4-2013

Small Mammal Bait Preference and Methods of Population Size Estimation in Subarctic and Arctic Ecosystems

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Environmental and Forest Biology
With Honors

April, 2013

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Chapter 1: Small Mammal Bait Preference in Interior Alaska

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ABSTRACT

Small mammals are commonly captured in baited traps for management-related estimates of population size and species diversity. Bait preferences by species may alter their trappability, affecting abundance or diversity estimates. Here our objective was to evaluate whether the trappability of different species varied according to bait type at 3 sites in interior Alaska. Between July and August of 2011, we deployed 200 Sherman live-traps spaced 10 meters apart at each site for 5 nights, and alternated 2 commonly used baits (a peanut butter/oat mixture or oats alone). We live-captured 52 animals of 6 species at the White Mountains site, 70 animals of 4 species at the Middle Tanana site, and 40 animals of 4 species at the Brooks Range site. We then tested for differences in initial capture and recapture rates using a McNemar's test. No significant differences were observed between bait types for any variable or species. A machine-learning program, TreeNet, provided further evidence that bait type explained less variance and was less predictive of the initial capture or recapture of a species than elevation, ground cover, or shrub cover. Thus, estimates of relative abundance and species diversity should be robust across studies, although different baits than those tested may have greater effects for certain small mammal groups. Further investigation should be pursued into whether this lack of preference is a result of food limitations caused by a short growing season in higher latitudes.

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ACKNOWLEDGMENTS

I would like to acknowledge Dr. Stephen V. Stehman for assistance in selecting statistical analyses, Salford Systems Ltd. for use of their product, Dr. William Shields for coordinating the honors program for which this research was undertaken and serving as a second reader, Sara Hansen for support and sage advice, Michael O'Brien for his editing expertise, and Dr. Falk Huettmann for his advice in experimental design. A special thanks to Andy Baltensperger for his support in the creation of this research and to Dr. Jaqueline Frair for her never-ending patience, enthusiasm for talking through the project, and for serving as an incredible mentor in wildlife research.

INTRODUCTION

Small mammal trapping, a common practice in the field of wildlife research has been used to document population sizes and community assemblages, estimate prey abundance for predators, track population cycles, and to monitor population health via hair and blood samples. Best practices for trapping small mammals and detecting small mammal presence have been the focus of considerable research effort (Buckner 1957, Beer 1964, Patric 1970, Anderson et al. 1983, McComb et. al 1991, Oswald and Flake 1994, Woodman et al. 1996, Parmenter et al. 2003). Whether different bait types differentially attract specific species, or attract more of a given species has been of particular interest (Buckner 1957, Beer 1964, Patric 1970; McComb et. al 1991, Oswald and Flake 1994, Woodman et al. 1996). Beer (1957), Buckner (1964), and Patric (1970) found that the most effective bait type in terms of capture numbers and species diversity was peanut butter or peanut butter mixed with oats, whereas Woodman et al. (1996) found approximately equal success for a mixture of peanut butter and oats compared to a suet mixture. Based on these studies, a mixture of peanut butter and oats is considered the standard bait for small mammal trapping in North America (Schemnitz 1996).

The majority of bait preference research in small mammals has been performed using “snap” traps in which the captured animal is killed, perhaps obscuring true bait preference (Bucker 1957, Beer 1964, Patric 1970). Consider an animal that either randomly or systematically searches the area each evening for food. They might encounter and investigate a novel feature, such as a trap, but fail to revisit that trap on consecutive nights, if they found the bait or the experience of being trapped distasteful. However, if they had a strong preference for a given bait, then they might be recaptured at a given trap over time. So live recaptures may provide more evidence for bait preferences than traps designed to kill the animal on its first encounter. The use of lethal traps is likely declining in many studies aiming simply to monitor abundance or species diversity, which do not require whole body specimens to be killed and collected. Bait preferences, and perhaps differences in the effect of baits on initial capture or recapture probabilities, in capture-mark-recapture studies remain underexplored. Herein, I tested whether bait preference could be detected in small mammals between two simple and cost-effective baits used in live traps. This research was performed in July-August, 2013 at three sites in interior Alaska, using baits of rolled or steel cut oats compared to a peanut butter-oat mixture.

METHODS

Study areas

The first site was located in the White Mountains in the Steese Mountain Recreation Area (Lat: 65.41095, Long: 145.98810). The elevation of the center point of the trap loops was 1119 meters. The site consisted of alpine tundra with little vegetation exceeding a height of 10 cm. The only woody vegetation growing up to a meter in height consisted of white spruce (*Picea glauca*) and willow (*Salix sp.*). The ground cover included various lichens, bearberry (*Arctostaphylos alpinus*), *Dryas sp.*, crowberry (*Empetrum nigrum*), dwarf birch (*Betula nana*), moss heather (*Cassiope stelleriana*), and alpine blueberry (*Vaccinium sp.).* The second site was an area within the Bonanza Creek Experimental Forest LTER in the Tanana River Valley (Lat: 64.70984, Long: 148.29433, Elev: 133m). This site was a lowland black spruce forest with shrub cover of labrador tea (*Ledum palustris*), highbush cranberry (*Viburnum edule*), and black spruce (*P. mariana*). The dominant ground cover included reindeer lichen (*Cladonia sp.)*, stair-step moss (*Hylocmium splendens*), lowbush cranberry (*Vaccinium vitis-idaea*), and blueberry

(*Vaccinium ovalifolium*). The third site was in Atigun Pass of the Brooks Range (Lat: 68.10358, Long: 149.50903, Elev: 1132 m). The site was alpine tundra with very little shrub growth. The ground cover included reindeer lichen (*Cladonia sp.*), bearberry (*A. alpinus*), *Dryas sp.*, cranberry (*V. vitis-idaea*), and sedges (*Carex sp.*). Shrub cover consisted of willow (*Salix sp.*), alpine blueberry (*Vaccinium alpinus*), and dwarf birch (*B. nana*). Common small mammals captured included Northern red-backed voles (*Myodes rutilus*), cinereus shrews (*Sorex cinereus)*, root voles (*Microtus oeconomus*), and singing voles (*Microtus miurus*), though 12 species were captured in total.

