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LETTER

Tropical field stations yield high conservation return on investment

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Abstract
Conservation funding is currently limited; cost-effective conservation solutions are essential. We suggest that the thousands of field stations worldwide can play key roles at the frontline of biodiversity conservation and have high intrinsic

value. We assessed field stations' conservation return on investment and explored the impact of COVID-19. We surveyed leaders of field stations across tropical regions that host primate research; 157 field stations in 56 countries responded. Respondents reported improved habitat quality and reduced hunting rates at over 80% of field stations and lower operational costs per km^2 than protected areas, yet half of those surveyed have less funding now than in 2019. Spatial analyses support field station presence as reducing deforestation. These "earth observatories" provide a high return on investment; we advocate for increased support of field station programs and for governments to support their vital conservation efforts by investing accordingly.

KEYWORDS
biodiversity, climate change, conservation funding, field stations, pandemic, primate-range countries, protected areas, return on investment, sustainability

INTRODUCTION

Funding for global biodiversity conservation, already a finite commodity, has been impacted by the COVID-19 pandemic (Gibbons et al., 2022). Despite trillions of USD mobilized in pandemic economic recovery, government resources to address the biodiversity and climate crises remain constrained, even though increased investment is urgently required (Mallapaty et al., 2022). In this context, governments and other funding agencies should adopt policies that must consider not just the quantum of biodiversity and climate finance mobilized, but also their conservation return on investment (CROI): a quantitative, and sometimes also qualitative, conservation outcome measured against the fiscal cost of providing that outcome (Cho et al., 2019).

Thousands of field research stations worldwide are at the frontline of biodiversity conservation, supporting significant advances in conservation, education, and research. Despite monitoring and reporting on critical ecosystem services, their value to national and international biodiversity conservation efforts is often not recognized (Eppley et al., 2022; NRC, 2014; Wyman et al., 2009). This lack of recognition of field stations is evidenced by reduced investment and funding cuts in the conservation sector since the COVID-19 pandemic began (Gibbons et al., 2022; Likens & Wagner, 2021; McCleery et al., 2020).

Field stations may be susceptible to funding cuts because the CROI of these entities is not well-understood or documented, and therefore difficult to assess. For example, conservation and research initiatives, particularly at field stations, are usually interdisciplinary, yielding a broad array of direct and indirect knowledge and data benefits that are often only realized over long time scales, making CROI multifaceted and more complex than typical cost–benefit analyses can capture (Boyd et al., 2015; Field & Elphick, 2019; Kujala et al., 2018). CROI analyses often focus on the cost of protecting a given, measurable area (Kujala et al., 2018), yet field stations in these areas enact a multiplicity of qualitative initiatives, including research, education, and public engagement, that have long-term objectives and little immediately measurable cost–benefit value (Tydecks et al., 2016). It is this foundation of difficult-to-quantify conservation outcomes that field stations need to use to demonstrate their true benefit-to-cost ratio (Cho et al., 2019).

Focusing on field stations in primate-range countries, we take stock of field stations' CROI and explore the impact of the pandemic on their work. Specifically, we assess the real and perceived impact of the pandemic on field stations across the global tropics and subtropics, while also quantitatively evaluating the importance of these sites to biodiversity conservation. We use both traditional measures of CROI, that is, forest area protected and species biodiversity incorporated, and nonquantitative measures of conservation success, such as variation in patronage of field stations, variability in research programs, job creation, and development of long-term datasets, to demonstrate the cost-effectiveness of conservation investment in field stations.

METHODS

We defined field stations as sites with permanent structure(s) owned, rented, or occupied by an institution or research group. Our field station definition was intentionally broad as we aimed to incorporate a wide range of field stations, including large, well-established multifunction institutions, to small sites managed by an individual research team.

Given the lack of an existing database for field stations (cf. Tydecks et al., 2016), we targeted field research stations in primate-range countries. Primates are a well-studied and diverse taxonomic order distributed throughout ~90 countries (Mittermeier et al., 2013) and are often considered important species critical to tropical ecosystem function (Chapman et al., 2017; Estrada et al., 2017). As such, using established primate research networks provided a suitable forum for surveying a range of field stations across a large number of tropical countries.

