Birds: incomplete counts—standardised mist netting

Version 1.0

This specification was prepared by Murray Efford and Deanna Dawson in 2012.

Contents

Department of Conservation
Te Papa Atawhai

Synopsis

Capture of birds in mist nets can provide data on population density and demography (productivity and survival). This specification focuses on mist netting to estimate population density and change in population density for several species at once, using standard passive techniques in which nothing is done to attract birds into nets.[1]

Multiple nets, typically 12 m long and about 2.7 m high, are placed in suitable locations on a study plot and operated over several days (some protocols require the days to be non-consecutive). Within a short time of capture, birds are extracted from the net and records are taken. Birds are marked with individually numbered aluminium bands so that recaptures can be recognised.

Mist-netting programmes designed to monitor population change (e.g. the Constant Effort Sites (CES) scheme[2] in the UK and the Monitoring Avian Productivity and Survivorship (MAPS) program[3] in North America) generally employ constant effort so that the number of adult birds captured indexes population size or density (Ralph & Dunn 2004). Results have also been expressed as a catch-effort index, e.g. number of captures divided by net-hours, if standard 12 m nets are used. Individual capture probability must be assumed to be constant over time and space if differences in the index are to be interpreted as differences in bird populations. Mist netting to derive an index of density has been strongly criticised because this assumption of constancy can seldom be justified (Remsen & Good 1996).

New, spatially-explicit capture-recapture methods are well suited to the analysis of data from intensive mist netting (Efford et al. 2004). Captures of some species decline rapidly over successive days of netting, probably because birds become net shy. This has contributed to a reluctance by ornithologists to use capture-recapture methods to estimate density, but modern methods of analysis can accommodate net shyness and other causes of variable-capture probability.

Mist netting is an intensive technique that requires operators with a high level of expertise. Some habitats and some sites within habitats are unsuitable for mist netting, and nets must be somewhat clustered so they can be checked frequently. These factors make it difficult to deploy nets using a rigorous sampling design. The application of mist netting to bird monitoring is also limited by the large investment of time required to obtain adequate samples.

Assumptions

For a constant-effort index:

- Per capita capture probability is constant over time and space (expanded in later points).

[1] Attraction (e.g. playing of recorded calls) can be used to increase capture rate, especially when there is a single target species. Attraction is difficult to standardise, and it introduces another potential source of variation in capture probability. It should nevertheless be considered in a future protocol.
[2] http://www.bto.org/volunteer-surveys/ringing/surveys/ces
[3] http://www.birdpop.org/maps.htm

- Either the nets sample all vegetation tiers, or the species of interest do not vary in their vertical distribution.
- Vegetation changes close to the net do not confound comparisons over time (dealt with by trimming higher growth in CES in the UK).
- Sufficient captures and recaptures are made for statistical comparison (suggest average 10 per sample).

For spatially-explicit capture-recapture:

- The bird population remains demographically closed throughout the survey period.
- At the time of survey, birds of the target species occupy territories or home ranges rather than wandering widely. (Statistical methods to deal with transients are under development).
- Numbers of captures and recaptures are high enough to apply the available methods for statistical modelling. Twenty recaptures per species is a desirable minimum.[4]

Advantages

- Relatively free of observer effects.
- Potentially useful for monitoring species living in habitats within which observation is difficult (e.g. dense undergrowth), and for those species with a high probability of retrapping.
- Capture-recapture modelling enables robust statistical inference, including assessment of critical assumptions and estimation of absolute density.
- Allows ancillary observations (e.g. while the birds are being handled) on diet, ectoparasites and disease, condition, age structure, capture-recapture estimation of survival, etc.
- Mist netting attracts the interest of skilled amateurs who, potentially, provide a willing work force.

Disadvantages

- Labour-intensive, and only suited to common species.
- Placement of nets is restricted by site requirements (ideal sites are level and shaded) and the need to move quickly between nets. As a result, rigorous spatial sampling is rarely attempted.
- Usually some vegetation clearance is needed around nets.
- Captured birds are at risk of injury or death from predators (particularly stoats), and from handling or temperature stress.
- Judgement is required on when weather conditions are suitable for nets to be operated safely (ideally little wind or rain).
- As there is no tradition of constant-effort netting in New Zealand, there is a lack of skilled operators here and limited awareness of the requirements.
- Operators risk being swamped when flocks are caught. Birds may get badly entangled and stressed during processing delays. Silvereye flocks can be particularly difficult.
- Analytical techniques are new and not widely understood.