<u>Trapping methods</u>

At each site, three 1km transect loops were created. Traps were spaced ten meters apart along these transects for a total of 100 traps per line. Every third trap was either a Museum Special (snap) or pitfall trap, with the remaining traps on each line made up of Sherman live box traps. Traps were placed for five nights, and checked in the morning and evening each day for a total of approximately 1005 trap nights for live traps at each site. Individual traps were placed without preference to location, but in a manner that allowed them to lie flat.

The two baits compared were steel cut oats and a mixture of peanut butter, rolled oats, and gelatin (to help allow shaping of bait). All odd-numbered live traps were baited with the oats, while all even-numbered live traps were baited with the peanut butter mixture (referred to simply as peanut butter). In this manner, each bait was paired with the opposite bait ten meters away, with either a snap or pitfall trap separating it from the next pair on the line (Figure 1).

Whenever a capture occurred, the species, sex, and age class (adult or juvenile) were recorded. A hair sample or blood sample (if dead) was taken from the animal for a related project, meaning that all recaptured animals could be identified by a missing patch of hair, but not identified to individual animal. The animal was then released after morphometric measurements were taken. The bait of the trap in which the animal was captured was recorded. I then visited each successful trap and recorded the elevation of it and its pair. I also took two photographs (facing due North judged by a compass); one of them at belt level, the other at knee level at both trap sites. The pictures taken at belt level were used to estimate shrub cover (all plants approximately 5 cm or taller than the ground) for each trap and its pair. The photographs taken at knee level were used to estimate ground cover (the area covered by lichen or plants rather than rock or bare soil).

In the Middle Tanana site, to avoid interference with other research on the same site, all trapping was done on a previously established grid within the experimental forest. For this reason, instead of creating three separate one-kilometer looping transects, one transect of three-kilometers length was created, following the existing trapping grid on the property. All other methods from the earlier site were maintained.

In the Brooks Range site, three transects of 100 traps each were placed, with one extra live trap on each line to replace broken traps of other types. Giving a total of 1015 trap nights for live traps in Atigun Pass. All other methods were maintained from the other two sites.

Statistical analysis

McNemar's tests (paired X^2 tests) were performed using site capture histories to determine whether significant differences existed between first capture or recapture rates for the two bait types. These tests were performed for all species combined, and N. red-backed voles separately, as the most frequently captured small mammal. The machine-learning program TreeNet® (Salford Systems) was also used to perform a multiple regression analysis to determine relative effects of elevation, shrub cover, ground cover, and bait type on relative capture rates and species presence.

RESULTS

In the White Mountains, 52 animals representing 6 species were captured in live traps with one additional species captured in a lethal trap. In the Tanana River Valley, 70 animals representing 4 species were caught in live traps. At the Atigun Pass, 40 animals representing 4 different species were captured in live traps. The most common species captured overall was the northern red-backed vole, followed by the singing vole, and the cinereus shrew.

No significant differences were found between initial capture or recapture rates for the two bait types either for all species pooled together (Table 1) or for northern red-backed voles considered separately (Table 2). The Brooks Range site was not included for the analysis of N. red-backed voles because of small sample size.

The rank order of factors most predictive of capturing the three most abundant species (red-backed voles, singing voles, and cinereus shrews) from analysis in program TreeNet® was elevation $\geq$ percent shrub cover $\geq$ percent ground cover $\geq$ bait type (Table 3) providing further support that bait type was not important.

DISCUSSION

Unlike Beer (1964), Buckner (1957), Patric (1970), and Woodman et al. (1996) we found little to no evidence that a mixture of peanut butter and oats was more effective as bait than simple oats in the capture of small mammals. Furthermore, bait type was less predictive of whether a species would be captured in a live trap than elevation, shrub cover, or ground cover. While based on past research it might have been expected that bait preference would be exhibited, we have failed to reject the null hypothesis, that there was no significant difference between capture or recapture rates between the peanut butter mixture and oats. Part of this lack of difference may be explained by the somewhat limited sample sizes (low capture rates) at some of our sites, however for the most frequently captured species, northern red-backed voles, differences should have been evident if they existed. However, it is also possible that the short growing season in Alaska may cause animals to take advantage of any available food subsidy regardless of type, creating a lack of preference in small mammals for a particular bait. According to our results, if bait preference does not have as great an effect on trapping of species as elevation, ground cover, and shrub cover, then small mammal trapping should be fairly effective regardless of the bait type used. However we only tested two specific baits, therefore it is also quite possible that a category of bait containing different elements (such as meat or dried fruit) might be more effective for certain groups than those tested, such as shown by Oswald and Flake (1994).

CONCLUSION

We found no evidence of bait preference within the small mammal communities sampled in this experiment. Further, we found that the site conditions were more likely to predict initial captures and recaptures than bait type providing evidence that small mammal trapping should be fairly robust regardless of bait type. Further research should be pursued into whether this lack of bait preference may be a result of food limitations caused by a short growing season in the high northern latitudes. If this pattern holds true, then field biologists performing small mammal trapping may feel comfortable using more cost-effective or easily handled baits.

APPENDIX

Table 1. McNemar's test results for all species (α= 0.05), statistical significance occurs where McNemar's value exceeds the critical value

Site Name	Capture Type	Number of captures	McNemar's Value	Critical Value
White Mountains	First	38	0.33	3.84
	Recapture	30	1.13	3.84
Middle Tanana	First	43	1.85	3.84
	Recapture	31	2.27	3.84
Brooks Range	First	28	0.60	3.84
	Recapture	2	1.41	3.84

Table 2. McNemar's test results for N. red-backed voles (α= 0.05)

Site Name	Capture Type	Number of captures	McNemar's Value	Critical Value
White Mountains	First	34	0.35	3.84

	Recapture	30	1.13	3.84
Middle Tanana	First	39	1.95	3.84
	Recapture	31	2.27	3.84

Table 3. Relative importance of analyzed variables as predictors of capture

Variable	Relative Importance Score (out of 100)
Elevation	90.98
% Shrub Cover	81.61
% Ground Cover	71.95
Bait Type	33.41

1 --10m-- 2 --10m-- 3 ... 4 ... 5 ... 6 ... 7...

O PB Museum PB O Pitfall O...

