Catching Bats (Chiroptera) in Tropical Forest Canopies

Most netting at ground level, provides the most commonly used method for sampling bats in tropical forests (Findley & Wilson 1983; Kunz & Kurta 1988; Heideman & Heany 1989). However, recent studies have shown that capture rates and species composition can vary dramatically in relation to net height (Bernard 2001; Cosson 1995; Francis 1994; Hodgkinson 2001; Ingle 1993; Kalko & Handley 2001; Zubaid 1994). Hence, without the use of canopy nets, some species of bat may be seriously under-represented in inventories and ecological studies (Francis 1994; Ingle 1994; Kalko & Handley 2001). The aim of this chapter, therefore, is to describe a canopy netting technique, modified from that of Whitaker (1972), which has been used successfully for the capture of fruit bats (Megachiroptera: Pteropodidae) in an old growth lowland dipterocarp forest in Malaysia. Although working on the same principle as its predecessor, this technique offers a number of potential advantages, including:

1. Fewer materials – all cheaply and easily obtained in most parts of the world.
2. Modified “falls” (vertical support ropes) – which prevent pocket loss, by maintaining net tension throughout the rig to heights of a least 30m.
3. A quick and easy method of net attachment – which allows at least nine nets to be handled simultaneously as a single unit.

Each net rig takes two people up to two days to construct, and costs approximately US$50 (excluding nets and labour). In recognition of the limitations of this technique, further notes are also provided on a canopy netting technique first described by Munn (1991).

Site Selection
To construct the net rig first locate a suitable site. The site must have two sturdy branches, of approximately the same height in the forest canopy, which:

1. Must be separated by a distance that comfortably exceeds the overall length of the mist nets
2. Must have clear space, directly below, in which the nets can be placed without obstruction from vegetation. A small to moderate amount of vegetation clearance may be required to achieve the latter, although this should obviously be minimized wherever possible.

Equipment and installation
The basic tools and materials required for the construction of the rig are listed below. The precise specifications, however, may vary according to local availability.

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>USE</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parang or machete</td>
<td>to clear vegetation, cut rope, and make posts</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>Purpose</td>
<td>Description</td>
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</tr>
<tr>
<td>Fishing line</td>
<td>to guide a thin rope into the canopy</td>
<td>heavy duty e.g. 10lb breaking strain</td>
</tr>
<tr>
<td>Fishing reel</td>
<td>to release the fishing line</td>
<td>open-faced spinning reel, with a line capacity of at least 150 m</td>
</tr>
<tr>
<td>Fishing rod (base section), or smooth pole</td>
<td>to hold the fishing reel.</td>
<td></td>
</tr>
<tr>
<td>Fishing weight</td>
<td>to add weight to the fishing line</td>
<td>size 8</td>
</tr>
<tr>
<td>Catapult or crossbow, plus plenty of rubber tubing</td>
<td>to fire the fishing line up into the canopy</td>
<td>choose a catapult model with a supporting arm brace</td>
</tr>
<tr>
<td>Thin rope</td>
<td>to guide a thick rope into the canopy, and to attach 'd' shackles to the anchor posts</td>
<td>approx. 2 mm diameter, preferably braided</td>
</tr>
<tr>
<td>Thick rope</td>
<td>to secure the rig in the canopy (i.e. cross-robe), hold the nets in position (i.e. the “falls”), and reduce the net sag in the middle of the stack (i.e. side loops)</td>
<td>approx. 10 mm diameter, preferably braided</td>
</tr>
<tr>
<td>Matches or cigarette lighter</td>
<td>to melt the rope ends and prevent fraying</td>
<td></td>
</tr>
<tr>
<td>'D' Shackles, or similar</td>
<td>to guide the “falls”</td>
<td>eight ‘D’ shackles required per stack</td>
</tr>
<tr>
<td>Tarpaulin</td>
<td>to protect the nets, catch splats, and wrap the nets during transit</td>
<td></td>
</tr>
<tr>
<td>Short rubber bungees</td>
<td>to bundle the tarpaulin</td>
<td></td>
</tr>
<tr>
<td>Black nylon thread</td>
<td>to link mist nets along their margins</td>
<td></td>
</tr>
<tr>
<td>Electrical tape</td>
<td>to cover knots and/or faults in the rope that may otherwise snag the net</td>
<td>pale-coloured tape may be preferable, since this can also be used to label and number the nets in the stack</td>
</tr>
<tr>
<td>Binoculars and powerful spotlight</td>
<td>to check nets for captured bats</td>
<td></td>
</tr>
<tr>
<td>Safety Equipment: Hard hat, impact-resistant face shield, goggles, thick leather gloves.</td>
<td>to protect head, face, and hands</td>
<td></td>
</tr>
</tbody>
</table>

