Capturing birds with mist nets: A review

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The mist net was developed by Japanese hunters over 300 years ago as a technique for capturing birds for food (Austin 1947, Spencer 1972). Today mist nets are undoubtedly the most commonly used method for capturing birds for research (Spencer 1972). As a result, many improvements and modifications in mist nets and their use have been suggested by netters for particular species and habitats. With a few exceptions, this information is widely scattered throughout the ornithological literature. Low (1957) has described basic mist-net operations. Methods for mist-netting in adverse weather conditions or particular habitats have been described by Bleitz (1970) and Spencer (1972). The most comprehensive reviews of mist-netting techniques presently available to netters are those of Wilson et al. (1965) and Bub (1967). In this paper we provide a review suitable for both novice and experienced netters emphasizing North American bird species and habitats.

GENERAL MIST-NETTING PROCEDURES

The standard mist-net setup includes the net, supported in sections (shelves) by cross lines (trammels), strung between two poles and attached with loops. Guy lines to the poles aid in keeping the net upright and the shelf strings taut. Although many modifications of this standard setup have been described for particular habitats and species (see subsequent sections of this paper), the basic method of capture is the same. Mist nets are constructed of very fine material similar to hair nets; when used properly, they are nearly invisible. Birds readily fly into the nets and when striking them from either side, become entangled in a hammock-like pocket formed by the loose netting supported by the tighter trammels. Low (1957), Bleitz (1957 & 1970), McClure (1964), and Wilson et al. (1965) have all detailed the general use of mist nets. More general descriptions have been written by Kuyava (1959) and Bridge (1963); these sources should be consulted by the novice netter. Permits to mist net birds must be obtained from both State and Federal agencies.

Nets, poles, and attachments

Since the first Japanese mist nets were introduced in North America by O.L. Austin, Jr. in 1947, several improvements have been made in their design. These include a choice of smaller and larger mesh sizes and the replacement of cotton, silk, and nylon webbing with monofilament nylon and terylene for increased strength and durability. Mist nets with a variety of specifications are now available commercially. Consult recent issues of this and other ornithological journals for suppliers.

Black mist nets are used most often since this color absorbs rather than reflects light. However, other colors are available for specific habitat conditions. For example, fine sand-colored nets have been effective in capturing shorebirds in open-beach areas (Bleitz 1961). Pale green-aqua, dark green, dark brown, and white nets have also been used successfully in marshes, forests and fields, mud flats, and snow-covered areas, respectively (Bleitz 1962b, 1964).

Various net sizes are also available. The standard mist net measures about 2 x 9 m (7 x 30 ft). Capture success can often be improved by increasing or decreasing net size to suit particular habitats and the behavior of the bird species to be captured. The maximum size of the net should not exceed the dimensions of the background. For example, Van Gessel and Kendall (1974) found that a background of swamp vegetation or mangroves was essential to prevent nets from being too conspicuous in marsh habitat. Net height can be adjusted by the addition or removal of shelves. Axell (1958a) and Minton (1958) found that single-shelf mist nets were more effective than standard size nets for capturing finches in areas with low cover and wading birds in open-shore areas. Two-shelf nets were effective in capturing redwings in orchards during winter (Waller 1972). Tall nets with as many as 12 shelves have been used successfully in mature forests (Austin 1947). Shortening the length of the trammels, thus increasing the amount of netting per unit length, provides more pocket in the net. The Merseyside Ringing Group (1971) found that this type of net adjustment improved capture rates for large bird species.

Mist nets are available in a variety of mesh sizes. In general, mesh size should correspond to the body sizes of the species that are to be captured. Heimerdinger and Leberman (1966) studied the comparative efficiency of 30 and 36 mm mesh mist nets. A greater percentage of large birds were captured in the 36 mm mesh; many of these birds were seen "bouncing off" the smaller size mesh. However, many small birds escaped by going straight through the 36 mm mesh. Ludwig (1969) has suggested net and mesh sizes useful for capturing specific bird species. Small-mesh nets (25 mm) have been used successfully for hummingbirds (Bleitz 1970). Karr (1979) suggested use of a combination of 30 and 36 mm mesh nets to capture terrestrial birds weighing 5 to 100 grams.

