal added to stick to trap treadles; hereafter referred to as peanut butter bait) were used. Traps on grids B2 and B3 were baited with 1) *yuca*; 2) plantain; 3) alternating fish or fresh beef; or 4) peanut butter bait. The alternating baits were placed in every other station and the baits at a station were alternated daily (e.g., if fish was at a station on day 1, beef was used on day 2, etc.). Thus four types of bait were offered at each trap station each night. A different baiting regime occurred on grid B1 because the larger Tomahawk traps likely have a better chance of capturing larger marsupials and small carnivores. A meat bait would be more appropriate for these species. Each grid was monitored for 20 consecutive nights, although not concurrently, from 29 September to 29 October, 1997, to determine the minimum length of time needed to characterize small mammal community structure on each grid. This relatively short time period was used to eliminate any effects of season, rainfall, or temperature on bait preference. Traps were checked, captured animals and remaining bait were removed, and traps disarmed at dawn each day. Traps subsequently were baited and armed in the afternoon.

Trap comparisons were conducted from 2 November to 20 December, 1997, on six larger grids comprising a 10 x 10 trap array with 15 m spacing between stations (2.25 ha of effective area - traps stations were considered to be in the center of each 15 m square, making the grid 150 m^2). To ensure that a complete, previously unsampled small mammal community was being assessed, these grids were distinct from the grids used for bait comparisons. Three grids each were placed in primary forest (numbered T1–T3) and secondary growth (T4–T6). Each station comprised one Victor, one Sherman, and one small (40 x 14 x 14 cm) Tomahawk trap. All traps were baited with peanut butter. Each grid was monitored for 10 consecutive nights. Traps were checked and disarmed at dawn each day, and captured animals and remaining bait were removed. Traps were baited and armed in the afternoon.

Six pitfall traplines were established, one adjacent to each of the larger grids (T1–T6). Distance from the grids ranged from 40–60 m. Pitfall traplines consisted of eleven 20 L buckets buried flush to the ground surface and placed 5 m apart under a continuous 50 m drift fence made of plastic (Voss and Emmons 1996; Hice and Schmidly 2002). Small holes were drilled in the bottom of each bucket to allow rainwater to drain. One unforeseen problem was that the holes also allowed groundwater to enter in low-lying areas. Traps were assessed for 10 consecutive nights concurrently with the corresponding grid in the same habitat. Traps were checked each morning at dawn. No bait was used and no liquid was introduced intentionally into the buckets (Sikes et al. 2011).

For each captured mammal, standard information was recorded (i.e., gender, reproductive condition, standard measurements of length, and weight), a standard museum skin and skull (or skeleton) were prepared, and tissues (e.g., heart, kidney, lung, spleen, liver, muscle) were collected. Individuals were subsequently identified to species when clean skeletal material was available. Specimens are deposited at the Museum of Texas Tech University, Lubbock, Texas (TTU), the Los Angeles County Museum of Natural History, Los Angeles, California (LACM), and the Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos, Lima, Peru (MUSM).

Differences in capture rates among bait types were evaluated separately for each grid (i.e., trap type) with a log-likelihood goodness-of-fit test (G-test). This was conducted with data from grids B1–B3 (the grids used in the bait comparisons). Data could not be pooled for all trap types because a G-test for heterogeneity indicated that the ratios were not homogeneous for all trap types. Nevertheless, overall results for bait types regardless of trap type are presented but not assigned a significance value.

Differences in capture rates among trap types were evaluated in a similar manner. Data from each of the six grids (T1–T6) were tested with a G-test for heterogeneity. This indicated no significant difference among grids (and therefore, habitat type), so data were pooled from all six grids and again analyzed with a G-test to determine whether differences in capture rates existed among trap types regardless of habitat type. Trap types (not bait types) also were compared to determine if they characterized mammal community structure (based on relative abundance) equally by using a log-likelihood ratio for contingency tables (G-test, Zar 1984) conducted with MatLab (version 5.3). One was added to each cell because a G-test cannot be conducted on a matrix that contains zeros; this makes the results of the test more conservative. Pitfall traps could not be evaluated in this fashion because the number of pitfall trap nights was not equal to that of the other trap types. Moreover, a G-test could not be conducted for bait comparisons because variable numbers of trap nights for each bait type confounded the analysis.

