6-2020

Can Increased Training and Awareness Take Forest Research to New Heights?

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Publication Information
Anderson, David L.; Schulwitz, Sarah; May, Matthew; Hill, Gregory; Koomjian, Will; and McClure, Christopher J.W. (2020). "Can Increased Training and Awareness Take Forest Research to New Heights?". *Trees, Forests and People, 1*, 100005. https://doi.org/10.1016/j.tfp.2020.100005

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Trees, Forests and People 1 (2020) 100005

Contents lists available at ScienceDirect

Trees, Forests and People

journal homepage: www.elsevier.com/locate/tfp

Can increased training and awareness take forest research to new heights?

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ARTICLE INFO

Keywords:
Canopy access
Ecological knowledge
Dunning-Kruger effect
Forest canopies
Safety
Web-based survey

ABSTRACT

Forest canopies contribute significantly to global forest biodiversity and ecosystem functioning, yet are declining and understudied. One reason for a knowledge gap is that accessing forest canopies can be difficult and dangerous. Thus, lack of relevant canopy access skills may compromise knowledge gain and personal safety. We assessed skill levels in canopy access methods and self-perception of skills amongst ecologists worldwide via a web-based survey, available in four languages. We obtained responses from expert arborists as a control group. From 191 respondents who said canopy access is relevant to their research (of 1,070 total responses), we found that ecologists are not attaining the full potential provided by existing methods of canopy access. Specifically, most respondents are unable to access much of the forest canopy, especially areas away from the trunk and between trees. The survey further revealed the common use of unsafe and inefficient practices among ecologists and that few are adequately equipped with aerial rescue skills. Importantly, ecologists with the lowest skill levels overestimate their expertise the most. Proper field techniques are key components of good science: they can improve study design, increase potential for data collection, and ultimately reveal greater knowledge on canopy organisms and processes. By safely allowing greater access to the forest canopy, proper techniques can reduce bias in our scientific understanding of forest ecology. To facilitate safe and effective canopy access for ecological research, we recommend increasing instruction and collaboration, implementing certification programs, and conducting audits of canopy research programs. With increased access to such opportunities, ecologists will acquire improved skills in accessing forest canopies, develop a greater appreciation for the full breadth of possibilities among methods of canopy access, and more safely and effectively gather the data needed to better understand forest ecosystems.

1. Introduction

Forest canopies are a major source of regional and global biodiversity, supporting as much as 40% of extant species (Ozanne et al. 2003). They contribute significantly to ecosystem function through processes such as photosynthesis, nutrient capture, soil production, and water interception and retention upon which surrounding ecosystems and human communities depend (Ishii et al. 2004, Sillett and Van Pelt 2007, Gotsch et al. 2016). Despite globally recognized importance, difficulty of access has resulted in a reduced understanding of forest canopies compared to lower forest strata, such that many important knowledge gaps remain (Nakamura et al. 2017). Tall heights and complex structure that characterize many forests (Sillett et al. 2015, Kramer et al. 2018) prevent visibility or contact with higher forest strata, complicating the study of canopy diversity or processes from the ground. Therefore, understanding much of the biodiversity and natural history on Earth depends directly on methods for accessing forest canopies.

Several methods facilitate physical access into forest canopies, including cranes (Nakamura et al. 2017), arboreal walkways (Lowman and Bouricius 1995), balloons and rafts (Mitchell et al. 2002), and ropes (Dial and Tobin 1994, Coffey and Andersen 2012). Importantly, access using ropes and specialized equipment (Jepson 2000; henceforth “rope-based access”) is the only method that is easily transported and relatively affordable (Anderson et al. 2015). Further, rope-based methods can provide access to all parts of the forest canopy, including branch tips, rotten snags, and open spaces between trees (Dial et al. 2004, Sillett and Van Pelt 2007, Kramer et al. 2018). For these reasons, rope-based methods offer almost unlimited potential for unbiased, replicable sampling of canopy spaces, organisms, and processes – an exciting promise.

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https://doi.org/10.1016/j.tfp.2020.100005
Received 26 March 2020; Received in revised form 29 May 2020; Accepted 1 June 2020
Available online 5 June 2020

An essential question is whether scientists are equipped with skills for complete and safe canopy access. Previous research revealed the frequent use and teaching of unsafe climbing practices by scientists (Anderson et al. 2015). Unfortunately, erroneous statements in the literature have also suggested that rope methods do not allow access to the entire canopy (e.g., Basset et al. 2003, Nakamura et al. 2017). These misunderstandings indicate that the use and potential of rope-based methods merit greater appreciation.