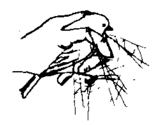
Bleitz (1964) has discussed the general construction and use of mist-net poles. A variety of materials have been used for poles. Bamboo and wood broomsticks have been used (Evans 1965), but may split when forced into the ground. To remedy this problem, Bubb (1960) and Bleitz (1964) devised methods for using aluminum tubing, although its strength is questionable. We have found that 4.8 m (16 ft) aluminum extension poles used by painters (Quik-Lok®, Wooster Brush Co., Wooster, Ohio 44691[1]), although expensive, are easy to handle and effective. Most netters, however, prefer to use jointed sections of thin-walled electrical conduit, preferably 1.3 cm (0.5 inch) to 1.9 cm (0.75 inch) in diameter (Peterson 1960, Ludwig 1968), since conduit does not have to be guyed as strongly as either bamboo or aluminum (McCamey 1969). Howell (1969) recommended using the heavier metal, 1.9 cm diameter, because of its decreased tendency to bow. Construction of inexpensive mist-net poles made of electrical conduit has been described by Castrale and Karr (1981).

Kale (1969) found that 1.3 cm diameter steel reinforcing rods work well as supporting stakes for portable net poles. Harwood (1973) developed a guying method that holds even in fine sand or mud.

Site selection and net placement

Generally, the site chosen for trapping should be within the preferred habitat of the bird species desired, as capture success is usually positively correlated with abundance. Nets are more productive when placed in shade or against a dark background, and sheltered from the wind (Marshall *in* French 1963). The removal of vegetation and debris from under the net helps prevent tangling and allows one to lower the net so that birds cannot fly beneath it.

Wise placement of nets can significantly increase capture success. Nets can be placed end to end (Terborgh and Faaborg 1973, Wright 1979), parallel to one another (Beckett 1965c), in a "V" or "L" formation (Carruthers 1965, Adkisson 1975, Zicus 1975, Graul 1979), in a loop (Karr 1979) or square (Artmann 1971, Cink 1975) around an area of bird activity, in a pattern within an established grid (Fluck 1960, Savidge and Davis 1971), or scattered throughout a study area in "good" locations (Karr 1979). When nets are arranged parallel or at angles to one another, it becomes difficult for birds to avoid one net without entangling themselves in another.



Weather and time of day

Weather (Stewart 1971, Quinlan and Boyd 1976, Robbins 1981a) and time of day (Stewart 1971, Grue et al. 1981, Karr 1981, Robbins 1981b, Skirvin 1981) can have a considerable effect on avian activity and net visibility, and therefore, mist-netting success. Sunlight and high humidity (dew) may increase net visibility and decrease capture success (Stewart 1971, Quinlan & Boyd 1976); cloud cover was associated with high capture rates (Quinlan and Boyd 1976). Quinlan and Boyd also found that capture success was negatively correlated with temperature and positively correlated with barometric pressure. Temperature appears to be a significant factor governing the beginning and end of a bird's daily activity periods (Eyster 1954). High temperatures tend to shorten activity periods, whereas very low temperatures inhibit activity (Robbins 1981a). Reasons for poor netting success during periods of low barometric pressure are not clear. Quinlan and Boyd suggested that because periods of high barometric pressure are associated with unfavorable weather conditions for migration, an increase in the number of captures during these periods may be due to birds "holding over" in study areas. The effects of weather on avian activity appear to vary among species (Robbins 1981a) and habitats (Grue et al. 1981). However, harsh weather (e.g., strong winds, rain) usually results in a reduction in capture rates, particularly in open habitats such as grasslands.

The effects of time of day on mist-netting success may also vary among species, habitats, and seasons (Karr 1981, Robbins 1981b). Bird activity and net visibility may change throughout the day. Generally, bird activity is greatest in the morning and late afternoon or early evening (Grue et al. 1981, Robbins 1981b). Precise times of maximum activity may vary with day length and weather conditions. For example, overcast skies tend to delay morning activity and cause early cessation of evening activity (Stewart 1971, Robbins 1981b). Consideration of the effects of weather and time of day on the behavior of the species to be netted may help maximize capture success.

[1] Use of trade names or names of suppliers is for identification purposes only and does not constitute endorsement by the Federal government.

Setting the net

Quickness and ease of handling can be valuable assets when mist-netting, particularly when time is limited (e.g., before dawn). It is important to reduce the mechanics to a routine operation. Given (1960), Burtt (1961), Johannsen (1962), Strnad (1962), Spencer (1967), McCamey (1969), Goldberg (1974), and Blackshaw (1980) have all devised different time-saving methods for the complete process of net erection. Bleitz (1964) and Adams (1968) describe techniques for handling oversized nets with 100 mm mesh for capturing ducks, hawks, and other large birds.