This method also was used to examine differences in capture rates among four size classes of mammals (< 50 g, 50–99 g, 100–249 g, and > 249 g) by trap type. In each case, if the overall G-test for contingency tables was significant, pair-wise comparisons were conducted to determine which trap types contributed significantly to the overall differences. When more than one analysis was conducted using the same data matrix, sequential Bonferroni adjustment was used to maintain the experiment-wise error rate at 0.05 (Sokal and Rohlf 1995).

Data were examined by two methods to determine the adequacy of sampling period. First, the number of species captured was plotted against effort based on number of consecutive days of sampling (this is equivalent to the number of trap nights because the same number of traps were assessed on each grid each night). Second, the number of species captured was plotted against success based on the number of individuals captured. Graphs were examined for a convincing asymptote to determine if the community had been completely sampled. A convincing asymptote was defined as a run that was at least twice as long as the previous run. Only data from the grids assessed for 20 nights (B1–B3) were used in this analysis.

Results

Type of bait.—During bait comparisons, 83 individuals representing 14 species were captured in 11,760 trap nights (capture rate of 0.70%). Peanut butter was the most effective bait overall, capturing 39 individuals, followed by *yuca* (25), plantain (9), fish (6), and beef (4). Peanut butter also captured the most species (11), followed by *yuca* and plantain (tied at six), and fish and beef (tied at four; Table 1). Rodents were taken with all bait types and marsupials were captured with all baits except fish.

Baits differed in effectiveness depending on trap type ($G = 32.194$, $df = 8$, $p < 0.001$; Table 1). In all trap types, peanut butter captured the most individuals. *Yuca* was nearly as effective as peanut butter for attracting rodents to Sherman and Tomahawk traps, but it attracted only one marsupial. Beef bait attracted mammals only to Tomahawk traps; no individuals were captured with beef in any other trap type. Plantain was marginally effective in Sherman traps (six of nine individuals) and captured only three individuals in other traps. Fish attracted three or fewer individuals to any trap type.

Type of trap.—Trapping during trap comparisons yielded 341 individuals representing 21 species in 18,660 trap nights (capture rate of 1.83%). The G-test for heterogeneity indicated the effectiveness of traps was independent of habitat type (i.e., primary vs. secondary forest; $G = 10.409$, $df = 15$, $p < 0.001$; Table 2), so data were pooled from all grids for subsequent analyses.

Trap types differed in effectiveness as inferred from capture success rates (number of individuals captured/number of trap nights). Capture rates among trap types differed significantly for the entire small mammal community ($G = 84.046$, $df = 15$, $p < 0.001$) as well as for the separate marsupial ($G = 94.942$, $df = 15$, $p < 0.001$) and rodent ($G = 975.593$, $df = 15$, $p < 0.001$) components of the community (Table 3). Generally, pitfalls captured about twice as many individuals as would be expected (based on a random distribution of captures) when compared to other trap types. Victor traps captured about 60% more individuals than the average for all trap types. Sherman traps were about equal to the average of all trap types. Tomahawk traps captured about half as many individuals as expected based on a random sampling distribution of captures (Table 3).

Body mass.—Small mammal susceptibility to different trap types differed depending on body mass (Table 4). The total number of individuals available for this analysis was 330, as an accurate mass could not be obtained for 11 of the individuals captured. The smallest individuals (mass < 50 g) were most effectively captured with pitfall and Victor traps ($G = 100.490$, $df = 3$, $p < 0.001$). Not surprisingly, Tomahawk traps were not effective for this size class because lightweight individuals do not readily trip the trap. For individuals that weighed from 50–99 g, Victor traps were most effective. Sherman and Tomahawk traps were much less effective than Victor traps, but were about equally effective to each other ($G = 21.938$, $df = 3$, $p < 0.001$).

