Studies in Avian Biology No. 29:187–196

RECOMMENDATIONS FOR THE USE OF MIST NETS FOR INVENTORY AND MONITORING OF BIRD POPULATIONS

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Abstract. We provide recommendations on the best practices for mist netting for the purposes of monitoring population parameters such as abundance and demography. Studies should be carefully thought out before nets are set up, to ensure that sampling design and estimated sample size will allow study objectives to be met. Station location, number of nets, type of nets, net placement, and schedule of operation should be determined by the goals of the particular project, and we provide guidelines for typical mist-net studies. In the absence of study-specific requirements for novel protocols, commonly used protocols should be used to enable comparison of results among studies. Regardless of the equipment, net layout, or netting schedule selected, it is important for all studies that operations be strictly standardized, and a well-written operation protocol will help in attaining this goal. We provide recommendations for data to be collected on captured birds, and emphasize the need for good training of project personnel.

Key Words: mist net, monitoring, recommendations, standards, technique.

Mist netting is a valuable tool for monitoring bird populations (Dunn and Ralph *this volume*). Since becoming widely available over the last half of the 20th century, mist nets have been employed in a wide variety of studies, often using very different protocols. Information has gradually accumulated about the effects on capture rates of netting equipment, spatial arrangement of nets, and netting protocol. We are now in a position to make recommendations on the best practices. It is important to use methods that are effective and efficient, because mist netting requires specialized training and intense effort. Standardization is crucial to preventing spurious variation in capture rates. Finally, using widely accepted and tested protocols whenever possible will facilitate comparison of results across studies, and pooling of data for common analysis.

This paper contains recommendations for mist netting that are appropriate for a wide variety of inventory and monitoring purposes, taking into consideration the welfare of captured birds. The paper integrates the latest information contained in this volume and prior literature, and represents a general consensus of the authors contributing to this volume and of other participants in the workshop giving rise to it (see Preface). All recommendations apply to all seasons, unless specifically noted otherwise, and are summarized in Table 1.

PRIOR TO SETTING UP A NETTING STATION

Study Design

The number and type of nets used, their placement, target levels of netting effort, and data to be collected, all should be chosen to address the study objectives most effectively. Therefore, prior to selecting station locations and setting up nets, it is important to clearly define goals for population parameters to be measured, geographic scope, temporal frames of interest, and targets for species and sample size. For example, species inventory projects may require netting in a wide variety of habitats, as opposed to a study whose objective is to compare population parameters among particular habitats. Long-term monitoring will require a location that is likely to remain accessible over the life of the study, and for some purposes it will be important that habitat also remain relatively unchanged. A desire to capture particular target species will influence the habitats and vegetation structure where netting should take place, and may require use of special net types or capture techniques (such as canopy nets, or lures such as water drip traps or tape recordings; e.g., Whitaker 1972, Wilson and Allan 1996, Sogge et al. 2001). For some habitats or species (including certain grassland birds), netting may not be the best means of obtaining population data, and other methods should be considered.

Objectives of the study should consider the most appropriate geographic scale, which in turn affects the number of netting stations to be established. Is the intention to compare results among several stations to contrast distinct habitats or management practices, or are data to be pooled from multiple stations and habitats to represent a region as a whole? Adding effort at a single station can enlarge sample size, which is particularly important for estimation of survivorship (Nur et al. 2000, *this volume*; Ballard

