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Ornithological Methods

A maneuverable canopy net for capturing large tropical birds

Una red de dosel maniobrable para capturar aves tropicales grandes

Nicholas J. Russo [1], *Kimberly M. Holbrook* [2], *Thomas Dietsch* [3], *Francis A. Forzi* [4], *Antoine S. A. Tekam* [5] and *Thomas B. Smith* [1,6]

ABSTRACT. Capturing birds of tropical rainforest canopies is important for answering many questions in ecology, evolution, and conservation, but canopy birds are often out of reach when using conventional mist-netting methods. Some methods exist to mist-net canopy birds, but modifications needed for target-capturing large frugivores are not well documented. Here, we describe a canopy netting method for capturing large, fruit-eating birds in rainforests. The methods presented here emphasize a large net area, maneuverability of netting, and collapsibility for safely preventing the escape of captured birds. During three different projects in the rainforests of Cameroon, this technique has resulted in the successful capture of hornbills (Bucerotidae), turacos (Musophagidae), and fruit pigeons (Columbidae). We recommend this technique for canopy bird research and encourage documentation of any modifications.

RESUMEN. Capturar aves en dosel de selvas tropicales es importante para responder muchas cuestiones acerca de ecología, evolución y conservación, pero las aves del dosel a menudo están fuera de alcance al utilizar métodos convencionales de redes de niebla. Existen algunos métodos para capturar aves del dosel con redes de niebla, pero las modificaciones necesarias para capturar grandes frugívoros no han sido bien documentadas. Aquí, describimos un método de red de dosel para capturar aves grandes que se alimentan de frutas en las selvas tropicales. Los métodos aquí presentados resaltan un área grande de red, maniobrabilidad de la red y colapsabilidad para prevenir de manera segura la fuga de las aves capturadas. Durante el desarrollo de tres proyectos diferentes en las selvas de Camerún, el empleo de esta técnica resultó en la captura exitosa de calaos (Bucerotidae), turacos (Musophagidae) y palomas frugívoras (Columbidae). Recomendamos esta técnica para investigaciones sobre aves del dosel y alentamos la documentación de cualquier modificación.

Key Words: *frugivore, hornbill, mist net, turaco, tropical forest*

INTRODUCTION

Canopy birds provide important ecosystem services, such as seed dispersal, pollination, and nutrient transport (Whitney et al. 1998, Naniwadekar et al. 2019, Sol et al. 2020). Knowing their distribution and behaviors enhances options to monitor biodiversity, especially as canopies become hotter and drier because of climate change (Scheffers and Williams 2018). Although canopy-dwelling birds can occasionally be captured in ground-based mist nets, they may never be captured if they rarely or never fly to lower vegetation strata. This problem has been overcome by mounting mist nets within canopies using a pulley system (Humphrey et al. 1968, Munn 1991). Pulley-mounted canopy nets require a clear path from ground to canopy through which a net can be raised, hundreds of meters of rope for mounting, and a quick and safe pulley mechanism for lowering netting to the ground. Our primary goal was to capture Black-casqued (*Ceratogymna atrata*) and White-thighed Hornbills (*Bycanistes albotibialis*) in Cameroon for movement tracking research. Although the method presented in Munn (1991) has proven to be effective for surveys of small birds, we opted for a design with much greater net area to increase the probability of capturing large (> 1 kg) birds. The method in Humphrey et al. (1968) allows for greater net area, but values independent operation over manipulation of the net area, which is critical when maneuvering a net around vegetation and collapsing netting around large birds that are liable to escape. In this paper, we describe a canopy-netting method that prioritizes safe maneuverability around vegetation and prevents large canopy birds from escaping.

Many studies requiring hornbill capture likely use a variety of canopy net methods, but offer few capture details (Poonswad and Tsuji 1994, Lenz et al. 2011, Naniwadekar et al. 2019) or cite one or two studies without describing modifications (Holbrook and Smith 2000, Chasar et al. 2014). Our method requires the technique described in Munn (1991) for shooting lines over tall trees and, similar to Humphrey et al. (1968), involves attaching nets bottom-to-top and fastening the net loops to a rotating net line. We modified the latter technique by allowing two rotating net lines to operate independently, which enhanced maneuverability around vegetation and allowed for quick changes in the "sag" of net pockets. Although this net design cannot be completed or operated independently, hiring local guides and assistants enhances efforts to find and capture species of interest. A pulley-mounted canopy net requires a team of at least four people for proper mounting but emphasizes safe maneuverability and quick descent to the ground. Over the past 30 years, this method has resulted in the targeted capture of 33 Black-casqued and 28 White-thighed Hornbills, four Great Blue Turacos (*Corythaeola cristata*), and 10 African Green-Pigeons (*Treron calvus*) in a tropical rainforest of eastern Cameroon.