Figure 1. Distribution of bait types among traps, O = oats, PB = peanut butter mixture

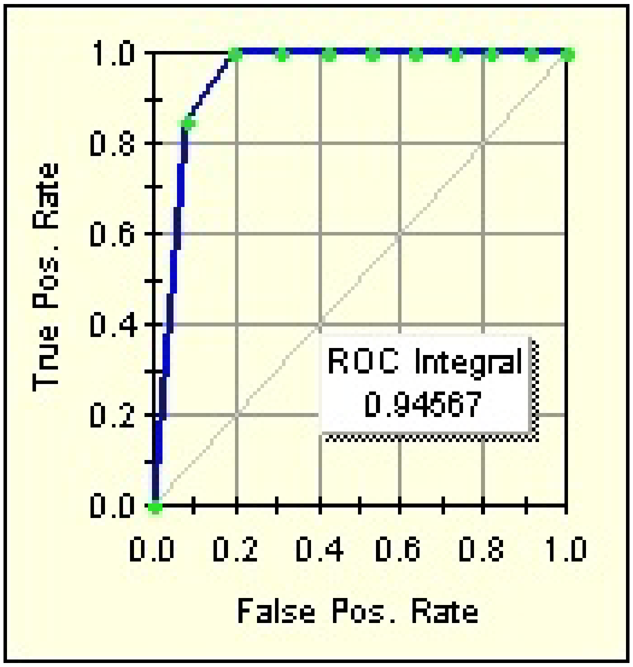

Figure 2. Simulated accuracy of model with samples removed when compared to predicted model.

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Chapter 2: An Evaluation of Small Mammal Capture Data Analysis Methods for the Small Quadrat Sampling Method in Western Siberia

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April, 2013

ABSTRACT

Many small mammal research projects use lethal trapping to create relative abundance indices to track changes in population size. These indices may be inaccurate due to a number of physical, biological, or anthropogenic factors (i.e. weather, seasonality, sampling design) affecting trappability. Our goal was to assess the utility of occupancy analysis and the creation of catch-per-unit effort regressions to estimate starting population size as alternatives to the creation of relative abundance indices to analyze habitat use. Small mammals were trapped using the small quadrat method at two field sites in Western Siberia in June and July of 2012. We compared and evaluated methods of analysis in terms of feasibility and estimated accuracy. Occupancy analysis estimated higher levels of occupancy among habitat types than relative abundance indices, but had high standard error values. Simulations revealed that more sampling occasions are necessary for increased accuracy of occupancy levels. Catch-per-unit effort population estimation showed high error in estimates of abundance among species and sites. Closed capture modeling in Program MARK estimated population sizes with low rates of error. We conclude that while occupancy analysis could provide further insight into small mammal habitat use, lethal trapping may violate the basic assumption that occupancy does not change during the sampling period. Further, the amount of additional sampling necessary for accurate analysis is unfeasible. We believe that estimation of starting population size using catch-per-unit effort regression may be a feasible method to analyze trapping data, but may result in inaccurate estimates as a result of error. Closed capture population estimation is also a feasible method and has lower estimates of variance around abundance, as well as the ability to better incorporate covariates.

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ACKNOWLEDGMENTS

I would like to acknowledge Dr. Jonathan Cohen for his assistance in selecting and performing methods of analysis, Elaina Burns for her editing expertise, Sara Hansen for moral support, and Dr. William Shields as a font of knowledge and second reader. Thanks also to Dr. Alexander Sokolov, Dr. Natasha Sokolova, Dr. Dorothee Ehrich, and Dr. Falk Huettmann for making field research in Russia a reality. Special thanks to Dr. Jaqueline Frair for her ability to always improve the quality of the work and for serving as a mentor and role model in wildlife research.

INTRODUCTION

Many small mammal research projects use removal or lethal trapping to create relative abundance indices to monitor and track changes in populations. These indices assume that the number of captured animals is proportional to the actual population size (Taylor et al. 2011). This assumption is rarely met in practice because trappability of animals may differ by season, between species, and within populations of the same species causing possible inaccuracies in comparisons of population sizes (Slade and Blair 2000, McKelvey and Pearson 2001, Taylor et al. 2011). Removal trapping does have some advantages over live-trapping (used for capture-mark-recapture studies) in ease of handling and measuring captured animals, lower cost, and less frequent checking of traps. (Hayne 1949). So in particularly remote areas, such as arctic and sub-arctic regions, removal trapping has been common.

One commonly used trapping configuration in the arctic and subarctic regions is the small quadrat method (Myllmaki 1971). This design involves 12 traps placed in groups of 3 at each corner of a 15m by 15m quadrat, with sampling quadrats spaced no closer than 200m to another quadrat in the same habitat type. This design has been used primarily in systematic sampling to calculate relative abundances in selected habitats (Myllymaki 1977; Taylor et al. 2011; Sundell et al. 2012; Henden et al. 2012; Thingnes 2012). A seemingly unused option for data analysis is catch-per-unit-effort (CPUE) regression to estimate starting population size with some measure of precision (Leslie and Davis 1939). This method, particular to removal trapping designs, assumes that fewer animals are captured each trapping session because individuals are removed from the total population in each session. After regressing the number of animals captured in a trapping occasion (x) against the cumulative total captured up until that occasion (y), one interprets the x-intercept as the starting population size, and the variance associated with the y-intercept yields a confidence interval around the starting population size. If robust to the small sample sizes and relatively few trapping nights conducted in this study, this approach would yield more information for comparison of animal populations than relative abundance indices alone (which may be more prone to variability due to variation in capturability among trapping sessions).

Another possible alternative for analysis of this removal trapping data is to monitor populations using a different state variable, such as the probability of site occupancy. The information from multiple sampling occasions may be used to estimate a probability of detection and correct the raw count of sites deemed occupied based on empirical captures (MacKenzie et al. 2002). Provided there is sufficient power in the traditional sampling design, estimation of site occupancy may provide more detailed data about habitat use and population changes through time than the raw counts of animals uncorrected by animal catchability (MacKenzie et al. 2002; O'Connell Jr. et al. 2006).

Closed capture modeling in Program MARK may provide another method of estimating the population size using removal data (White and Burnham 1999). Though generally used in capture-mark-recapture analysis, closed capture modeling can be used with removal data by fixing recapture rates at zero.