The use of unsafe methods and the misunderstanding of the range and scope of movements afforded by rope-based methods begs an interesting question: does misperception obstruct the use of good climbing practices in science? The misperception about one's abilities or thought processes, known as a metacognitive bias, was popularized as the Dunning-Kruger Effect (Kruger and Dunning 1999). Kruger and Dunning observed how the absence of skills that engender competence also deprives the subject of the knowledge necessary to evaluate competence, leading to an overestimation of expertise when skills are low. We speculate that the Dunning-Kruger effect may affect the self-perception of climbing expertise among scientists. If so, it could explain the promotion of unsafe methods and be an important barrier to adopting better practices. Importantly, revealing the existence of such biases would open opportunities to directly address such challenges. Doing so could simultaneously make research safer and provide opportunities for ecologists to literally reach new heights in forest canopies and explore expanded research agendas.

Our objective was two-fold. First, we aimed to assess the expertise level with rope-based methods held by the scientific community at large. Second, we sought to assess the perception that climbing scientists held of their climbing expertise. To meet these dual objectives, we queried ecologists directly by performing a web-based survey distributed globally in four languages. This study has the potential to reveal important barriers to conducting science, and highlight the need for potentially life-saving and research-enriching opportunities for the tree climbing research community.

2. Methods

2.1. Target audience, survey design, and dissemination

We designed a web-based survey in the platform Qualtrix. Due to recent changes in European law, we were unable to obtain email lists of ecologists or distribute the survey directly to participants via email. We therefore distributed it via listservs, newsletters, and social media groups managed by professional societies and frequented by ecologists. The survey was available in English, Spanish, French, and Portuguese. Additionally, we obtained a control sample by sharing the survey with a preselected group of arborists from the USA and Canada known for their expertise in climbing the tallest and most difficult trees. We included responses from this small group of specialists to characterize the full range of skills needed for total canopy access.

To avoid drop-out fatigue, the survey was designed to require ≤15 minutes for completion (Fowler 2014). Question sequence followed a skip-logic branching design allowing respondents to only see and answer questions pertinent to questions answered previously—i.e., a certain response to one question would deliver the next relevant question, or skip irrelevant questions. The survey was available from 30 October to 26 November 2018.

To restrict survey responses to scientists whose research programs require climbing trees, our target audience, the survey began with a filter question: "How relevant is tree climbing to your research?" Participants who indicated tree climbing was not relevant to their research were excluded from the full survey. To assess participant self-perception of climbing expertise, the second question asked participants to rank their skill-level in tree climbing on a scale of 1 – 10 using a sliding tool. The self-perception question was presented before the full survey so that viewing the survey would not affect the respondent's self-perceived climbing expertise.

We assessed climbing expertise across five skill sets selected *a priori* to distinguish novice from advanced climbers. We defined advanced skills as those required for total and safe canopy access—all points within and between tree crowns, regardless of tree height or crown complexity. The five skill sets were: (1) climbing tall trees, which requires greater technical expertise with increasing height due to increasing complexity of branching structure in taller trees (one question); (2) installing climbing lines, which reveals expertise to place ropes or other lines from the ground (six questions); (3) methods and equipment options, which assessed respondents' knowledge of advanced climbing systems that improve efficiency, facilitate movement in tree crowns, and improve safety (two questions); (4) lateral movement, which describes the ability to move horizontally within the canopy, techniques necessary for accessing branch tips and open spaces between trees (five questions); and (5) aerial rescue, which assessed the experience and practice necessary to rescue a stranded climber (one question). We emphasize that skill categories were intended to be complimentary rather than exclusive. For example, climbing tall trees and installing climbing lines require some similar skills. Therefore, no one skill category is indicative of high or low expertise. The full survey is available as Supplemental Appendix A1.

2.2. Analysis

We used individual rubrics to award points for each question as a basis for quantifying respondent expertise. Because questions and rubrics varied in complexity, we standardized responses on a 10-point scale to weight questions evenly. We calculated participant scores for each of the five skill sets to represent respondent expertise in a given skill. We then calculated a composite score describing a person's overall climbing expertise across all skill sets. Using Kruskal-Wallis tests, we examined whether arborists scored significantly higher than ecologists across skill-sets.