Table 1. Captures by bait type. Hyphenated numerical sequences represent, in order, total number captured in Sherman traps, Tomahawk traps, and Victor traps. Bait types are PB = peanut butter, Y = yuca*, P = plantain, F = dried, salted fish, B = fresh beef. Empty cells indicate that no individuals of a particular species were captured by a particular bait.*

Species	PB	Y	P	F	B	Total
Didelphimorphia						
Marmosa waterhousei	0-1-0					1
Marmosops bishopi			1-0-0			1
Marmosops noctivagus	3-0-0	1-0-0	1-0-0			5
Metachirus nudicaudatus	1-0-0				0-1-0	2
Rodentia						
Hylaeamys perenensis	6-6-6	5-1-5	2-1-1	1-0-1		35
Hylaeamys yunganus	0-1-0	2-0-2	0-1-0	0-0-1		7
Mesomys hispidus					0-1-0	1
Neacomys spinosus	1-0-0					1
Neacomys tenuipes	4-0-0	1-0-0	1-0-0	1-0-0		7
Nectomys squamipes		1-0-0			0-1-0	2
Proechimys brevicauda	0-2-0					2
Proechimys cuvieri	2-0-4	4-0-3	1-0-0	1-1-0	0-1-0	17
Proechimys quadruplicatus	0-0-1					1
Proechimys simonsi	1-0-0					1
Total	39	25	9	6	4	83

For larger individuals (100–249 g), pitfall and Sherman traps were least effective, Tomahawk traps were most effective, and Victor traps were less effective than Tomahawk traps and more effective than Sherman or pitfall traps (G = 16.565, df = 3, $p < 0.001$). The largest small mammals (> 249 g) were captured equally by Victor and Tomahawk traps, but none were taken in Sherman or pitfall traps (G = 12.812, df = 3, $p < 0.001$) because they can not readily enter the former, and can escape from the latter.

Characterization of community structure.—Different trap types did not equally sample the overall small mammal community (G = 72.164, df = 40, $p = 0.001$; Table 2). The distribution of individuals among taxa sampled by Sherman and Victor traps was indistinguishable (G = 24.569, df = 20, $p = 0.218$), but Tomahawk traps captured a larger proportion of larger mammals (>100 g body mass; Victor: G = 38.991, df = 20, $p = 0.007$; Sherman: G = 53.229, df = 20, $p < 0.001$). If the community is split between marsupial and rodent components, no difference in community structure was detected by different trap types for the marsupial community (G = 11.503, df = 14, $p = 0.646$) and rodents followed the same pattern as the overall community (overall: G = 56.786, df = 24, $p < 0.001$; Sherman vs. Victor: G = 45.201, df = 12, $p = 0.083$; Tomahawk vs. Victor: G = 26.496, df = 12, $p = 0.009$; Sherman vs. Tomahawk: G = 45.201, df = 12, $p < 0.001$).

Table 2. Captures by type of trap. Trap types are P = pitfall, S = Sherman, T = Tomahawk, and V = Victor. Empty cells indicate that no individuals of a particular species were captured by a particular type of trap.

Species	P	S	T	V	Total
Didelphimorphia					
Didelphis marsupialis			1		1
Marmosa waterhousei			1	3	4
Marmosops bishopi				3	3
Marmosops noctivagus	2	2	2	16	22
Metachirus nudicaudatus			3	1	4
Monodelphis adusta	2				2
Philander andersoni			1		1
Philander opossum			2	1	3
Rodentia					
Holochilus sciureus				1	1
Hylaeamys perenensis	1	19	13	33	66
Hylaeamys yunganus		9	5	20	34
Neacomys spinosus	2	15	2	19	38
Neacomys tenuipes	6	22		16	44
Nectomys squamipes			1		1
Oecomys bicolor	3	2	1	9	15
Oecomys roberti	1				1
Oligoryzomys microtis	7	8	1	16	32
Proechimys brevicauda			6	8	14
Proechimys cuvieri		4	15	15	34
Proechimys quadruplicatus		1	1	12	14
Scolomys melanops	2	1	1	3	7
Total # of individuals	26	83	56	176	341
Total # of species	9	10	16	16	21

Table 3. Capture rate [(number of individuals captured/total number of trap nights) x 100], number of trap nights, number of individuals captured, and number of individuals expected to be captured based on a random sampling distribution for each trap type by taxa.