METHODS

Study area

This study was conducted in three phases in the Dja Faunal Reserve of eastern Cameroon and the nearby villages of Bifolone and Kompia. The first phase occurred from November 1995 to September 1996 (Holbrook and Smith 2000, Holbrook et al. 2002), the second phase from February to September 2009

[1]Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA, USA, [2]The Nature Conservancy, Arlington, VA, USA, [3]U.S. Fish and Wildlife Service, Carlsbad, CA, USA, [4]Partners for Sustainable Development, Buea, Cameroon, [5]University of Yaoundé I, Yaoundé, Cameroon, [6]Institute of the Environment and Sustainability, University of California, Los Angeles, CA, USA

(Chasar et al. 2014), and the third phase from June 2021 to September 2023. After the first phase, research teams were trained in this technique by an expert. Canopy net research in the Dja Faunal Reserve occurred within the Bouamir Research Site, a 25 km^2 study area near the center of the reserve (3°11′ N, 12°48′ E). Bouamir is composed mainly of mature tropical lowland rainforest, swamps dominated by *Raphia* palms, floodplains dominated by Uapacaceae trees, and inselbergs (grassy peaks) reaching up to 760 m above sea level (Whitney and Smith 1998). Villages of the Dja periphery contain logged forests mixed with agricultural and agroforestry plantations.

Assembling nets

Canopy nets were constructed by attaching four mist nets (127 mm mesh, 2.8 m height) bottom-to-top using 36.29 kg (80 lb.) strength trammel line (Avinet). Net attachment consisted of tying the bottom trammel line of one net to the top trammel of the next net roughly every 1.5 m using a square knot with a tiny length of trammel line and then weaving an additional, continuous trammel line through each mesh opening along the length of the net. Care was taken to ensure all nets were of the same length and stretched taut throughout the process. We constructed canopy nets from both 6 m and 12 m mist nets. An alternative to attaching multiple nets together is to order custom nets with the desired number of shelves.

Placing the canopy net

Because our goal was to target-capture large (300–1700 g) frugivorous birds, each net location satisfied the following criteria: (1) stretched level with the crown of a fruiting tree visited by the target species; (2) placed along an observed flight path of the target species; (3) placed in front of a tree producing fruits in at least 25% of the crown; (4) placed adjacent to two trees of the same or greater height as the fruiting tree; (5) required minimal clearing of vegetation; and (6) could be hidden by adjacent vegetation. Every net we constructed incurred tradeoffs among these criteria, usually between bird visitation rates and effective net position.

Fruiting tree species in the diet of Black-casqued and White-thighed Hornbills are well known (Whitney and Smith 1998, Whitney et al. 1998, Poulsen et al. 2002, French and Smith 2005). Focal trees were selected according to an early-morning observation, when feeding hornbills are most active (05:45–08:00; French and Smith 2005). Normally, trees were selected if they attracted at least six hornbills during the observation period, and some attracted > 20 in one morning. *Staudtia kamerunensis* (fruiting April–June) and *Pycnanthus angolensis* (fruiting June–October) tend to attract large numbers of both Black-casqued and White-thighed Hornbills. Turacos and fruit-pigeons were captured at fruiting *Musanga cecropioides* trees in nets placed alongside repeatedly used perches.

Fruit abundance in the crown of candidate trees was assessed visually to estimate whether enough ripe and ripening fruits remained to attract hornbills for at least one week. We selected a net position after identifying branches of two nearby trees that could support the main line of the canopy net and ensure the net would be raised level with the top of the target tree's crown, as described below. The nets were also placed where they were most likely to intercept the flight paths hornbills used to enter and exit the tree. Setting up a canopy net required clearing understory vegetation along the full length of the net lane, as is standard for ground-based mist nets. We often chose net sites within a natural gap and used a high-limb chainsaw or makeshift pole pruner to prune any branches that could touch the netting.