[4] This includes repeat recaptures, but it is preferable that the 20 recaptures are spread over several individuals.

Suitability for inventory

Standard mist netting is generally unsuited to species inventory in New Zealand because it is expensive, selective, and limited in the range of species that are detected with high probability. Conditions that make the method attractive for species inventory elsewhere (e.g. high species richness and difficulty of identification without capture) do not apply here.

Suitability for monitoring

Mist netting has the potential to provide accurate estimates of absolute density and trend in density for some species and situations. The large cost in staff time will preclude use of mist netting in most operational situations. More experience is needed with the method under New Zealand conditions to define the limits to its usefulness.

Skills

Practitioners must:

- Obtain appropriate permits to trap, handle and mark birds, along with any relevant ethics committee approvals
- Be skilled in handling birds and extracting them from mist nets
- Have high proficiency in bird identification, and be familiar with criteria for determining the sex and age class
- Apply sound judgement regarding risks to birds from adverse weather, failure to maintain frequency of net checks, etc.

Resources

The basic requirements for mist netting are:

- Banding permit
- Banding pliers
- Mist nets
- Cloth bags for holding birds
- Poles for mist nets
- Bands

Other equipment and on-site details will vary depending on the species present and site conditions. It is desirable to use a standard recording sheet and to fix the locations of net sites by GPS.

"Handling and banding permits, appropriate-sized metal bands, banding pliers, and mist nets can be obtained from the Banding Office, Department of Conservation, P.O. Box, 10 420, Wellington. Animal Ethics Committee approval will also need to be obtained. Ensure all mist nets are the same size and have an appropriate mesh size for the target species." (Spurr & Powlesland, 2000).

Criteria for aging and sexing passerines of European origin are documented in detail by Svensson (1992). Heather & Robertson (1997) give useful tips for many New Zealand species (under 'In the hand' in each species account).

The effort needed to obtain a single estimate of density by mist netting may be estimated as follows: Experience in North America suggests setting a target of 20 recaptures per species; this can be expected to yield a density estimate with a standard error about 30% of the mean[5] (cf. Efford et al. 2004, figure 2). Assume one capture of the target species per 100 net-hours (see 'Case study A'), and that sampling is sufficiently intensive that 50% of all captures are recaptures. In easy terrain, 25 nets can be operated simultaneously by two skilled operators. Thus, 4000 net-hours, or 16 days of 10 hours each, would be required to achieve the target number of recaptures.

Minimum attributes

The following information is critical when using mist netting to obtain an index of relative abundance. The importance of recording other attributes will depend on your objectives.

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272).

Minimum attributes to record:

- Location
- Net layout (a map of relative positions of numbered net sites, within < 10 m)
- Sampling design, including a description of how net sites were chosen
- Records of all captures and recaptures, including recaptures within a day:
    - Observer's name
    - Band number
    - Net number
    - Date
    - Time of capture (within 1/2 an hour)
    - Species
    - Age class and sex, if able to be determined
    - Other, such as body weight, deformities, etc.

For each netting-day, record:

- Hours the nets were operated
- Weather
- Notes on incidents, such as deaths on handling.

[5] Maximum likelihood estimates have similar precision to those from inverse prediction (Borchers & Efford 2008).

Data storage

Collate, consolidate and store mist netting information securely as soon as possible, and preferably immediately on return from the field. The key steps here are data entry, storage and maintenance for later analysis, followed by copying and data backup for security. If data storage is designed well at the outset, it will make the job of analysis and interpretation much easier. Before storing data, check for missing information and errors, and ensure metadata are recorded.

Storage tools can be either manual or electronic systems (or both, preferably). They will usually be summary sheets, other physical filing systems, or electronic spreadsheets and databases. For mist netting surveys, electronic data recording should be done using an Excel spreadsheet, with separate worksheets for the net layout, capture records and explanatory material. The first seven columns of the capture worksheet should be structured so they can be cut and pasted directly into a text file for input to the DENSITY software[6] (Efford et al. 2004). These columns are as follows:

1. **Location and session code**
   A single alphanumeric code (up to 10 characters, with no blanks) for the study area and netting session, e.g. EGL1Apr06
2. **Band number**
   Must be unique within each species
3. **Day of the netting session**[7]
   Number days 1, 2, 3, etc.
4. **Net number**
   An alphanumeric code, e.g. 1, 2, 3 etc. or 'EGL1A', 'EGL1B', 'EGL1C', etc.
5. **Species**
   An alphanumeric species code
6. **Age class code**
   These codes from the NZ Banding Scheme were provided by Graeme Taylor, May 2006.The codes may require refinement and definition for particular species:
   - J = juvenile (any bird from fledging to 1 year old)
   - SA = subadult (any bird from 1+ years old but not yet in adult plumage and bill colour)
   - A = adult (any bird in adult plumage and bill colours)
   - U unknown
7. **Sex**
   M = male
   F = female
   U = unknown