TABLE 1. SUMMARY OF RECOMMENDED PROCEDURES FOR MIST-NETTING STUDIES

Parameter	Season	Recommendations
Station location(s)	All	Stations likely to be accessible for life of study
		Study-specific requirements are addressed
		Capture rates are sufficient to meet study objectives
Number of nets	All	Sufficient for sample size objectives to be met
		Matched to number of personnel available, at effort level sustainable for life of study
Mesh size of nets	All	Most suitable size for target species, or use range of sizes for species inventory
Net placement	All	Convenient and fast to check
		Study-specific criteria are met (nets placed to sample target species or habitats, or systematically sample several habitats)
	Breeding and wintering	Grid arrays to maximize territorial individuals captured and increase recapture probability, although lines may be better for sampling territorial birds when size of individual ranges are unknown or are variable among target species
Net density	All	1–5 nets/ha to sample as many territories or home ranges as possible
		>1–5 nets/ha, if desired, when birds are not territorial
Distribution of sampling periods[a]	All	Equal sampling periods throughout season
Number of sampling periods	Breeding	Demography: 10 to 12 consecutive 10-day periods, covering whole breeding season
		Abundance/site fidelity: minimum of 3 sampling periods per season, but more is better
	Wintering	1–3 sampling periods per season is a common protocol, but more frequent sampling is likely to provide better information
	Migration	Annual abundance indices and long-term trends: near-daily sampling, either at a single station or spread among a cluster of stations[b]
		Comparison of abundance among stations within years: 5–10 sampling periods (with simultaneous netting sessions)
Length of netting session[c]	Breeding	One day/10-day period (multiple stations pooling data), or up to 7/10-day period (single station studies where greater sample sizes are required, capture rates remain high enough for continued netting to be efficient, or sampling periods are relatively few)
	Wintering	1–2 days, or longer if capture rates remain high enough for continued netting to be efficient
	Migration	Annual indices of abundance or age ratio: near-daily netting through season
		Comparison of abundance among stations within a year: one or more days per netting session (preferably with simultaneous sampling at stations to be compared)
Hours of operation	All	At least 4 h, starting at dawn (unless peak activity of target species occurs at a different time)
		Effort level should be sustainable over life of study
Standardization	All	Standardize all equipment, net placement, and effort parameters within stations
		Standard protocol can differ among stations if direction and magnitude of temporal changes is being studied, but not if capture rates are being directly compared
		Maintain stable vegetation height and density at net sites to extent possible.
	Breeding and wintering	Mark–recapture studies require less strict adherence to constant effort than studies relying on indices, but equipment, net placement, and vegetation at net sites should still be standardized
Training	All	Ensure that all participants are trained to standards of the North American Banding Council
		Train all participants to follow a standard protocol that is detailed in a written document
Data	All	Develop field recording and data management procedures to ensure uniformity in collection of all relevant data, and to enable rapid analysis
		Collect metadata relevant to station (including protocols and at least basic habitat description)
		Record daily effort data

[a] Period within which a netting session of 1+ consecutive days will take place.

[b] Effect on results of pooling less than daily data from each of several stations has not been tested (Dunn and Ralph *this volume*).

[c] Period of consecutive days of netting within a sampling period.

et al. *this volume*). However, increased netting within a site can sometimes lead to net avoidance, and may not sample a directly proportional increased number of territories. Increasing number of stations may often enlarge sample size more than increasing effort within a site, and sampling at multiple stations allows estimation of sample variance at the same time that overall sample size is increased (Burton and DeSante *this volume*). Sometimes, the sample size needed for a good measure of annual survival can often be obtained only by combining results from a network of stations (Hilton and Miller 2003). Single stations are poor at tracking annual changes in regional productivity for at least some species (Nur et al. 2000), but as few as 3–10 stations may be sufficient to produce representative regional results (Bart et al. 1999, Ralph et al. *this volume b*). Of course, pooling data among stations can obscure important differences among sites.

Once a decision has been made to establish multiple stations, further decisions are needed on how many, how far apart, and in what habitats they should be placed. The number of stations to be established should be based on target sample size (see below), as well as on availability of funding and personnel. If there is a likelihood of high turnover in the set of stations contributing data for pooled analysis, the effect of such turnover on quality of results also should be considered. Optimal spacing of stations will depend on study objectives (e.g., study of juvenile dispersal or adult emigration may require stations to be clustered). For the greatest power to represent an entire region, stations should be distributed according to geographic or habitat strata.

Before beginning the study, an investigator should decide upon the desired precision of an estimate or the effect size to be detected, which will help determine the minimum sample size required (number of mist-net stations and nets, number of birds captured and recaptured, or both). For survival analyses, the minimum sample size will be determined primarily by the number of birds recaptured. For comparisons of productivity, the number of mist-net stations and number of birds captured will be considerations. A preliminary estimate of sample size required to meet study objectives can be made through review of published papers on similar studies, or consultation with a statistical expert. Because of variability of capture rates among species, plans should be made for a pilot study and power analysis of preliminary data to allow for adjustment of effort.