Constructing a pulley-mounted canopy net

We constructed each canopy net using the following procedure:

Step 1. We tied a 57 g (2 oz.) fishing weight to fishing line using a fisherman's knot and used a slingshot to shoot the weight over a branch in the canopy. This involved two people: one to shoot the fishing line and another to hold the reel (see Munn 1991). Unlike Munn (1991), we used Daisy wrist rocket slingshot bands without modification and brought at least eight replacements. Slingshot bands usually broke after 2–3 months of regular use. We also used 36.29 kg (80 lb.) strength braided fishing line and only spherical weights (unlike Munn 1991, who advised teardrop-shaped weights).

The fishing weight caused the fishing line to fall from the other side of the branch and to the ground. In the rare event that the weight rolled around a branch or became stuck, we tugged firmly on the fishing line and released quickly to allow the weight to fall. For trees 20–50 m tall, we allowed the weights to reach the target branch and fall naturally, but if we set a net at a shorter tree, the slingshot operator often cast the fishing line, then clenched it for a brief moment to stop the weight once it reached the target branch, according to Munn (1991). This practice prevented the weight from passing over higher branches.

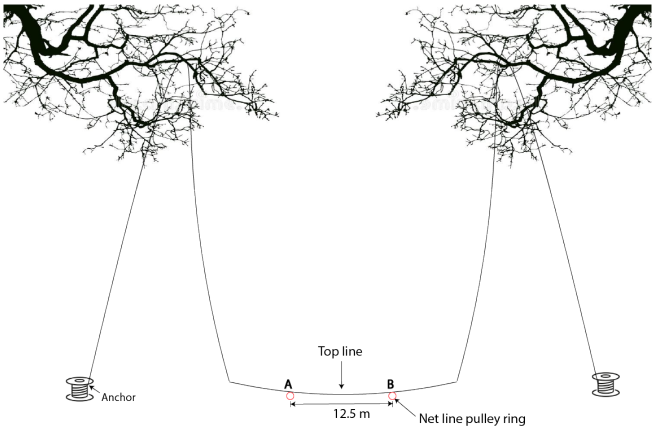
Step 2. We snipped the weight from the fishing line and then tied the fishing line to the end of a spooled nylon cord (we used 3.175 mm, or 1/8" solid braided nylon cord or parachute cord) using a few knots and secured the attachment with duct tape. The ends were tapered with duct tape so the cord would not catch on vegetation. We chose black cord to minimize visibility, and ensured the material was smooth enough to pass through vegetation. We pulled the cord over the branch and back to the ground by reeling in the fishing line. One person pulled steadily on the fishing line from the launching side with gripped garden gloves while another person reeled in the fishing line, and a third person released the nylon cord from its spool. A fourth person was helpful for keeping the fishing line taut as it reached the reel. This process brought the nylon cord over the branch to the launching side.

Step 3. We chose a second branch more than 16 m from the first branch as another hanging point for the top line of rope (Fig. 1). We repeated steps 1 and 2 to pull the rope over the second branch, then attached the two ends of cords together to form a single top line. We reinforced the knot with tapered duct tape.

Step 4. We attached two stainless steel rings (5–6 cm diameter, no thicker than 1 cm) approximately 12.5 m apart (or 6.5 m for a 6 m net) while the top line was still accessible from the ground. The true length of the net needed to be measured first and the distance between rings adjusted accordingly. These rings acted as the pulley system for the net lines (Fig. 1).

Step 5. We used a third and fourth spool of nylon cord to construct each of the two net lines. We set the net lines by pulling a new cord through each of the metal rings (A and B in Fig. 1). We tied

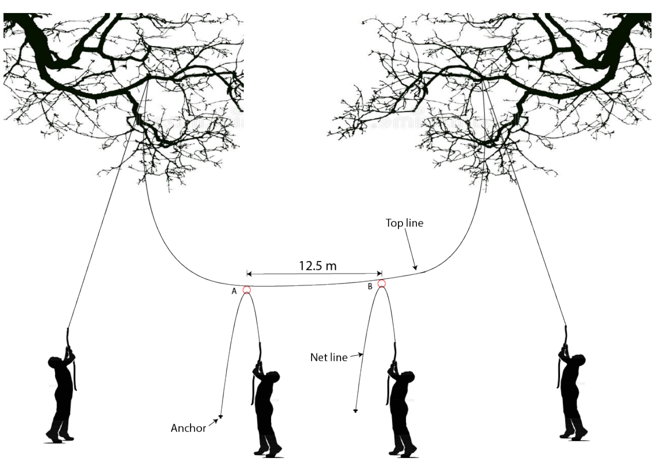
Fig. 1. Setting the top line of the canopy net and attaching two stainless steel rings (A and B), through which the net lines will pass. The ropes forming the top line will remain attached to a spool and may need to be anchored to nearby trees.



one end of each net line to a small tree or similar anchor and kept the other end free. The free ends were allowed to unravel from their spools while the net was constructed and raised.