Trap type	All Mammals	Didelphimorphia	Rodentia
Pitfall			
Capture rate (%)	3.94	0.61	3.33
Trap nights	660	660	660
Number captured	26	4	22
Number expected	12	1.38	10.65
Sherman			
Capture rate (%)	1.38	0.03	1.35
Trap nights	6000	6000	6000
Number captured	83	2	81
Number expected	109	12.54	96.78
Tomahawk			
Capture rate (%)	0.93	1.67	0.77
Trap nights	6000	6000	6000
Number captured	56	10	46
Number expected	109	12.54	96.78
Victor			
Capture rate (%)	2.92	0.38	2.53
Trap nights	6000	6000	6000
Number captured	175	23	152
Number expected	109	12.54	96.78
Total captured in all trap types	340	39	301

Table 4. Number of individuals captured in each of four size classes in each of four trap types. Trap types are P = pitfall, S = Sherman, T = Tomahawk, and V = Victor.

Mass	P	S	T	V	Total
< 50 g	22	58	7	78	165
50–99 g	3	21	19	53	96
100–249 g	0	2	13	21	36
> 249 g	0	2	16	15	33
Total	25	83	55	167	330

Adequacy of sampling period.—All species captured on the three grids combined during 20 consecutive nights were captured in the first 11 nights (6,468 trap nights total) of trapping (Fig. 1). If each grid is examined individually, new species were encountered until night 15 (2,940 trap nights) on one grid and until night 11 (2,156 trap nights per grid) on the other two grids (Fig. 1).

In addition to the species-time curve, the data were analyzed by plotting cumulative number of species versus cumulative number of captures for each grid separately as well as for all grids combined (Fig. 2). For the grids assessed for 20 consecutive nights, an asymptote was approached between 18 and 36 captures, which correspond to nights 11 and 15, respectively (Fig. 2). If all three grids are examined simultaneously, the asymptote is approached after 68 captures, which also coincides with 11 nights (Fig. 2).

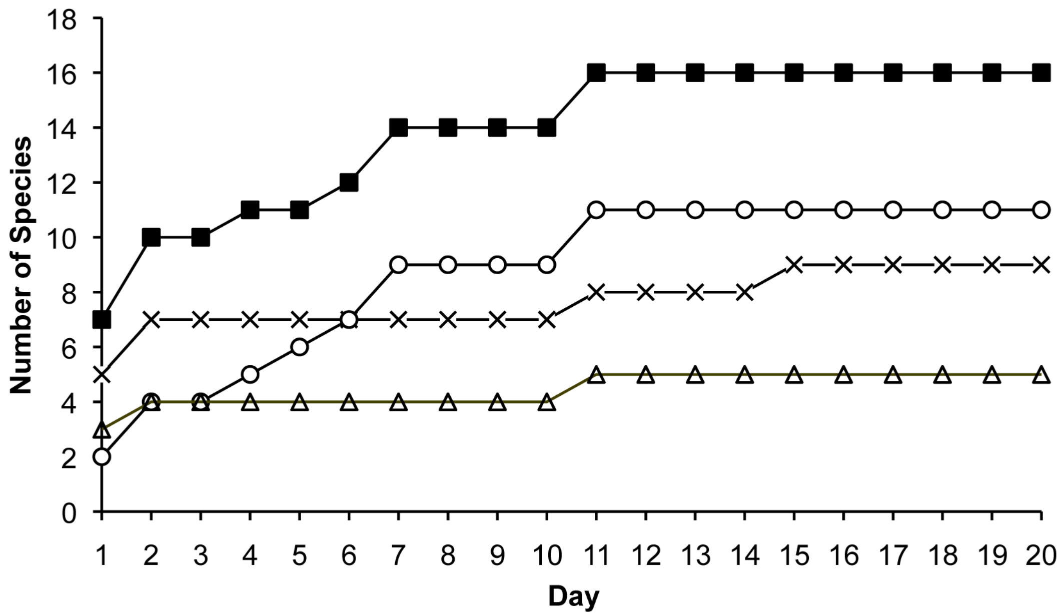

Figure 1. Species accumulation as a function of time (i.e., effort) on each of three grids monitored for 20 days. Open circles = grid B1; x = grid B2; open triangles = grid B3; solid squares = pooled data for all grids.