Researchers should be well aware that mist-net captures are indices of the population being monitored, and that the proportion of the true population that is captured is unknown and variable (Nur et al. *this volume*). Much variation in capture proportion can be avoided through good study design and standardizing protocols, but capture proportion is not necessarily constant over time or space, thereby introducing potential bias into comparisons among indices (Sauer and Link *this volume*). Whenever feasible, the parameter of interest (e.g., adult population size) should be studied using mark–recapture techniques or other means of estimating capture probability (Dunn and Ralph *this volume*, Peach and Baillie *this volume*, Nur et al. *this volume*, Kendall et al. *this volume*).

Monitoring of population size and demography nearly always benefits from standardized netting. It is therefore recommended that alternative net placements be tested in a pilot study, such that a standardized array can be maintained without further change throughout the actual study period. Pilot work should also test the most appropriate distribution and length of sampling periods for a particular study. Careful thought should be given to the likelihood that the proposed netting schedule (daily hours of operation as well as duration and frequency of netting sessions) can be sustained over the intended life of the project, after station operators' initial flush of enthusiasm has waned.

Training

All personnel should be well trained before beginning a study that involves use of mist nets. Such training should include the operation and care of nets, safe and ethical handling of birds, procedures for obtaining permits, and record keeping. Hands-on training should be done under the tutelage of a bander experienced in the use of mist nets and adept at training, and can be arranged by contacting a certified trainer, a local bird banding organization, or bird observatory. Such resources can be found by searching the Internet or by contacting the U.S. or Canadian banding offices.

All prospective participants in a mist-netting study should follow the guidelines in the appropriate North American Banding Council training guide (Hull et al. 2001; North American Banding Council 2001a, b; Russell et al. 2001). These guides are very detailed, so here we need only to emphasize the importance of appropriately training all project personnel. Joint training sessions for all participants in a particular study, regardless of experience level, is particularly desirable to ensure uniformity of technique (Dale *this volume*) and familiarity with the specific study protocols.

NETS

Selecting a Station Location

Locations for mist-netting stations should be selected in accordance with the geographic scope of the study and question being addressed, but the choice should be tempered by accessibility, security from disturbance, and availability of personnel and support facilities. Often, station locations will be chosen to sample a pre-selected group of locations or habitats, perhaps employing a stratified or other sampling design. Depending on the study objective, it may also be very important to select specific locations with high capture probabilities (e.g., for studies involving mark–recapture). Capture rates are usually higher in riparian and shrubby habitats than in forest, in part because many birds fly above net level when vegetation is taller than the nets. If multiple stations are being established and study of dispersal is not a research objective, stations should be at least 1–5 km apart to ensure that most individuals will not be caught at more than one location (Ralph et al. *this volume b*).

For migrating birds, the most suitable study locations for long-term trend monitoring are ones from which birds are likely to move on as quickly as possible (i.e., locations that are not especially attractive for stopover), because some current methods for trend analysis assume that each day's count is an independent sample of the population (Dunn and Hussell 1995). By contrast, if the monitoring questions involve interest in stopover ecology, suitability of habitat, resident birds, and similar questions, then it may be preferable to find locations that have large populations of birds overall, including migrants with more lengthy stopovers. Locations for abundance monitoring during migration should be selected where overall habitat change will be minimal (Kaiser and Berthold *this volume*). Otherwise, change in use of the area by migrants could be interpreted as a change in the size of the breeding population in the region from which the migrants came (Ballard et al. 2003). Suitable locations with relatively stable habitat include those kept at an early successional stage by natural processes (such as regular flooding), or locations where the station operator has permission to cut vegetation regularly throughout the study area to maintain habitat structure and vegetation height at relatively stable levels.

Number of Nets

The number of nets used at each station should be defined both by the target sample size (related to the study questions) and by the ability of available personnel to handle the normal rate of capture. The North American Banding Council (2001a) gives detailed guidelines on the balance between bird numbers and the number of personnel. In general, most well-trained people can handle 5 birds/h. We suggest that if capture rates at a two-person station regularly exceed 50 birds in a 5-h period, consideration should be given to adding personnel, or reducing the number of nets. If the capture rate is consistently less than 3 birds/person-h, consideration should be given to increasing the number of nets (if higher numbers are needed to meet study objectives), or to having a single person operate the station and sending other personnel to operate additional stations.