Keeping the net free of tangles is a problem often encountered when erecting mist nets. An assistant can be of value in this situation. While one person holds one end of the net at one pole, the other unfolds and untangles the net (keeping it taut) as he slowly makes his way toward the remaining pole. Once the net is untwisted, the trammels are attached in sequence. If the net is "tethered," the tethered trammel should be at the top. Otherwise, it makes no difference whether the top or bottom loop is placed on the pole first. Birds can be captured by striking either side of the net. Marking of the top trammel loops for identification will expedite alignment of the loops on the poles. It is important to secure the poles firmly so the trammels are kept taut. Spacing between trammels should be adjusted so that the netting will form a deep enough pocket to prevent birds from bouncing off when they hit. Blackshaw (1980) developed an "H card" (plexiglass) on which mist nets may be wrapped and a mist-net pole spacer (string) which facilitate net erection when an assistant is not available.

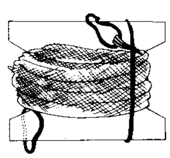
Boring holes for setting net poles can be a tedious process, especially when the ground is dry and hard. Grisez (1965) found that soil sampling augers and tubes are good tools for this purpose. Wiseman (1969) used a solid steel rod, 2.5 cm (1.0 inch) in diameter, with a dull point on one end for boring holes.

An alternative to boring holes is the portable net-pole base. These can be constructed of cement (Neel and Neel 1963) or wood (Spencer 1968). Frazier (1964) developed a more sophisticated base with a small section of pipe that protrudes from the base for pole attachment. If the ground is soft enough, Dunlap (1978) suggests driving an electric fence post into the ground and then sliding the net pole over it. Evans (1965) found it easier to use extra guys, instead of boring holes or using portable net-pole bases. With Evans' system poles need only be pinched slightly and pushed a few cm into the ground.

Various techniques have been used to keep nets secure on the poles once they have been anchored. Junior (1965) used spring clips and screw eyes to attach his nets. Spencer (1968) and Lueshen (1969) suggested drilling holes in the poles and attaching the trammel loops to a wire or twistem threaded through the hole to keep the net in place. Use of automotive hose clamps to fasten trammel loops to the poles facilitates adjustment of net height and tautness (Castrale and Karr 1981). Netting may, however, become tangled with items used to fasten loops to poles. To avoid this problem, Frazier (1963) used strips of inner tube fastened to the poles with snaps. Lawrence and Richards (*in* Lawrence et al. 1964) developed the "Jersey Holdfast," a short length of molded plastic covering from electric cable through which the mist-net loop is threaded. When the plastic is pushed hard against the pole, the loop will not slip. Flynn (see Lawrence et al. 1964) has also devised a technique to prevent loops from sliding by using a rubber band and washer. These three techniques also keep even tension on the trammels, preventing sagging due to high humidity. Goldberg (1968) has designed adjustable net pole straps made from elastic webbing that also solve this problem.

Wind can present problems to netters as slack netting may be forced down the trammels toward one end of the net. Placement of nets perpendicular to the direction of the wind can avoid this problem, but this is not always possible. Cannon (1959) used fisherman's split shot to hold the netting firm on the trammels. Wolfling (1961) proposed the use of rubber cement to do this with less weight. Spencer (1962) suggested that "tethering" the netting to the top and bottom trammels would make mist nets virtually wind-proof. Indeed, tethered mist nets remain in position on the trammels even when placed parallel to the flow of the wind. Although tethered nets may be purchased, Liddy (1963), Wilson (1963b), Yunick (1966), Robertson (1967), and Gavrilov (1977) describe different methods for tethering nets.

Obstacles such as streams, trees, and hard soil can frustrate even the most experienced netter. Bergstrom (1956a) recommended bending nets around a smooth pipe to avoid these barriers. Other helpful hints for mist-netting in woody, sandy, and rocky areas are provided by Warburton (1964).



Luring or driving birds into the net

Hutchison (1967) observed that baiting the mist-net site increased his capture success. Wilson et al. (1965) remarked that dripping water also attracted birds, especially in arid regions.

The use of live decoys may be the most effective method of luring birds into the net. In fact, Austin (1947) thought it was the single most important feature of the art of mist netting. Hardman (1965) has described the general technique of mist netting with decoys; however, there are also several specialized methods. Artificial decoys have also been used in certain instances. Loftin and Olson (1960), McClure (1964), Yunick (1965), and Dusi *et al.* (1971) used silhouette decoys to net shorebirds.