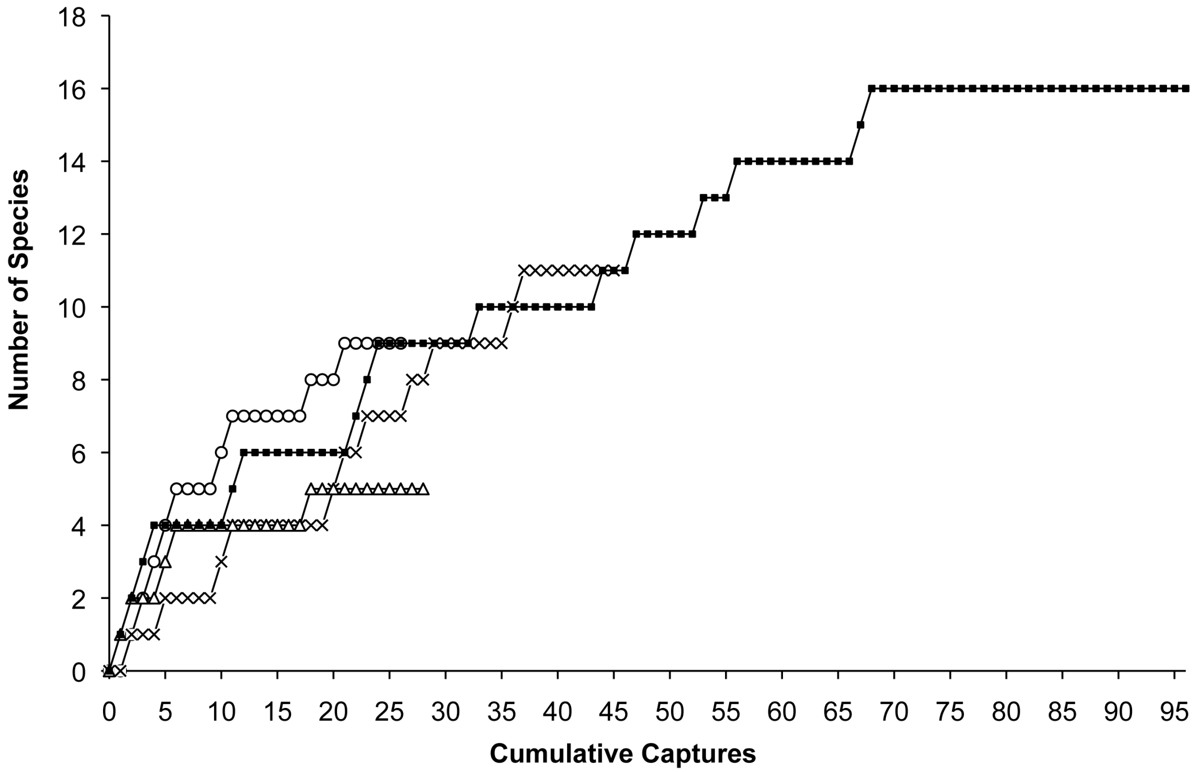

Figure 2. Species accumulation as a function of cumulative captures on each of three grids monitored for 20 days. Open circles = grid B1; x = grid B2; open triangles = grid B3; solid squares = pooled data for all grids.

DISCUSSION

One other study has examined the effect of bait type on capture success of small mammals in lowland Neotropical rainforest (Woodman et al. 1996). However, they only compared two types of bait – a suet bait and a peanut butter bait. Although the two baits differed in odor and nutrient content, they were equally effective at attracting small mammals to traps. This contrasts with the results of this study, in which peanut butter was the most effective bait based on number of captured individuals and species. However, the baits compared in this study differed more in odor, appearance, and nutrient content than did the baits used by Woodman et al. (1996). Moreover, the two types of bait Woodman et al. (1996) used were offered on alternate nights, not simultaneously, so individuals did not have a choice of bait on the night of capture. This could confound the results if particular nights were less suitable for capturing small mammals due to heavy rain or a full moon with little cloud cover. In this study, four types of bait were offered in adjacent traps on the same night, an arrangement that controlled for effects of weather.