Questionnaire survey

We recruited individuals with leadership roles (e.g., Director/Manager; Principal Investigator; long-term personnel at the site) at field stations via direct email contact. We used several email lists and publicly available contact information, including (1) current or former members of the IUCN SSC Primate Specialist Group (PSG), a group of more than 700 experts across the world, and members of primatological societies affiliated with the International Primatological Society; (2) contact points for Herbariums (https://sweetgum.nybg.org/science/ih/); (3) contact points for field stations on the Association for Tropical Biology and Conservation website; and (4) contact points for field stations with membership in the International Organization of Biological Field Stations.

The survey was conducted between late March and early June 2022 and was available in English, French, and Spanish. The 70-question survey solicited both objective (e.g., location) and subjective (e.g., risks to field stations' perpetuity, likelihood of closure, impact of conservation programs) information about field stations (see Appendices S1 and S2 for survey background and questionnaire).

Finally, we present an estimated median annual cost for operating field stations. Assuming a 5-km radius of direct field station effect on biodiversity (Campbell et al., 2011; Wintle et al., 2019), each field station impacts 78.54 km^2 of habitat. We divided the median annual budget of field stations surveyed by this assumed area of direct impact. As with any social survey extrapolation, these data should be treated as estimates of the quantified benefits and costs of field stations, particularly as the scale of "direct field station effect" can vary across different contexts and species.

Spatial analysis

To quantify the impact of field stations on species conservation, we estimated the number of species ranges intersecting field stations using IUCN Red List for Threatened Species range maps (version 2022.1; IUCN, 2022) for all terrestrial tetrapods assessed as threatened (i.e., Critically Endangered, Endangered, or Vulnerable), non-threatened (Least Concern, Near Threatened), and data deficient. We calculated the number of species per taxonomic group with geographic ranges overlapping field station locations per region. We then summarized the total number of species per taxon covered by field stations in different continents and by Red List category, while accounting for duplicates across field sites. This approach leads to an overestimate of species occurring at each site since geographic range maps can include unsuitable habitats for the species (Rondinini et al., 2006). However, this problem is likely mitigated by the aggregation of data across many field stations covering diverse habitats (i.e., a species not occurring in one field station can be present in others within its range). This analysis serves as a coarse estimate of the proportion of species with a threatened or data deficient status over the total (including non-threatened species) intersecting with the field stations in our study.

To evaluate whether field stations prevent forest cover loss, we documented changes in forest cover loss over time both at field stations and at similar, nearby areas outside of field stations' influence (i.e., control points). We randomly sampled these potential control points from a donut-shaped band at least 5 km from the field station, but not farther than 50 km (Figure S1). From these potential control points, we selected the 10 points that were most similar to the field station with respect to several environmental and anthropogenic conditions: initial tree cover, protection status, temperature, precipitation, human population density, anthropogenic modification, and road density, using statistical matching (Andam et al., 2008; Joppa & Pfaff, 2011; Stuart et al., 2011; Sze et al., 2022). See Appendix S3 for full methods, variable names, and sources. We then used the Global Forest Change index v1.8 (Hansen et al., 2013) to quantify differences in forest cover loss between field stations and the mean of their 10 matched controls, weighted to increase the contributions of the control points most similar to the field station, over time (Appendix S3). This satellite-derived forest cover loss data are available for the years 2000–2020 (Hansen et al., 2013). Thus, we measured the total forest cover loss between the field station's specific founding year or from 2000, whichever was later, and until 2020, that is, the most recent year available.

RESULTS

Respondents provided information on 157 field stations in 56 countries, representing 62% of the 90 countries in which primates naturally occur. Each major geographic region where primates occur was represented: 28% of these field stations were in Central and South America, 52% in Africa, and 20% in Asia. Eighty-five percent of all field stations ($n = 145$) were located in, or adjacent to, a formally protected area. At the time of the survey, most field stations (93% of $n = 145$) were still operating and had been in existence for an average of 22 ± 2.4 years (mean ± 95% confidence interval, range: 0–97 years, $n = 154$ stations).