Sometimes the number of nets that can safely be operated varies widely from day to day, for example, during migration seasons, or at locations where high winds often make certain nets unusable. In such cases, a core group of nets can be designated that includes nets opened on essentially all days that netting takes place. One or two additional groups can then be defined, of nets that will be closed first (as a unit) when some nets must be closed. A variable representing the net groups opened each day can then be added to analyses to model the effect of variable effort.

Net Placement

Several factors should be considered in deciding how to place nets within the study area.

Ease of checking nets.—A person should be able to complete a net round within about 15 min or less, if no birds are captured. Rounds can be longer if one person can patrol nets constantly and someone else processes the birds, as long as birds are never left in a net for much more than 30 min (North American Banding Council 2001a). If the study design allows, it is efficient to place nets in an array that brings the observer back to the starting point at the end of the net round (e.g., circular or grid array, rather than linear).

Habitat.—Many studies require sampling of particular habitats, species, or locations. If there are no such constraints, nets should be placed where (a) capture rates will be reasonably high, (b) nets are sheltered from prevailing winds, and (c) vegetation at net sites can be manipulated to maintain it at a relatively constant stage for the duration of the study. For relatively random sampling, making no prior assumptions about movements of birds or relative use of habitat, nets should be placed systematically across a study area or with some element of randomization in placement and orientation.

Net density.—The optimal distance between nets varies widely with research question. Number of species inventoried will increase with low net density and sampling of a large area. For studies of adult population size and survival rates, obtaining large sample sizes and having high capture and recapture probabilities will increase precision of estimates (Pollock et al. 1990). As net density is increased, capture probability of individual adults will increase but effective population size sampled will decrease to a certain threshold, which will be related to size of home range or territory.

If territorial birds are being captured, then nets should be spaced at distances appropriate to sampling as many territories as possible (DeSante et al. *this volume*). Nur et al. (*this volume*) and Ballard et al. (*this volume*) found that resident birds >200 m from nets had a very low probability of capture, and Remsen and Good (1996) indicated that species with typically short flight distance would be captured with lower probability than species making longer flights. DeSante et al. (*this volume*) suggested a net density of 1–1.5 nets/ha as a good starting point for breeding season studies for studies of North American breeding birds, whereas 5 nets/ha is the recommendation of the French STOC monitoring program (Suivi Temporel des Oiseaux Communs; C. Vansteenwegen, pers. comm.).

Faaborg et al. (*this volume*) used linear arrays of nets set end to end for winter sampling in the Neotropics. This design is less efficient for sampling many territories (either breeding or wintering) than is a more dispersed array of nets, because several nets may fall within the territory of a single bird when they are set end to end. Moreover, relatively small shifts in territory location between years can have a large effect on recapture probability. However, this design should increase capture probability for birds whose territories are being sampled, which could be important if netting effort at a station is very limited. Moreover, a linear array of nets should sample species with a wide range of territory sizes, whereas dispersed nets could be less efficient in this circumstance.

For capture of migrating birds, nets can be placed much closer together than if territorial birds are the target.

Type of Nets

Mesh size should be appropriate to the target species (Heimerdinger and Leberman 1966, Pardieck and Waide 1992, Jenni et al. 1996). Small birds become unduly tangled in large-mesh nets, whereas large birds often bounce out of small-mesh nets. Capture rate and ease of using nets also depends on net material and fullness. For most passerines, capture rates are highest using 30- or 36-mm-mesh nets (as measured by the maximum stretch), but certain study objectives (e.g., species inventory) might well require use of a variety of mesh sizes. Nets of standard dimension (12 m long, with four panels) are recommended because they are easier to handle than very long or very high nets, and non-standard nets or novel placements should be used only if especially needed (e.g., Whitaker 1972, Wilson and Allan 1996). See North American Banding Council (2001a) for additional information on net types.

SCHEDULE OF OPERATION

Choice of Seasons

Netting across seasons can provide valuable data on within- and between-season movements that could be missed by more limited efforts (e.g., Ralph and Hollinger 2003). However, limiting netting to specific seasons may be important for certain studies. Species-specific migration seasons can be defined as the period in which 95% of the individuals of the target species pass through a particular area, as in Hussell et al. (1992). It can be useful to define species-specific breeding seasons in a similar way, as the period in which 95% of individuals in an area confine their breeding activities, from territorial establishment until post-breeding dispersal of juveniles. Using these definitions, post-breeding dispersal is that period between the breeding season and fall migration, and "wintering" season is the period between fall and spring migration. Because the timing of these seasons, particularly the periods of dispersal and migration, can vary markedly with species, age, sex, location, and year, the best dates for study will have to be determined individually for each locale.