Step 6. At least one person was needed to guide each net line to ensure the cord unraveled smoothly, while two other people slowly pulled the top line into the canopy (Fig. 2). Care was taken to maneuver net lines and rings away from potential obstacles while raising them into the canopy. It was helpful to have another person with binoculars observing the rings as they were raised to help direct them to the desired position. Once the top line was in the canopy, the ends of the top line were tied to the base of a tree, with excess cord wrapped around a spool.

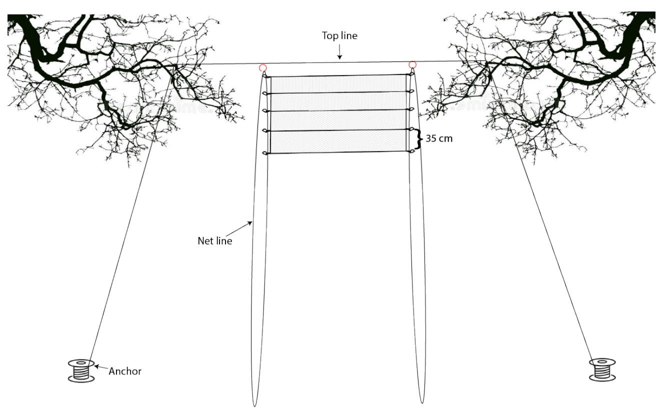
Fig. 2. Constructing the net lines and attaching them to the top line. Two people pull the top line into the canopy while a third and fourth person guide the net line pulley rings (A and B) around vegetation by steering the net lines, which are anchored on one end to a nearby sapling.



Step 7. For each net line, we approximated the additional length of cord needed to attach the canopy net and then cut it from the spool. We tied the two ends of each net line together and reinforced the knot with duct tape. This formed a single loop with which we raised or lowered the net by pulling on the free side of the loop. Excess cord lay on the ground in a neat pile.

Step 8. We attached the mist net "wall" to the net lines (after completing the steps in the section "Assembling nets"). We tied a mist net loop on each net line at the same height. We always tied the first mist net loop directly below the duct-taped attachment point on the net lines. We tied another mist net loop on either net line each about 35 cm from the first loop, which is the approximate height of one mist net pocket. We approximated this distance as the length between the thumb joint and elbow for a person 1.6 m tall or shorter. Modifying the depth of net pockets for any other target species may require some trial and error; the net pockets should be open enough for the target species to enter, and deep enough to prevent the birds from escaping. Several birds have bounced off our nets or quickly flapped themselves free because pockets were too shallow. A "wall" of four attached mist nets had 17 sets of loops on the net lines, with each loop separated by about 35 cm. We attached the net wall one loop at a time using an overhand knot from a bunched loop of the net line and unfurled the net slowly by pulling downward on the free end of both net lines. A plastic bag contained all netting until the net wall was completely unfurled. We raised the net until the top loops sat just below the rings (Fig. 3). Tying the first set of net loops directly below the duct-taped attachment point of the net lines helped to prevent a loop from passing through a ring once the net wall reached the top line.

Fig. 3. Attaching the mist net "wall" to the net lines and raising it into the canopy. Note that each net line forms a loop before the net is attached. Only four net pockets are shown for clarity. In addition, the net lines will be much longer than shown in the figure to allow for attachment to nearby logs or saplings once the net reaches the top line.



Step 9. We collapsed the net wall completely into a durable plastic bag by pulling upward on the free side of each net line. The net stayed in the bag overnight, hidden in vegetation.