Conservation, livelihoods, and research supported by field stations

Most survey respondents were of the opinion that, in comparison to other areas of the country where there were no field stations, the presence of a field station improved the habitat quality of the surrounding area (83% of $n = 153$ stations), reduced rates of hunting (86% of $n = 147$ stations), and improved enforcement of the law with regard to wildlife use/extraction (67% of $n = 148$ stations; Figure 1a–c). Almost all field stations surveyed had at least one full-time staff member (93% of $n = 149$ stations), with nearly half having between 5 and 75 staff (Figure 1e). Furthermore, 93% of field stations ($n = 144$ stations) hired locals. Almost all (98%) of the field stations were used by researchers ($n = 151$ stations; Figure 1f). In a normal (pre-COVID-19) year, the field stations were collectively used by ~725–3315 researchers, with most field stations hosting researchers from two to five countries. Field stations were also used by students (83%), volunteers (60%), trainees or apprentices (47%), tourists and the general public (36%), and patrol guards, rangers, or other park authorities (11%). In a typical year, the field stations ($n = 142$) surveyed here received a total of ~11,055–18,950 visitors from the general public, excluding outliers (i.e., a few field stations were on sites receiving tens of thousands of visitors per year; Figure 1g). The total number of scientific articles published across 150 of the field stations in a typical year ranged from ~330 to 1255 papers (Figure 1h).

Almost all field stations surveyed (97% of $n = 141$ stations) collected long-term data (Figure 1d), with one out of five (19% of $n = 142$ stations) sharing all their long-term datasets publicly and another 11% sharing some datasets publicly. In addition to primate research, field stations hosted research on 4.2 ± 0.3 other taxonomic groups or ecological disciplines ($n = 140$ stations; Figure 1i).

The effect of field stations on biodiversity and forest cover

Based on our 5-km radius, the field stations in our study potentially overlapped with the IUCN Red List geographic ranges of 1215 terrestrial vertebrates that are listed as either threatened (1045) or data deficient (170), including 156 amphibians, 218 reptiles, 366 birds, and 475 mammals (169 of which are primates). The majority of these species were found in Africa (499), followed by Asia (377) and the Neotropics (342). An average of 13 threatened or data deficient species were covered by the field stations in Asia, 6.8 in the Neotropics, and 5.9 in Africa (Figure 2).

We successfully matched 153 field stations to control points that were similar climatically and with regard to the level of anthropogenic influence they face and their starting forest cover (Appendix S3). Though global deforestation rates have increased over time, when we assessed the effect of each field station location against their matched control points, we found that forest cover loss was significantly less near field stations ($p < 0.05$), showing 17.6% less deforestation overall (Figure 3). This trend was mainly driven by field stations throughout Africa (22.0% less deforestation at field stations, $p < 0.05$). Nevertheless, the average forest cover was also less near field stations in the Neotropics and Asia, with 13.2% ($p = 0.16$) and 12.0% ($p = 0.26$) less deforestation, respectively.

Field stations' CROI and the impact of COVID-19

Typical operating budgets (in a non-COVID-19 year) were often small, with half of the field stations running on less than US$50,000 (55% of $n = 118$ stations; interquartile range: US$200,000). Assuming a 5-km radius of direct field station impact on biodiversity (Wintle et al., 2019), the associated median annual cost is ~US$637/km^2. Forty percent of field stations had budgets between US$50,000 and US$500,000. These budgets were often sourced from three or fewer different funding sources, and one-quarter (23%) had only one type of funding source. Three-quarters of field stations (76% of $n = 140$ stations) relied partially or exclusively on one-off grants for funding, half (49%) relied partially or exclusively on earned income, and just one-third (34%) had secured streams of income or endowments.

The COVID-19 pandemic caused half of the field stations (48% out of $n = 128$ stations) to close partially or completely from March 2020 to June 2022. At the time of the survey, almost one quarter (22% of $n = 156$ stations) remained partially or completely closed due to COVID-19.

