

# Teaching Biology in the Field: Importance, Challenges, and Solutions

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*Learning that occurs in a field setting is a powerful experience that promotes the development of new generations of creative scientists, enhances environmental literacy, and instills social responsibility in our citizens. Institutional challenges to field studies include decreasing financial resources and increasing regulatory concerns. These are coupled with changing student interests, in particular the growing misconception that field study is not relevant to many biological careers. Collectively, these factors contribute to a significant decline in field-study opportunities for students and lack of pedagogical guidance for instructors interested in conducting field courses. Nature and culture are inextricably linked, and we all benefit from including diverse backgrounds and perspectives in field experiences. We suggest expanding the definition of “the field” to include human-influenced ecosystems, as well as more conventional natural habitats. More than ever, the world needs the passion, insight, and wisdom that come from field studies.*

*Keywords: field biology, field studies, education, environmental science, natural history, experiential education*

**M**ore than 70 years ago, Aldo Leopold (2013 [1938]) decried the loss of field studies in biology education. The subsequent decades have only amplified this decline. For example, within the past 20 years, both Schmidly (2005) and Hafner (2007) described the significant loss of field-based opportunities in mammalogy, and Wilcove and Eisner (2000) described the “impending extinction of natural history.” More recently, a group of prominent British biologists published a call to arms warning that “the decline in field biology skills in the UK has reached crisis point” (Warren 2015). Clearly, the concerns voiced by Leopold are more relevant than ever.

Field-based education is particularly critical to the biological sciences, providing fundamental training for key disciplines such as behavior, ecology, evolution, systematics, and conservation science (Eisner 1982, Wilson 1982, Fleischner 2005, Baggott and Rayne 2007). Field studies underlie the conceptual and technical bases for these disciplines and are required to ensure their healthy growth. Now, as society struggles to respond appropriately to losses of biodiversity, range shifts due to climate change, and the emergence of new human pathogens, the decline in opportunities for field study means that subsequent generations of biologists will be increasingly divorced from the primary setting, the natural

environment, in which the phenomena that they study occur. As the capacity to modify biological systems expands from genomes to ecosystems to global cycles, it is imperative that scientists and the broader public are able to critically evaluate the outcomes of these changes in the context of complex natural settings. Within academia, this need also applies to the educators charged with training future generations of problem-solvers (Pauly 1995). In summary, field studies are an essential component of every scientist’s training.

There is already a growing disconnect between the recognized importance of field experiences and the increasingly limited opportunities for gaining relevant field-based training (Barrows et al. 2016). As Mogk and Goodwin (2012) noted, “the field setting is one of the important crucibles where science and scientists codevelop.” Geoscientists in the United States (Mogk and Goodwin 2012) and bioscientists in the United Kingdom (Smith 2004, Boyle et al. 2007, Scott et al. 2012, 2013, Lambert and Reiss 2014) have already taken steps to address this problem. By comparison, biologists in the United States have made little effort to counter the decline in field experiences in science education.

With these concerns in mind and with support from the National Science Foundation, in March 2016, we convened a working group of researchers and educators with the

purpose of addressing three questions concerning the future of field-based education in biology: (1) Why are field-based educational experiences important to advancing biological knowledge? (2) What challenges threaten opportunities for students to engage in field-based educational experiences? And (3) how can we enhance field-based pedagogies in biology? Here, we explore each of these questions and offer suggestions about how best to ensure that future generations of biologists will be able to engage in the seminal experiences that occur in field settings.

### Definitions

We distinguish between three overlapping terms that, collectively, represent the intersection between nature and the *in situ* learner. *Natural history* encompasses a broad range of definitions (summarized in Fleischner 2005), all of which share the central theme of the direct observation and description of organisms, communities, and habitats, including attentiveness to associated geology, hydrology, and other physical factors. *Field biology* is rooted in natural history but typically places greater emphasis on using observational and experimental data to advance conceptual models and theory. Biologists should be cautious about dichotomizing natural history and field biology (Greene 2005), however, because the two are closely intertwined and observations of natural systems provide a foundation for more concept-driven studies of biology. Finally, *field studies* encompass a wider range of disciplines—biology, geology, anthropology, and humanities—each of which may require developing essential competencies needed to live and work in outdoor settings, as well as more specialized skills relevant to the specific discipline and line of inquiry. Although our expertise is in biology, as science educators interested in maximizing benefits for all students, we emphasize the importance of *field studies*, because this term includes natural history and more hypothesis-driven exploration of multiple scientific disciplines.