Step 10. We arrived at the canopy net the next morning before dawn and waited until bat activity ceased, which typically left us 5–10 minutes to raise the net before the first hornbill arrived. At least one morning of observation was needed to time arrival and unfurling of the net. We raised the net wall into the canopy by having two people pull downward on the free side of both net lines at the same speed. A third person was typically required to guide the net out of its bag and keep the mesh from touching the ground. Once the net was raised to the top line, we tied each net line to a nearby sapling. This knot was sturdy but easy to access and undo (see Video S1).

Step 11. We monitored the net from a blind constructed beforehand in dense vegetation (Fig. 4). When a bird was caught, we immediately untied the net lines from nearby saplings and carefully pulled them toward each other, just enough to deepen the net pockets and keep the bird from escaping, while preventing a complicated extraction from the net. Lowering the net involved two people pulling upward on the net lines at an even speed, with care taken to maneuver around vegetation. Our team was normally able to lower a bird to the ground in 30 s or less, with the bird's weight providing most of the force.

Fig. 4. Canopy mist net raised to full height, in front of a fruiting Staudtia kamerunensis. Normally the net should not be this visible to the target species. Still, we captured one Black-casqued Hornbill in this net on a gray morning with low visibility in the canopy.

RESULTS AND DISCUSSION

Since 1993, we have used this technique to capture 33 Black-casqued and 28 White-thighed Hornbills. We have found net height and low visibility to be better predictors of capture success than the number of hornbills visiting the tree each morning. The capture rate varied from 1 to 10 hornbills per month, depending on the size and shape of fruiting tree crowns and seasonal rains, which affected visibility in the canopy. We also target-captured four Great Blue Turacos (*Corythaeola cristata*), 10 African Green-Pigeons (*Treron calvus*), and 11 Hammer-headed Fruit Bats (*Hypsignathus monstrosus*) using this technique. By-catch was exceedingly rare when target-netting large hornbills. However, we occasionally captured other bird species over the years, most of which were large-bodied and unable to pass through the net (Table S1).

We recorded no injuries to wildlife from the use of this method. We monitored nets continuously from opening to closing and brought birds carefully to the ground as soon as they were captured. The ability of either net line to move independently greatly increased the flexibility of the netting and allowed us to maneuver the mesh around vegetation. This feature allowed us to construct nets in dense rainforest and safely lower and extract all birds. Successful nets yielded 1–6 hornbills and were operated until shortly before depletion of fruits in the crown, when hornbill visits diminished. In many cases we were able to construct a 12 m canopy net on two different sides of the same tree with minimal clearing of vegetation.

It is important to note that we sourced all materials for this project from the United States, and many of the required materials may not be readily available in tropical countries (Table S2). Mist nets (127 mm gauge) must be sourced from companies specializing in field biology, such as Avinet (http://www.avinet.com). Ropes and fishing materials may be locally sourced but will require trial and error to find the most useful varieties. The large quantity of rope required for this technique (up to 1000 m per net) may limit the number of nets that can be deployed at a study site. We sourced nylon ropes and stainless steel rings from hardware stores and fishing lines, reels, and sinkers from sporting goods stores. Slingshot bands were available through sporting goods companies, but local laws can sometimes prevent their sale or shipping. In tropical countries, there may be options to fashion slingshots from locally available rubber or improvise another type of catapult system.

Over several years of trial and refinement, the pulley-mounted canopy net presented in this paper has become a reliable method for target-capturing large birds of tropical canopies, and especially frugivores. We encourage any researchers using this technique to cite Munn (1991), which forms the foundation of this technique. The canopy net method presented in this paper enabled us to study the movements, habitat selection, and seed dispersal patterns of four species of bird and one bat species (Holbrook and Smith 2000, Holbrook et al. 2002, Chasar et al. 2014). Finally, we encourage researchers who use this technique to include local and Indigenous communities when assembling research teams and promoting the conservation of canopy birds, especially in tropical locations. Learning the needs of tropical communities and public perception of species of interest is critical, as well as communicating results at the conclusion of the project.

Author Contributions:

TBS and KMH conceived the idea and design of the study. NJR, TVD, FAF, and ASAT performed further research to refine the methods and apply them to other systems. NJR wrote the paper with substantial input from all authors. TBS, NJR, KMH, TVD, and ASAT provided substantial materials, resources, and funding.

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Data Availability:

Data on capture totals are presented within the paper; code sharing is not applicable to this article because no data were analyzed in this study.

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Supplemental material

Table S1 "By-catch" species captured in canopy nets since 2009 while targeting the capture of Black-casqued and White-thighed Hornbill, Great Blue Turaco, and African Green-pigeon.