We followed Kruger and Dunning (1999) in comparing perceived expertise across quartiles of actual scores. We first built a linear model regressing differences between perceived and actual percentiles against actual score quartiles. A significantly negative slope would suggest that as expertise declined, the tendency to overestimate expertise increased. We further tested for differences between actual and perceived skills within the first and fourth quartiles of the actual scores using paired t-tests.

3. Results

Of 1,070 people who initiated the survey, 879 (82%) indicated tree climbing was not relevant to their research, 123 (12%) indicated it was somewhat relevant to their research, and 68 (6.4%) indicated tree climbing was highly relevant. After eliminating respondents for whom tree climbing was not at all relevant, the remaining pool of participants considered for statistical analysis was 191, although this number varied slightly per question because skip-logic precluded some respondents from answering certain questions. Ninety-four percent of respondents took the survey in English, followed by Spanish (5%), French (1%), and Portuguese (1%). Six of 20 invited arborists participated as a control group.

3.1. Tree climbing expertise of ecologists is low

Ecologists scored significantly lower than the control group on a 10-point scale in all five skill sets: (Fig. 1). Scientist median scores were below 2.5 for all skill sets, whereas arborist's median scores ranged from 5.0 to 9.0 per skill set. The median composite score derived across all skill sets, intended to represent overall canopy