### The importance of field education

The value of field study is vast: Field experiences create not only better science but also better scientists, citizens, and people, thereby substantially affecting the human–nature relationships that form the basis for sustainability (Fleischner 2011, Mogk and Goodwin 2012, Tewksbury et al. 2014, Barrows et al. 2016). Ecologist Paul Dayton (2011) has noted that “there is simply no substitute for actually experiencing nature, to see, smell, and listen to the integrated pattern that nature offers an open mind.” Indeed, observing nature is the touchstone for understanding how life works; therefore, field studies serve quite literally as the *grounding* for the biological sciences. At the same time, field experiences often force observers to question and to re-evaluate their assumptions about how the natural world operates. Accordingly, field observations can lead to the recalibration of research strategies for exploring biological phenomena (Greene 2005), explanations for which are often subsequently tested using

information collected by observational approaches in the field (Sagarin and Pauchard 2010). In short, field observations reveal patterns that inspire explanation and that in many cases lead to the construction of formal hypotheses to explain natural phenomena.

Field study also promotes the development of place-based understanding (Billick and Price 2011). In part, this is because students who engage in field experiences have greater opportunity to cultivate the critical connections to real places that transform abstract concepts into tangible realities (figure 1). This outcome is not limited to biologically defined locations but extends to the cultural, social, and political settings in which field studies occur (van Eijck 2010). Sense of place (Stegner 1992) can be a powerful motivator for learning and stewardship (Robertson et al. 2015, Haywood et al. 2016); therefore, individuals who become strongly connected to a specific setting tend to become more effective advocates for all elements of that environment.

On an individual level, field studies often spark a “sense of wonder” (Carson 1965, Dayton and Sala 2001) that can launch students on a path of discovery-based science, resulting in lifelong commitment to careers in natural, environmental, and medical science. Field experiences, in particular residential and other immersive experiences, also provide unparalleled opportunities for the development of intra- and interpersonal skills that are crucial to effective leadership. Such experiences can lead to greater interaction between the affective and the cognitive, thereby providing a bridge to higher-order learning (Rickinson et al. 2004). The unpredictability and unfamiliarity of field conditions challenge students to become more independent, resourceful, self-confident, and self-aware (Boyle et al. 2007, Lu 2015). Because students often interact with individuals from diverse backgrounds while in the field, they encounter values and worldviews that they might not otherwise experience. In short, field settings provide crucial opportunities for students to learn from one another. Away from their accustomed environments, students are often more receptive to novel experiences, and sharing time in the field cements collaborations and strengthens professional and personal communities. Moreover, there is clear evidence that field courses contribute to improved academic performance and cognitive learning in undergraduate biology students (Easton and Gilburn 2012).

Field experiences encourage multiple ways of knowing: *observing* nature (extracting understanding), *conversing with* nature (developing empathy), and *participating in* nature (using resources). Although students arrive in the field with different types and degrees of experience, most quickly realize that each of these ways of knowing offers valuable insights into how the world functions. In summary, field experiences help students to become fully realized scientists and human beings. Given the pedagogical and personal benefits of field studies, what prevents more educational institutions from offering significant field opportunities to



**Figure 1.** Field-biology education in a variety of natural and cultural contexts (clockwise from upper left): (a) immersed in Alaskan wilderness; (b) collecting nonnative geckos in a California strip mall; (c) setting a small mammal trapline at a university reserve; (d) exploring the aquatic world of a Belizean estuary. Photographs: (a) Thomas L. Fleischner, (b) Robert E. Espinoza, (c) Corey Welch, (d) Gretchen A. Gerrish.

their students? What is needed for students to gain access to more life-changing field experiences?