Adkisson (1975) remarked that the success of mist-netting may rely on an actively calling decoy. He also found that an available perch near the net increased capture rates. The song of the species in question or other calls may attract many birds to the netting area (Tallgren 1969). Vocalizations of the Screech Owl (*Otus asio*) have been especially effective (DeWire 1973). A bird uttering distress calls while in the net may attract additional birds (Gerstenberg and Harris 1976). If no live, actively calling decoys are available (it is unlawful to use protected species as live decoys in North America without appropriate State and Federal permits), a stuffed bird accompanied by an imitation whistle or tape recording of the song may suffice (Johnston 1965). Tape recordings should be used sparingly during the breeding season as they may disrupt nesting activity.

Capture success can be increased not only by luring devices but also by physically driving birds in the direction of the net (Odum and Hight 1957). This technique has been especially successful for capturing roosting species (Van Gessel and Kendall 1974). However, caution should be exercised so birds are not driven out of the area altogether (Wilson et al. 1965). When possible, one should drive birds through a habitat lane (Dennis 1956b) so that they are "funneled" toward the net. Experience and timing are important factors. If birds are driven too fast, they may prematurely scatter or fly over the net.

Tending the net

Certain tools and accessories can be helpful in tending mist nets. Yunick (1967) designed an apron which can be used to hold nets, tools, guy lines, and other items. Jenkinson and Mengel (1970) devised a technique for easy handling of mist nets in the dark. Jewell (1978) developed the "band-o-lite" which signals the netter from a distance when a bird is captured. Containers must be available to hold birds removed from the net. Bags of various materials have been used by Lane (1963a) and Reisinger (1968). Reisinger (1963) also designed a "high rise apartment holding and gathering cage." Bleitz (1962a) recommended use of mosquito head nets for holding birds. It is preferable to store each bird in a separate darkened bag or compartment. In some cases, individuals of different species or even conspecifics cannot be housed together without their harming one another. Nets should always be furled when not in use and be checked periodically during harsh weather to prevent damage. Neel (*in* French 1963) and Beckett (1965a) used clothespins and pipe cleaners to keep nets furled and prevent wind from unraveling them.

Care of netted birds

Although the safety of mist nets to birds has been questioned (Dennis 1956a, Detwiler 1957), most net casualties seem to be caused by human error rather than net failure (e.g., birds left in the nets too long, hasty removal of birds from nets; Bergstrom 1956b). However, safety of netted birds can be a problem because large numbers can be captured in a short period of time (for example, see Mead 1974). Important safety precautions have been described by Bergstrom (1956b), Dennis (1956a), Duvall (1957), and Wiseman (1977). Nets must be tended more often than traps. Sufficient help must be available to man the nets so that birds are removed soon after they are captured (within 30-60 min in good weather, or within 15 min if birds may be exposed to direct sunlight). Nets should not be used during moderate to heavy precipitation or high winds. In rain or snow, netted birds may easily become chilled. Should birds become wet, they should be held in dry cloth bags until they dry out. Karr (1979) found that a mixture of honey and rum administered in small quantities with an eye-dropper may speed the recovery of wet birds. When using untethered nets during strong winds, captured birds may be strangled as the slack netting tightens up on the trammels. In addition, the longer birds are left in nets the more tangled they may become and the greater the chance of predation. When aerial nets are used, birds should be removed from the bottom of the net first, followed by the upper portions of the net as they are lowered. If nets are erected over water, the bottom shelf should be set high enough to prevent drowning since nets sag considerably with the weight of captured birds. We believe that nets should not be left unfurled overnight unless they are constantly tended. Even with the low capture potential, damage from and harm to nocturnal animals can be a problem.

Care should be taken when removing birds from a net. McClure (1964) and Shreve (1965) explain the various techniques available. One must first determine from which side the bird entered the net. Many netters prefer to free the legs first and gradually work the rest of the bird out of the net. However, Dater (1960a) describes a technique in which the wings are untangled first. Beckett (1966) has developed a method for freeing large birds such as gulls and terns.

Dismantling and storing the net

In dismantling a net, the trammels are collected to form a single strand (furling) and the loops are tied together at both ends. While the net is kept taut, one should carefully fold the net hand-over-hand to the other end. The net is then tied together in a bundle and placed in a storage container (see Blackshaw 1980 for alternate method of dismantling nets using an "H card"). If care is taken to avoid tangling, future erection of the net will be easy.