For some studies, netting across the boundaries of seasons can cause problems for analyses because of misclassification of transients. For example, inclusion of late migrants in a study of survival rates of local breeders may bias results because one cannot distinguish mortality from emigration through netting alone (Pollock et al. 1990). Even though transients can be dealt with to some degree with mark–recapture analyses (Brownie and Robson 1983; Pradel et al. 1997; Nur et al. 2000, *this volume*), it may be best for survival studies to avoid such complications to the extent possible, through judicious choice of netting dates (DeSante et al. *this volume*).

It has been suggested that capture of local residents during the migration season could lower the chances of recapturing those individuals during the breeding season due to net avoidance. This, in turn, could bias certain kinds of population studies, although statistical methods exist for reducing such bias. No reduction in capture probability across seasons was found by Nur et al. (*this volume*), but only one species has been investigated. If studies are being carried out both in the migration and the breeding season, consideration can be given to using a different study area for each season. On the other hand, if capture of late-migrating individuals will not bias results of a particular breeding season study, it will be most efficient to use a single study area, and to define the breeding season as beginning when the first summer residents arrive, even though migrants may still be passing through.

Number and Length of Sampling Periods

The number and length of sampling periods (each containing a netting session of one to several consecutive days) should be selected on the basis of study objectives, tempered by availability of personnel and accessibility of the station. Multiple and evenly spaced sampling periods are important, both to increase sample size and to ensure that annual samples are not biased by within- and between-year variation in abundance or capture probability of age and sex groups. Optimum length of sampling periods will depend upon the selected length of netting sessions within these periods (see below), and the desired length of gaps between netting sessions.

The MAPS protocol calls for dividing the breeding season into 10-day sampling periods, which we recommend as the standard unless there is need for more frequent sampling. Wintering season studies frequently sample only 1-3 times/season (e.g., Faaborg et al. *this volume*). Although this may be sufficient for detecting site fidelity and long-term changes in use of a location (e.g., Latta and Faaborg 2002), monthly or more frequent sampling should offer better opportunities for detecting intra-seasonal variation in movements of age and sex classes, and for greatly increasing precision of population parameter estimates.

For monitoring population change of migrating populations, it is best if sampling is conducted daily or near daily, to allow modeling of the effects of date and weather on number of migrants present, and to increase precision of parameter estimates (Dunn et al. *this volume a*, Hussell *this volume*, Thomas et al. *this volume*).

Length of Netting Sessions

Depending on the length of the gaps between successive netting sessions, personnel may be able to rotate among stations and sample several locations within a single sampling period. Moreover, gaps allow birds to lose net shyness between sampling periods (see below), and can decrease the chance of recapturing transients within seasons, making it easier to identify transients in mark–recapture models (Pradel et al. 1997). Regardless of the number of days in each netting session, we recommend that nets be operated for the same number of days in each session so that capture effort will be the same in each sampling period.

The MAPS protocol calls for 1 day of netting per 10-day sampling period, which produces a sufficient sample size when data are pooled among many stations. In other studies, especially where stations are visited infrequently and may be quite inaccessible, or when larger sample sizes are needed to determine local (rather than regional) metrics, it may be desirable to net for two, three, or more days in a row to catch the maximum number of birds possible. It is often found that netting for more than 3 days in a row becomes unproductive because of net avoidance, so that few naïve birds remain to be captured (Burton and DeSante *this volume*, Faaborg *this volume*). Even birds stopping over during migration may show net avoidance after first capture (Dorsch 1998). Some evidence suggests that recapture probability may be depressed for as much as a month after capture or even longer, based on tropical wintering birds (Faaborg et al. *this volume*; J. Faaborg, pers. comm.). However, DeSante et al. (*this volume*) suggested that in temperate breeding birds, net avoidance may last only a week or less, and in some species there is no evidence of any net avoidance (Nur and Geupel 1993a, Ballard et al. *this volume*). Whenever feasible, the presence and duration of net avoidance should be studied for each target species to determine the most efficient netting schedule for a particular study (Burton and DeSante *this volume*).

