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EFFECTS OF MIST-NETTING FREQUENCY ON CAPTURE RATES AT MONITORING AVIAN PRODUCTIVITY AND SURVIVORSHIP (MAPS) STATIONS

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Abstract. Data from the Monitoring Avian Productivity and Survivorship (MAPS) Program were analyzed to evaluate the effect of frequency of operation (number of days per 10-day period) of mist nets at MAPS stations on capture rates of adult and young birds. A negative relationship existed between netting frequency and the number of captures of adult birds per unit effort. This suggests that net avoidance by adult birds can be an important consideration at higher frequencies. There also was a negative relationship between netting frequency and the rate of capture of individual adults; this demonstrates saturation of effort. With regard to young birds, however, netting frequency had no effect on either type of capture rate. These results indicate that data from stations run at high frequencies will produce inflated productivity indices by lowering capture rates of adults but not of young. Thus, when pooling data from stations operated at differing frequencies for large-scale demographic monitoring, the data must be adjusted to control for netting frequency. We interpret these findings and suggest more rigorous approaches to the study of these phenomena.

Key Words: capture rate, MAPS, mist net, net avoidance, netting frequency, productivity.

Constant-effort mist netting has been shown recently to be a viable method of monitoring demographic parameters of landbird populations (Baillie 1990; Baillie et al. 1986; Butcher et al. 1993; DeSante 1992; DeSante et al. 1993a,b; Nur and Geupel 1993a,b; Peach et al. 1991, Ralph et al. 1993). However, many questions remain regarding the optimal design of monitoring programs using mist netting, not least of which concerns the frequency at which mist nets should be operated (Nur and Geupel 1993b, Ballard et al. *this volume*). The question of how often to operate mist nets is not merely academic. Mist netting, although providing information not readily obtainable by other methods, such as point counting, is relatively labor intensive. Managers and researchers need to know what sampling effort is required to produce accurate and precise estimates of the target parameters (e.g., population size, productivity, survivorship, recruitment) in the most efficient manner possible. Furthermore, to avoid undue disturbance to the birds themselves, netting should not be conducted at a frequency higher than that necessary to obtain the desired information.

From a bird's point of view, there is no reward associated with being captured in a mist net. Common sense and anecdotal evidence suggest that after such an experience (particularly if repeated), birds are likely to stay away from the net for some time. This phenomenon is known as "net avoidance" or "net shyness," although it is debatable whether birds are avoiding the nets themselves, the net sites, both, or neither. The existence, magnitude, and duration of net avoidance undoubtedly vary among species and probably among individuals, and are likely to increase with repeated capture. At the population level, different age classes are likely to show different degrees of net avoidance due to behavioral differences and degree of naiveté. The degree of net-site avoidance undoubtedly depends to some extent on the site's proximity to a bird's nest in the breeding season, and on its proximity to food, shelter, or other resources, and thus net-site avoidance may vary seasonally.

Net avoidance is generally assumed to exist in mist-netting studies, but few studies have been conducted to examine its magnitude and effects on indices and estimates of population parameters. Stamm et al. (1960) documented steady declines, which they attributed to net shyness, in capture rates of all species combined immediately before and after spring migration in Maryland. As further evidence, they found a marked increase in capture rate, followed by another decline, after relocating their nets (an indication that birds learned to avoid the site of capture, rather than recognizing the nets *per se*). Swinebroad (1964), however, was unable to demonstrate net avoidance in a New Jersey Wood Thrush (*Hylocichla mustelina*) population and in fact had a higher-than-expected proportion of recaptures (based on population estimates from spot mapping); he concluded that placement of nets in areas of high activity within actively defended thrush territories resulted in a disproportionately high rate of repeat captures.

The variation in the results of these studies is further evidence that the intensity of net avoidance varies according to species, season, and perhaps even to population. However, Stamm et al. and Swinebroad banded at highly irregular intervals ranging from 1 to 21 days, making meaningful interpretation and comparison of their results difficult.