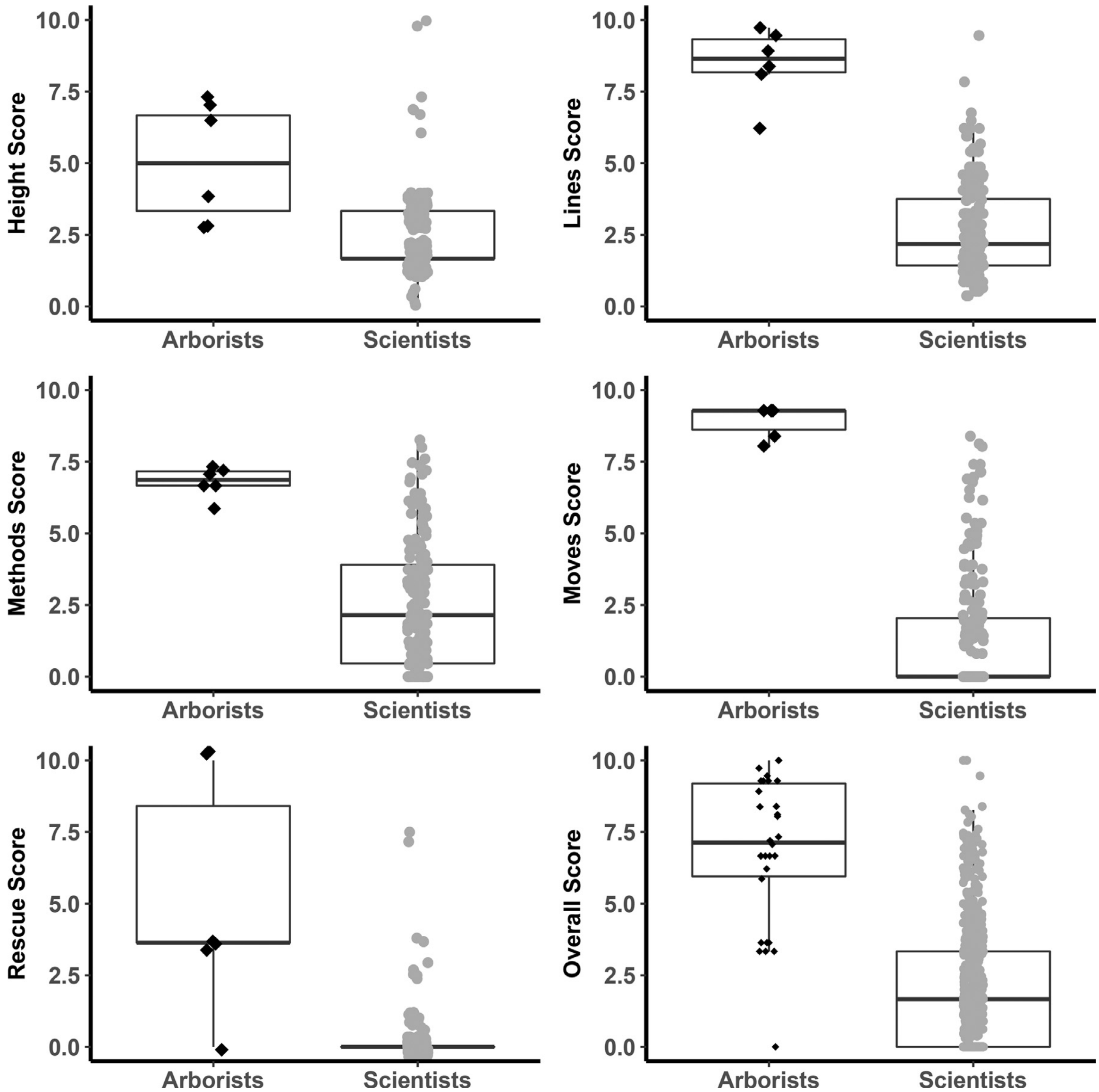

Fig. 1. Scientists scored lower than arborists in six skill areas that comprise canopy access expertise: climbing tall trees, installing climbing lines, knowledge of methods and equipment options, lateral movement in the canopy, and aerial rescue. See Methods for more detailed descriptions of skill sets. As a result, overall expertise in canopy access was significantly and dramatically lower for scientists than arborists (bottom right).

access expertise, was below 2.5 of 10 for ecologists and above 7.5 for arborists. Only 12 ecologists (6.3%) achieved scores > 5, and only two ecologists achieved scores comparable to those of arborists (Fig. 1), in contrast to 68 indicating that tree climbing was highly relevant to their research.

Experience accessing the canopy decreased with distance from the trunk (Fig. 2). Fifty-one percent of ecologists reported no experience accessing outer branches (Zone 3 in Fig. 2). Further, 79% of ecologists reported no experience accessing branch tips and the open space between trees (Zone 4 in Fig. 2, only reached via aerial traverse). By comparison, 100% of arborists reported experience accessing all parts of the canopy alone (i.e., unaided by another climber).

3.2. Unsafe climbing practices and overconfidence

Ecologists reported a number of unsafe practices. Thirty percent reported free climbing in the canopy without a rope or other safety backup (20 of 66 respondents who answered Question 14; Supplement A1). Twenty-three percent (15 of 66 respondents who answered Question 14; Supplement A1) reported using handheld ascenders for self-belay (i.e, to provide life support during lateral movements, and to control falls in the canopy). Use of climbing spikes to access areas away from the trunk was reported by 18% of respondents (11 of 63 respondents who answered Question 17; Supplement A1). Finally, two-thirds of ecologists reported having no training in aerial rescue techniques (45 of 68 [66%] respondents who answered Question 18; Supplement A1).

Differences between self-perception and actual scores provide a clear example of the Dunning-Kruger Effect (Fig. 3). Individuals with the lowest composite scores overestimated their expertise most, with individuals in the lowest quartiles of scores overestimating their percentile by 23, on average (Fig. 3; $t = 5.41$, $df = 48$, $p < 0.001$). Conversely, individuals in the highest quartile of scores underestimated their percentiles by 18 (Fig. 3; $t = 5.24$, $df = 43$, $p < 0.001$). Thus, the difference between perceived and true expertise of ecologists decreased with the quartile