Despite the possibility of net avoidance, near-daily netting effort may be necessary during the breeding season to capture representative numbers of breeding adults or locally produced young birds, which may be present on the study plot for only a few days after fledging (Ballard et al. *this volume*). Optimal length of netting sessions therefore varies with study species and objectives.

During seasons when birds are relatively resident, abundance is assumed not to vary systematically from day to day, such that samples collected from a variety of locations on different days will give the same results as if all samples had been collected simultaneously. However, temporal change can be rapid, even during the breeding season, and species differ in the timing of breeding activities (Ralph and Hollinger 2003, Ballard et al. *this volume*). For within-year comparisons among locations, therefore, netting sessions should be paired temporally to the extent possible.

During migration, abundance and species composition of migrants present at any given station are very likely to differ from day to day, depending largely on weather and date in the season. Studies aimed at comparing habitat use by species or age classes during migration should therefore sample all stations on the same days, especially if relatively few netting sessions can be undertaken. Over a period of years, however, a network of stations operated on different days should provide similar information, although with greater variance.

Daily Timing of Operations

Netting normally should take place early in the morning, because capture rates are usually highest in the first 4-6 h after dawn when birds are most active. To obtain a good sample of the birds present, nets should be open for at least 4 h (weather permitting), as is the norm at the vast majority of stations. Depending on objectives of the study, and on predictable availability of personnel, nets can be run for a longer period, even for the entire day (e.g., Kaiser and Berthold *this volume*). This may be the preferred option in situations where birds are known to be active throughout the day (Faaborg et al. *this volume*; E. Mallory, unpubl. data), or when logistics make it more efficient to increase effort within a netting session than to add visits to the station. Whatever the choice of daily hours of operation, that level should be sustainable throughout the expected life of the study to maintain standardization of data collection (see below).

DATA TO BE COLLECTED

Bird Data

There is broad agreement on basic data that should be collected for every bird captured, but ongoing discussion on how much extra data should be taken that banders have no plans to use in their own analyses (e.g., time of day that a bird was weighed, fat score, or molt). However, these data can be of great value when pooled with those from other study locations (e.g., Dunn 2002), and in some cases only pooled data can provide samples large enough for analysis. As long as the data can be collected without stress to birds (i.e., holding and handling times are not too great), we recommend that banders collect all data listed in Table 2. Physical samples, such as blood for genetic study or feather samples for genetic or isotopic analysis, should only be collected as part of a specifically designed project for which necessary permits have been obtained.

Methods used for taking measurements and for recording skull pneumatization should follow the recommendations of the North American Banding Council (2001a, b). Pyle (1997) provided detail on aging and sexing birds by plumage characteristics.

We recommend that a camera be kept on hand at every netting station to document characteristics of birds that are unusual (as well as to document habitat at net sites; see below).

Other Data

We recommend that information on station operation be recorded at a level of detail that would allow others to reconstruct the study if desired. These metadata should include at the minimum: definition of the boundaries of the study area, number and type of nets, individual net locations (carefully mapped with compass orientation and preferably GPS documented), and schedule of operation.

Depending on the goal of the study, it may be necessary to collect detailed data on vegetation in and around the study area, including the type, density, and height of each vegetation type at each net site. Even if not part of the study, we recommend that a simple, broad habitat classification be done each year, as described in Ralph et al. (1993). Annual photographs of net sites can also aid in documenting habitat. This material will provide important evidence for interpreting the factors responsible for capture rates at each net site over the course of the study. A brief description of the landscape in which the study area is embedded can also help in interpreting results, and can be helpful when comparing results among different projects. Plotting net locations onto a topographic map or aerial photograph is a good way to document landscape and land use characteristics of the surrounding area.

In addition, banders should record daily effort data, including date, hours of opening and closing nets, which nets were open (if not all), and names of personnel participating. We recommend also that a daily narrative be written, covering any events that may have affected results (e.g., presence of

TABLE 2. RECOMMENDATIONS FOR COLLECTION OF DATA ON CAPTURED BIRDS.