My objective was to compare CPUE regression and site occupancy approaches to the use of simple trapping indices to assess population abundance and habitat use of rodent species at a high and low population density site in Western Siberia. Ultimately I compare the approaches in terms of ease of implementation, precision of parameters estimated, and likelihood of meeting assumptions using lethal trapping and the small quadrat method.

METHODS

We conducted field work at two sites in the Yamal-Nenetsky Autonomous Region of Russia, in Western Siberia. One study site consisted of two sampling units near the town of Labytnangi (66°39‘34.5” N, 66°24‘31.9” E). This area is at the northernmost edge of the low shrub tundra subzone (Walker 2000). Topography was fairly flat with some low hills, and a large number of small lakes and ponds. Vegetation communities were characterized by small trees (<15m in height); typically birch (*Betula* spp.) and Siberian larch (*Larix sibiricus*). The second site was located in the Erkuta River Basin of the Yamal Peninsula (68°13’ N, 69°09’ E). The Erkuta site consists of flat tundra with hills reaching 40 meters in height, and some sandy cliffs on the banks of the numerous rivers and lakes running through the region (Ehrich et al. 2012).

Between the two study sites, four habitat types were sampled. Forest (F) habitat was characterized by the presence of trees (in this case, always *Larix sibiricus*), as well as some shrubby vegetation including dwarf birch (*Betula nana*). Forest habitat existed at the Labytnangi field sites, but was not present at the Erkuta field sites. Wet tundra (W) contained thick layers of *Sphagnum* moss, and frequently *Carex* spp., and tussocks of *Eriophorum* spp., as described in Ehrich et al., 2012. These sites tended to be the lowest laying, found near bodies of water or at the bottom of slopes. Dry tundra (D) included upland areas with short vegetation characterized by *Rhododendron tomentosum*, *Vaccinium* spp., *B. nana* and *Eriophorum* spp. Thickets (T) consisted of willow (*Salix* spp.), usually interspersed with alder (*Alnus* spp.), adjacent to a productive grass/herb meadow (Henden et al. 2010).

A small quadrat was 15x15 meters, with 3 traps as recommended by Taylor et al. (2011) placed selectively (along runways or near rodent holes) within a 3m radius of each corner for a total of 12 traps per quadrat. Sampling quadrats were distributed equally among habitat types with 4-6 quadrats per habitat type (Table 1). Labytnangi field sites were labeled Kharp (H) and Obskaya (O), while Erkuta sites were named K, L, and R. Within a habitat type, quadrats were placed at least 20m from the edge of the adjacent habitat type, and at least 200m from a quadrat of the same habitat type. Traps were left in place for two (Units R and L) or three (Units H, K, and O) consecutive nights to help prevent excessive capture of immigrant individuals (Taylor et al. 2011) and checked daily. This resulted in 576 trap-nights for units H and O, 432 trap-nights for units R and L, and 648 trap-nights for unit K. Trapping occurred from June 7-11 in Labytnangi, and July 18-28 in Erkuta.

I first created a relative index of abundance for each species using capture numbers by unit and habitat type. Then I used raw capture numbers from each sampling session pooled across units to estimate starting population sizes using the catch-per-unit-effort regression approach proposed by Leslie and Davis (1939). Given a minimum of 3 trapping occasions, a linear regression model is fitted to the number captured in each trapping session (y) against the cumulative number of captures up to that point (x). The predicted x-intercept for the regression line provides and estimate of the starting population size (i.e. the abundance of the species before individuals were removed by trapping), and its variance is used to estimate a 95% confidence interval for initial population size. Models were fit to each sampling unit (H, O, R, L, and K) using maximum likelihood modeling in SAS software (SAS Institute Inc.) and slopes and intercepts verified using the least squares regression method. An estimate statement in procnlmixed was used to request a derived estimate of starting population size as the negative y-intercept over the slope (the x-intercept). Procnlmixed models use the delta method to calculate variance and confidence limits on estimates.

Capture histories were created for the Labytnangi units (H and O) and analyzed in Program MARK with recapture rates fixed at zero to represent removal trapping. Model likelihood comparison was used to select the best model, and estimates were model averaged in the event of uncertainty. Data was pooled between the two units for the most frequently captured species, and field site was input as a group effect.

Finally, Program Presence (MacKenzie et al. 2002) was used to estimate probability of site occupancy, Ψ, and detection probability, *p*-hat, for each unit, and each habitat type for different species. Each trap-night was considered a separate sampling occasion, and each small quadrat was considered a separate sampling unit for analysis of occupancy.

RESULTS

Over 2,664 trap-nights 81 animals of 6 species were captured in the 5 trapping units, with the great majority of captures occurring at the Labytnangi field site (Table 2). Captures in Labytnangi consisted of northern red-backed voles (*Myodes rutilus*), field voles (*Microtus agrestis*), and tundra voles (*M. oeconomus*). Species trapped in Erkuta were the narrow-skulled vole (*M. gregalis*), Middendorff's vole, (*M. middendorffii*), and the Eurasian collared lemming (*Dicrostonyx torquatus*).

Relative abundance indices in the Labynangi field site showed that populations of *M. rutilus* were relatively high in the forest habitat type (3.56 captures/100 trap-nights), relatively low in the thicket (0.955 captures/100 trap-nights) and dry habitat plots (0.174 captures/100 trap-nights), and not found in wet tundra sites. *M. oeconomus* capture rates were relatively low (range 0.087-0.347 captures/100 trap-nights), but spread across all habitat types, except dry habitat. *M. agrestis* was captured within thicket habitat at the Obskaya site (0.52 captures/100 trap-nights), but not found in any other habitat type or location. Summaries of absolute numbers of capture by habitat type can be found in Table 2.

In the Erkuta field site *M. gregalis* was captured in thicket habitat in each of the sampling units in low numbers (range 0.463-0.694 captures/100 trap-nights) and not captured in other habitat types. *M. middendorffii* was only captured in the K unit within wet habitat (0.309 captures/100 trap-nights). *D. torquatus* was captured in thicket (range: 0.231-0.309 captures/100 trap-nights) and dry habitat (0.463 captures/100 trap-nights).

