International Journal of Primatology, Vol. 25, No. 1, February 2004 (© 2004)

Tree Climbing Strategies for Primate Ecological Studies

Alain Houle,[1,3,4] Colin A. Chapman,[2] and William L. Vickery[1]

Received November 13, 2002; revised April 11, 2003; accepted June 17, 2003

Primate ecological studies can benefit from accessing the canopy to estimate intra-tree and inter-tree variation in food availability and nutrient value, patch and subpatch depletion, foraging efficiency, as well as nest structure and nesting behaviors, parasitic transmission and predator detectability. We compare several ways to access the canopy and examine their suitability for studies of primates. Two of them—the Single Rope Technique and the Climbing Spur Method—allow people to safely access almost all kinds of trees, regardless of their size, height or shape. Modern climbing gear and contemporaneous safety protocols, derived from rock climbers, speleologists, and industrial arborists, are reliable and appropriate for primate ecological studies. Climbing gear is specialized and still expensive for students, but tree climbing can be dangerous during specific maneuvres. Consequently, formal training and preliminary experience are essential before attempting to collect data. We discuss the physics of falling, risk assessment associated with a fall, knots, gear and safety precautions. Finally, we propose a Tree Climbing Safety Protocol adapted for 2 climbing methods and primate field ecology. Researchers should be aware that climbing safety depends on their own judgment, which must be based on competent instruction, experience, and a realistic assessment of climbing ability. Therefore, the information we provide should be used only to supplement competent personal instruction and training in situ. Although most primate

[1]Groupe de Recherche en Écologie Forestière interuniversitaire, Département des Sciences Biologiques, Université du Québec à Montréal, C.P. 8888, Succ. Centre-Ville, Montréal (QC), Canada, H3C 3P8.
[2]Department of Zoology, University of Florida, PO Box 118525, Gainesville, FL 32611-8525; and Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, NY 10460.
[3]Present address: Department of Anthropology, Peabody Museum, Harvard University, 11 Divinity Ave, Cambridge, MA 02138.
[4]To whom correspondence should be addressed; e-mail: alain.houle@globetrotter.net.

observations have been and will mostly be done from the ground in the future, canopy information complements the observations. Canopy data will add a significant new dimension to our knowledge of primates by providing strategic information otherwise unavailable.

KEY WORDS: canopy access; tree climbing; single rope technique; climbing spur method; primate ecology; microhabitat.

INTRODUCTION

Ecologists are more frequently exploring the forest canopy to investigate scientific questions (Lowman and Wittman, 1996; Moffett, 2001; Wilson, 1991). Primate ecological studies can also benefit from accessing the canopy. While climbing trees might appear very challenging, an impressive set of tools derived from mountaineering, speleology and industrial arboriculture is available at reasonable cost (Cox and Fulsaas, 2003). We (1) explore the value of accessing the canopy for primate ecological studies, (2) review methods to access the canopy, (3) discuss specific tree climbing techniques useful for primate ecological studies, namely the Single Rope Technique and the Climbing Spur Method, and (4) analyze what happens when a climber falls, including the physics of falling, risk assessment associated with a fall, knots, gear and basic safety precautions needed to prevent injury from a fall.

Researchers should be aware that climbing safety depends on their own judgment, which must be based on competent instruction, experience, and a realistic assessment of climbing ability. Researchers using the techniques presented here should engage a professional instructor to learn climbing methods and safety protocols. Therefore, the information we provide should be used only to supplement competent personal instruction.

Significance of Tree Climbing for Primate Ecology

Climbing trees can facilitate the estimation of food availability, and productivity and defensibility among and within individual trees. Food items can be collected to estimate their nutritional value and toxin levels. Light is vertically stratified within individual small plants and the photosynthetic rate is correlated with the availability of light (Raven *et al.*, 1992; Taiz and Zeiger, 1998). Thus, it is likely that the amount of light within trees is stratified, and fruit and new leaves will vary vertically in quantity and quality. This can be tested by climbing trees to sample fruit and leaves. Young leaves contain lower levels of toxins or are nutritionally better than mature leaves

(Chapman and Chapman, 2002; McKey *et al.*, 1981), and folivorous primates may respond behaviorally to a vertically differential production of young leaves within trees. Accessing the canopy can also help to evaluate food regeneration after exploitation. For example, one might want to measure the ripening rate and synchronicity of fruit as a function of light availability and time interval since the tree was last depleted. Nutritional quality and toxin tolerance may be related to intraspecific and interspecific dominance status, coexistence mechanisms and general specific adaptation.

Accessing the canopy can help to measure patch depletion and foraging efficiency. An ecological concept used to measure foraging efficiency is the giving-up density, i.e., the amount of food abandoned by the foraging group (Brown, 1989). In 1999-2000 in Kibale National Park, Uganda, we measured 1025 giving-up density values, of which 695 were collected from within the canopy, while 330 measures were collected from the ground in small or defoliated trees. In large leafy trees, a limited amount of data can be gathered from the ground, and accessing tree crowns can significantly increase the accuracy of fruit counts. In our case, the estimation of giving-up-densities would have been impossible in two-third of the sample without tree climbing.

Animals are expected to feed close to each other when food is abundant and far from each other when food is rare (nearest neighbor hypothesis: van Schaik *et al.*, 1983). This hypothesis can be partially tested from the ground by observing the distribution of monkeys when they arrive at the patch versus just before they abandon it. However by accessing the canopy, one is in a position to measure the biomass and density of food and thus accurately correlate interindividual distance with food abundance.

Nesting behavior among apes (Baldwin *et al.*, 1981; Fruth and Hohmann, 1993; Sugardjito, 1983) and sleeping site selection and related behaviors among monkeys (Di Bitetti *et al.*, 2000; Heymann, 1995) are topics of much interest. For example, Aquino and Encarnacion (1986) demonstrated competition and sharing of sleeping holes among *Aotus* and other nocturnal mammals in the Amazon. Sleeping habit studies would benefit too from canopy access. For example, in March 2000, 2 primate ecologists were opening a chimpanzee (*Pan troglodytes*) nest in Kibale National Park to examine its structure, when a dwarf galago (possibly *Galago thomasi*) suddenly came out of it. They also found a galago nest inside a second chimpanzee nest (Llorente *et al.*, 2003).

How monkeys see the fruit and which fruit ripening category they prefer are important questions. It would be interesting to evaluate food choice as a function of the food items' spectral colors, as it might help to better understand the evolution of color vision. Climbing trees to collect fruit would facilitate such studies.

Trichromatic color vision—the capacity to discriminate red-green and yellow-blue color spectra—is characteristic of catarrhine primates and might be an advantage for long-range detection of either ripe fruit or young leaves against a background of mature foliage. Dominy and Lucas (2001) have shown that 4 trichromatic primate species in Kibale eat leaves that are color discriminated by red-greenness, a color axis correlated with high protein levels and low toughness, and fruit that are color discriminated by both red-green and yellow-blue channels. Their results suggest that leaf consumption, a critical food resource when fruit is scarce, might be important in maintaining trichromacy in catarrhines. Samples included food dropped by primates but mostly food collected by a tree climber (P. Lucas, pers. comm.).

Thomas Gillespie (pers. comm.) conducted a comparative study of the infection risk to colobines in forests of differential levels of human degradation: pristine, heavily logged, and fragmented. He climbed trees to retrieve 1 m^3 canopy plots from branches used by the red colobus (*Piliocolobus tephrosceles*) and the black-and-white colobus monkeys (*Colobus guereza*) during feeding and travel. He analyzed the plots via a sedimentation technique to determine the density of infective parasite forms.