The first four of these fields are required by DENSITY. The last three provide for selection of subsets of data via a 'capture filter'. The *X*-*Y* coordinates of nets must be provided in a separate text file under the column headings 'Net number', '*X*', '*Y*', where *X* and *Y* should be the full metre easting and northing from GPS.

[6] http://www.landcareresearch.co.nz/services/software/density/
[7] Actual date and time should appear in later columns of the spreadsheet.

Copy and/or backup all data, whether electronic, data sheets, metadata or site access descriptions, preferably offline if the primary storage location is part of a networked system. Store the copy at a separate location for security purposes.

Analysis, interpretation and reporting

Capture-recapture analysis of mist netting data should use spatially-explicit maximum likelihood methods (Borchers & Efford 2008) as implemented in DENSITY version 4. Seek statistical advice from a biometrician or suitably experienced person prior to undertaking this type of analysis and check for the latest version of the software. The text below provides a brief overview of the critical analytical steps.

Exploratory phase

The main form of the DENSITY software provides tools for viewing and checking capture data. Map capture locations with the ‘Captures’ button on the toolbar. Display individual movements by right-clicking the map and selecting ‘Show tracks’. Check the distribution of movements with ‘Histogram of distances’ on the ‘Movements’ tabbed page. Check daily counts on the ‘Summary’ tabbed page. Changes to the capture data may be made as you go by editing the capture file (double click on file name box), but remember to ‘File | Save’ and ‘Read data’.

Model selection

Spatially-explicit models are defined on the ‘Options’ page ‘ML SECR’, accessed by clicking ‘Specify model’. The analyst usually compares several models to find the one that best fits the data. Models may include net shyness (a learned response to capture, i.e. avoidance of the sites or strata occupied by nets), individual differences in range size, and various other effects. Click the ‘GO’ button on the main toolbar to fit a model (this may take several minutes). Results appear in the log file, with a model selection criterion (AIC); the smallest value of AIC indicates the ‘best’ model, but models within 3.0 of this AIC should be considered. Model averaging (see ‘Model averaging calculator’—docdm-59563) is an option here (Burnham & Anderson 2002).

Final analysis and inference

Although an estimate may be obtained for one place and time, the aim of analysis will often be to determine whether the density of a bird population differs between study areas, treatments, or times. This may be cast as a model selection problem, where the choice is between a model that assumes a constant density and a model that assigns different densities to the two study areas (for example). Study areas are treated as independent ‘groups’ in the usual terminology of capture-recapture modelling (e.g. Williams et al. 2002, p. 427), or ‘sessions’ in DENSITY. Model selection uses AIC (e.g. Burnham & Anderson 2002). Confidence intervals may be constructed from the asymptotic variances, by profile likelihood, or by bootstrapping (Borchers & Efford 2008).

Case study A

Case study A: mist netting of forest birds for an index of density

Yellow-crowned parakeet (photo: C. Mahoney).

Synopsis

Bird population density was compared among three different-aged stands at North Okarito, Westland, using both transect counts and capture rate in standard mist nets. Some species (kererū, bellbird, silvereye, robin and tūī) were more common in older stands, from which it was inferred that they are likely to be adversely affected by selective logging ('coupe-logging') of old stands. This case study illustrates methods used historically for analysing mist net data, and provides data on species-specific capture rates in New Zealand forest.

Objectives

- Predict the likely effects of coupe-logging on forest birds in South Westland.

Sampling design and methods

Three different-aged stands of rimu forest formed a mosaic within a 100 ha study area. Birds were counted on five transects 600 m long for 6 days every second month over 2 years. Each transect traversed multiple stands, but each sighting was assigned to a stand (young, mature and old).

Standard mist nets (2.7 m high × 12.2 m long; 38 mm mesh) were placed in approximately equal numbers in the different stand types (9 in young stands, 13 in mature stands and 10 in old stands), 150 to 300 m apart. Each net site was sampled, with nets checked regularly, for 7 to 8 hours centred on the middle of the day on 2 days every second month for 2 years, avoiding days of heavy rain. All birds captured were banded and released at the site of capture.