### Challenges to field education

To understand and, ideally, to reverse the ongoing decline in field-based student experiences, the factors that limit such opportunities must be identified. Here, we outline multiple institutional, pedagogical, and cultural factors that serve to impede field studies in an educational setting (figure 2).

**Institutional hurdles.** Higher education has changed dramatically since Leopold wrote about the importance of field studies in the 1930s. Now, instructors interested in providing field experiences must negotiate a complex suite of financial, logistical, legal, and attitudinal hurdles that usurp time that could be spent working with students and engaging them in field-based learning opportunities. Over time, these hurdles may sap the energy and morale of even the most dedicated instructors, thereby reinforcing the cycle of decline for

courses that include a field component (e.g., Hafner 2007). Because these challenges are often unfamiliar to those who have never engaged in field studies, the responsibility for advocating for field courses falls almost entirely on the diminishing subset of faculty who are already committed to offering such opportunities.

Relative to lecture-based coursework, field-based instruction can be expensive. For example, if students and instructors travel to an off-campus site, food and lodging must often be provided, and, depending on the nature of the course, specialized equipment and supplies may be required. Accordingly, the per-student cost of intensive field-based biology courses can be considerably greater than that for lecture-only courses. The more appropriate comparison, however, is with laboratory-based biology courses, which are often significantly *more* expensive per student than field courses. For example, the Biology Department at Middlebury College offers a two-semester introductory biology series consisting of (a) Ecology and Evolution, which