Species Common Name	Scientific Name	Number of Captures
Piping Hornbill	*Bycanistes fistulator*	5
White-crested Hornbill	*Horizocerus albocristatus*	1
African Pied Hornbill	*Tockus fasciatus*	1
Red-billed Dwarf Hornbill	*Lophoceros camurus*	1
Black Dwarf Hornbill	*Horizocerus hartlaubi*	1
Long-tailed Hawk	*Urotriorchis macrourus*	1
African Wood Owl	*Strix woodfordii*	1
Afep Pigeon	*Columba unicincta*	1
Splendid Starling	*Lamprotornis splendidus*	8
Swamp Greenbul	*Thescelocichla leucopleura*	1
Yellow-crested Woodpecker	*Chloropicus xantholophus*	1

Table S2 Essential materials for constructing a canopy net, including suggested sources, quantities, and price estimates.

Material	Source	Quantity	Approx. Unit Price (USD)
Mist nets: 127 mm nylon, 12 m	Avinet	4	$141
Trammel line: 36.29 kg, 91.44 m (80 lbs., 100 yds)	Avinet	3	$15
Stainless steel ring: 6 mm x 60 mm (1/4" x 2 3/8")	Home Depot	2	$9
Fishing line: 36.29 kg, 300 m (80 lbs., 328 yds)	Amazon	2	$10
Solid braided nylon rope: 3.175 mm, 152.4 m (3/8 in., 500 ft.)	Uline	4	$138
Spinning fishing reel	Shimano	1	$57
57 g (2 oz.) Cannonball/bullet fishing sinkers (10 pack)	Stellar Fishing	2	$20
Wrist rocket slingshot	Daisy	2	$21
Slingshot replacement bands	Daisy	10	$4.40
Forestry safety helmet with face shield	TR Industrial	2	$27
Protective safety glasses (12 pack)	BISON LIFE	1	$16

Using the canopy net technique to capture fruit bats

We constructed canopy nets for bats using the same technique, but with songbird mist nets (38 mm mesh). The mist net wall was placed only about 8 m in the air but intercepted a regularly used flyway in front of a daily roost. Using this technique, we captured 11 Hammer-headed Fruit Bats (*Hypsignathus monstrosus*) and six Egyptian Fruit Bats (*Rousettus aegypticus*).

Video S1 Link: https://youtu.be/Yl040eykTPo

This video demonstrates how to construct and operate the canopy net described in the manuscript. It is part of the Wilson Ornithological Society's Bird Handling Series. All footage was collected during fieldwork with iPhone, Android, or Canon digital cameras. We used Adobe

Premiere Pro software to edit and splice all footage and add the narration audio. We created a subtitle script using Descript software. Adobe Premiere Pro can generate subtitles but Descript is a free software that outperformed Adobe for this task, both in terms of automatic generation and ease of the editing process. The output from Descript was a .srt file. We loaded both the video and subtitle files into Handbrake software to burn the captions into the video.

Appendix 2. French translation of the article abstract and keywords.

Un filet du canopée manœuvrable pour arrêter les grands oiseaux tropicaux

RÉSUMÉ

Capturer les oiseaux vivant dans les canopées des forêts tropicales est important pour répondre à de nombreuses questions en matière d'écologie, d'évolution, et de conservation, cependant ces oiseaux sont souvent hors de portée en utilisant des méthodes de capture conventionnelles de filets japonais. Certaines méthodes de capture ont été décrites, mais les modifications nécessaires pour capturer les grands oiseaux frugivores ne sont pas bien documentées. Nous décrivons ici de nouvelles méthodes pour capturer les grands oiseaux frugivores des forêts tropicales. Les méthodes présentées mettent l'accent sur une grande surface de filet, la maniabilité du filet et la possibilité qu'il se plie pour empêcher, en toute sécurité, la fuite des oiseaux capturés. Au cours de trois projets différents dans les forêts tropicales du Cameroun, nos méthodes ont permises de capturer avec succès des calaos (Bucerotidae), des touracos (Musophagidae), et des pigeons forestiers (Columbidae). Nous recommandons cette technique pour la recherche sur les oiseaux de la canopée et encourageons la documentation de toute modification.

Mots-clés : filet japonais, forêt tropicale, frugivore, calao, touraco