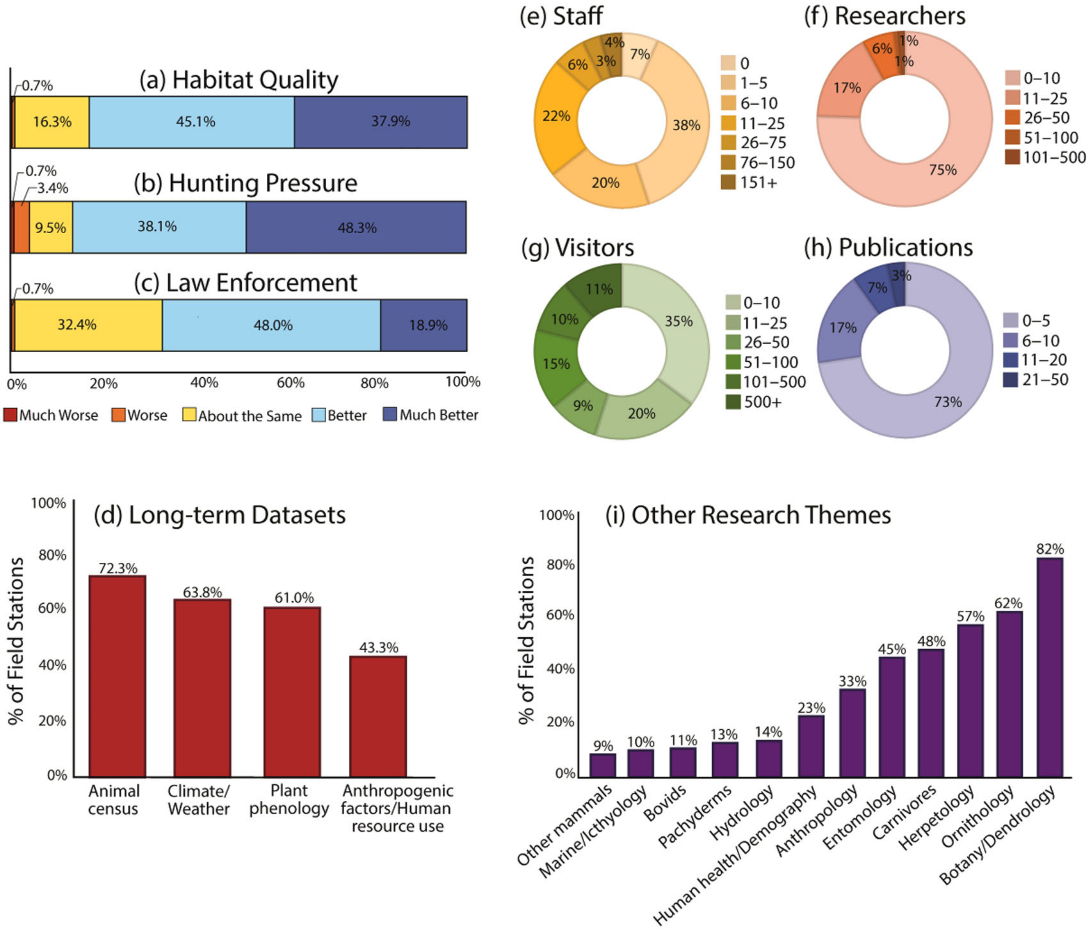

FIGURE 1 Selected results from our field stations survey. Compared to areas without field stations, survey respondents provided their perception of the impacts of field stations on (a) habitat quality, (b) hunting rates, and (c) law enforcement. Many field stations reported having (d) long-term datasets, some of which are publicly available. Each field station provided general information, so we present the total annual (e) staff employed, (f) researchers, (g) visitors, and (h) publication output of surveyed field stations. In addition to primate-related studies, (i) other research themes were common at many field stations.

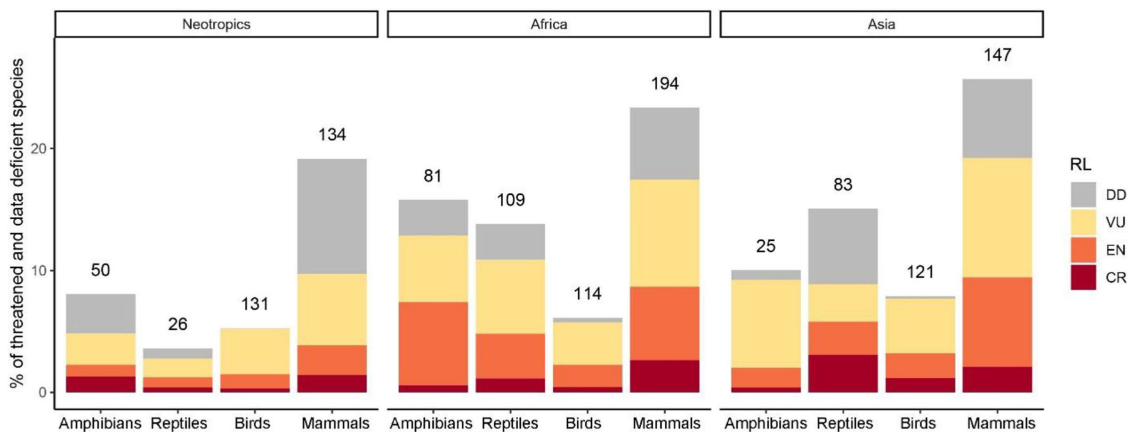

FIGURE 2 Percentage of threatened (i.e., Critically Endangered, Endangered, and Vulnerable) and data deficient species per taxonomic group categorized by geographic region, as listed on the IUCN Red List of Threatened Species (IUCN, 2022). The species list is obtained by intersecting all available species range maps for the different taxonomic groups with the 157 field stations across 56 countries. Percentages are calculated over the total number of species present (including Least Concern and Near Threatened species). The absolute number of threatened and data deficient species per taxonomic group is indicated above each bar.