Canopy Access Techniques

Accessing the canopy is relatively easy, thanks to the modern techniques and tools used in rock climbing, speleology and industrial arboriculture. Although climbing trees for scientific purposes started at the beginning of the last century, most progress was made after Perry (1978) created the Single Rope Technique and arborists developed the Climbing Spur Method (sometimes called the Buckingham Climbing Technique). The two methods allow people to access practically all kinds of trees, regardless of their size, height, and shape. Other scientists have contributed to further develop Perry's original idea (Laman, 1995; Mitchell, 1982; Moffett and Lowman, 1995; Nadkarni, 1988; Whitacre, 1981; Wilson, 1991).

There are many other ways to access the canopy. Table I is a comparison of them and their suitability for field primatology. We only detail the Single Rope and Climbing Spur Methods because they are the most suitable for studies of primate ecology. Of course, simply using ladders or long-pole cutters are also recommended, especially in low canopy forests, but they typically allow the researcher to access the lower part of the canopy.

Single Rope Technique

We can summarize the Single Rope Technique into 6 general temporal steps. The first step is to define and assemble all gear needed (Appendix I)

Table I. Methods of canopy access with an emphasis on their relevance for primate ecological studies. Utility for primate ecological studies is personal opinion. Moffett and Lowman (1995), Hallé *et al*. (2000) and Mitchell (1982) provide more detailed descriptions of the methods. The approximate cost for the Single Rope Technique is derived after Appendix I (prices for each item were obtained in January 2003 from a rock climbing store in Montreal, Canada), Climbing Spur Method from a forestry supplier and includes the rappelling gear and the saddle. Canopy Raft from Hallé *et al*. (2000), and other methods from Moffett and Lowman (1995). Note that costs for the crane include $240,000 for its purchase and $40,000 per year for maintenance, security and operator (prices for year 1993; cf. Moffett and Lowman, 1995), while costs for the canopy raft exclude the purchase of the dirigible and the canopy raft which can be estimated to US $1.5 M (cf. Hallé *et al*., 2000)

Method	Cost for 1-year project (US $)	Cost for 5-year project (US $)	Mobility for primate ecological studies	Utility for primate ecological studies and comments
Single Rope Technique	$950	$1350	Almost complete	Appropriate. Trees can be climbed rapidly as needed. Does not hurt trees. Personal instruction mandatory.
Climbing Spurs (Buckingham)	$800	$1200	Almost complete	Appropriate. Important damage to some species of trees. Use should be limited to trees that can tolerate spur damage. Can access trunk with DBH ranging from 10 to 100 cm. Full body harness recommended.
Ladder	$500	$600	Intermediate	Appropriate. Mostly useful for low canopy studies. Complex to install in high canopy. Hardwood only. Damage the trees if ladders need to be screwed to the trunk during high canopy ascents.
Peconha	$20	$30	Intermediate	Inappropriate. Limited to small trees. DBH < 40 cm. Physically and mentally challenging. Safety questionable.
Boom	$5,000?	$5,500?	Intermediate	Inappropriate. Limited use. Complex system. Two to 4 people needed to move the heavy metallic structure.
Canopy Raft (Dirigible)	$14,000–$68,000	$68,000–$340,000	Complete	Inappropriate. Too expensive. Scares the primates. Media-related approach for primate conservation? Useless for primate ecological studies.
Rope Web	$500?	$1000?	Very Low	Inappropriate. Useless for primate studies. Complex to install.
Tower	$10,000?	$11,000?	Very Low	Inappropriate. Expensive. Complex to install. Limited use.
Crane	$280,000	$480,000	Very Low	Inappropriate. Too expensive Complex to install. Limited use.
Walkway/Tram	$15,000	$16,000	None	Inappropriate. Expensive. Complex to install. Limited use.

and get all climbing training and experience before departure for the field. Inexperienced climbers should attend at the very least two climbing courses, one of which must be in situ.

The second step is to determine which crowns should be accessed. Once a tree is targeted, the objective is to install a climbing rope. This can be done by throwing a fishing line into the crown, ideally over two major branches or branch junctions. One can use a bow with a fishing line reel (Wilson, 1991, p. 103). Once the fishing line has been positioned in the crown, it is used to pass a stronger rope (2–6 mm diameter) into the tree, which is then used to pull the climbing rope into the canopy.

The third step is to attach one end of the climbing rope to a solid trunk and climb the other end with mechanical ascenders (Figures 1a and 1b). All ascenders employ a toothed cam (Figure 1a), allowing the ascender to slide freely in one direction on a rope, but to grip tightly when pulled in

---

Gear required for climbing trees with the Single Rope Technique, some shown in actual use.
a) Mechanical ascenders. On the left, the upper ascender or Jumar (note the pulley in upper left). On the right, the chest ascender or Croll. Note the inclined teeth on both ascenders.
b) Mechanical ascenders shown in actual use. Note the loop into which one foot is inserted, allowing the lower limb to provide the elevation. The two pulleys on the upper ascender reduce the amount of energy needed to climb up by about two-thirds. Inset: the rope positioned in the chest ascender, the latter installed between the chest harness (up) and the seat harness (down). The rope introduced in the upper ascender is locked with a cavabiner.
c) Proposed rappelling system. It involves the use of both a figure-8 descender (upper right) and a mechanical autoblocker (lower left). The two lower right carabiners are locked to the seat harness. The lower left non-locking carabiner is used as a handle to ease the opening of the autoblocker and start the descent. We used a quickdraw to increase the distance between the seat harness and the figure-8 descender. This minimizes the chances of accidentally holding the rope above the rappel device: the panic grabbing reflex. The use of the nonlocking carabiner as a handle to ease the opening of the autoblocker serves the same purpose. Indeed, in a panic context, the climber will instinctively grab the rope below the autoblocker (OK), rather than the autoblocker itself (dangerous). This is the safest rappelling system for tree climbers.
d) Rappelling system shown in actual use. The model is right-handed. For a right-handed person, both the rope below the mechanical autoblocker and the nonlocking carabiner are grabbed by the dominant hand. The other hand holds the rope between the mechanical autoblocker and the figure-8 descender.
e) Autoanchoring using a daisy chain. Note the multiple set of clickable loops that allow the climber to adjust the length of autoanchoring. Inset: the upper carabiner is an automatic locking carabiner: rapid and safe clicking. The lower right carabiner is an ordinary locking carabiner attached to the seat harness before the ascent; the daisy chain is therefore ready to be used. The lower left carabiner is nonlocking and toothless (easy removal), and shortens the daisy chain to limit the length of a potential fall.
f) ATC device and self-rescue knot shown in actual use for an emergency descent. Inset: the locking carabiner is attached to the seat harness. The dominant hand holds the rope below the ATC or any rappel devices (lower right of inset).
g) Climbing rope chewed by a nocturnal animal. The rope was left overnight in a *Ficus exasperata*. Because the chewed part was located on the upper surface of the branch, where the rope was resting and the nocturnal animal had moved on, the damaged section could not be seen from the ground.