In experiments conducted in lowland Atlantic Forests, Cerqueira et al. (1990) and Astúa et al. (2006) found that different baits attracted a different subset of small mammal communities. Cerqueira et al. (1990) compared bacon, banana, corn, and peanut butter with *yuca* and found that marsupials where more frequently captured with bacon and rodents with peanut butter with *yuca*. Astúa et al. (2006) only compared two types of bait, bacon and peanut butter, and found that marsupials were preferably taken with bacon and rodents with peanut butter.

Although in our study peanut butter was the most effective bait overall, other baits could be used success-fully, depending on the goal of the study. For example, *yuca* was as effective as peanut butter for capturing rodents in live traps, so if an investigator were interested in sampling only the rodent community, *yuca* could be used instead of peanut butter. This has additional benefits because peanut butter is not readily available in many locations and is more expensive than *yuca*. Several other potential baits may be locally available, including pineapple, ripe bananas, other local fruit, canned tuna or sardines, and canned cat food.

Several studies have examined the effect of trap type on capture success of small mammals in South America, two in Peru (Pizzimenti 1979; Woodman et al. 1996), several in Brazil (Cerqueira et al. 1990; Astúa et al. 2006; Santos-Filho et al. 2006; Umetsu et al. 2006; Caceres et al. 2011), and one in French Guiana (Voss et al. 2001). The results of these studies are variably comparable to the results from this study.

Voss et al. (2001) worked in lowland forested habitats in French Guiana, but the results presented were pooled from Victor and Sherman traps, therefore making it impossible to directly compare their results with the results obtained from our study. Moreover, they did not statistically analyze any of their results in a comparative manner to determine whether a significant difference existed with respect to the effectiveness of trap types. They simply point out that particular trap types "...appeared to be maximally effective for some taxa and relatively ineffective for others" (p. 167, Voss et al. 2001).

Although Pizzimenti (1979) worked in a different habitat type and therefore sampled a much different small mammal community than that present at RNAM, some of his results were similar to those obtained in this study. For example, he found two types of snap traps (Museum Specials and McGill rat traps) to be more effective than Sherman live traps based on capture rate at eight sites in the Andes of southern Peru. He also found that Sherman traps captured more lightweight individuals than did snap traps. Although Victor snap-traps captured the most lightweight individuals at RNAM, 58 out of 83 total individuals taken by Shermans were in the lightest weight class (< 50 g, see Table 4), demonstrating that Sherman traps were effective at capturing lightweight individuals at RNAM as well.

Caceres et al. (2011) also worked in a different habitat type than that found at RNAM. They pooled results of Sherman and wire traps (roughly equivalent to Tomahawk traps) in their analyses, but some comparisons with results from our study are still possible. For example, they found that "there was a generally trending for lighter [weight] individuals to be caught in pitfall traps" (p. 48, Caceres et al. 2011), but analyses were conducted at the species level, not by grouping individuals into weight classes independent of species. Lighter weight individuals also were more frequently captured in pitfall traps at RNAM. Caceres et al. (2011) used a larger Sherman trap and slightly smaller wire trap than we did, making comparisons with our results difficult. However, they did find that "cage wire traps favored the capture of larger species" (p. 50, Caceres et al. 2011) and attribute this to the somewhat larger size of the wire traps compared to the Sherman traps. We also found that Tomahawk traps tended to capture heavier individuals than did other traps types.

Two studies were conducted in the Brazilian Atlantic Forests (Astúa et al. 2006 and Umetsu et al. 2006). Astúa et al. (2006) compared Sherman and Tomahawk traps of the same sizes used at RNAM, although they placed one of each trap type at a trapping station, one in a terrestrial and the other in an understory position, thus not providing more than one trap type to select from for terrestrial species. They also pooled understory and terrestrial capture data for each trap type, again making comparisons difficult. They did find that Sherman traps captured smaller individuals than did Tomahawk traps, echoing our results and those of Caceres et al. (2011).