Additional high nets (18.2 m high × 18.3 m long; 38 mm mesh) were operated at four sites to assess bird use of higher vegetation tiers.

Results

Transect counts and mist net captures were summarised by species and expressed as number per 100 hours of observation. Data from both years were pooled to increase sample sizes for analysis. A chi-squared goodness of fit test was used to test the hypothesis that counts differed between stand types or seasons after adjusting for the number of hours spent sampling. Counts on transects varied significantly with stand age in eight species. Numbers of birds captured in mist nets varied significantly with stand age in only four species. This difference was attributed to the smaller absolute numbers of captures compared with sightings.

Table 1. Capture rates of birds caught in standard mist nets in different-aged stands of rimu in North Okarito Forest. Data from two years were pooled. Adapted from Spurr et al. (1992), tables 3 & 6 (species averaging less than 0.2/100 net-hours are omitted). * = a significant difference between stands ($P < 0.05$), NS = not significant.

	Number caught per 100 net hours					
	Young stands	**Mature stands**	**Old stands**		**Total captures**	**Percent recaptures**
Brown creeper	0.6	0.8	2.3	*	63	12.5
Grey warbler	1.2	1.6	0.8	NS	64	4.9
Fantail	1.5	1.7	0.9	NS	72	9.1
Robin	0.7	1.3	1.3	NS	58	38.1
Tomtit	2.6	2.8	2.6	NS	138	12.2
Rifleman	0.8	0.4	0.1	*	20	0
Bellbird	2.9	2.9	4.5	*	176	23.1
Blackbird	1.2	1.1	0.7	NS	51	13.3
Silvereye	4.2	2.7	14.4	*	359	0.5
Chaffinch	1.5	2.2	1.5	NS	94	3.3
Net-hours	1449	2097	1635			

Recapture rates varied widely between species, but were generally too low for capture-recapture analysis. Net avoidance after first capture may have contributed to low recapture rates in some species, but at present there are no data to shed light on this. The very low recapture rate of silvereyes may reflect their mobility.

Kererū and tūī were seen fairly often on transects (20/100 h and 15/100 h respectively) but seldom caught in mist nets. The top tiers of high nets (> 12 m) were particularly effective for catching bellbirds, silvereyes and chaffinches. Overall capture rates were very much higher in autumn than in other seasons for all the commonly caught species except blackbird, and the seasonal effect was extreme for silvereyes.

Limitations and points to consider

This study is a unique application of systematic passive mist netting in New Zealand forests. The tabulated capture rates are a good guide to what can be expected elsewhere.

No attempt was made to adjust for varying detection probability in either sampling method. Counts using the transect method were therefore influenced by unknown and varying effects of season, weather and habitat structure, despite considerable attention to standardisation of methods. With mist netting, the nets preferentially sampled the understorey. Brown creepers appeared to differ in their use of young and old stands: Use of old stands was biased towards the lower vegetation tiers, so capture rates in standard mist nets were greatest in old stands, despite captures in high mist nets suggesting greater overall density in young stands.

This study was not designed to yield capture-recapture data. More recaptures could have been obtained by concentrating effort in one or two seasons rather than netting year-round, and by netting for more days in fewer stands. Starting earlier in the morning might have increased the overall capture rate.

Modern statistical methods offer some advantages over the more traditional analyses used by Spurr, Warburton & Drew in 1992. For example, a generalised linear model with log link (i.e. Poisson regression) could be fitted to each count data set; this would remove the need for arbitrary pooling before analysis and allow the possibility of estimating overdispersion (for an example see Purcell et al. 2005). Likelihood ratio tests could be used to compare models with and without an effect of stand age.

References for case study A

Purcell, K.L.; Mori, S.R.; Chase, M.K. 2005: Design considerations for examining trends in avian abundance using point counts: examples from oak woodlands. *Condor 107*: 305–320.

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Case study B

Case study B: mist netting of forest birds for an estimate of absolute density

Synopsis

The population density of breeding birds in an eastern United States deciduous forest was monitored by C. S. Robbins between 1961 and 1972 (Efford et al. 2004). Further mist netting was conducted on the same site by D. K. Dawson and M. G. Efford in 2005. These data are used here to illustrate spatially-explicit capture-recapture methods. The inverse prediction method used by Efford et al. in 2004 for model fitting has been superseded for mist net data by the methods of Borchers & Efford (2008).