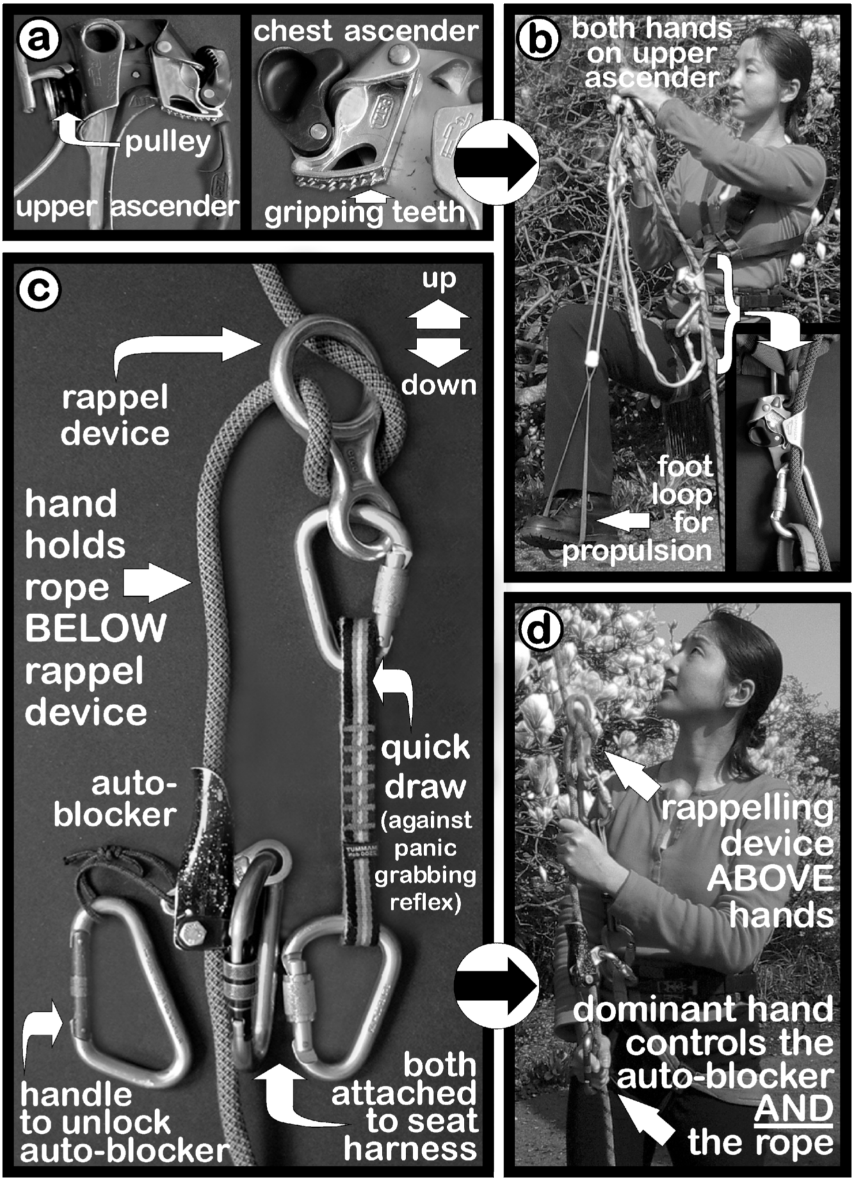
a
pulley
upper ascender
chest ascender
gripping teeth
b
both hands on upper ascender
foot loop for propulsion
c
up
down
rappel device
hand holds rope BELOW rappel device
auto-blocker
quick draw (against panic grabbing reflex)
handle to unlock auto-blocker
both attached to seat harness
d
rappelling device ABOVE hands
dominant hand controls the auto-blocker AND the rope

Fig. 1.

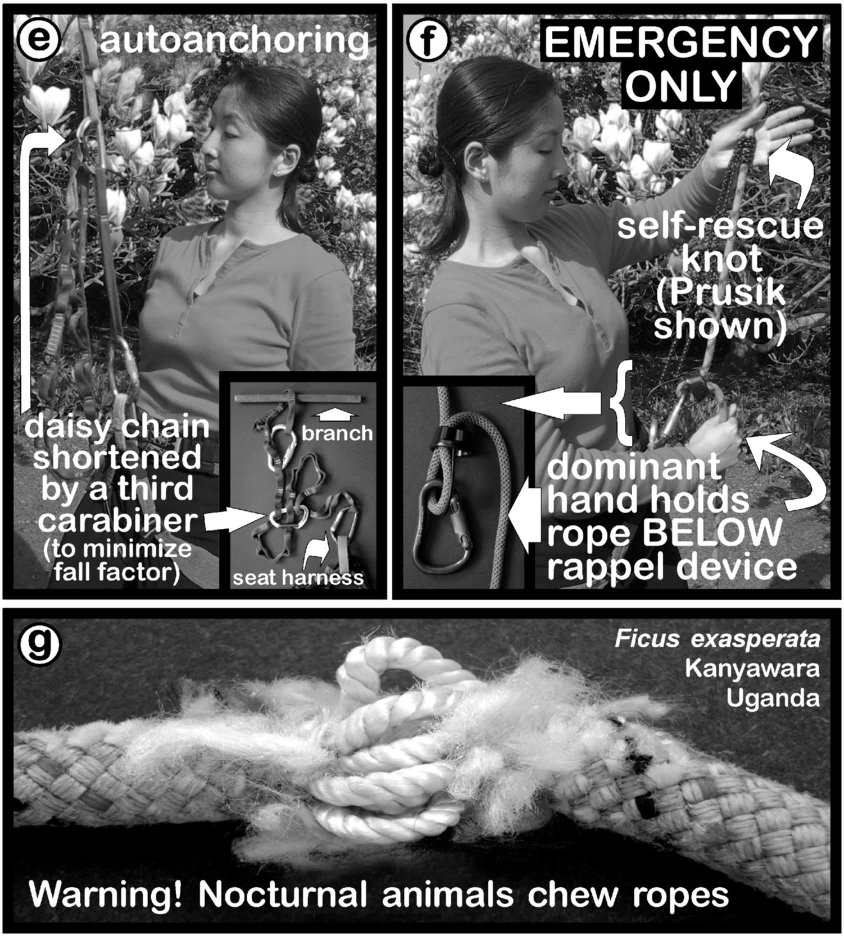

Fig. 1. Continued

the opposite direction. They also have a trigger or a locking mechanism to keep them from accidentally coming off the rope. To climb, one needs 2 mechanical ascenders, one attached to the seat harness (upper ascender) and another one attached to the chest harness (lower ascender). One can move up the climbing rope by 1) suspending oneself on the lower ascender (this ascender is therefore holding the climber's weight), 2) sliding the upper ascender as high on the climbing rope as possible, and 3) moving up with the assistance of the upper ascender. By doing so, the climbing rope slides freely through the lower ascender. One thereafter just has to suspend oneself on the lower ascender and repeat the sequence again. The upper ascender is tied to a loop into which one foot is inserted, and one leg is used to provide the elevation. An upper ascender incorporating 2 pulleys greatly reduces the strength needed to move up, a must for primate ecologists who plan to access the canopy on a regular basis.

Before ascending, it is important to double-check whether all gear works correctly and has been properly set, and that all safety protocols have been followed. One way to remember is to use acronyms. Many have been invented; we propose the following one: "B.A.R.K.E." (modified from Luebben, 1993). Consider a belay, defined as the safety system to which the climber is attached, as opposed to an anchor which is a support over which the climbing rope is free to run, like a branch or a carabiner. B.A.R.K.E. stands for Belay/Buckle, Anchor, Rappel, Knot and Emergency. Before leaving the ground, one must verify whether the Belay is solid, the seat harness Buckle has been locked, the Anchor is solid, all necessary gear to Rappel is attached to the seat harness, and the belay has been locked with an appropriate Knot. Finally, one must be prepared for any Emergency. For example, one might want to bring additional gear, including a small knife, extra material to climb down (like an ATC: Figure 1f), and extra runners and carabiners. A safe climber double-checks the B.A.R.K.E. system before leaving the ground. People should be informed where the ascents will be attempted and when the climber expects to return. Finally, it is imperative to master at least one self-rescue knot, e.g., the Prusik knot.

The fourth step, once positioned correctly in the tree, is to prepare for an immediate descent, should an emergency arise. Possible emergencies include sudden sickness, storms or the possibility of being attacked by potentially dangerous animals, including primates. Emergencies occur rarely but primate ecologists must be ready to face them.