When a suitable site has been located, the first stage in rig construction is to fire a weighted fishing line over the branches in the canopy, using a catapult or crossbow. Depending on the height of the trees, this can be done from the ground, or by climbing a nearby tree to gain a better vantage point. A fishing reel, attached to the end section of a fishing rod (which is stuck into the ground or held away from vegetation), must be used to allow the smooth release of the line (Francis 1994; Munn 1991). Once in place, this fishing line can be used to feed two thin guide ropes up into the canopy (Figure 1). These are then used to feed the main cross- rope over the two supporting branches, and, in so doing, raise the falls into position in the gap between. Figures 1 to 3 illustrate the sequence of events. The cross- rope must be tied securely at either end, to two sturdy trees, to hold whole the rig.
in place. The ‘falls’ are held in position on the cross-rope by paired ‘D’ shackles (Figures 2 and 3). These are approximately 30 cm apart and to increase the tension on the net, are attached so that the innermost shackles of each pair are separated by a distance that slightly exceeds the overall length of the mist nets – including the loops. However, this distance should be increased, if there is a large discrepancy between the heights of the two supporting branches (see Hints & Tips, below).

To anchor the falls ropes at the bottom of the rig, four posts must be driven deeply into the ground and ‘D’ shackles attached with thin nylon chord (Figure 4a and 4b). The falls can then be threaded through the lower ‘D’ shackles, and secured into position on the inside of the rig, using a combination of two knots – as shown in Figure 5. Since the falls are untied during each net change, it is advisable that the lower knot should be tied relatively loosely at this stage, with plenty of extra slack.

To carry the nets up and down the rig, net carriers can be constructed from thick chord, bound with electrical tape (Figures 6a and 6b). These carriers should sit freely, between the upper and lower knots of the falls, allowing the ropes to rotate freely without twisting. Once the carriers are in place, the nets can then be threaded onto the rig, by unfastening the lower knot of the falls and passing this
rope up, through the side loops of the mist nets, taking care to ensure that all the loops are added in the correct sequence! A length of tarpaulin, spread on the ground between the falls, will help to keep the nets free of litter and vegetation, and will also be useful for collecting the faecal splats of fruit bats when the nets are in use. The top loops of the uppermost mist net, which are added last, should be tied directly onto the carriers. The falls ropes can then tightened, taking up the extra slack, and the lower knot fastened securely and wrapped with electrical tape, to reduce the risk of snagging. The nets can then be hoisted into the canopy, by pulling on the falls at both ends of the rig, and joined together along their margins, using short lengths of black nylon thread. To reduce net sag (and, hence, prevent pocket loss), short loops of thick nylon chord can be tied around the falls at every second net (Figure 7a and 7b). All nets should also be labelled and numbered in sequence (starting from the bottom up), to record the capture height of all netted bats.

Once joined, any number of mist nets can be added or removed from a single rig within approximately five minutes by two people. To remove the nets, a short length of rope is threaded through the side loops, at either side of the net — again, taking care to ensure that all loops are included in the correct sequence! The ends of the rope are then tied together securely, to make a continuous loop, and the nets released, by untying the falls. The falls can then be re-fastened loosely, with plenty of slack, and the nets folded and wrapped in the tarpaulin using short rubber bungees. This process is simply reversed, to return the nets to the rig.

Field trials
During a two-year field study in Malaysia (Hodgkinson 2001), 24 rigs were constructed within approximately one and a half square kilometres of forest. All rigs were six-metres wide and up to 30 metres tall, with a maximum net area of 162 square metres. Although capture rates varied within each rig, according to net height (Hodgkinson 2001; Hodgkinson et al, in prep.), the average capture rate per 6 x 3 m mist net within each rig ranged from 0.01 to 0.14 bats per mist net hour (0.08 ± 0.04 [mean ± 1 S.D], n = 24). Bat species captured, ranged in body mass from 3.5 to 80.0 g. Other incidental captures included nocturnal birds, flying lizards, frogs, and squirrels, and even a flying lemur! Although some rigs were
damaged by high winds, which caused the main cross-ropes to snap, most rigs were still fully operational and in good working condition for at least one year.