Catch per unit effort plots estimated that the starting populations of the Kharp unit included 32.11 *Myodes rutilus* (95%CI: 16.32-47.90), and 8.67 *Microtus oeconomus* (95%CI: 1.39-15.95) (Figures 2a-2b). The starting community of Obskaya was estimated at 29.78 *M. rutilus* (95%CI: 22.90-36.66), 7.73 *Microtus agrestis* (95%CI: 6.57-8.89), and 2.00 *Microtus oeconomus* (95%CI: -2.50-6.50) (Figures 2c-2e). Catch per unit effort plots were not created for the Erkuta field site due to insufficient trapping occasions.

Within the Kharp and Obskaya sampling units the best occupancy model for *M. rutilus* indicated differences in both occupancy (Ψ) and probability of detection (*p*-hat) by habitat type, although this model did not significantly differ by AIC from a model with effects of habitat on probability of detection alone. Effects of survey, or sampling occasion, on probability of detection and null models were tested in addition to effects of habitat resulting in ΔAICs of greater than 2 from the best model. *M. rutilus* occupied all forest units (Ψ=1.00, SE=0.00), almost all thicket habitat (Ψ=0.97, SE=0.70), but only a fraction of the dry tundra habitat (Ψ=0.13, SE=0.12). Low capture rates made occupancy analysis inappropriate for any species besides *M. rutilus* at the Labytnangi field site, which was the most frequently captured species.

Closed capture models in Program MARK were also used to estimate population sizes for *M. rutilus* in the Kharp and Obskaya units. Recapture rates were fixed at zero to represent removal trapping. Models were tested incorporating effect of site on probability of first capture and population size. The best model was a null model, however parameters were model averaged to account for a difference of less than 2 in the ΔAIC. Model averaged population size was estimated to be 27.2 animals (SE=2.39) at both Kharp and Obskaya, with probability of detection (*p*-hat) varying insignificantly from 0.541 (SE=0.097) at Kharp to 0.559 (SE=0.093) at Obskaya.

Program Presence in a simulation with p-hat set at 0.2155 (lowest estimated probability of detection), 36 sites, and 3 visits to each site, showed that only when the true occupancy was higher than 0.40, was probability of occupancy (Ψ) estimated within 15% of true occupancy (Figure 12). Simulations using a true occupancy of 0.1, 36 sites, and 3 visits to each site, showed that p-hat must be 0.5 or higher to estimate Ψ within 15% of the true occupancy (Figure 13). Simulations using a true occupancy of 0.1314 (the lowest estimated occupancy), a p-hat of 0.2155, and 24 sites showed that 6 or more surveys would be necessary to estimate Ψ within 15% of the true occupancy (Figure 14). MacKenzie and Royle (2005) recommend that with a true occupancy of 0.1 and a detection probability of 0.2 at least 7 repeat surveys should be conducted to estimate occupancy accurately, supporting the accuracy of our simulations.

DISCUSSION

Relative indices of abundance provide a simple number of animals captured in a particular habitat, but lack the ability to quantify error and ultimately assess index accuracy. These indices can be used to compare changes in habitat use over time, but may be affected by changes in trappability, and should not be used for comparison among species. This method is advantageous as it requires a small amount of data and a single trapping occasion, and is currently employed at the field sites in Russia. The small quadrat method allows sampling of varying habitat types over a large spatial area for the creation of these indices.

The catch-per-unit effort regressions provided abundance estimates, but had a high rate of error. Only the Obskaya site was found to be significantly different than 0 (p=0.05) with an estimate of 7 field voles (95%CI: 5-12). This method is feasible in that it requires a minimum of 3 trapping occasions to provide an estimate. However, estimates tended to have high confidence intervals despite a large sample of captured animals. Further, estimates of population size were provided for the entire field site rather than the individual sampling grids thereby reducing its spatial resolution as compared to the other methods. The small quadrat method may also provide useful data for catch-per-unit effort analyses so long as trapping is continued for a sufficient number of nights.

Closed capture modeling provided abundance estimates for the K and O units with fairly low rates of error. This method, like the catch-per-unit-effort regressions, requires a minimum of 3 trapping occasions, and has a lower spatial resolution than relative abundance indices or occupancy methods. However, given sufficient capture data, this method could be used to determine effects of habitat, group, and time on capture rates, and may therefore provide greater analysis options that relative abundance indices. This method is also compatible with the small quadrat method as a source of data collection.

Occupancy analysis estimated habitat use for the different species, but error was relatively high in all cases. Simulations showed that the number of surveys performed was insufficient to predict occupancy with accuracy when the true occupancy was low. Further, low probability of detection caused overestimation of site occupancy and high error. Finally, it is possible that the method of lethal trapping violates one of the basic assumptions of occupancy modeling. Occupancy modeling assumes that the occupancy status of a site does not change during the sampling period. If a sufficient number of animals are removed due to trapping such that the occupancy of the patch is changed this assumption is violated and results are compromised. This method is the least feasible as it would require a greater number of trapping occasions (ideally 6 or more), it may violate a basic assumption of its modeling, and would likely lead to the capture of migrant animals if conducted for the ideal duration. The small quadrat method provides a sufficient number of sampling sites for occupancy analysis provided spacing is far enough to be considered independent, but is not feasible in terms of the duration of trapping necessary.

CONCLUSION

While the creation of relative abundance indices are not an ideal method of tracking change in population size and habitat use, it appears to be one of the best options that can be used with removal trapping and the small quadrat method. These indices showed that *M. rutilus* populations were found across all habitat types except wet tundra in the Labytnangi sites with higher levels in forest habitat, field voles were found only in thicket habitat, and tundra voles used all habitat types except dry habitat in low numbers. In the Erkuta site, these indices showed that narrow-skulled voles were only captured in thicket sites, Middendorff's voles only in wet sites, and collared lemmings in thicket or dry habitat. Occupancy analysis estimated that *M. rutilus* occupied the majority of forest and thicket habitats and a low proportion of dry habitat, and was infeasible for analysis of other species due to extremely low capture rates. Catch-per-unit effort plots estimated starting population sizes for sampling units, but with high rates of error. These regressions may also have some use in the analysis of trapping data, as long as the number of trapping occasions is sufficient. Closed capture modeling in Program MARK can be considered the most effective method of analysis, as it provided estimates of population sizes with low estimates of error. Knowledge of the efficacy of these methods of analysis may allow future researchers to better select a sampling design for their specific purpose and requirements of feasibility.