The fifth step is obviously to collect data. The final step is to descend the tree via rappelling. If one plans to be back in the same tree at a later time, we recommend the climbing rope be used to install a cheap, ordinary rope in the tree which will serve to re-install the climbing rope. One should never leave the climbing rope overnight since nocturnal animals may chew them (Figure 1g).

Sometimes it is necessary to remove the upper ascender from the rope and place it above a branch because the rope cannot be distanced from the branch while weighted from below. Before removing the upper ascender, it is critical to tie in short, i.e., to use the loose climbing rope just below the lower ascender to tie a figure-8 loop, and clip that loop into the harness with a locking carabiner. This prevents a fall should the lower ascender break while transferring the upper ascender. As an additional precaution, one may want to carry a spare Prusik sling just in case an ascender fails.

The advantages of the Single Rope Technique include that: 1) it provides access to practically all trees; 2) trees can be accessed rapidly and as needed; 3) it is relatively safe when used properly; 4) it does not damage the tree; 5) trees can be descended rapidly in case of an emergency; and 6) gear is reliable having been individually tested for strength and quality under conditions established by the Union Internationale des Associations d'Alpinisme, hereafter UIAA. Inconveniences include: 1) moving horizontally is difficult and requires some experience; 2) it is a relatively expensive method; 3) it can be dangerous during specific maneuvers, especially just before the descent (e.g., to correctly install the figure-8 descender as shown in Figure 1c is critical, since an incorrect installation can lead to a free fall, or when the climber works above the last anchor) 4) preliminary experience is mandatory; and, 5) the amount of gear needed, hence the total weight that must be carried in the field, can be considerable, so climbers must be in good physical shape.

Climbing Spur Method

This method involves using strong metal boots with sharp gaffs pointing inwards at the instep which support the climber (Mitchell, 1982). A leather belt is attached to a full body harness or a tree saddle, and is passed around the trunk, branches or aerial roots. This belt holds the climber during her or his ascent (Fig. 4 in Mitchell, 1982). The ascent is made by alternatively jabbing the gaffs into each side of the trunk. The adjustable pole strap is used to scale trunks from 10 to 100 cm DBH. Larger trees can be accessed via a belt with steel cable cores, and several belt sizes should be part of the tree climber kit.

The advantages of the Climbing Spur Method include: 1) its low price; and 2) the autonomy it gives the climber, including horizontal movement into the canopy. Inconveniences include: 1) it damages the tree; 2) preliminary experience under supervision is mandatory; and 3) it takes more time to climb up and down than via the Single Rope Technique, though one might compensate by rappelling rather than climbing down with the spurs.

If the same tree must be climbed many times, this method is not recommended as it may have long-term effect on tree survival. To determine how much damage could be done to trees accessed with the climbing spurs, we noted whether spur holes were later infested by insects, losing sap, parasitized by mushrooms, or whether bark formed again and recovered the original hole. For the 26 species of trees monitored, 20 exhibited no sign of insect or mushroom invasion and were not bleeding. Since local employment is a critical issue for conservation, we recommend that primate researchers hire local climbers who master the use of spurs to climb trees (contra Moffett and Lowman, 1995) but only on those trees that are known not to be spur-sensitive.

Climbing Fundamentals

The Physics of Falling

How dangerous is tree climbing? For the Single Rope Technique, one way to answer this question is to consider whether the tree climber is located above or below the last anchor. An anchor is a support over which the climbing rope is free to move, like a branch in a tree. The last anchor is the highest point of support over which the rope has been passed. When the climber is located below the last anchor, the risk of falling is practically nil because there is no slack in the rope: the latter is attached on the ground at the belay, goes up until it passes over the branch and comes back down to the climber. However, when the climber moves above the last anchor, the risk of falling is real, because loose rope accumulates between the climber and the last point of support, i.e., the last anchor. In such a case, the length of the fall is twice the distance between the climber and the last anchor, a kind of pendulum effect. Therefore, the risk of collecting data in a tree largely depends on whether the climber must work above or below the last anchor.

In any tree, a risky solution for the climber is obviously to set the last anchor over a branch located in the lowest part of a tree crown, forcing the climber to work above the last anchor, with a constant risk of falling. The safest strategy is to position the climbing rope over the highest solid branch in the tree. Then, the climber can work most of the time below the last anchor, thus minimizing the risk of falling.

Sometimes it is not possible to work below the last anchor because of tree structure, or because the highest part of the canopy must be accessed for scientific purposes, such as collecting food for nutritional analyses. Two strategies for the experienced climber can be used to minimize the risks related to gathering data above the last anchor: autoanchoring and dynamic belaying (Cox and Fulsaas, 2003). Autoanchoring is attaching oneself with a second set of climbing gear once positioned above the last anchor (Figure 1e). A shock-absorbing device like a daisy chain (Figure 1e) is recommended for autoanchoring. The expression dynamic belaying refers to the way the energy is absorbed during a fall. In dynamic belaying, the energy of the fall, instead of being absorbed in a small fraction of a second as during static belaying, is spread out and absorbed during a longer period of time, thus substantially increasing the climber's safety. To understand how the notion of dynamic belaying applies to tree climbing, one can consider the fall factor (Cox and Fulsaas, 2003).

Understanding the fall factor is critical if and only if the climber decides to move higher than the last anchor. It does not apply when the climber stays below that anchor. It is a dimensionless number that varies from 0 to 2, and is defined as the distance of the fall, divided by the length of the rope which absorbs the fall. Thus, a 5-m fall absorbed by 50 m of climbing rope results in a fall factor of 0.1 (5 divided by 50 = 0.1). The same fall factor value is obtained for a fall of 2 m if the rope which absorbs the energy of the fall is 20 m long (2/20 = 0.1). The resultant forces are the same because the energy of the longer fall is absorbed by a proportionally longer rope (Cox and Fulsaas, 2003). A fall factor <0.5 is considered by experienced climbers to be safe, between 0.5 and 1.0 is risky, between 1.0 and 1.5 is dangerous, and between 1.5 and 2.0 is extremely dangerous. Extreme danger includes the real possibility that the weakest link in the safety system might break. Even if it does not, the climber can incur severe injuries, notably to the vertebral column. Paradoxically, a longer fall might be safer than a shorter fall. For instance, a free fall of 20 m absorbed by 50 m of rope in an emergent tree is safer for the climber than a free fall of only 2 m but absorbed by 1 m of rope in a small tree (fall factor of 0.4 versus 2, respectively). Although the fall factor assessments are arbitrary, they offer a rough safety guide. A safe climber not only considers the fall factor theory but also puts it in practice while in the tree.

Figure 2 presents 2 additional scenarios to illustrate the importance of the fall factor concept, except that this time the length of the fall is identical in both conditions. The difference relates to the climber's protection strategy. In condition A (Figure 2), the climber ties no knot with the climbing rope, so the latter can run freely at the last anchor and any backup anchors, then she or he moves above the last anchor. In condition B (Figure 2), the climber ties a solid knot at the last anchor, then she or he moves above it. The objective of this exercise is to calculate which of the 2 scenarios is safer. We set in both cases the distance of the climber above the last anchor to 3 m and the distance between the last anchor and the belay on the ground to 15 m. The fall factor in condition A is only 0.33: length of fall of 6 m divided by 18 m of rope which absorbs the energy of the fall, i.e. 3 m of rope between the climber and the last anchor, plus 15 m of rope between the last anchor and the belay. Condition A is thus a safe practice (fall factor <0.5). However, if the tree climber ties a knot at the last anchor as in condition B then she or he moves 3 m above it, the fall factor reaches the maximum, 2: length of fall of 6 m divided by only 3 m of rope absorbing the fall. Only 3 m of rope can absorb the energy of the fall in condition B because the climber has tied a knot at the last anchor; indeed, the 15 m of rope below the last anchor