Objectives

- Did the population density of common forest bird species at Patuxent Research Refuge, Maryland, decline over the period 1961–1972?
- Does mist netting provide data suitable for capture-recapture analysis?

Sampling design and methods

The study site was in deciduous forest on the Patuxent Research Refuge, Maryland, USA. Forty-four standard mist nets (2.7 m high × 12 m long; 30 mm mesh) were erected on a 4 × 11 grid (100 m spacing between rows, 61 m spacing along rows) and operated from dawn to dusk for 6 non-consecutive days in late May to early June each year 1961–1972.

For additional sampling in June 2005, 44 nets were placed about 30 m apart in an elongated rectangle (570 m × 100 m). The site was sampled for 9 hours per day for 9 non-consecutive days.

Data collection

Nets were checked at roughly 40-min intervals. New birds were banded and identified to species, age class, and sex (when possible). Net number, time and date of capture were recorded for all captures. Birds were released near the net.

Results

Capture-recapture models for the 1961–1972 data on red-eyed vireo (*Vireo olivaceus*) were compared by AIC (Borchers & Efford 2008). The best model included a declining trend in density, net shyness, and annual variation in the home range size (Table 2). Birds were 56% less likely to be caught after they had been caught once (SE 6%). The overall trend for 1961–1972 (Fig. 1) was estimated at –5% per annum (95% CI (–9%, –1%)). This trend, when extrapolated to 2005, predicts a density of 0.3 / ha. Although netting in 2005 yielded an estimate of density with wide confidence limits (5.0 / ha, 95% CI (1.6, 15.3)), it is clear nevertheless that the original trend was not sustained over 1972–2005.

Table 2. Spatially explicit capture-recapture models for red-eyed vireo at Patuxent Research Refuge. Mist-netting data is that of C.S. Robbins 1961–1972. The models were used to evaluate evidence for net shyness and trend in the density. Np = number of parameters in model. ΔAIC = difference in AIC between the current model and the best model. All models used a 'hazard rate' detection function with shape parameter *b* constant over years. The models shown are a subset of those considered in the full analysis.

Model		Np	AIC	ΔAIC	Notes
1	D(.) g0(.) σ(.)	4	10810.5	66.3	All parameters constant
2	D(log(D) ~ β0 + β1.year) g0(.) σ(.)	5	10788.0	43.8	Log-linear trend in density
3	D(year) g0(g0C(.), g0R(.)) σ(.)	16	10756.6	12.4	Annual variation in density; net shyness
4	D(log(D) ~ β0 + β1.year) g0(g0C(.), g0R(.)) σ(year)	17	10744.2	0.0	Log-linear trend in density; net shyness; annual variation in scale (range size)