**Limitations**

Despite sampling up to 30 m, some species of bat are seldom captured. This is particularly true of those species mainly active above the forest canopy. In the case of fruit and nectar-feeders, above-canopy species can be most effectively captured at fruiting and flowering trees, using a standard technique described by Munn (1991). This technique uses vertically strung mist nets, supported by poles, which are individually hoisted into the canopy on the end of a single pulley rope (Figure 8). 'Canopy mist nets', designed for this technique, are available from Avinet (Rinehart & Kunz 2001), priced $85 (3 x 6 m) and $125 (3 x 12 m), but can also be constructed from standard mist nets, by re-threading the shelf strings (Munn 1991). Above-canopy insectivores, by contrast, can often be captured over rivers, or in open spaces at the forest edge, using ground nets.

As with any other form of mist netting, the canopy net rigs, described in this chapter, are also strongly biased in relation to diet – since most echo-locating insectivorous bat species, of the forest interior, are particularly adept at avoiding mist nets. Unfortunately, no satisfactory method is currently available for catching these species in the forest canopy. However, acoustic monitoring can be used to identify the echolocation calls of certain species (e.g. Kalko 1995; Kalko & Handley 2001; O'Farrell & Miller 1997, 1999).

**Conclusion**

Although simpler methods of netting (e.g. Munn 1991) can offer similar rates of capture (Francis 1994; Hodgkison 2001; Zubaid 1994), the continuous net coverage
of the canopy net rigs, provides a large surface area for the capture of bats and can also reveal details in habitat use which would otherwise remain undetected (Hodgkison 2001; Hodgkison et al in prep.). Therefore, despite the extra costs in time and labour, this technique is recommended for all surveys and inventories, and is particularly recommended for any study on fruit and nectar-feeding bats which is concerned with the vertical partitioning of complex forest habitats.

**Hints & tips**
- Practice making low rigs first.
- When firing the catapult or crossbow, slow the release to the fishing line with your hand, as soon as the weight, or bolt, clears the desired branch (Munn 1991).
- Always test the rigs in daylight first. Pay particular attention to the falls. Should twisting occur, you may need to increase the distance between the falls – particularly when there is a large discrepancy between the heights of the two supporting branches. This can be achieved by lowering the rig and re-positioning the upper ‘D’ shackles.
- Always have binoculars to hand, both during rig construction and when netting at night.
- Use a powerful spotlight at night, and check the nets every 15 minutes for captured bats – lowering the nets if necessary.
- Remove captured bats from the bottom nets first!
- Avoid working on moonlit nights – since bright conditions can drastically reduce capture rates.
- Reduce net shyness (when the bats know that the nets are in place and so avoid them), by rotating between different sampling points.
- Remove the nets from the forest after use – to keep them dry and free of debris, and to avoid opportunistic theft!

**Safety**
When firing the catapult or crossbow protect head and face at all times with a hard hat and face shield. Thick leather gloves should also be used to protect the hand that holds the catapult (Munn 1991) and to protect against friction burns particularly when pulling on resistant ropes. Remove all jewellery and watches and avoid clothing with excessive zips, buckles, and buttons.

Always beware of falling debris. A hard hat should be worn at all times, and safety goggles are also recommended – particularly when netting at tall fruit-laden
trees. Test the strength of all supporting branches, and be particularly wary of branches heavily laden with fruits and/or epiphytes. Also avoid trees with recently fallen branches!

Never operate canopy nets during high winds, or during and immediately after heavy rain, since this can increase the risk of falling debris. Remove all fishing line from the forest, as this lasts for a long time and can be hazardous to animals. Lastly avoid scratches and bites from captured bats!

**Mist net suppliers**

AVINET INC., PO Box 1103 Dryden, New York 13053-1103 U.S.A. Tel: Toll free US & Canada (888) 284-6387 or Local/International (607) 8443277. Fax: (607) 844-3915 Website: www.avinet.com

BRITISH TRUST FOR ORNITHOLOGY, BTO, The Nunnery, Thetford, Norfolk, IP24 2PU, UK. Tel: (44) (0) 1842-750050 Fax.: (44) (0) 1842-750030 Website: www.bto.org

ECOTONE, ul. Slowackiego 12, 81-871 Sopot, POLAND. Tel.: (48) 58-552-3373 Fax.: (48) 58-552-1535. Website: www.ecotone.pl

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**Literature cited**


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