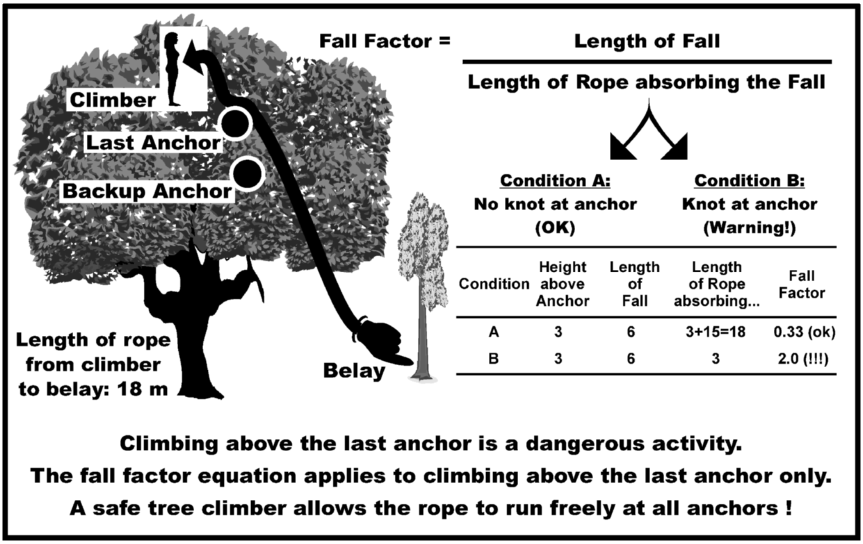

Fig. 2. The theory of the fall factor and two different tree climbing scenarios involving (A) a safe versus (B) an extremely dangerous condition. Note that the fall factor theory applies to ascents when (and only when) the tree climber is located above the last anchor. The black line represents the climbing rope, the arrow: the attachment of the researcher to the rope, the hand: one end of the rope attached to a solid trunk on the ground (the belay), the upper black-and-white circle: the last anchor which would support a fall, and the lower circle: an additional anchor, should the upper one fail because of the shock provided by a fall. The length of rope absorbing the fall is the amount of rope between the climber and the next knot. Assuming the amount of rope between the last anchor and the belay is 15 m in both scenarios, the length of rope that would absorb a fall in Condition A is 18 m (3 m of rope between the researcher and the last anchor, plus 15 m between the last anchor and the belay). However, the climber in Condition B has made a knot with the climbing rope at the last anchor before moving above it, dangerously shortening the amount of rope which could absorb the energy of a fall (3 m).

is useless. Condition B is thus an extremely dangerous practice (fall factor >1.5).

When applied to tree climbing, the dynamic belaying and fall factor concepts urge tree climbers to let the rope running freely over branches or branch junctions, i.e., no knot using the climbing rope should be tied at these points. When the dynamic belaying principle is applied (Figure 2) and complemented with autoanchoring (Figure 1e), climbing above the last anchor is relatively safe though we recommend that apprentice climbers get experience below the last anchor before attempting an ascent above the last anchor.

Appendix II presents the variation of the fall factor in 28 individual trees which were climbed during a 1-yr primate field study in Kibale. It illustrates how the fall factor varies as a function of the climber's height above the last anchor and the amount of rope available to absorb a potential fall. All climbing conditions involved a fall factor lower than <1, and were strictly complemented with autoanchoring. When trees are split as small versus emergent, small trees, with a mean fall factor of 0.48, were marginally more dangerous to climb than emergent trees, with a mean fall factor of 0.35 (Mann-Whitney, $U = 53.0$, $p = 0.08$). This is best explained by the shorter rope available to absorb a fall in small trees.

Another strategy in tree climbing related to dynamic belaying is to increase shock absorption via a dynamic climbing rope versus a static climbing rope. A dynamic rope offers greater elasticity than a static rope. We recommend that inexperienced tree climbers use a dynamic rope.

The Climbing Rope

The rope is may be the most important piece of equipment related to the climber's safety. Modern climbing ropes are composed of a core of braided or parallel nylon filaments encased in a smooth, woven sheath of nylon (Cox and Fulsaas, 2003). Kernmantle ropes are now the only climbing ropes approved by the UIAA. There are two kinds of climbing ropes: dynamic and static. For the same diameter, the dynamic rope offers more elasticity than a static rope and hence can endure higher impacts. Tree climbing rarely involves major falls, but the possibility is real, mostly when the climber moves horizontally in the tree or higher than the last anchor (Figure 2). The protective sheath of a static rope is more abrasion resistant than the sheath of a dynamic rope, and therefore is more appropriate for primate field research. However, a static rope cannot endure severe falls and only experienced tree climbers should consider its purchase. Another factor to consider is the rope diameter. The larger the diameter of a rope, the greater is its energy-absorbing capacity. Descending gear requires a minimum diameter of 10 mm. It is also important to consider whether the rope will be used in a wet environment. Wet ropes become difficult to manage, check fewer falls, and have *ca.* 30% less strength when they are wet (Cox and Fulsaas, 2003). Overall, we recommend that inexperienced tree climbers purchase a dynamic UIAA-approved 11 mm climbing rope, ideally water-repellent. For the advanced climber, a static 10 mm rope coupled with an explosive quickdraw—a kind a shock-absorbing device attached at the belay—is more appropriate: cheaper, long-lasting sheath, less annoying elasticity while ascending, and lighter.

Stepping on a rope is a common form of abusive treatment that grinds cutting particles into and through the sheath (Cox and Fulsaas, 2003). Over time, the particles act like small knives that slice the rope's nylon filaments.

It is hard to decide when to retire a rope. Its condition depends on many factors including frequency of use, the care it has received, its age, and the number of falls it has endured. As a general guideline, a dynamic rope used daily should be retired within a year, while a rope used 2–3 days per week should offer about 2 years of service (Cox and Fulsaas, 2003). A static rope can last twice the time of a dynamic rope. After one very severe fall with fall factor 1.5, any rope should be replaced immediately. The climbing rope is the most important and sensitive equipment, and a safe climber takes great care of it.

Knots

Knots allow the climber to use the rope for many special purposes: to tie into the rope, to temporarily anchor to a branch, to tie 2 ropes together, to use slings to climb the rope itself, and much more. Climbers rely most heavily on 12 different knots (Cox and Fulsaas, 2003; Vines and Hudson, 1992). A tree climber should practice them until tying them is second nature, including in the dark at cold temperatures.

The novice climber should master at least, eyes closed, the following set of tested knots: Figure 8 Follow-through (also called the Flemish Bend), Figure 8 on a Bight, Double or Triple Fisherman's Knot (also called Grapevine), and one self-rescue knot like the Prusik or Bachman or Klemheist Knot. For intermediate and advanced climbers, there are the Butterfly Knot, Equalizing Figure 8, Water Knot (Ring Bend), Girth Hitch, Stopper Knot, Munter Hitch or Clove Hitch, and for rescuing an injured colleague, the Munter Mule.

Contrary to common belief, knots are weaker than the rope used to tie them. Moreover, they do not all offer the same strength. In case of a sudden shock, any chain of safety will break up at the weakest link, most often at the weakest knot. The different types of Figure 8 Knots are known to break at 75–80% of rope strength, the Double Fisherman's Knot at 65–70%, Water Knot at 60–70%, Overhand Knot and Clove Hitch at 60–65%, and the Square Fisherman's Knot at a very poor 45% (Luebben, 1993). An 11-mm climbing rope can support 3,000 kg. In this case, if the weakest link is a Square Fisherman's Knot, then the rope theoretically can break up at 1,300 kg of pressure (45% of 3,000). Regardless of the knot, one should tie it neatly, keeping the separate strands of the knot parallel and free of twists.