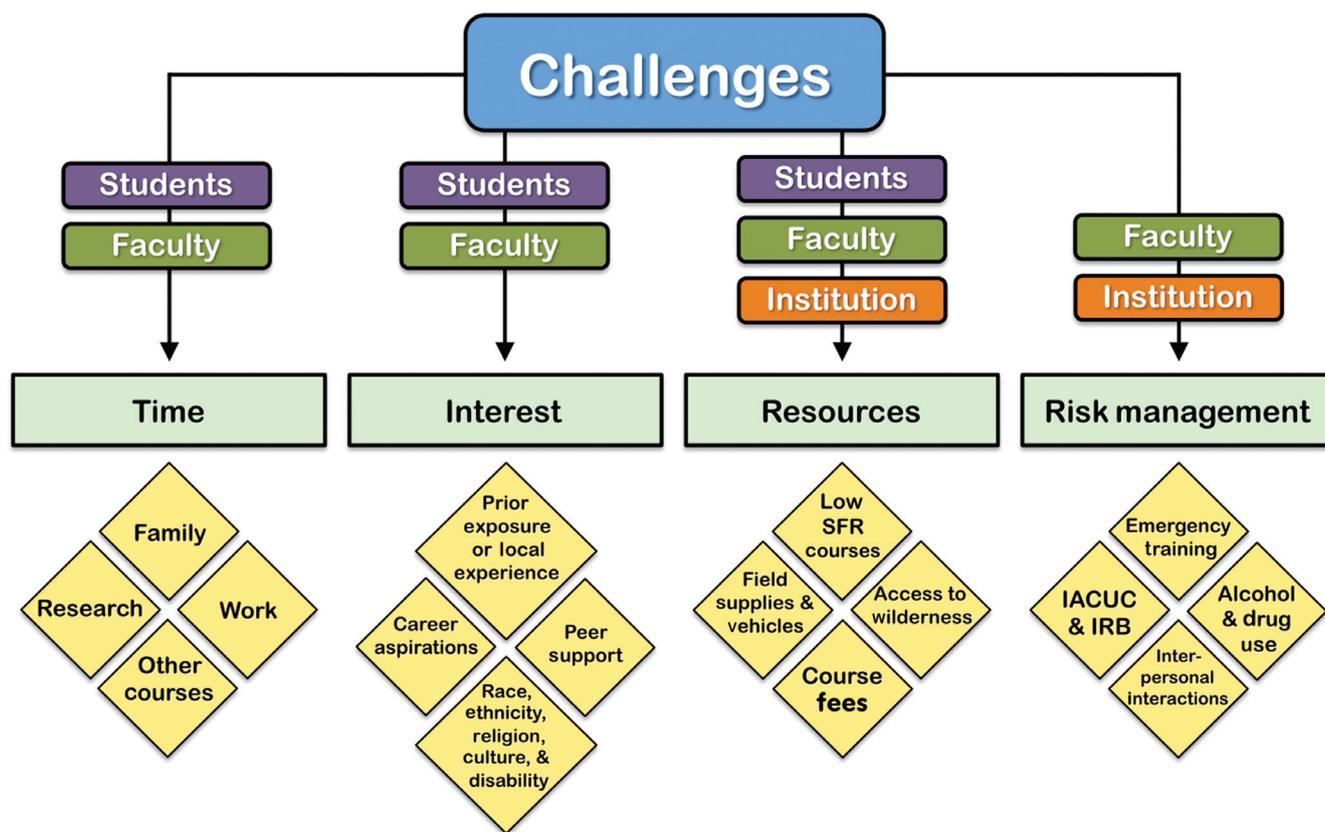


Figure 2. Challenges to offering field studies at colleges and universities. (IACUC, Institutional Animal Care and Use Committee; IRB, Institutional Review Board; SFR, Student–Faculty Ratio)

features field components, followed by (b) Cell Biology and Genetics, which is a lecture–laboratory course. During the 2015–2016 academic year, the cost per student for Ecology and Evolution was less than two-thirds that for Cell Biology and Genetics (Stephen C. Trombulak). This difference was even more dramatic in upper-level courses, with the per-student cost of field-oriented classes being less than a quarter of that for courses with substantial lab components (Stephen C. Trombulak). Enrollment in field courses often tends to be low relative to lecture or lab classes; therefore, as campus budgets continue to decrease, field-based offerings provide easy targets for reducing educational costs. Although some programs may respond by passing the costs of field trips directly to students, this “solution” often prevents some undergraduates from participating because of financial constraints. Therefore, any effort to protect or to expand undergraduate field experiences must include a financial model that ensures access by all students. We need to transform the perception of field courses from “too expensive” to “priceless.”

Institutional regulations can also limit opportunities for field study. Ever-increasing liability concerns serve to constrain time in the field. Such regulations now include specialized training for driving vans, piloting boats, mitigating risk, providing emergency medical care, and maintaining

harassment-free learning environments (Clancy et al. 2014). Field studies may require appropriate governmental permits and, in the case of vertebrates, an approved Institutional Animal Care and Use Committee (IACUC) protocol (NRC 2011). None of these requirements are frivolous, and they have contributed to safer, more ethical field studies. The burden of regulatory compliance, however, is substantive and often falls on individual instructors. This burden is amplified when a lack of familiarity with field studies renders many campus regulatory groups ill prepared to make well-reasoned decisions regarding proposed field activities. Because faculty, when faced with these demands, may choose to abandon field experiences, efforts to promote field studies must address the associated significant regulatory and logistical challenges.

Field courses also require extraordinary effort that is typically undertaken without adequate institutional support for out-of-class faculty time invested in planning, pretrip reconnaissance, logistic preparation, and fulfillment of the regulatory demands of training, liability, and permitting. Furthermore, field studies that require extended time away from campus impose professional and personal costs, because field instructors are constantly on call as teachers, mentors, safety officers, and, frequently, guidance counselors. While fulfilling these roles, instructors are unable to

engage in research or other career-promoting activities, particularly when field activities extend over multiple days. In summary, the demands of field courses generally far exceed those of campus-based classes.

This extra effort is rarely acknowledged by academic administrators, which may deter faculty interest in teaching field courses. Indeed, administrators may actively discourage participation in such courses, particularly for junior faculty. Increasingly, these challenges are coupled with a perceived tendency for biology departments to favor hiring laboratory-based researchers, thereby potentially further undercutting the pool of individuals available to offer field courses. Removing these roadblocks will require that institutions proactively identify obstacles and actively incentivize field courses. These changes begin with acknowledging both the importance of experiential studies of natural history (Fleischner 2005, 2011, Greene 2005) and the significant effort required to provide these crucial student experiences.