APPENDIX

Table 1. Distribution of sampling quadrats by unit across habitat types.

Unit Name	# of Forest Quadrats	# of Thicket Quadrats	# of Dry Tundra Quadrats	# of Wet Tundra Quadrats	Total # of Quadrats
Kharp (H)	4	4	4	4	16
Obskaya (O)	4	4	4	4	16
K	0	6	6	6	18
R	0	6	6	6	18
L	0	6	6	6	18

Table 2. Total captures by species and habitat type.

Unit Name (Total # of trap nights)	**Habitat Type**	***Myodes rutilus***	***Microtus oeconomus***	***Microtus agrestis***	***Microtus gregalis***	***Microtus middendorffii***	***Dicrostonyx torquatus***
H	Forest	19	1	0	0	0	0
(576)	Thicket	4	2	0	0	0	0
	Dry	2	0	0	0	0	0
	Wet	0	0	0	0	0	0
O	Forest	22	0	0	0	0	0
(576)	Thicket	7	2	6	0	0	0
	Dry	0	0	0	0	0	0
	Wet	0	0	0	0	0	0
K	Thicket	0	0	0	3	0	2
(648)	Dry	0	0	0	0	0	0
	Wet	0	0	0	0	2	0
R	Thicket	0	0	0	3	0	1
(432)	Dry	0	0	0	0	0	2
	Wet	0	0	0	0	0	0
L	Thicket	0	0	0	2	0	1
(432)	Dry	0	0	0	0	0	0
	Wet	0	0	0	0	0	0

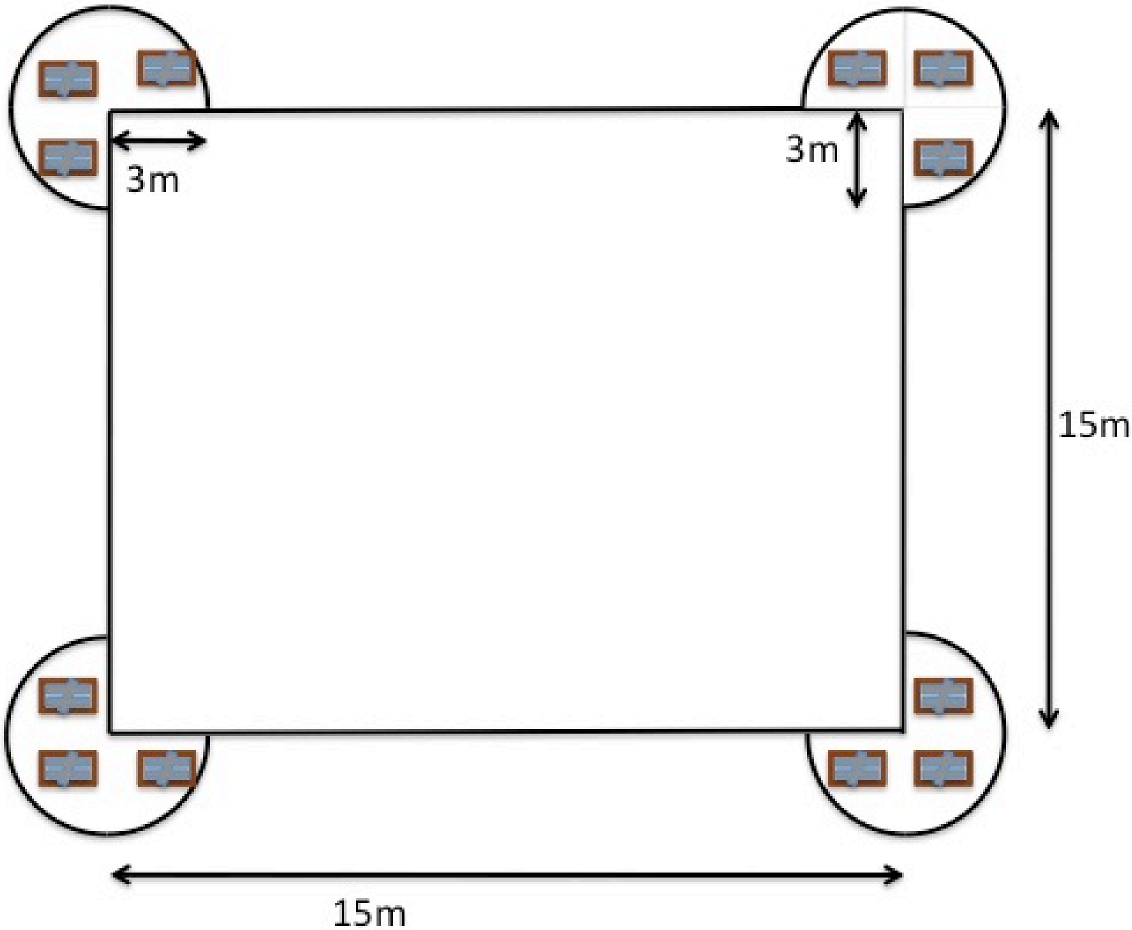

Figure 1. Diagram of a small quadrat showing the placement of 3 traps within a 3 meter radius of each corner.