Harnesses, Mechanical Ascenders and Other Gear

Figures 1a to 1g present the most important gear necessary to climb trees with the Single Rope Technique. With properly fitted leg loops, the seat harness transfers the force of a fall over the entire pelvis (Cox and Fulsaas, 2003). Hardware loops are desirable to carry descending gear, carabiners, runners of different length, binoculars, field book and other equipment. A chest harness is needed for additional comfort and additional safety. One mechanical ascender—the handle or the Jumar^{TM} (Figures 1a and 1b)—is locked to the seat harness through a runner. A second mechanical ascender—the chest ascender or the Croll^{TM} (Figures 1a to 1b)—is independently locked to the chest harness. Once in the tree crown, the climber uses a daisy chain (Figure 1e) to autoanchor to a branch or a branch junction, independently of the climbing rope. Very short runners or quickdraws like the one on the right of Figure 1g have little value in tree climbing, except for the rappelling system (Fig. 1c and 1d). One should purchase long or very long webbings (120 cm in length), because the climber is often far from suitable branches. Carabiners are another versatile and indispensable tree climbing tool. These ingenious snap-links are used for belaying, rappelling, prusiking, clipping to safety anchors like branches, securing the rope to points of protection, and many other purposes. Carabiners for climbing require a UIAA minimum breaking strength of 2,000 kg along the long axis and 400 kg along the minor axis (Cox and Fulsaas, 2003). One should always make sure the force on a carabiner falls on the long axis and be especially careful that the gate does not receive the load. Locking carabiners with a sleeve that screws over one end of the gate to prevent accidental opening give a wider margin of safety for rappelling, belaying or clipping into anchors. Some locking carabiners are manufactured with a spring that automatically positions the sleeve whenever the gate is closed; it locks automatically. It is recommended to use an automatic double-locking carabiner at the belay, an automatic simple-locking carabiner to autoanchor in the canopy (the upper carabiner in Figure 1e), ordinary locking carabiners everywhere along the chain of safety, and finally non-locking carabiners for non-safety purposes, e.g., to attach one's binoculars. Branches may be slippery during the rainy season, thus we recommend the use of ice crampon shoes. Finally, one should not buy or use used equipment if its history is not known.

Rappelling

Rappelling can be so easy and exhilarating that one can forget what a serious undertaking it is. In fact, experienced climbers consider rappelling as one of the most dangerous aspects of climbing. However, if safety protocols are carefully followed, one should have no trouble using it.

A rappel system has 4 basic requirements: a rope, an anchor, the climber, and a means to apply friction to the rope. Having attached one end of the climbing rope to a solid trunk and climbed the other end with mechanical ascenders, the climber descends the same end of the rope: single-strand rappelling (Cox and Fulsaas, 2003). Most climbers use a mechanical system as their principal rappelling method, and all operate essentially the same way. The strand of the rope is run through a rappel device attached to the seat harness (Figures 1c and 1d). As the rappel begins and gravity pulls the climber downward, the rope slides through the device. The braking hand controls this natural pull by adjusting the amount of friction on the rope as it runs through the device. For additional safety, we recommend distancing the rappelling device from the seat harness by installing a quick-draw between the two (Figure 1c, center right, the short tri-color runner). This prevents the climber from accidentally grabbing the climbing rope above the rappelling descender—strategy against the panic grabbing reflex—because friction through the device is applied only when the climber controls the rope from below the descender. We also recommend for safety purposes the use of a mechanical auto-blocker like the Shunt™ while rappelling (Figure 1c, lower left). Such a device, which once saved one of us from a 25-m fall, automatically blocks the climber should one's hands be removed from the rope or the rappel device be misused. A mechanical autoblocker is useful to work hands-free in the canopy. An autoblocker knot can replace the mechanical autoblocker, but it is more difficult to manage and less useful for primate field studies. One must be prepared to use another rappel method should any of the rappelling devices be lost, dropped or broken (Cox and Fulsaas, 2003). One way to circumvent the problem is to permanently attach an additional rappel device to the back of the seat harness. One can also make a rappel device through a set of 6 carabiners (Cox and Fulsaas, 2003). Researchers should not overlook our 2 strong recommendations regarding rappelling, i.e. to distance the descender from the seat harness—panic grabbing reflex—and to use a mechanical auto-blocker: automatic backup safety device (Figures 1c and 1d).

DISCUSSION AND SAFETY CONSIDERATIONS

Although it is not a prerequisite to climb trees to study the canopy (Korine *et al.*, 2000), especially when trees are very small (Lynch and Gonzalez, 1993), it has proven to be useful in many fields of ecology (Lowman and Wittman, 1996; Llorente *et al.*, 2003). Accessing the canopy will help to explain aspects of primate ecology, such as food availability, dietary quality, foraging efficiency, patch depletion, nesting behavior, and predator detectability.

To get canopy information relevant for research on moving animals like primates, one must be able to climb trees efficiently and safely, and the tree climbing method itself should offer as much mobility as possible. The Climbing Spur Method and the Single Rope Technique are both efficient, safe when used properly and offer the climber almost complete mobility. We recommend them for primate ecological studies.

Climbing trees raises some ethical issues, one of which is the simultaneous presence of primates and people in the same tree. Sometimes, researchers might need to climb out of the tree before the primates arrive to minimize effects of their presence, especially when species are not habituated to people in the canopy. During our study in Kibale, one of our research objectives was to identify which fruit colors monkeys and chimpanzees selected. Being physically close to primates in the same tree, while they foraged, improved the quality of our observations. We noticed that the closest distance in the canopy between a human being in the same tree as foraging primates varied in Kibale with the species and their habituation to people on the ground. Red colobus accepted a closest distance of 30 m and never entered a tree occupied by a human being. Red colobus were always very nervous and gave numerous alarm calls, though they tended to calm down after 10–15 min. They were aggressive and defiant towards climbers, and caution should be used if they are present. Black-and-white colobus always stayed calm, showed signs of curiosity towards us in the canopy, tolerated a closest distance of 15 m, but never entered a tree occupied by a human being. Grey-cheeked mangabeys (*Lophocebus albigena*), blue guenons (*Cercopithecus mitis*), red-tailed guenons (*C. ascanius*) and chimpanzees (*Pan troglodytes*) all entered a tree when a climber was present. However, mangabeys were very careful to stay away from the climber (closest distance was 12 m), and showed signs of nervousness. Blue and red-tailed guenons and chimpanzee all entered trees occupied by a climber on a regular basis, all stayed calm and came closer to observers: 8 m, 3 m and 0.5 m, respectively. One should never climb a tree already occupied by primates since chances are that the climber will disturb their activity, even for habituated species. Overall, Kibale primates accepted the climber in the same tree crown if they were habituated to humans on the ground.

Safety Considerations

We propose a Tree Climbing Safety Protocol involving the following 20 points:

1) Preliminary climbing experience should include at least 2 courses, one of which should be outdoors, and climbers should get the experience they expect to need before departure to the field, including emergency procedures.
2) Tree climbers should learn about the fall factor theory and be able to put it in to practice while in trees.