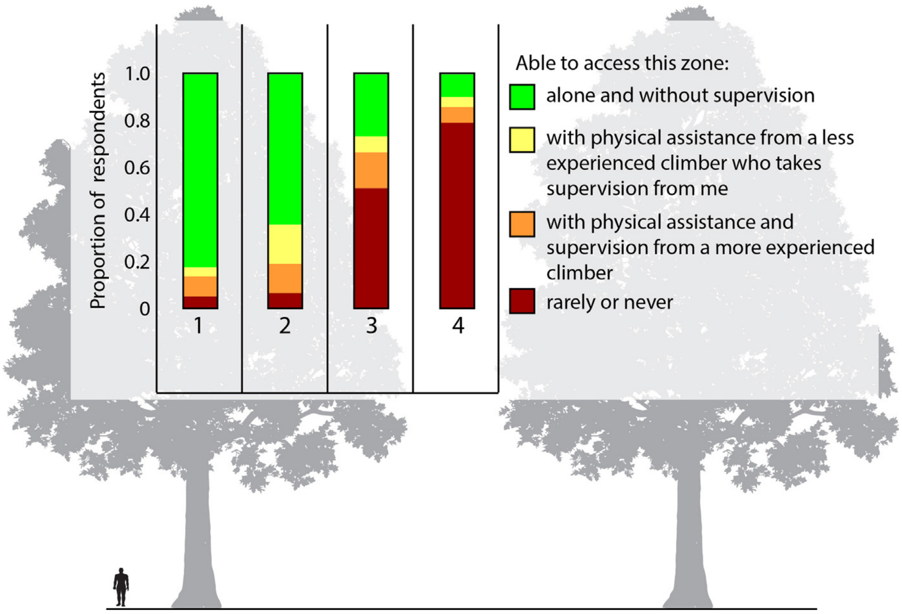

Fig. 2. Responses to the question: "Describe your experience accessing each numbered zone of the illustration below." Vertical boxes represent four zones of a tree crown with increasing difficulty of access: Zone 1 = adjacent to the stem; Zone 2 = mid-branch; Zone 3 = outer branches and branch tips; Zone 4 = open spaces between trees. Color shading depicts proportions of responses by 191 ecologists. Whereas 100% of arborists reported being able to access all canopy zones alone and without supervision, there was an inverse relationship between distance from the tree stem and ecologists' reported experience to access canopy zones.

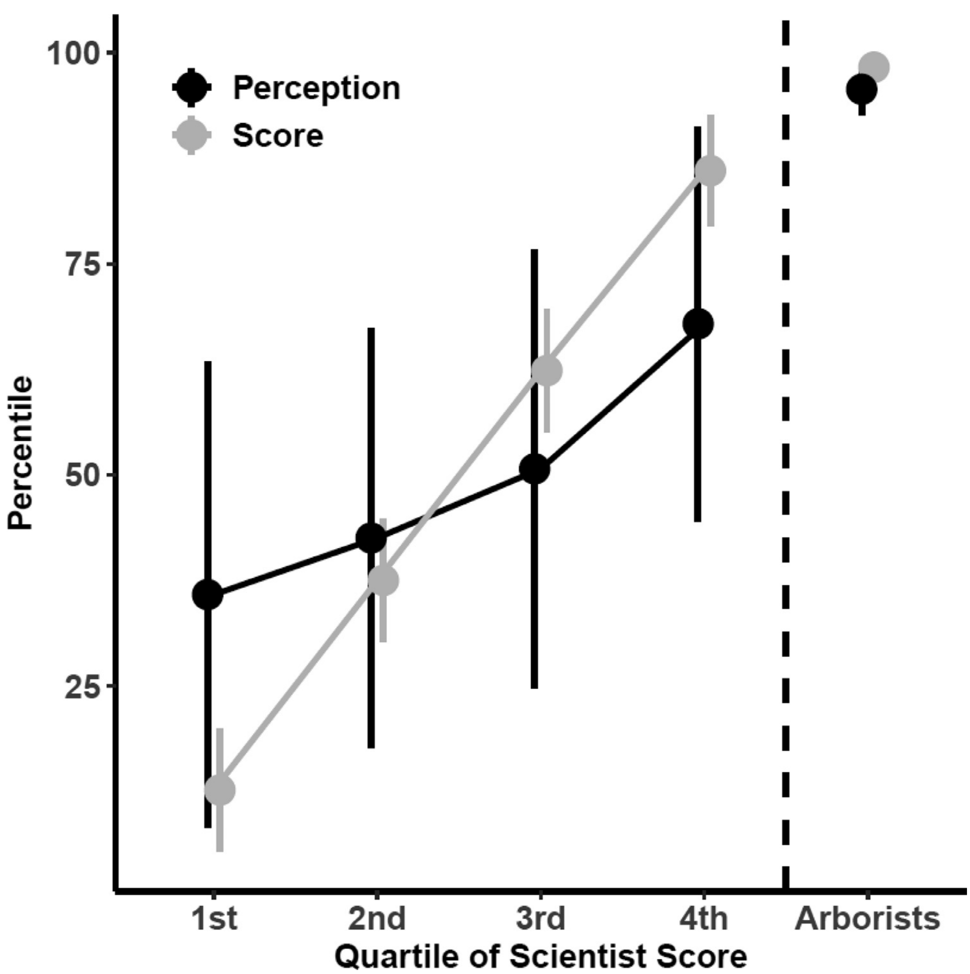

Fig. 3. Comparison of self-perceived canopy access expertise (black points and lines), and level of expertise demonstrated via survey (gray points and lines), for 191 ecologists who climb for research and six arborists recognized by their peers for possessing expert canopy access skills (right). The significant difference in the first quartile between perceived and demonstrated expertise is characteristic of the Dunning-Kruger effect.