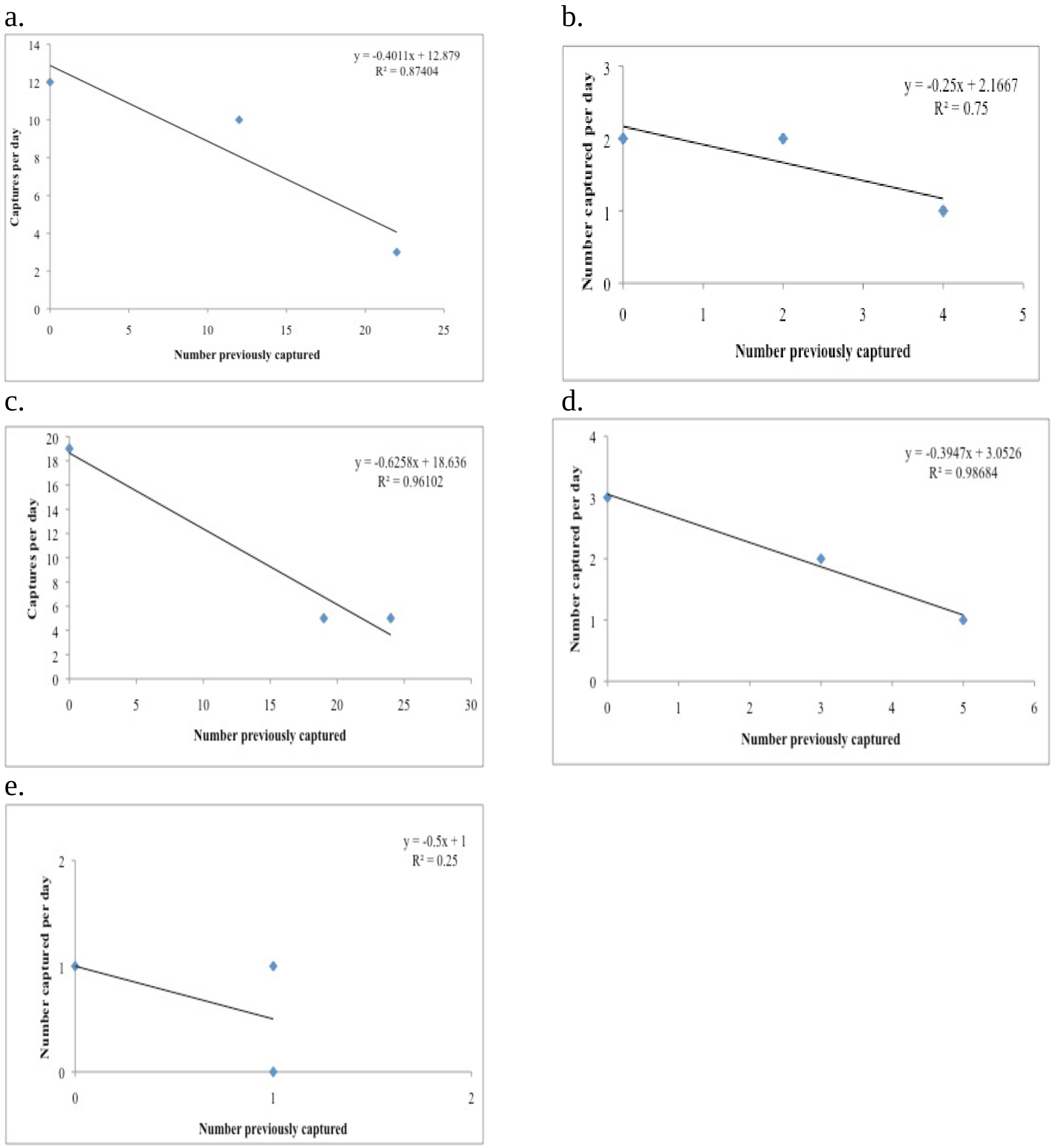

Figure 2. Catch per unit effort regressions for Kharp unit *Myodes rutilus* (a), Kharp *Microtus oeconomus* (b), Obskaya *M. rutilus* (c), Obskaya *Microtus agrestis* (d), and Obskaya *M. oeconomus* (e), Yamalo-Nenets Autonomous Region, Russian Federation, June 2012. Estimate of starting population size occurs where regression line would cross x-axis.

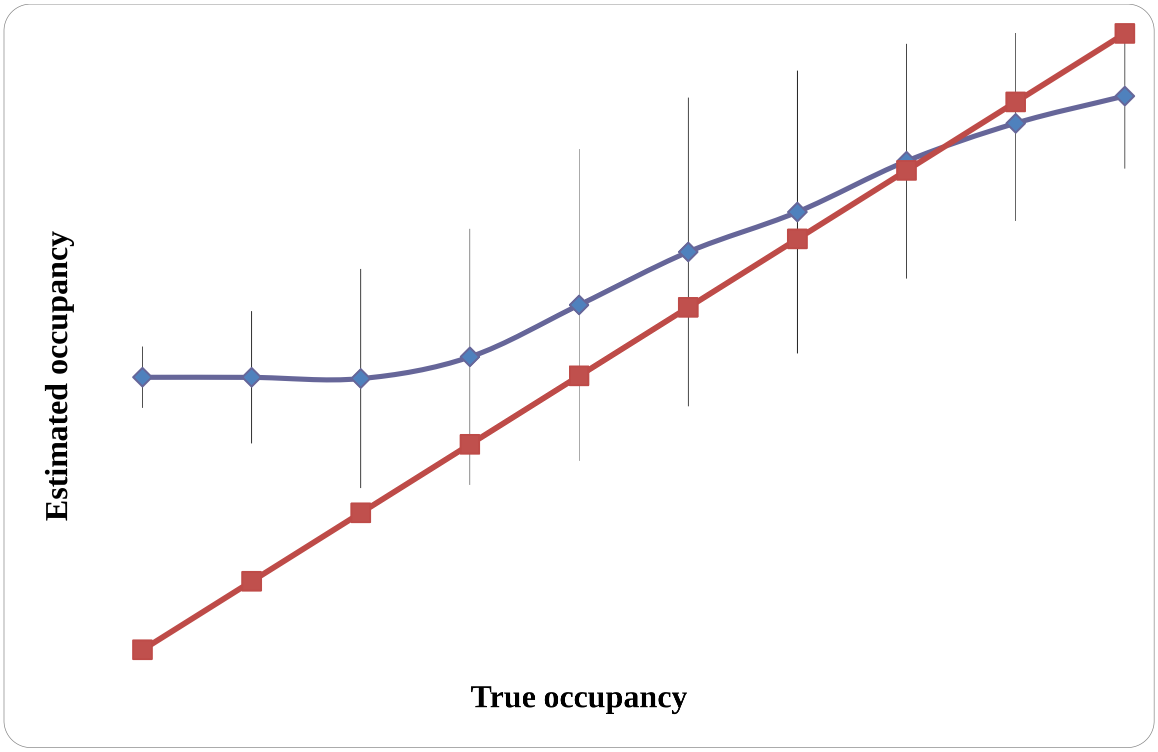

Figure 3. Simulation results for the effect of changes in true occupancy on estimated occupancy (Ψ) with expected effect for comparison. *p*-hat = 0.2155, 36 sites, 3 visits/site.