3) A minimum number of knots need to be mastered, and their relative strength as well as their usefulness in different contexts, notably during an emergency, should be understood. A tree climber should practice the knots until tying them is second nature, including in the dark on cold rainy days.
4) Static ropes should only used by experienced climbers and should be coupled with an explosive quick-draw, while inexperienced climbers should use dynamic ropes only.
5) All gear must be UIAA approved.
6) The climbing rope should be passed, whenever possible, over 2 solid anchors, one just above the other, and the solidness of trees, branches and branch junctions must be considered in any climbing attempt.
7) The relative height of the last anchor is an important safety issue, since the higher it has been positioned, the lower the chance the researcher will have to climb higher than this position. This is critical because risks of falling mostly occur when the climber moves higher than the last anchor.
8) Mechanical ascenders must be attached independently, one to the seat harness and the other to the chest harness, providing additional safety should one set of links break.
9) Extra gear to climb down should be permanently attached to the back of the seat harness.
10) One might want to use acronyms to remember and double-check which safety precautions must be observed before ascending or descending.
11) The climbing rope must run freely at any anchors, and the climber should not attempt to tie any knots at these points.
12) It is imperative to tie in short while ascending before any ascenders are removed from the climbing rope (to tie in short means to make a knot with an adjacent section of the climbing rope and attach oneself to it).
13) One must autoanchor while in the tree, i.e. to attach independently from the climbing rope, providing a second and independent element of safety (the first is the attachment to the climbing rope via the mechanical ascenders or the rappelling system). Use a shock-absorbing device like a daisy chain when autoanchoring.
14) All gear must be attached while in the tree, obviously not to drop them, but also to avoid hurting anyone below the tree.
15) An automatic double-locking carabiner should be used at the belay, and only locking carabiners should be used in the chain of safety.

16) One must be aware of the danger of rappelling and the risks it represents. We recommend distancing the rappelling device like the figure-8 descender from the seat harness by installing a quick-draw between the two, which prevents the climber from accidentally grabbing the climbing rope above the rappelling device (cf. the panic grabbing reflex). We also recommend the use of a mechanical autoblocker which automatically blocks the climber should she or he remove her/his hand from the rope.
17) An extra Prusik sling should be brought in case a mechanical ascender or the mechanical autoblocker fails.
18) Once in the tree, we recommend that climbers prepare themselves for an emergency descent (installation of the rappelling device and the mechanical auto-blocker) before beginning to collect data. When necessary, one should be ready to move down the tree within seconds.
19) Climbing ropes are precious and might represent the most important gear of the primate researcher. Such ropes should never be left in a tree overnight because some nocturnal animals chew them. Stepping on the rope, especially with dirty boots, is a form of abuse and should be avoided.
20) The researcher should be able to assess her or his personal physical and psychological limits related to climbing: complexity of ascents, how fatigue and stress affect personal decisions, etc. Tree climbers might want to be careful about overconfidence, bad judgment, and longterm fatigue.

Climb Smart!™ is a public information program of the Climbing Sports Group, a trade association of the climbing industry specialized in rock and ice climbing. We adjusted their safety recommendations to tree climbing as follows: 1) Check your knots and harnesses buckle. 2) Inspect yourgear and replace it as necessary. 3) Know your partners and their habits, if you are not climbing alone. 4) Check your belay—are you sure you are on? Is the belay reliable? Is it static or dynamic? Is the last anchor located high or low in the tree crown? Are you located below or above the last anchor? If you fall, what will the fall factor be? 5) Read and remember all warnings; they can save your life. 6) Keep an eye on the weather. 7) Branches break and trees fall—check your holds. 8) Always double check your rappel system. 9) Wear a helmet. Finally, the Climb Smart! educational program concludes by saying "Climbing is dangerous, and the best strategy is to stack the odds in your favor. Remember, your safety is your responsibility." We agree with this program. Safety is not an objective, but a strict requirement of canopy research undertaken.

Safety is an important issue during field study and even more when climbing trees is involved (Laman, 1995; Mitchell, 1982; Moffett and Lowman, 1995; Perry, 1978; Whitacre, 1981). No paper, no book can alert people to every hazard, neither can it anticipate the limitations of every person. Therefore, the descriptions of techniques and equipment in this paper are not representations that a particular technique or tool will be safe for everyone. Climbers assume responsibility for their own safety. Understanding current conditions and common sense are the keys to a safe ascent. Andrew Field established a series of walkways in the Venezuelan forest canopy. Tragically in 1984, he fell to his death (Mitchell, 1986). He was an experienced tree climber. Researchers should be aware that their climbing safety depends on their own judgment, which must be based on competent instruction, experience, and a realistic assessment of climbing ability.

ACKNOWLEDGMENTS

We thank the Uganda Wildlife Authority and the Makerere University Biological Field Station for allowing us to work in Kibale National Park. Funding for the research was provided by the Fonds FCAR of Québec (Canada, now NATEQ), Natural Sciences and Engineering Research Council of Canada, the Wildlife Conservation Society, National Science Foundation (grant numbers SBR-9617664, SBR-990899), and the "Groupe de Recherche en Écologie Forestière interuniversitaire" of the Université du Québec à Montréal. A very special thank to Raymond Ross for his generosity to visit the canopy in Kibale, to share his 25 years of expertise in mountaineering, to review the manuscript, to double-check the fall factor calculations, and to support the Tree Climbing Safety Protocol. We also express our gratitude to Marina Llorente, Miki Matsubara, Moses Musana and Denis Sebugwawo for their assistance in the field, Richard Wrangham and two anonymous reviewers for their constructive comments on the paper, and Moses Musana, Louise Ross, and Paule Tremblay for sharing their experience at climbing.

REFERENCES

Aquino, R., and Encarnacion, F. (1986). Characteristics and use of sleeping sites in *Aotus* (Cebidae: Primates) in the Amazon lowlands of Peru. *Am. J. Primatol.* 11: 319–332.

Baldwin, P. J., Pi, J. S., McGrew, W. C., and Tutin C. E. G. (1981). Comparisons of nests made by different populations of chimpanzees (*Pan troglodytes*). *Primates* 22: 474–486.

Brown, J. S. (1989). Desert rodent community structure: A test of four mechanisms of coexistence. *Ecol. Monogr.* 59: 1–20.

Chapman, C. A., and Chapman, L. J. (2002). Foraging challenges of red colobus monkeys: Influence of nutrients and secondary compounds. *Comp. Biochem. Physiol. A.* 133: 861–875.