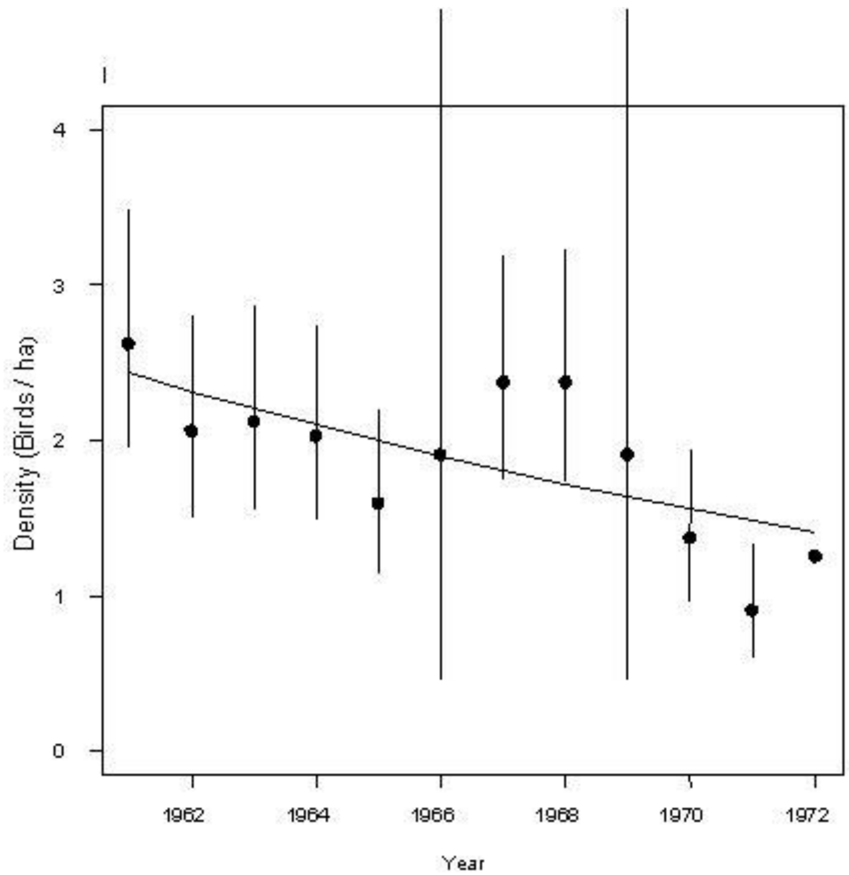

Figure 1. Breeding density of red-eyed vireo at Patuxent Research Refuge, Maryland 1961–1972. Points are annual estimates from Model 3, with 95% confidence intervals. Curve is log-linear trend from Model 4 ($\lambda = 0.95$, 95% CI 0.91–0.99). Y-axis units are birds per ha.

Table 3. Capture rates of birds caught in 44 standard mist nets in deciduous forest, Maryland, USA. Captures were made over 9 days in June 2005 (approximately 3560 net-hours) (D.K. Dawson & M.G. Efford, unpubl. results). Species with fewer than 0.2 captures per 100 net-hours were omitted.

Species	Number caught per 100 net-hours	Total captures	Percent captures
Acadian flycatcher	0.48	17	47.1
Carolina wren	0.36	13	30.8
Downy woodpecker	0.25	9	33.3
Hairy woodpecker	0.45	16	50.0
Louisiana waterthrush	0.79	28	46.4
Ovenbird	1.63	58	53.4
Red-eyed vireo	1.71	61	23.0
White-breasted nuthatch	0.25	9	44.4
Wood thrush	1.74	62	48.4

Full details of technique and best practice

Indices of population density derived from standardised mist netting (or catch per unit effort) are time consuming and require significant training to develop the skills required to catch, handle and mark birds safely. As a method of surveying birds, the return is often poor in relation to the effort required. However, there are other reasons to catch birds (e.g. for measurement of demographic parameters) that may justify the use of the technique.

Several monitoring schemes use catch per unit effort to monitor bird populations, the best known being the UK Constant Effort Sites (CES) scheme (Peach 1996) which has also been adopted by a number of European countries (Gibbons & Gregory 2006). A similar scheme is also run in the North America (the MAPS Program; DeSante et al. 1993, 1999).

Alternatively, changes in the size of the adult population can be calculated using simple index-based methods (number of individuals caught per season) or more complex methods using mark-recapture methods. Capture-recapture modelling enables robust statistical inference, including assessment of critical assumptions and the estimation of absolute density (see 'Case study B'). Analytical software (e.g. DENSITY) has been specifically written to provide density estimates from this sort of data. Analysts should seek appropriate advice before applying these methods.

The way mist netting is employed to count birds will vary depending on circumstance (e.g. the requirement for an index or density estimate, species, habitat, distribution) so an all-encompassing guide to best practice is impractical. Nevertheless, some general guidelines (using the CES and MAPS schemes as examples) are possible:

- Sites should be at least 9 ha (preferably 20 ha) and contain good populations of breeding birds.
- The number and length of nets set should remain constant from year to year, with a density of nets of around 1.25–1.5 per hectare.

- Nets should be positioned so that capture efficiency is maximised according to the prescribed probability-based sampling design (random, systematic, etc.). If mist netting is being done in tall forest, nets must be raised to sample canopy species, otherwise results will be biased toward species inhabiting the understorey.
- Nets should be set in exactly the same location each year and be operated for a consistent number of hours per day (e.g. 6 morning hours) each year.
- The mesh size of the nets should be standardised within a study to avoid biases in the number and types of species captured.
- No baits or call playbacks are used to attract birds to nets.
- All birds captured, including retraps, are identified, aged and sexed, and all unbanded birds banded.

More useful applications of standardised mist netting methods include:

- Indices of post-fledging productivity can be calculated from the ratio of adults to juveniles captured late in the breeding season.
- Adult survival rates can be calculated from recaptures of banded birds between years. These will be conservative estimates as those adults that have survived but are not recaptured are assumed to have died.
- Absolute density estimates can be calculated by modelling capture-recapture data using the program DENSITY.

References and further reading

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Appendix A

The following Department of Conservation documents are referred to in this method:

docdm-59563	Model averaging calculator
docdm-146272	Standard inventory and monitoring project plan