Fig. 4. Rope-based methods offer almost limitless potential for gaining ecological knowledge in forest canopies. Pictured clockwise: A) Sap flow is measured in situ with external sensors to understand epiphyte resiliency to drought, Monteverde Cloud Forest Reserve, Costa Rica. Photo credit Sybil Gotch, Franklin and Marshall College. B) Access to vertebrate breeding habitat, here the nest of the Endangered Black-and-chestnut Hawk-Eagle, Colombia. Photo credit Gonzalo Ignazi, International Black-and-chestnut Hawk-Eagle Project. C) Passive recording devices are deployed in Pacific equatorial forests, Jama Coaque Reserve, Ecuador, to collect data on vertebrate presence used to inform corridor placement between protected areas. Photo credit Shawn McCracken, Third Millennium Alliance. D) Malaise trap adapted for deployment at canopy level for research on insect pollinators in rustic coffee plantations, Universidad Científica del Sur, Peru. Photo credit Erick Reátegui.

of their actual abilities (Fig. 3; slope = -0.14, SE = 0.02, $p < 0.001$, $R^2 = 0.26$). Arborist scores were only 2.6 percentiles higher than their perceived expertise (Fig. 3).

4. Discussion

4.1. Climbing expertise and forest research

Our results reveal a high self-perception of canopy access skills despite low levels of demonstrated expertise across skill sets that comprise climbing competency. We acknowledge that a small number of ecologists are highly accomplished tree climbers, but argue that the overall low level of climbing expertise possessed by ecologists working in forest canopies or accessing trees is a barrier to building knowledge on ecological processes and organismal biology occurring high in forests.

Several unsafe methods and the misuse of climbing equipment observed in this study warrant clarification to improve personnel safety. One-third of respondents reported free climbing in the canopy. Climber falls are the leading cause of fatality among tree care workers, and disconnecting from the climb line or tree is a major source of falls (Ball et al. 2020). Industry standards require climbers to stay connected at all times (American National Standards Institute 2017). A quarter of respondents described using hand-held ascenders for lateral movement or to control falls while climbing. Mechanical ascenders with toothed cams are not compatible with or approved for primary life support on ropes or for fall protection (Kane 2011, American National Standards Institute 2017). One-fifth of respondents reported using climbing spikes for lateral movement. Using climbing gaffs or spikes for lateral movements increases the risk of personal injury (gaffing oneself in the leg, or leading to a dynamic fall in the canopy) and is the least efficient method for lateral movements (i.e., requires more time and strength than moving on ropes). Finally, two-thirds of respondents have not received training in aerial rescue methods, an essential skill for assuring the safety of field personnel working in the canopy. Taken together, these practices increase risk of severe injury or death, while decreasing climbing efficiency and research output.

Importantly, poor climbing skill paired with a misunderstanding about the potential or limits of climbing methods likely impact forest research during planning, data collection, and publication phases of scientific research. During the study design phase, misconceptions about access may limit the scope of research questions if some parts of the canopy are deemed inaccessible. In the field, the challenge of accessing all parts of a tree crown can affect the selection of study specimens or distribution of treatments by eliminating samples from areas beyond the skill level of the researcher. Haphazard or uneven selection of study specimens leads to overestimation of effect sizes (Zvereva and Koslov 2019) and false inference (Pannucci and Wilkins 2010). In forest canopies, known for strong microclimatic gradients (Madigosky 2004), it is conceivable that uneven sampling can lead to systematic errors (Huston 1997).

We cannot overemphasize the almost unlimited potential that modern canopy access methods have for gaining ecological knowledge in trees and forests (Fig. 4). Climbing trees with ropes grants full access to the complete spectrum of above-ground habitats and organisms. Because rope-based methods are relatively affordable and highly portable, they can be used in forests anywhere, regardless of preexisting infrastructure (e.g., cranes, walkways, or roads), allowing flexibility in study design and increased sample sizes while reducing pseudoreplication. The caveat is getting there.

Forest canopies contribute significantly to forest biodiversity and function, and play important roles benefitting human communities, such as the interception, retention, and surface release of atmospheric water. Large, old trees are amongst the most challenging to access, yet are in decline worldwide (Lindenmayer et al. 2012). Getting more scientists safely into trees while increasing the awareness of the potential for total canopy access should lead to a fuller understanding of forest ecology.