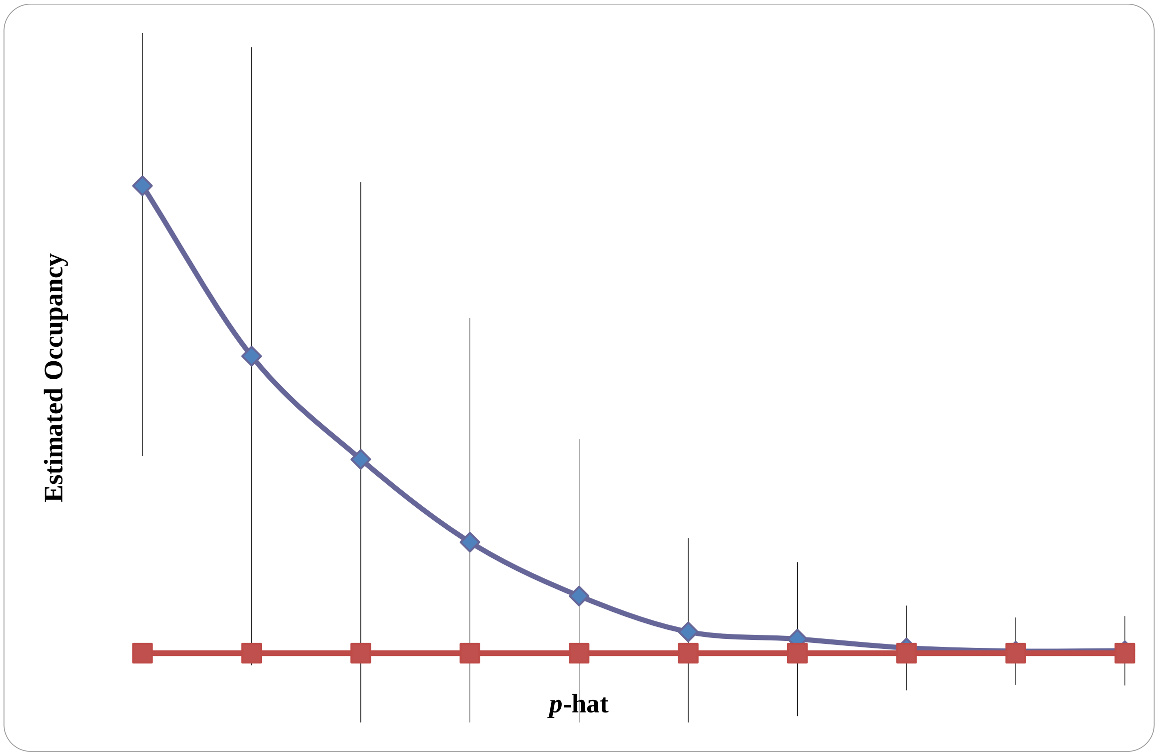

Figure 4. Simulation results for the effect of probability of detection (*p*-hat) on estimated occupancy with expected effect for comparison. True occupancy = 0.1, 36 sites, 3 visits/site.

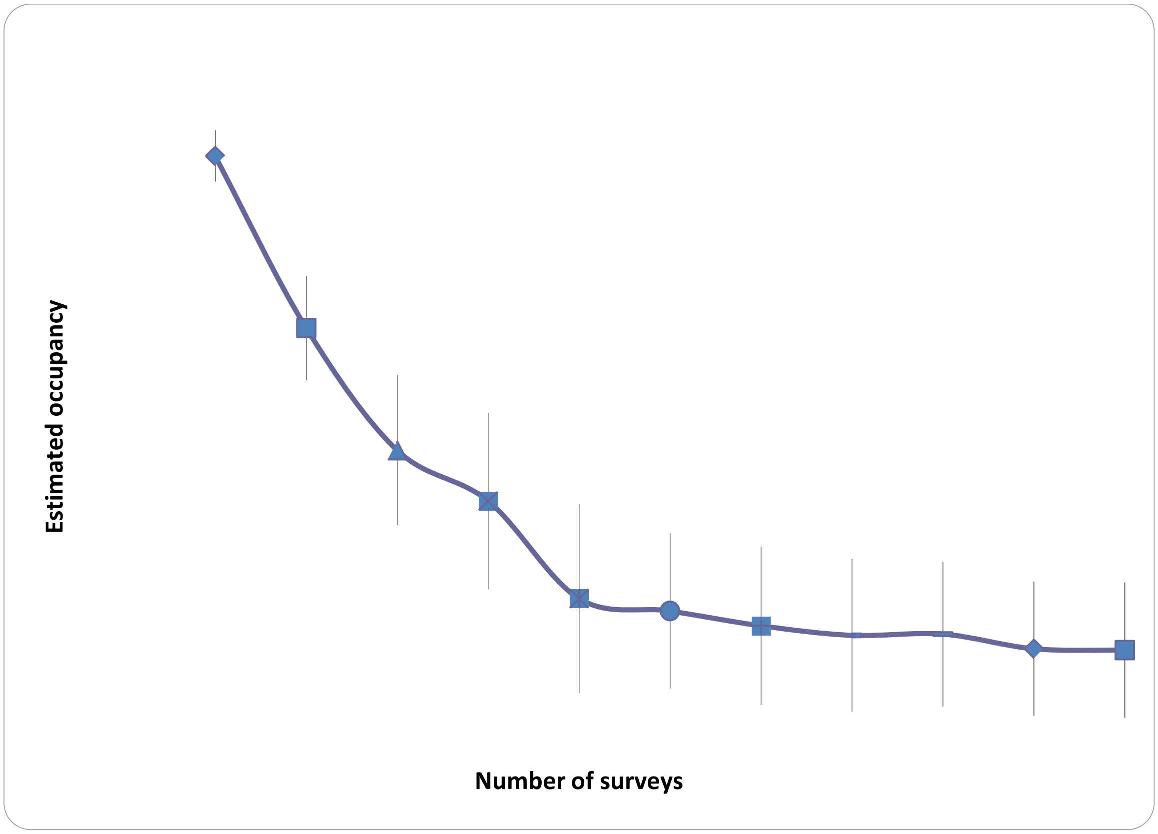

Figure 5. Simulation results for the effect of survey number on estimated occupancy. True occupancy = 0.1314, *p*-hat = 0.2155, 24 sites.

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