Umetsu et al. (2006) compared pitfall and Sherman traps. They found pitfall traps to be more efficient than Sherman traps, with a substantially higher capture rate (15.53% vs. 2.58%). We also found pitfall traps to have a higher capture rate than Sherman traps (3.94% vs. 1.33%), but the differential effectiveness was not nearly as striking as that found by Umetsu et al. (2006). They found no difference in the weights of individual captured by pitfall or Sherman traps, whereas we found pitfalls to be more effective at capturing lighter weight individuals. However, Umetsu et al. (2006) used substantially larger pitfall traps than were used at RNAM (60 L vs 20 L volume), which may have prevented larger individuals from escaping from their traps.

They also found that pitfalls captured a significantly greater number of species than did Shermans (29 vs. 14), whereas we found that the two trap types captured nearly the same number of species (9 vs. 10), although pitfall traps captured two species not captured by any other trap type in our study.

The habitat, semi-deciduous sub-montane forest in Mato Grosso, Brazil, and small mammal community sampled by Santos-Filho et al. (2006) are quite different from that present at our study site in Peru, but their trapping methods were similar. They compared the same four trap types used in our study, although the pitfall traps they used were coned shaped (ours were flat-bottom buckets) and the snap traps they used were somewhat shorter that Victor rat traps (90 x 150 mm vs. 85 x 175 mm). They reported a higher overall capture rate than we recorded at RNAM (2.9% vs. 1.8%). However, capture rates for snap traps were the same in both studies (2.9%). Contrary to our results, pitfall traps had the lowest capture rate of all trap types used in the Mato Grosso study, 1.3%, whereas pitfalls had the highest capture rate, 3.9%, at RNAM. They also found that Sherman traps were the most effective trap type, with a capture rate of 4.7%. At RNAM, Sherman traps only had a capture rate of 1.4%. Finally, they found Tomahawk traps and snap traps to be roughly equal in effectiveness (2.7% capture rate), whereas Tomahawk traps were the least effective trap type at RNAM, with a capture rate of 0.9%.

The differences in the effectiveness of trap types at the two study sites is undoubtedly due to differences in the species composition of the small mammal community present at the two sites. In Mato Grosso, marsupials comprised almost 60% of the individuals captured; at RNAM they were only 11.7% of the total. Pitfall traps are not particularly effective for capturing many species of marsupials (with the exception of *Monodelphis* spp.). Most of the marsupials captured in Mato Grosso were larger marmosines that could easily escape from pitfall traps or simply did not encounter the traps because they are semi-arboreal in their habit. Of rodents, 20.5% of the individuals captured at RNAM belonged to the genus *Proechimys*, which, because of their large size, do not readily enter Sherman traps. In Mato Grosso only 5.8% of the rodents captured belonged to this genus. The remaining species (with the exceptions of *Mesomys* and *Dasyprocta*) were small- to medium-sized rodents that could easily enter and trip a Sherman trap. The relatively high effectiveness of Sherman traps at Mato Grosso and low effectiveness of them at RNAM is most likely due to the relatively high abundance of Proechimys at RNAM and low abundance of this genus at Mato Grosso.

The study most comparable to ours was conducted by Woodman et al. (1996) in the Reserva Cuzco Amazónico in southern Peru. The habitat sampled by Woodman et al. (1996) is similar to that of RNAM, as is the small mammal community assemblage. They compared two of the traps used in our study, Sherman traps and Victor rat traps. They found that snap traps took 3.5 times as many individuals as did Sherman traps. Although only twice as many individuals were captured in snap traps as in Sherman traps at RNAM, the results at both sites indicate that snap traps are more effective than other trap types for sampling the small mammal fauna present in lowland Neotropical rainforest habitat.

Woodman et al. (1996) found that the two trap types they used sampled the community similarly based on relative abundances of species. This also was true at RNAM, where the proportions of the community sampled by Sherman and Victor traps were indistinguishable. The results obtained at Cuzco Amazónico differed from those at RNAM in regard to body mass. Whereas Woodman et al. (1996) found no difference in the size classes of small mammals captured in either trap type, at RNAM there was a significant difference between Victor and Sherman traps ($G = 18.02$, $df = 3$, $p < 0.001$) with Sherman traps capturing relatively more smaller and fewer larger individuals.