Fig. 5. Rope-based methods can provide access to all points in the canopy. In A) a climber traverses between two trees, i.e., is able to access open spaces while suspended on ropes. Traverses between and within tree crowns reduce damage to fragile organisms like epiphytes, and provide access to otherwise unclimbable places, like delicate branch tips or rotten snags. Traversing between tall trees can be more expedient for accessing new trees than climbing from the ground, improving worker efficiency and research output. Alternately, some tall trees are only accessible via traverse, and not from the ground (e.g., the crown may not be visible from the ground). Training in methods and equipment selection and use are essential. Photo credit August Schilling Photography. B) Climber trainings accelerate learning and improve safety. Trainings offered for free or low cost in developing countries build local capacity for independent canopy research. Photo credit Juan Carlos Rivas Flores, Fundación Alianza Natural Colombia.

Increased training with and exposure to modern canopy access methods will increase researcher expertise, opening access to all parts of forest canopies, and is an important tool for building local and independent capacity for canopy research (Fig. 5).

4.2. Recommendations

Forest ecology awaits better understanding. We thus make four recommendations. (1) Recognize the problem. Targeted education can increase appreciation for the qualities and uses of rope-based canopy access, and build self-awareness as a precursor to improving individual climbing skills. Workshops and lectures at conferences can build awareness for the breadth of climbing methods and their suitability for meeting different research needs. The creation and dissemination of educational materials targeting scientific audiences will impart sound knowledge on climbing methods. These must be authored and reviewed by teams of qualified climbing scientists and arborists. (2) Develop international standards for certifying scientific tree climbers, instructors, and schools. Currently, no formal authority exists for certifying tree climbing in science, or for collecting data on climbing accidents. Established certification programs for scuba diving like the National Association of Underwater Instructors (NAUI), and the University of California diving control boards provide a model for tree climbing. Certification has been linked to a reduction of safety breaches and recreational diving fatalities (Buzzacott et al. 2009) offering hope for improving climber safety in science. Further, international standards would make clear a person's qualification level in tree climbing, which can be presented during job applications. Until tree climbing schools are widely audited, readers can obtain reputable information from Jepson (1999), Coffey and Andersen (2012), and websites like www.climbingarborist.com. Tree climbing equipment can be obtained from suppliers listed in Anderson et al. (2015). (3) We recommend audits of academic research proposals, tree climbing programs, and university climbing schools by boards of qualified climbing scientists and arborists. Audits could require the development of safety plans for hazardous fieldwork (Gochfeld et al. 2006), a common component of arboricultural operations. Universities enforce mandatory safety training for tasks as mundane as glassware disposal. Trainings are repeated regularly and participants are scored, or certified, before being allowed to perform those activities. Given these values and safety precautions, the lax oversight of tree climbing is notable. (4) Cooperation can open canopy access to more scientists and non-scientists alike. Training programs developed through partnerships between arborists and ecologists can improve the quality and quantity of scientific climbers. Trainings offered for free or at low cost through collaborations of arborists, ecologists, and industry are an excellent method for spreading local capacity for independent canopy research in developing countries. Arborists enjoy assisting canopy research, aiding ecologists who may not climb for a variety of reasons. Bioblitzes are high-intensity events of short-duration where small teams of trained climbers provide access to large teams of scientists, generating huge quantities of data for specific forest sites.

Declaration of Competing Interest

The corresponding author confirms on behalf of all authors that there have been no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated.

Acknowledgments

We thank the scientists and arborists who took the survey and made this research possible. J. Luce commented on the survey during its design and N. Nadkarni provided comments on an early version of the manuscript. Participants at Petzl America's 2019 Arborist Climbing Symposium offered constructive feedback that refined our methods and conclusions. WesSpur Tree Equipment kindly provided images used in the survey. P. Brandt (Spanish); B. Poythress, V. Lamarre, and M. Tetreault (French); and A. Costa (Portuguese) kindly translated the survey. We thank the more than 20 scientific societies that helped disseminate the survey. Conversations in trees with B. Price and B. W. Anderson motivated us to undertake this study. The research protocol and all four translations of the survey were reviewed and approved by the Boise State University Office of Research Compliance (protocol number 000-SB18-210).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tfp.2020.100005.

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