Keeping the net loops together helps prevent tangling. Bleitz (1958) recommended using pipe cleaners to tie the loops together. Mather (1958) used a piece of string in a similar way. He tied a knot in the middle of the string to the top loop, threaded one end through the other loops, and tied both ends of the string together. With this method, the loops may be placed on the pole with the string attached. Once the knot is untied, the loops will fall into place on the pole. We prefer to tie a knot to each consecutive loop (using one piece of string) allowing for enough space for separation of the loops when on the poles. This modification of Mather's technique keeps the loops in order, permitting more rapid separation of the shelf strings. A convenient mist net loop holder cut from polyethylene has been designed by Axell (1958b).

Bleitz (1964) and Reisinger (1968) have explained methods for storing mist nets in bags. Houston (1969), however, preferred to use plastic mayonnaise jars. Many netters have found it difficult to distinguish between the sizes and individual characteristics of their mist nets. Sheppard (1967) and Jones (1968) have developed tags whereby each net can be easily identified whether suspended on poles or stored in a container.

Mist net repairs

Since mist nets are expensive and lose their effectiveness when damaged, it is worthwhile to keep them in good shape. Two methods for replacing worn trammels have been devised by McNeil (1967) and Sorensen (1968). Often the knots in mist-net loops become unraveled. Tears in the netting are also common. Trust (1961, 1973), Wilson et al. (1965), Steventon (1970), Allsop (1972), Leverton (1979), and Reynolds (1979) describe general repair of mist nets.

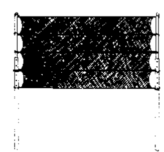
TECHNIQUES FOR MIST NETTING WITHIN PARTICULAR HABITATS

Wetlands

Mist netting within aquatic habitats presents problems not encountered on dry land. Lerch (1955) and Rose (1963) describe techniques for capturing birds inhabiting these areas. Nets are manned from a boat, and extremely long poles are used. Minton (1965) devised an "M-shaped" support for keeping nets containing birds above water.

Knorr (1963), Lane (1963b), Carruthers (1965), Page (1967, 1970), and Gerstenberg and Harris (1976) discuss techniques for mist netting several species of shorebirds within their respective habitats. Within tidal areas, nets must be watched at all times and moved frequently because of fluctuating water levels (Page 1967). Nets should be set at right angles to the waterline in order to capture birds foraging along the water's edge. Capture rates are usually greatest when mud flats are freshly exposed during low tide (Gerstenberg and Harris 1976). Various techniques for driving shorebirds into strategically placed nets have been described by Carruthers (1965). Johns (1963) used a modified, horizontally placed mist net to capture birds when they walked beneath it. Knorr (1963) suggested that 61 mm mesh nets are the most effective for capturing shorebirds, since they are difficult to remove from smaller mesh nets. Owing to their keen eyesight, shorebirds are not easily netted on moonlit nights (Lane 1963b).

When capturing ducks and geese, net visibility is a major problem. The large nets necessary to capture these species are conspicuous, so netting must be done when daylight is reduced (i.e., daybreak, dusk, or when skies are overcast) unless the net can be camouflaged effectively (Frost 1974). Briggs (1977) has developed a net that is both 80 percent higher and less visible than the standard mist net. A deep pocket is also necessary to capture ducks and geese. This, as described previously, is accomplished by shortening the length of the trammels without decreasing the netting.



Grasslands

To capture an adequate number of birds in an open grassland habitat, a large number of nets must be set in such a pattern that birds become confused and entangle themselves in one net while attempting to avoid another (Martin 1969). Various placement patterns have been described by McClure (1956, 1964). Best locations appear to be in very short grass (less than 15 cm, 38.2 inches) within a meter or two from tall (0.6 - 1.0 m, 23.6 - 39.4 inches) grass (Imhof 1960). Another effective site for net placement is within a lane of "head-high" weeds (Katholi 1966). Driving birds into nets within grasslands has also been effective (Odum and Hight 1957).

Shrublands

We are not aware of any references dealing specifically with techniques for mist-netting birds within shrublands. However, as in most habitat types, areas containing food or water, or breaks in the habitat (e.g., hedges, fencerows, washes) may be the most productive. Within dense shrublands, narrow trails may have to be cleared prior to net placement.