Because of territoriality, there is a limited pool of adult birds available at a given site. After these birds have been captured in a given year, an increase in effort will not increase the number of resident individuals captured, although non-breeding birds will continue to be captured. Thus, in a closed population, the capture rate of new individuals (i.e., first captures) is likely to decline as effort is increased, a phenomenon known as "saturation of effort." The length of time taken to reach saturation is dependent on population size, capture probability, and net density, in addition to sampling frequency.

Ballard et al. (*this volume*) found that nets operated five days a week (about 7 days out of 10) captured 50% more locally produced hatch-year Wrentits *(Chamaea fasciata)* than did nets run in the same study plot either once every ten days or twice a week (about three days out of ten). However, the number of locally breeding adult Wrentits captured did not differ significantly among the various regimes. These results suggest that saturation is a more significant issue with adult birds than with young; this is what one would expect, since adults tend to be more sedentary than young birds during the breeding season.

Monitoring Avian Productivity and Survivorship (MAPS) Program protocol (DeSante 1992; DeSante et al. 1993b, 2002) is for nets to be operated on one day per 10-day period. This recommendation was made to increase the number of stations by making them easier to operate, decrease the variability among stations, and minimize disturbance to the birds. Nur and Geupel (1993a,b), however, recommend that nets be operated as frequently as possible to increase annual capture probabilities, and to distinguish between residents and transients, based on multiple captures of the former, so as to be able to exclude the latter from survivorship estimations. Nur et al. (*this volume*) found that locally breeding Wrentits were captured repeatedly at their study site, while non-breeders were not. Furthermore, Sauer and Link (*this volume*) suggest that estimation of the degree of bias in population-parameter indices is possible by estimating capture probability, the reliability of which will be improved by increasing the number of samples. On the other hand, Pradel et al. (1997) suggest that sufficiently spaced capture sessions nearly always will preclude multiple captures of transients, making them easier to identify and exclude from survivorship analyses.

Obviously, no single netting regime is optimal for all purposes. Our contention has been that, for demographic-monitoring purposes, operation of nets once per 10-day period over at least six periods will provide sufficient within- and between-year recaptures to discriminate effectively between residents and transients, and that if additional effort is possible, more information would be provided by the establishment of additional stations than by increased effort at existing stations.

Some MAPS stations (mostly stations operated by bird observatories and other avian research centers and established prior to the inception of the MAPS Program) operate their nets more frequently than once per 10-day period. Thus, data from MAPS stations provide an excellent opportunity to examine the effects of netting frequency on capture rates across a wide spectrum of sites.

METHODS

MAPS mist-netting protocol is described in DeSante (1992) and DeSante et al. (1993b, 2002). At the end of each breeding season, banding data (including species, age, sex, and band number) are submitted to the Institute for Bird Populations (IBP) for analysis, along with detailed information on mist-netting effort (date, number of nets, opening and closing times, total net hours). Baseline descriptions of each station, including primary habitat type, are kept on file at IBP.

We used 1992 MAPS banding data to assess the relationship between netting frequency (number of days of operation of mist nets per 10-day period) and total capture rates (numbers of all captures, including repeats, per unit effort) as a measure of net avoidance. We also examined the relationship between netting frequency and rate of first capture (numbers of newly captured individuals, excluding repeats, per unit effort) as a measure of saturation. We used 600 net-h as the unit of effort; this represents one season's effort at a station consisting of ten 12-m nets operated for 6 h/day at a frequency of 1 day/period for 10 periods.

Stations were grouped into four primary habitat types: "forest," "woodland," "scrub," and "meadow." We first conducted ANOVAs using netting frequency and habitat and their interaction as main effects. Habitat had highly significant effects on both total and first capture rates (all age classes pooled; $F_{3,166} = 18.61$, $P < 0.001$). Forest and meadow habitats were underrepresented at netting frequencies higher than 1 day/period, so we excluded from further analysis stations in these two habitats. Capture-rate data from woodland and scrub habitats were log transformed prior to further analysis in order to meet the assumptions of the models used; frequency data did not require transformation.