Cox, S. M., and Fulsaas, K. (2003). *Mountaineering: The Freedom of the Hills*, 7th Edn. The Mountaineers, Seattle.
Di Bitetti, M. S., Luengos, Vidal E. M., Baldovino M. C., and Benesovsky V. (2000). Sleeping site preferences in tufted capuchin monkeys (*Cebus apella nigritus*). *Am. J. Primatol.* 50: 257–274.
Dominy, N. J., and Lucas, P. W. (2001). Ecological importance of trichromatic vision to primates. *Nature* 410: 363–366.
Fruth, B., and Hohmann, G. (1993). Ecological and behavioral aspects of nest building in wild bonobos (*Pan paniscus*). *Ethology* 94: 113–126.
Hallé, F., Cleyet-Marrel, D., and Ebersolt, G. (2000). *Le Radeau des Cimes: L'exploration des canopées forestières*, JC Lattès, Paris.
Heymann, E. W. (1995). Sleeping habits of tamarins, *Saguinus mystax* and *Saguinus fuscicollis* (Mammalia; Primates; Callitrichidae), in north-eastern Peru. *J. Zool.* 237: 211–226.
Korine, C, Kalko, E. K. V., and Herre E. A. (2000). Fruit characteristics and factors affecting fruit removal in a Panamanian community of strangler figs. *Oecologia* 123: 560–568.
Laman, T. G. (1995). Safety recommendations for climbing rain forest trees with "single rope technique." *Biotropica* 27: 406–409.
Llorente M., Sabater, Pi J., and Houle, A. (2003). Possible association between *Galago thomasi* and *Pan troglodytes schweinfurthii* in the Kibale National Park, Uganda. *Folia Primatol.* 74: 80–84.
Lowman, M. D., and Wittman, P. K. (1996). Forest canopies: Methods, hypotheses, and future directions. *Ann. Rev. Ecol. Syst.* 27: 55–81.
Luebben, C. (1993). *Knots for Climbers*, Chockstone Press, Evergreen, Co.
Lynch, J., and Gonzalez, A. (1993). Canopy nutrient allocation in relation to incident light in the tropical fruit tree *Borojoa patinoi* (Cuatr.). *J. Am. Soc. Hort. Sci.* 118: 777–785.
McKey, D. B., Gartlan, J. S., Waterman, P. G., and Choo, G. M. (1981). Food selection by black colobus monkeys (*Colobus satanas*) in relation to plant chemistry. *Biol. J. Linn. Soc.* 16: 115–146.
Mitchell, A. W. (1982). *Reaching the Rain Forest Roof. A Handbook on Techniques of Access and Study in the Canopy*, Leeds Lit. & Phil. Soc./UNEP, Leeds.
Mitchell, A. W. (1986). *The Enchanted Canopy: Secrets From the Rainforest Roof*, Fontana/Collins, Glasgow.
Moffett, M. W. (2001). The nature and limits of canopy biology. *Selbyana* 22: 155–179.
Moffett, M. W., and Lowman, M. D. (1995). Canopy access techniques. In Lowman, M. D., and Nadkarni, N. M. (eds.), *Forest Canopies*, Academic Press, San Diego, pp. 3–26.
Nadkarni, N. (1988). Use of a portable platform for observations of tropical forest canopy animals. *Biotropica* 20: 350–351.
Perry, D. R. (1978). A method of access into the crowns of emergent and canopy trees. *Biotropica* 10: 155–157.
Raven, P. H., Evert, R. F., and Eichhorn, S. E. (1992). *Biology of Plants*, 5th Edn., Worth Publishers, New York.
Sugardjito, J. (1983). Selecting nest-sites of Sumatran orangutans, *Pongo pygmaeus abelii* in the Gunung Leuser National Park, Indonesia. *Primates* 24: 467–474.
Taiz, L., and Zeiger, E. (1998). *Plant Physiology*, 2nd Edn., Sinauer Associates, Sunderland, MA.
van Schaik, C. P., van Noordwijk, M. A., de Boer, R. J., and den Tonkelaar, I. (1983). The effect of group size on time budgets and social behaviour in wild long-tailed macaques (*Macaca fascicularis*). *Behav. Ecol. Sociobiol.* 13: 173–181.
Vines, T., and Hudson, S. (1992). *High Angle Rescue Techniques: A Student Guide for Rope rescue Classes*, 2nd Edn., The National Association for Search and Rescue, Mosby, St Louis.
Whitacre, D. F. (1981). Additional techniques and safety hints for climbing tall trees, and some equipment and information sources. *Biotropica* 13: 286–291.
Wilson, E. O. (1991). Rain forest canopy: The high frontier. *Nat. Geogr.* December: 78–107.

Appendix I. Gear for the Single Rope tree climbing technique

STRICT MINIMUM
Static 10 mm (for experienced climbers) or dynamic 11 mm (for inexperienced climbers) climbing rope, *ca.* 70 m long. The protecting sheath of dynamic ropes is rubbed rapidly in the forest. A static rope must be used alongside a shock absorbing runner, like an explosive quick-draw.
Seat harness and chest harness. Both must be comfortable.
2 double autolocking carabiners, one of which should be used to lock the climbing rope at the base of a trunk, i.e. at the belay. By autolocking in two different ways, it increases the chance that the carabiner will not open accidentally.
11 locking carabiners (multi-purpose uses) + 1 screw link (to attach the lower mechanical ascender to the chest harness, Fig. 1b).
8 nonlocking carabiners (multipurpose uses).
Mechanical autoblocker (safety mechanical device used during rappelling and other purposes; Shunt™ or equivalent; Fig. 1c and 1d). Mandatory.
Figure-8 descender (Fig. 1c and 1d).
Static quick draw ~50 cm long (between the Figure-8 descender and the seat harness; see Fig. 1c and 1d). Mandatory.
4 webbings ~120 cm long (belay around tree trunk, secondary belays around main and smaller branches).
2 daisy chains (safety webbing adjustable to a large set of branch size). A must in tree climbing. The two chains are attached to one another. Each is 1.3 m long, total length: 2.5 m long. Safe clicking available each 8 cm (Fig. 1e).
Hand mechanical ascender with two pulleys (the pulley system allows the climber to save energy; a must for primate ecological studies). Jumar™ or equivalent.
Chest mechanical ascender (suspender, second ascender). Part of the ascending system, attached to the chest harness (Fig. 1a and 1d). Croll™ or equivalent.
UIAA tested 6 mm rope for self-rescue knot *ca.* 1 m long. Mandatory.
High-quality 3-5 mm rope (used after the fishing line to install the climbing rope in the tree). Recommended length: 150 m.
Low-quality nylon rope (bought from local market). For a sample size of 30 individual trees with a mean climbing height of 25 m, one needs 1500 m of rope. The ropes are left in trees overnight and used later to reinstall the climbing rope (read warning in Fig. 1g).
Slingshot (to send the fishing line in the tree (max. 15 m of power). Bow and crossbow are more expensive but more powerful and more precise; strongly recommended if budget allows.
1 fishing reel with cover (to be attached ahead of the slingshot).
10 rolls of fishing line (7 to 9 kg of strength).
50 fishing sinks (size ¾ to 1).

Appendix II. Variation in the fall factor of 28 individual trees climbed during a 1-yr primate field study. Trees divided as main canopy tree (m) versus emergent tree (e) to compare which of the 2 categories presents a higher climbing risk. Height and length in m

Tree species	Climber's height above last anchor	Length of potential fall	Length of rope which would have absorbed the fall	Fall factor
Celtis durandii (m)	10	20	22	0.91
Celtis durandii (m)	5	10	19	0.53
Diospyros abyssinica (m)	5	10	24	0.42
Diospyros abyssinica (m)	6	12	21	0.57
Diospyros abyssinica (m)	4	8	25	0.32
Diospyros abyssinica (m)	7	14	26	0.54
Diospyros abyssinica (m)	7	14	25	0.56
Diospyros abyssinica (m)	6	12	26	0.46
Fagaropsis angolensis (e)	6	12	30	0.40
Fagaropsis angolensis (e)	9	18	25	0.72
Ficus brachylepis (e)	2	4	26	0.15
Ficus exasperata (e)	4	8	28	0.29
Ficus exasperata (e)	4.5	9	31	0.29
Ficus exasperata (e)	6	12	35	0.34
Ficus exasperata (e)	6	12	25	0.48
Ficus exasperata (e)	4.5	9	34	0.26
Ficus exasperata (e)	2.5	5	26	0.19
Ficus exasperata (e)	11.5	23	32	0.72
Ficus exasperata (e)	7	14	29	0.48
Ficus exasperata (e)	4.5	9	31	0.29
Ficus exasperata (e)	5	10	30	0.33
Ficus exasperata (e)	4	8	30	0.27
Ficus exasperata (e)	6	12	30	0.40
Ficus natalensis (e)	6	12	29	0.41
Ficus natalensis (e)	3	6	24	0.25
Monodora myristica (m)	4	8	30	0.27
Strychnos mitis (e)	1	2	21.5	0.09
Uvariopsis congensis (m)	1.5	3	16	0.19
Mean	5.3	10.6	26.8	0.40

Note. Fall factors calculated as length of potential fall divided by length of rope which would have absorbed the fall (Fig. 2). No knot has been tied at the last anchor (equivalent of Figure 2, condition A). Climber's height above last anchor was measured with a 50-m tape. The use of a second independent safety device (like a daisy chain, Fig. 1e and text) has not been considered in calculations because there is the real possibility for a climber to fall before the additional safety device could be properly installed. All trees located in Kanyawara (Kibale N.P., Uganda), UTM: N36, 2 km of radius from 0.56567 North 30.35684 East.