Data type	Comments
Mandatory	
Data required by Banding Offices	Date, location, band number, auxiliary marking status, species, age, sex
	Age, sex, or both should be recorded as "unknown" unless designation is at least 95% certain
Retrap status	First capture vs. retrap
Recommended	
Subspecies	If difficult to distinguish or unusual, record characters used to identify
Tail length	If needed to identify subspecies
Bill dimensions	If needed to identify subspecies
Tarsus length	If needed to identify subspecies
Skull pneumatization	Record score in appropriate season, and use routinely in combination with plumage characters that are not known to be at least 95% accurate
Breeding condition	Record condition code in appropriate season
How aged and sexed	Record codes for how aged and sexed (e.g., codes used by MAPS; http://www.birdpop.org/DownloadDocuments/manual/
	Newband.PDF), recording presence of brood patch or cloacal protuberance, eye color, molt limits, tail shape, or other criteria on which aging and sexing is based
Wing length	Banders in the Western Hemisphere are advised to measure unflattened wing chord (the norm in North America), which is thought by some to be most reproducible and which allows most opportunity for direct comparison and pooling of data; Europeans usually measure flattened wing chord (or length, or both, of the eighth primary; Kaiser and Berthold *this volume*)
Weight	Specify weighing equipment in station protocol
Fat score	Ralph et al. (1993) is widely used in North America, but use of Kaiser (1993a) may lead to less variation in scoring among observers (Dunn 2003)
Time of handling	Select time of start or end of net round, or time of weighing (for standard use; record time to nearest 10 min)
Net of capture	Useful in assessing factors affecting capture rates (habitat, distance from nest); some people also record side of net and net panel in which individuals are captured
Molt	In appropriate season, record details or, at a minimum, the presence or absence of wing and body molt
Notes	E.g., on aberrant plumage, disease or parasites, deformities, or to note that photos were taken; record extent of juvenile plumage; record probable age and sex if designation was <95% certain

predators, windstorm, or other disturbance). Records should be kept as well of factors that could affect year-to-year results (such as insect epidemics or presence of heavy fruit crops in the study area). If weather variables are to be used in analyses, it often may be easier to obtain computerized data from a nearby weather station than to record it in great detail at the netting station. Nonetheless, weather conditions on site may differ from weather office records (particularly wind speed and occurrence of local showers), so keeping simple local records can be worthwhile, and will aid in interpretation of daily capture rates. Automated weather stations can be purchased relatively inexpensively.

STANDARDIZATION

Most monitoring studies are intended to detect temporal and spatial variation in bird abundance or demographic parameters. It is therefore crucial that capture operations be standardized as much as possible over time and space. Without standardization, ascribing variation in capture rates to test variables can be criticized, because it always can be argued that the variation may have resulted from changes in capture protocol. Standardization will help minimize variation in capture probability and allow use of more powerful yet parsimonious statistical models in estimation of survival and population size (Peach and Baillie *this volume*, Sauer and Link *this volume*). If a change in protocol is required (such as new net locations or different hours of operation), we recommend that the old and new protocols be used on alternate dates for a year or two so that the effect of the change can be appropriately modeled in analysis. This approach, however, is cumbersome and expensive in time and effort. It is far preferable to conduct a pilot study to determine the optimal equipment, net placement, and operation protocol, and then follow that protocol strictly throughout the life of the project.

NETS

We strongly recommend that net number and placement be held constant when abundance monitoring is a study objective. It is often tempting to open more nets when extra personnel are available or to add or alter net sites during the course of a study. However, this can bias results, because net sites are not equal in the number and types (species, age, sex) of birds captured. For example, birds captured per net-hour could differ between years simply because in one year nets were placed where they were particularly efficient at catching the target species.

Type of net (length, height, and mesh size) also should remain constant if at all possible, and if several types of net are used, the different types either should be placed always at the same location, or rotated frequently and on a regular schedule among all possible locations. Net characteristics such as the relative fullness of nets between trammel lines, whether or not nets are tethered, and material of construction (nylon vs. polyester) also may affect capture rates (North American Banding Council 2001a), but their effects have not been rigorously tested. The rule of thumb is to use exactly the same type of net (from the same maker if possible) in each location throughout the life of the study.