Mean values ±1 SE are reported. Gallinaceous birds and hummingbirds were excluded from analysis because most MAPS operators do not have permits to band them.

RESULTS

Data from 76 MAPS stations in woodland and scrub habitats were available for analysis. Netting frequency at these stations ranged from 0.8 to 5.2 day/period (day/p) with a mean of 1.4 ± 0.10 day/p over an average of 9 ± 0.26 periods. Total capture rate of adults ranged from 23.2 to 357.6/600 net-h (mean = 139.6 ± 9.21); total capture rate of young ranged from 7.4 to 818.9/600 net-h (mean = 98.8 ± 13.46). Rate of first capture ranged from 16.6 to 343.5/600 net-h for adults (mean = 113.9 ± 7.62) and from 7.4 to 786.7/600 net-h for young (mean = 92.0 ± 12.83).

The effect of netting frequency on capture rates did not differ between the two habitats analyzed (woodland and scrub) for either adults or young (frequency × habitat effect, $F_{1,73} = 0.7$, $P = 0.42$).

Combining habitats, increasing netting frequency significantly reduced total capture rate of adults ($F_{1,73} = 6.9$, $P = 0.01$); however, it did not affect total capture rate of young ($F_{1,73} = 0.4$, $P = 0.51$). Netting frequency also affected first capture rate of adults ($F_{1,73} = 9.3$, $P < 0.01$) but not of young ($F_{1,73} = 1.3$, $P = 0.26$). Figures 1–4 illustrate, using non-transformed data, the trends for each of the two habitats. The slopes were negative in all cases, regardless of statistical significance. However, the r values were all less than 0.3, indicating that netting frequency did not explain much of the variance in capture rates, even for adults.

DISCUSSION

We found that net (or net-site) avoidance (as measured by decline in total capture rate) and effort saturation (as measured by decline in rate of first captures) can be significant in constant-effort mist-netting operations. Net avoidance and effort saturation during the breeding season appear to operate primarily on adults (presumably territorial, breeding individuals). The difference between adults and young is likely due to the higher degree of mobility among young during the breeding season.

Net avoidance and saturation, although distinct phenomena, have a similar effect on bird population studies: they result in inflated indices of productivity by lowering the capture rates of adults, but not of young. Statistics developed by Baillie et al. (1986) for the Constant Effort Sites Scheme, and adopted in the MAPS Program, use the number of individuals captured, rather than capture rates, in population size and productivity analyses. Stations are almost certain to capture more individuals by increasing their netting frequency and thus would contribute more data to these analyses, but, at least in regard to adults, this increase is not proportional to the increase in effort. Due to saturation, one cannot simply divide the number of individuals by the frequency of effort, as this would underestimate adult-population size and overestimate productivity. This is documented by DeSante et al. (*this volume*) in the case of a single station operated nearly daily. One solution might be to select data from a single day of operation from each period, either randomly or by some other criterion, for use in these analyses. DeSante et al. (*this volume*) demonstrate that this technique produces valid results. Another approach might be to calculate the total number of individuals captured using only the first day in each period, then only the second, and