Woodlands and forests

In woodland habitats, mist nets are most effective when placed in the shade of trees or in narrow trails cut where the maximum concentration of birds is likely to occur (Bub 1967). The bottom trammel should not be more than several cm above ground so that thrushes and other ground-dwelling birds cannot fly beneath the net (Grom 1962).

In mature forests, however, many species of birds are found in the canopy which may be of considerable height. Dickerson (1959), Dietert (1960), Klingenberg (1960), Jones (1962), Robertson (1964), Mullins and Farnell (1966), DeHaven (1969), Nixon (1972), Sappington and Jackson (1973), Collins (1976), Karr (1979), and Mease and Mease (1980) have developed different methods for raising mist nets within the canopy by modifying nets and poles. However, poles can be extended only a certain amount without bowing or becoming unmanageable and excessively heavy. To solve this problem, McClure (1964), Greenslaw and Swinebroad (1967), Humphrey et al. (1968), Bleitz (1970), Whitaker (1972), and Ryan (1981) have described techniques for elevating mist nets above the forest floor without the use of poles. In most of these techniques, the limbs of trees are used to support nets in the forest canopy.

TECHNIQUES FOR MIST NETTING PARTICULAR SPECIES

There are many references scattered throughout the literature which deal with specialized mist-netting techniques for particular bird species. We have arranged these sources by avian order and family (A.O.U. 1957) in Table 1 (see page 8).

USE OF MIST NETS TO STUDY BIRD POPULATIONS AND COMMUNITIES

Mist nets have been used effectively in studying bird populations and communities. Specific cases have included study of the routes, timing, and intensity of migration (Bergstrom and Drury 1956; Baird et al. 1958, 1959; Fluck 1960; Galindo et al. 1963; Beckett 1965b; Klimkiewicz 1970; Bailey 1974; Karr 1976a), species composition, abundance, and spatial distribution within habitats (Odum and Hight 1957; Stamm et al 1960; Karr 1971, 1976b; MacArthur and MacArthur 1974; Willson and Moriarty 1976), and the transmission of avian disease (Anderson et al. 1966, Sussman et al. 1966). However, because capture success may be affected by a number of factors, one must be careful in planning and conducting mist net operations and in the use and interpretation of capture data. Net characteristics (e.g., mesh size) and placement, capture effort (i.e., number and size of nets and time in operation), habitat, season, time of day, weather, availability of help, and the behavior of desired species before and after capture (e.g., net shyness) must be considered when comparing data for different localities, species, or seasons. Of these factors, capture effort has received the most attention by netters, probably because means of standardization are not obvious.

The measure of capture effort currently used by netters is the "net hour." Net hours are usually calculated by multiplying the number of 12-m, 4-shelf mist nets (or equivalent net area) by the sum of the hours the nets were open. Catches may then be expressed as the total number of birds per 100 (Karr 1981) or 1000 (Ralph 1976) net hours. A modification of this approach (Ralph 1976) is the use of the daily average number of birds captured per unit effort (net hours). Use of a daily average permits quantification of the day to day variation in capture success (standard deviation) suitable for use in statistical tests. Although the use of net hours has been criticized (Hall 1967, Warburton 1967), expression of capture success per unit effort appears to be essential if data from different studies are to be comparable. However, expression of capture success per unit effort alone does not ensure comparability; many other variables (see above) may also influence capture rates. While it may be possible to determine correction factors for some of these within local areas (e.g., time of day, Ralph 1976), we suggest, as have others (Beimborn 1967; Robbins 1968; Karr 1979, 1981), that netters make an effort to standardize their operations with respect to these variables, and that they record essential information such as the number, size, mesh, and placement of nets, habitat characteristics, date, time of day nets are opened and closed, weather conditions, and the appropriate data on the birds captured (e.g., species, age, sex, weight, molt, time of capture, band number). Regular and accurate collection of this information will increase the scientific value of mist-net data.

Use of mist nets in conjunction with mark-recapture techniques may facilitate study of avian population dynamics and the movement of one bird species relative to another. For example, mist nets and mark-recapture techniques may be used to estimate the number of catchable resident and transient individuals within a particular habitat. Two factors must be considered

Table 1. Published reports on mist-netting techniques for particular bird species.