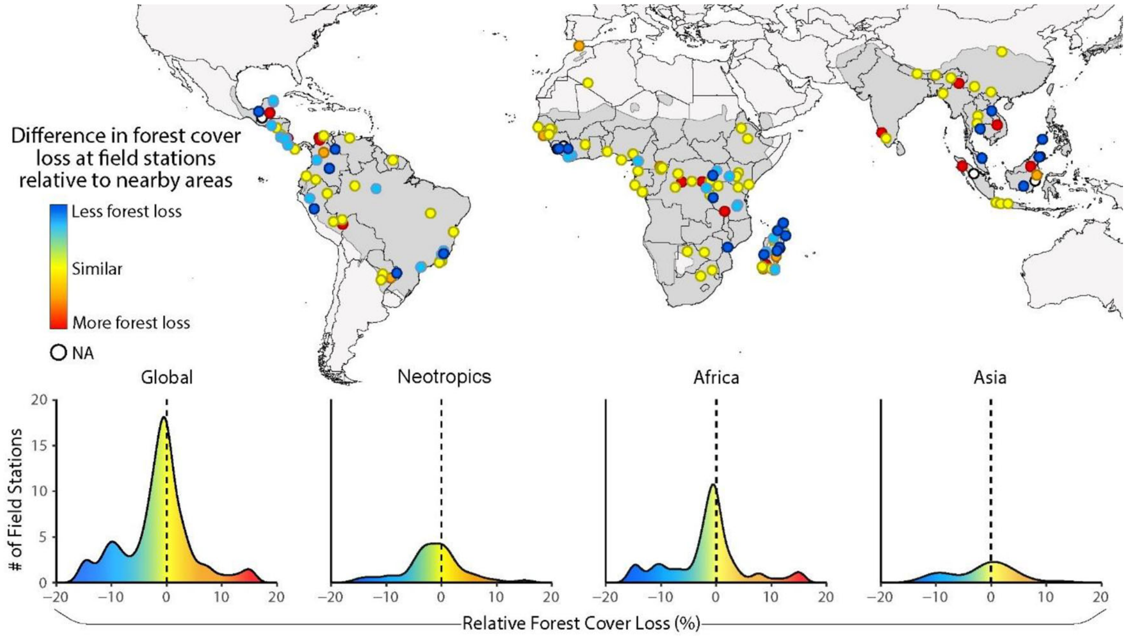

FIGURE 3 Map of field station locations surveyed ($n = 157$) across the global distribution of primates (Jenkins et al., 2013), indicated by the darker gray. Field station color indicates the change in forest cover loss for each site compared to its matched control points since 2000 or the founding of the field station, whichever was most recent. Sites with white dots (NA) are ones for which suitable matched points could not be located ($n = 4$). The density plots show that field stations reduce deforestation globally (64% of field stations exhibited less forest cover loss than the surrounding area). This trend is driven by less forest loss at field stations in Africa (69% of field stations) and the Neotropics (60%), but less so in Asia (58%), perhaps due to the smaller sample size.

Most respondents (72% of $n = 143$ stations) had been able to visit the field station at some point after the global onset of the COVID-19 pandemic in March 2020, and most stations (76% of $n = 143$ stations) had put adaptive measures in place to mitigate the impact of the pandemic on work at those sites. Since March 2020, half (50% of $n = 131$ field stations) had less or much less funding, compared to 9% with more funding.

Looking forward, just under half of the field stations (46% of $n = 137$ stations) anticipated being able to continue 76%–100% of the work they would have done before COVID-19. Furthermore, 15% of field stations said they expected to continue only 0%–25% of their work.