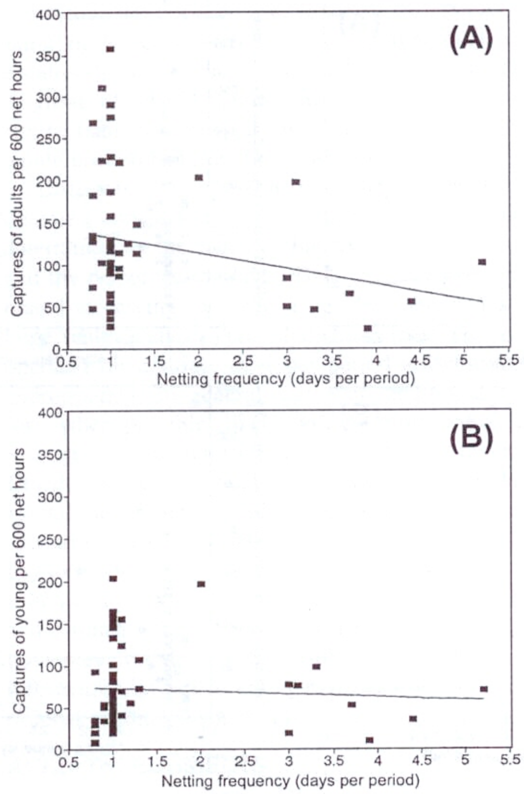

FIGURE 1. Total capture rates of (A) adults and (B) young vs. netting frequency at 54 MAPS stations in woodland habitats in 1992. (A) r = 0.25, slope = –18.7; (B) r = 0.07, slope = –3.6.

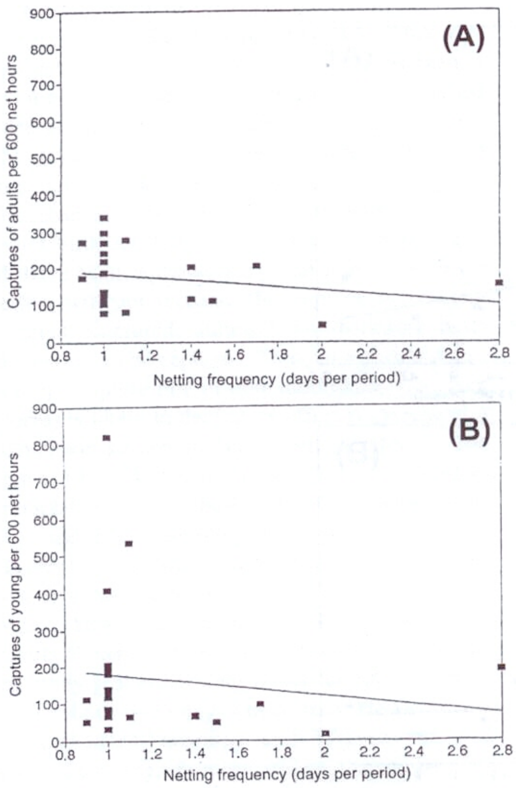

FIGURE 2. Total capture rates of (A) adults and (B) young vs. netting frequency at 22 MAPS stations in scrub habitats in 1992. (A) r = 0.25, slope = –46.1; (B) r = 0.14, slope = –59.32.

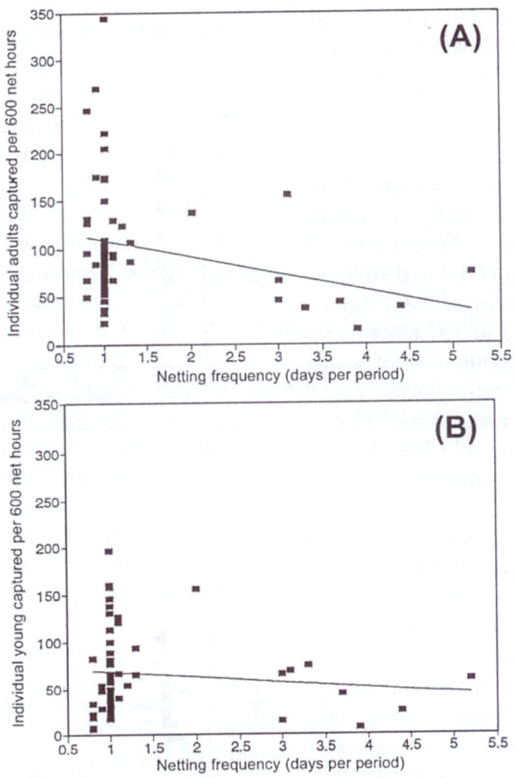

FIGURE 3. Rates of first capture of (A) adults and (B) young vs. netting frequency at 54 MAPS stations in woodland habitats in 1992. (A) r = 0.27, slope = –17.1; (B) r = 0.13, slope = –5.9.

so on, and use the average. The first approach would be the simpler, whereas the second could increase the accuracy and precision of the indices.