Classification & common name[1]	Reference
Gaviiformes	
Red-throated Loon	Okill (1981)
Procellariiformes	
Hydrobatidae (storm petrels)[2]	Mainwood (1978)
Ciconiiformes	
Ardeidae (herons, egrets)	Dusi et al. (1971)
Threskiornithidae (ibises)	Dusi et al. (1971)
Anseriformes	
Anatidae	
Canada Goose	Zicus (1975)
Black Duck	Frost (1974)
Blue-winged Teal	Briggs (1977)
Wood Duck	Tolle and Bookhout (1974), Briggs (1977)
Spectacled Eider	Dau (1976)
Oldsquaw	Alison (1975)
Falconiformes	
Accipitridae (hawks)	Stewart and McKean (1962), Clark (1971)
Galliformes	
Tetraonidae (prairie chickens)	Silvy and Robel (1968)
Blue Grouse	Schladweiler and Mussehl (1969)
Sharp-tailed Grouse	Artmann (1971)
Phasianidae	
Bobwhite	Cink (1975)
Gruiformes	
Rallidae	
Water Rail*	Leonard (1981)
American Coot	Crawford (1977)
Charadriiformes (shorebirds, waders)	McClure (1956, 1964), Minton (1958), Loftin and Olson (1960), Stallcup (1962), Knorr (1963), Lane (1963b), Carruthers (1965), Yunick (1965), Page (1967, 1970), Spencer (1972), Van Gessel and Kendall (1974), Gerstenberg and Harris (1976), Graul (1979)
Charadriidae	
Mountain Plover	Graul (1979)
Scolopacidae (upland sandpipers)	Dorio et al. (1978)
Common Snipe	Tuck (1967), Fogarty (1969)
Jack Snipe*	Parr (1958)
Japanese Snipe*	Milledge (1975), Lane (1978)
American Woodcock	Sheldon (1960, 1967), Slade (1969)
Phalaropodidae	
Wilson's Phalarope	Johns (1963)
Columbiformes	
Columbidae	
Mourning Dove	Harris and Morse (1958), Beckett (1965c)
Strigiformes	
Strigidae	Clark (1971)
Great Horned Owl	Grigg (1975)
Long-eared Owl	Weaver (1966)
Screech Owl	Goldberg (1976)
Saw-whet Owl	Petersen (1963), Walkinshaw (1965), Kittle (1968)
Caprimulgiformes	
Caprimulgidae	
Whip-poor-will	Walkinshaw (1965), Jenkinson and Mengel (1970)
Common Nighthawk	Walkinshaw (1965)
Chuck-will's-widow	Jenkinson and Mengel (1970)
Apodiformes	
Apodidae (swifts)	Milne and Scott (1959), Hawley and Mead (1962), Spencer (1972)
Chestnut-collared Swift*	Collins (1967)
Palm Swift*	Collins (1972)
Short-tailed Swift*	Collins (1967)
White-throated Swift	Collins (1971)
Piciformes	
Picidae (woodpeckers)	Jackson (1977)
Pileated Woodpecker	Rumsey (1968), Bull and Pedersen (1978)
Red-headed Woodpecker	Rumsey (1968)
Passeriformes	Frazier (1959), Nolan (1961)
Hirundinidae (swallows)	Lerch (1955), Rose (1963), Speek (1971), Collins (1972), Spencer (1972), Mead (1974)
Barn Swallow	Samuel (1970)
Cliff Swallow	Lueshen (1962), Bullard (1963), Samuel (1970)
Bank Swallow	Dater (1960b), Yunick (1970)
Purple Martin	Katholi (1966)
Sand Martin*	Mead (1963), Bruhn (1965), Meylan (1966)
Turdidae (thrushes)	Grom (1962), Galindo et al. (1963)
American Robin	Dykstra (1968)
Wood Thrush	Swinebroad (1964)
Motacillidae	
Yellow Wagtail	Walker (1960)
Meadow Pipit*	Evans (1960)
Bombycillidae	
Bohemian Waxwing	Tallgren (1969)
Sturnidae	
Starling	Lerch (1955)
Grey Starling*	McClure (1956)
Meliphagidae	
Yellow-faced Honeyeater*	Wilson (1963a)
Fucous Honeyeater*	Wilson (1963a)
White-cheeked Honeyeater*	Liddy (1964)
Parulidae	Flynn (1964)
Prairie Warbler	Nolan (1961)
Yellow-breasted Chat	Thompson and Nolan (1973), Thompson (1977)
Ploceidae	
House Sparrow	Sappington and Jackson (1973)
Icteridae	Lerch (1955)
Bobolink	Martin (1969)
Red-winged Blackbird	Lerch (1955), Rose (1963), Seubert (1963), Beckett (1965c)
Common Grackle	Beckett (1965c)
Fringillidae (finches, sparrows)	Odum and Hight (1957), Axell (1958a), Tallgren (1969), Adkisson (1975)
Indigo Bunting	Johnson (1965)
Twite*	Orford (1967)
Savannah Sparrow	Imhof (1960)
Tree Sparrow	McClure (1956)