DISCUSSION

Field stations are viewed to deter illegal natural resource extraction and defaunation (Figure 1) and reduce deforestation in regions that are not on track to meet their forest protection goals (i.e., Neotropics, Africa; Figure 3; FDAP, 2022). These benefits to biodiversity cost a median US\$637/km^2, assuming a 5-km radius of effect (e.g., Campbell et al., 2011; Wintle et al., 2019). This gives field research stations a strong positive CROI, similar to the proposed budgets in the Africa Park Network for effective management (Lindsey et al., 2018). Indeed, most surveyed field stations reported operating budgets that are half—or even less—of the global mean budget for protected areas, US\$1,689/km^2, adjusted for inflation (James et al., 1999). Like protected areas, these conservation sentinels would yield an even greater CROI with reliable and increased funding.

Field stations also benefit conservation efforts in a variety of other ways: they support the production of scientific articles, training and awareness, local economic expansion, and maintenance of irreplaceable, multidecadal climate and biodiversity datasets (e.g., Chapman et al., 2017; NRC, 2014; Sharma et al., 2022). The field stations we surveyed estimated they cumulatively produce ~1255 scientific articles annually. The amount of published research stemming from these locations provides a critical contribution to conservation initiatives: continually updating and improving essential information used for evidence-based decisions in a cross-discipline field (Christie et al., 2021; Kareiva & Marvier, 2012). Field stations also provide a hub for intergenerational and international collaboration and learning. Field station respondents reported hosting up to 3315 researchers each year, including students, scientists, conservation professionals, and community members, with a further ~18,950 visitors annually. Given the evidence that conservation messaging to ecotourists is strongly influenced by interactions between visitors and researchers/professionals (Fernández-Llamazares et al., 2020; NRC, 2014), field stations represent a unique convocation of these disparate biodiversity enthusiasts. Furthermore, 93% of field stations incentivized conservation initiatives by hiring from local communities, improving both local livelihoods and the success of their conservation programs (Wali et al., 2017). In fact, the involvement of local nationals in management positions, and in some cases ownership, is what allowed over half of the field stations surveyed to remain at least partially operational during the pandemic.

Unfortunately, it is evident from our study and others that field stations, like the biodiversity they protect, are at risk (Likens & Wagner, 2021). Half the surveyed field stations had budgets reduced from their 2020 numbers and are now facing global inflation. With each global crisis, the resilience of field stations decreases (Schubel, 2015), and current events foreshadow years of difficulty for these institutions. Recent global crises have triggered higher energy prices, increased human population densities, and increased food insecurity across many high-biodiversity countries (Benton et al., 2022) and have led to increased natural resource extraction (Rawtani et al., 2022). Likewise, the threat of global recession (IMF, 2022) is impacting field station budgets, which cannot accommodate rising inflation.

Most field stations typically function autonomously, perhaps explaining why few studies have explored the aggregate impact of their work (cf. NRC, 2014; Tydecks et al., 2016; Wyman et al., 2009). Despite this, our study suggests that field stations cumulatively make a substantial contribution to conservation. Conservation science relies on quantitative evidence collected at field stations to provide foundational knowledge for designing effective strategies (Kareiva & Marvier, 2012), and while those strategies tend to be focused regionally, their shared expertise can inspire solutions globally (NRC, 2014).

While field stations alone cannot ensure the persistence of species, we found that they are more successful at protecting local wildlife populations, among other clear and quantifiable conservation benefits at a relatively low cost. Meanwhile, countries throughout the Neotropics and Africa struggle to meet forest protection goals (FDAP, 2022), and global protected area personnel numbers and capacity are insufficient for effectively safeguarding biodiversity (Appleton et al., 2022; Maxwell et al., 2020). Though our approach was mostly limited to tropical field stations hosting primate research, we would expect comparable positive impacts of field stations globally. Accordingly, failing to include field stations in international policy frameworks that address the global biodiversity crisis represents a profound missed opportunity (Strier et al., 2021; Wyman et al., 2009). We urge funders to reverse their declining support of long-term field station programs and increase investment beyond prepandemic levels. Similarly, we encourage governments and universities, both in the tropics and elsewhere, to recognize field stations as crucial, high-CROI tools for meeting conservation targets and to adopt policies that will promote the establishment and growth of field stations. These policies should incorporate strategies/contingencies to ensure long-term conservation and research activities, including through crisis periods, such as occurred during the COVID pandemic.

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CONFLICT OF INTEREST STATEMENT

All authors are affiliated with one or more field stations; thus, the perception of multiple conflicts of interest exists.

DATA AVAILABILITY STATEMENT

Due to our IRB ethics approval, we are unable to provide any individual/field station identifying information; however, anonymized data and statistical codes used to support this study can be found in the following repository: https://github.com/SHoeks/FieldStationConservation.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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