The problem of net avoidance becomes significant in breeding-bird monitoring programs in two cases. One is when nets are operated prior to the period under investigation, because resident or early-arriving breeders could be captured during this time and might not be captured again that year due to net avoidance. This is especially true if the nets are operated prematurely and frequently, as for a spring-migration monitoring program. This could act to decrease adult population size indices, increase productivity indices, and reduce survivorship estimates.

The second case in which net avoidance may affect population studies is when a station is operated at a very high frequency. Survivorship models using within-year recaptures to identify residents require a certain period of time between captures, typically 10 days (Buckland and Baillie 1987, Peach 1993, Peach et al. 1990). Stations operated at very high frequencies actually may lower their ability to identify residents, since these birds may be captured several times in rapid succession and avoid the nets thereafter, thus not reappearing in the data set after the necessary time interval has elapsed.

An additional issue is the relationship between annual recapture probability and netting frequency. Increasing recapture probability increases the precision of survival estimates, as does increasing the number of samples (Pollock et al. 1990). For the purpose of estimating interannual survivorship, however, an entire season represents a single sample, regardless of netting frequency. Increasing netting frequency undoubtedly does increase recapture probability, but the exact relationship between these two variables has not been examined across a broad spectrum of sites. Increasing netting frequency certainly does not proportionately add adult birds to the catch.

A more formal approach to the study of net avoidance, but beyond the scope of this paper, would be to

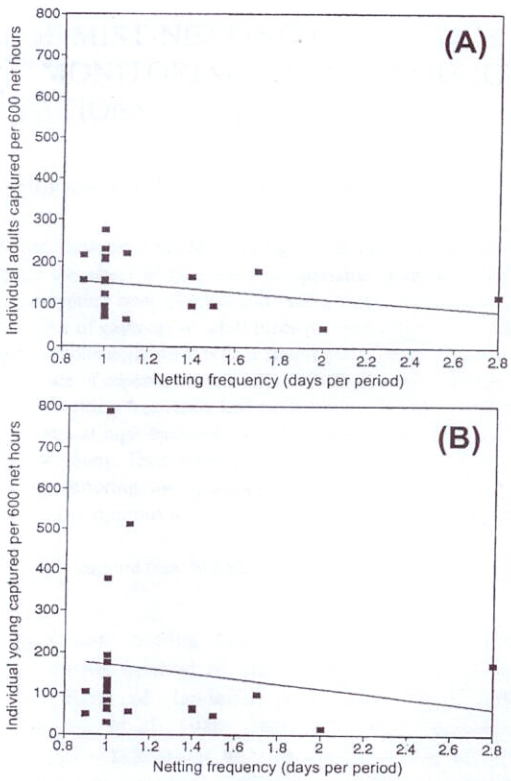

FIGURE 4. Rates of first capture of (a) adults and (b) young vs. netting frequency at 22 MAPS stations in scrub habitats in 1992. (a) r = 0.25, slope = –35.4; (b) r = 0.14, slope = –58.2.

estimate within-year recapture probabilities. Such an approach has been used in closed population estimation models that allow for capture probability to vary by response to capture (Otis et al. 1978), but to our knowledge has not been used to assess the effects of sampling frequency. Such a study could be done on a station-by-station basis, using only a single species or group of related species and a set of stations in similar habitat operated at various frequencies, and it would need to be limited to resident individuals.

Ultimately, the optimum frequency at which to operate a constant-effort mist-netting station will be determined by the specific objectives of the project and the resources available. Data from stations operated at varying frequencies can be combined for large-scale analyses, provided those from stations operated on multiple days per period are adjusted appropriately. In general, however, additional effort, when possible, likely will be more valuable to large-scale monitoring programs if used for establishment of additional stations nearby in similar habitat, rather than repetition. Increasing the number of stations providing data and standardizing the effort expended at these stations will increase the precision and reliability of regional monitoring indices and estimates. Furthermore, clusters of similar stations may provide valuable dispersal and philopatry information, as well as giving more accurate pictures of local conditions and trends.

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