[1] A.O.U. (1957, 1973, 1976).
[2] Reference(s) pertain only to those species within parentheses.
* Species not found in North America.

when mark-recapture techniques are applied to mist-net data (MacArthur and MacArthur 1974). First, birds that have been captured and released may avoid nets in the future (net shyness). Capture rates of resident species typically decline rapidly after the first day and after 3 to 5 days are extremely low (Karr 1981). Regular movement of nets within a study area may reduce net shyness (Fluck 1960, Galindo et al. 1963), but probably cannot eliminate it. Net shyness appears to vary among species; the Wood Thrush *(Hylocichla mustelina)* and Brown Creeper *(Certhia familiaris)* seem to be "smart" species (avoid nets), while the White-throated Sparrow *(Zonotrichia albicollis)*, Song Sparrow *(Melospiza melodia)*, and Yellow-bellied Sapsucker *(Sphyrapicus varius)* appear to be "dumb" (easily recaptured, MacArthur and MacArthur 1974). Second, captured individuals of a particular species may fall into one of two categories: (a) permanent or seasonal residents who may all be eventually captured if nets are operated long enough, or (b) transients (floaters, nonbreeders) which move through the area, and which may not be easily separated from resident individuals. Because of these two factors, traditional mark-recapture methods cannot be applied to mist-net data. Recognizing this, MacArthur and MacArthur (1974) developed a regression procedure for estimating the total number of resident individuals within the effective capture area of a net and the number of transients captured per day. Manly (1977) used the method of moments to estimate the same parameters. An advantage of Manly's approach is that approximate variances for the estimates are available.

Mist nets have been used effectively in a variety of ornithological studies. They appear to be particularly useful in studies of shy oı secretive species, in areas (or seasons) where birds rarely sing, or when the researcher is not familiar with the species within his study area (Karr 1981). New applications of mist-net techniques to the study of birds are, undoubtedly, forthcoming. However, as with any other sampling technique, their use should be judicious. Netters should avoid inferences which may not be supported by their data. For example, reference to "densities" (birds/unit area) should be avoided as the effective capture area about a net is not known for individual species. Researchers should also be careful when using capture data to compare the relative abundance of species within habitat types; comparisons between habitats with different vegetative strata (e.g., shrubland vs forest) may not be valid unless all vegetative strata are sampled (Karr 1981). Finally, researchers should consider the potential deficiences and biases associated with the use of mist nets (for additional examples, see Karr 1979, 1981) when selecting the sampling method best suited to the objectives of their study.

ADVANTAGES OF MIST NETS

The greatest advantage of mist nets is their superiority over various other trapping methods in capturing most species of birds. Mist nets have been compared with other methods of capture by Williamson (1957), Kirsher (1963), Lane and Liddy (1965), and Pienkowski and Dick (1976). In most comparisons, mist nets proved to be the most effective trapping method. In addition, the portability and versatility of mist mets allow for easy transportation (Wilson 1963c) to where the desired bird species occur, whether it be in the middle of a swamp or high in a forest canopy. The Heligoland trap, although effective for capturing large numbers of transients in areas of concentration, cannot be easily transported (Williamson 1957). Mist nets have been used in conjunction with Heligoland traps to increase their effectiveness (Woodford 1959, Hussell and Woodford 1961). Being very non-selective, mist nets also allow the netter to capture a wider range of species than the other more selective trapping methods (Low 1957). In considering their ease of handling and effectiveness, it is not surprising that mist nets are the most widely used method of capturing birds.

SUMMARY

Herein we have tried to provide a comprehensive review of mist-netting techniques suitable for both novice and experienced netters. General mist-netting procedures and modifications developed by netters for particular bird speices and habitats are included. Factors which influence capture success, including site selection, net specifications and placement, weather, and time of day, are discussed. Guidelines are presented for the care of netted birds and the use of mist-net data in the study of bird communities. The advantages of the use of mist nets over other methods of capturing birds are also discussed.

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