Finally, height of the net affects capture rates. Nets should be set such that a bird captured in the lowest panel just clears the ground (North American Banding Council 2001a), unless the study goals require otherwise (e.g., inventory studies in which ground-hugging species could be missed using normal settings). Some netting stations mark poles with tape showing where each net loop should go to ensure uniformity among personnel in the way nets are set each day. Thibodeau (1999) felt this unnecessary because he found that most birds were captured in middle panels of nets at his station. However, Jenni et al. (1996) found a higher capture rate in upper panels, suggesting that variation in the height of the top of the net could indeed affect overall capture rate.

Any use of lures (bait, water drip traps, tape recordings) should normally be avoided, because it difficult to use them in a standardized manner. In some monitoring studies, however, their use is important (e.g., Sogge et al. 2001; or for nocturnal netting of owls, Erdman and Brinker 1997). Lures should be used on a regular schedule and either should be placed in the same location at each use or rotated regularly among placements. Sound lures should use the same recordings throughout the study and should be broadcast on standard equipment at a specified volume. Digital recordings (solid state or CD) are less subject to degrading than are tape recordings.

SCHEDULE OF OPERATION

Just as net locations are not equal in number and kinds of birds (species, age, sex) that are captured per net-hour, neither are time periods equal (hour in day, day in season). If the schedule of operation changes in a systematic way during the study (e.g., running nets in the morning in one year, but all day in another), then birds captured per net-hour will likely differ between temporal samples solely because of the change in schedule. If nets are operated longer on some days than others, we recommend that analysis be limited to the time period in which nets are always open, as with MAPS (see DeSante et al. *this volume*). Capturing a bird during non-standard hours, however, may result in net avoidance during subsequent standard netting hours, such that excluding data from these non-standard periods from analysis might result in biased estimates of population parameters. Although the likelihood of this happening probably varies seasonally, it may be advisable to avoid non-standard netting within study areas where standardized protocols are in place and net avoidance is suspected to occur.

It is not critical that dates of netting sessions within each sampling period be exactly the same year after year, but they should be paired as closely as practicable. Length of the netting session (consecutive netting days) also should be standardized to the extent possible, to ensure that effects of net-avoidance are the same in every sampling period.

Habitat

Even if netting is completely standardized, changes in vegetation around nets can cause changes in the numbers and kinds of birds captured, independently of changes in local bird populations (Ballard et al. 2003). More birds fly over nets as vegetation becomes taller and fuller, and more (or fewer, depending upon the species) may be captured if understory vegetation fills in gaps next to net lanes. It is therefore important either to choose net sites at which vegetation is likely to remain relatively unchanged for the life of the study, to control vegetation at the net site through regular trimming and thinning, or to use mark–recapture methods to track changes in capture probability over time (Kendall et al. *this volume*). As noted above, we recommend that photography and vegetation assessment be undertaken each year at each net site to document vegetation height and density, and to serve as a reference for vegetation management.

Written Protocol

An important aspect of maintaining standardization is to prepare a formal operating protocol for the project. This requires clearly defining the standards, serves as a reference for future personnel, and also serves as a record of metadata that are relevant to the use and interpretation of results. The protocol should describe the exact net locations, type of net to be used at each net site (with full detail on maker, material, mesh size, dimensions, etc.), schedule of operation, instructions on keeping habitat around nets at a clearly defined constant height, methods used for measuring birds or taking fat scores, and all other operational details. The protocol should be sufficiently detailed so that a person experienced in mist netting, but without experience of the study or study location, could continue the study without any guidance beyond the written protocol. While ensuring standardization of operations and quality of data, a protocol also will contribute to safety of birds (e.g., by providing instructions on frequency of net checks and procedures to use in case of bad weather).

CONCLUSION

All people using mist nets should use methods that are ethical and ensure safety of birds that are captured. Beyond that, it is important to select netting methods that will best meet the specific objectives of each study. Whenever possible, however, researchers should use the recommended and commonly used protocols described here, to provide the most opportunity for direct comparison of results among independent studies.

ACKNOWLEDGMENTS

This paper benefited from discussion among all workshop participants and authors (see list in Preface). We especially appreciated reviews contributed by G. Ballard, D. F. DeSante, G. R. Geupel, D. J. T. Hussell, J. Faaberg, N. Nur, C. M. Francis, P. Pyle, and A. A. Whitman.