Based on our results, several recommendations can be made. If only one type of trap can be employed, or if traps must be carried a long distance so that heavy or bulky traps would be prohibitively difficult to transport, Victor traps are recommended. However, if it is feasible, additional types of traps should be deployed to obtain a more accurate assessment of the small mammal community. Pitfall traps, while time-consuming to set, capture species not captured in other trap types, as well as smaller and younger individuals. They also had a higher capture rate compared to other types of traps (3.94% vs. 1.75%). Tomahawk traps captured more large marsupials and rodents than did other trap types, so it is important to use them when surveying these groups. This study is in agreement with the recommendations of other investigators, in that a variety of trap types and placements (not just on the ground) is important for capturing as many species as possible (Woodman et al. 1996; Voss et al. 2001; Lambert et al. 2005; Santos-Filho et al. 2006). This is particularly important in lowland Neotropical rainforest, where species richness is high, density is relatively low, and the masses and niches of different species exhibit considerable variation.

Species-time curves have often been used to assess how completely a community has been sampled. However, many problems are associated with this method, which have been discussed at length (Colwell and Coddington 1994; Voss and Emmons 1996; Simmons and Voss 1998). These include factors inherent in both sampling methods and the fauna being sampled, such as lack of uniform effort throughout the sampling period, use of standardized grids versus opportunistically placed traplines, effects of season on the trapability of the small mammals, and the uneven distribution of individuals across the landscape. However, none of the aforementioned problems with regards to sampling methodology are applicable to this study. The same number of trap nights was recorded on each grid each night, and grids were identical in size and configuration of trap stations. Effects of season were controlled by conducting each comparison (bait or trap) during a short time period within one season.

Woodman et al. (1996) suggested that traplines should be monitored for a minimum of seven consecutive nights in lowland Neotropical rainforest to sufficiently sample common and rare species, and to estimate community composition. However, Woodman et al. (1996) only assessed traps for 12 consecutive nights; therefore, conclusions about how additional effort could have impacted their results could not be drawn. The same is true for work conducted along the Rio Juruá in Brazil, where Patton et al. (2000) monitored traps for seven consecutive nights. Voss et al. (2001) monitored terrestrial traplines for 8 to 14 consecutive nights, but no analysis of the results from individual traplines was provided.

Because of the problems associated with species/time curves, species/cumulative capture curves are thought to better characterize the sampling process. Therefore, data obtained during bait comparisons are presented in both manners (see Figs. 1 and 2). Both kinds of curves suggested that a sampling period of at least 11 consecutive nights was necessary to adequately sample species of mammals present on a grid in rainforest habitat. The number of nights necessary to fully sample the small mammal community of an area probably varies seasonally and geographically. Although all species captured on any individual grid were taken in the first 11 consecutive nights, additional species were added subsequent to this study as trap nights, captures, and field hours were accumulated. The number of consecutive nights and total field hours to be expended depends on constraints of time and money, the balance of diminishing returns, and the specific objectives of the research.

In summary, there is no fast or easy way to exhaustively inventory a small mammal community in lowland Neotropical rainforests, where species richness is higher and many species are rarer, than in structurally simpler temperate habitats (Morris 1968; Pucek and Olszewski 1971; Woodman et al. 1995; Voss et al. 2001). In concrete terms, our results suggest that a variety of traps must be deployed for a minimum of 11 consecutive nights to be more or less certain that all species present in the local area have been captured. The more types of traps and the more varied their placement (i.e., arboreal, terrestrial, mid-canopy), the more likely the maximum number of species will be captured. Since new species are often added to inventories after many months in the field (Voss et al. 2001), trapping should continue for as long as feasibly possible. Moreover, traps should be placed in as many habitats as possible, because many Neotropical mammals are habitat specialists (e.g. *Oligoryzomys microtis*, *Scolomys melanops*). Although peanut butter bait was preferred at RNAM, bait preference may depend on locale, season, habitat, or species of interest, so a variety of baits should be used when possible.

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