**Student interest.** At academic institutions where field study is considered an integral component of professional training, student interest in field courses is high and often exceeds available enrollment. For example, student demand for introductory and advanced field courses is robust at Prescott College (Thomas L. Fleischner); Middlebury College (Stephen C. Trombulak); SUNY College of Environmental Science and Forestry (Robin Wall Kimmerer); the University of Washington (Julia K. Parrish); the University of California, Santa Cruz (Christopher Lay, Kenneth S. Norris Center for Natural History, personal communication, 31 December 2016); and the University of California, Los Angeles (Daniel Blumstein, Department of Ecology and Evolutionary Biology, personal communication, 2 January 2017). As evidence of the potential for sustained interest in field courses, the vertebrate-natural-history course at the University of California, Berkeley, which includes weekly field trips, has been taught for more than 100 years (Christina Fidler, Museum of Vertebrate Zoology, personal communication, 3 January 2017). In these programs, the field experience becomes a hallmark of the institution, distinguishing graduates from their peers in employment and graduate study opportunities. Accordingly, institutions that neglect or even discourage field study are missing significant opportunities to foster student interest and are failing to provide students with training experiences that are fundamental to multiple scientific disciplines.

Despite an often-inherent interest in natural history, many students of biology choose curricula that do not include field studies (Smith 2004). Many biology departments emphasize preparation for careers in biomedicine, with field studies often viewed as being of marginal relevance to this professional trajectory. This perception persists despite recent changes to the Medical College Admissions Test (Beck 2015) and medical school admissions criteria that place greater emphasis on evolutionary biology and, by extension, the natural world. This is reflected in student perceptions that

field courses do not enhance employability (Mauchline et al. 2013) and are not relevant to modern biology (Barnett et al. 2006). These assumptions overlook evidence that many significant discoveries, including those likely to benefit human health, come from the field (e.g., Calisher et al. 2007, Pourrut et al. 2007, Ostfeld and Keesing 2012). Clearly, greater effort needs to be made to inform students of the essential role that field study plays in biomedical science.

Declining participation in field studies may also reflect large-scale societal shifts that have altered the precollege environments of many students. For example, as much of the world has become more urbanized (Thornbush 2015), childhood exposure to nature has diminished (Louv 2008). Sense of place for many of today's students does not extend to remote landscapes, which may be perceived as intimidating. At the same time, loss of contact with the natural world may affect the capacity to engage with field settings. For example, extensive use of cell phone and computer screens has been shown to alter the human visual system (Sewall 2012). Consequently, the shift to increasingly human-modified environments creates a negative feedback loop that serves to increase emotional and physical distance from nature and therefore to decrease interest in field-based educational experiences.

Many of our most pressing socioecological issues lie at the intersection between culture and nature, and cultural diversity is essential to sustainability. Field experiences are crucial for developing the next generation of environmental professionals, but at present, undergraduate participation in field studies is not reflective of human cultural diversity (Baker 2000, Arismendi and Penaluna 2016). Multiple factors contribute to the underrepresentation of multiple groups defined by race, ethnicity, gender, geography, and socioeconomic background (Van Velsor and Nilon 2006, Cotton and Cotton 2009). For first-generation students from economically disadvantaged backgrounds, a focus on nature may be perceived as contrary to improved financial prospects, and the study of wild places and wild organisms may seem irrelevant to social-justice concerns. Whereas suburban students brought up in the tradition of backyard explorations, weekend hikes, and summer family vacations to national parks may leap into a field course without concern, an urban student who has never spent a night outdoors may find a field experience daunting (Cotton and Cotton 2009). A female student may be reluctant to live under field conditions in a group consisting primarily of males because of cultural norms or fear of harassment, especially from men perceived as higher in professional hierarchies (Clancy et al. 2014). Disabled students may be discouraged from field studies even if their disabilities can be accommodated (Hall et al. 2004, Boyle et al. 2007). Designing field courses that respect and accommodate student differences will be crucial to ensuring that such experiences are accessible to all, with the resulting diversity of perspectives enriching for all learners.

**New pedagogical attitudes and approaches.** By definition, field studies occur outdoors. Not surprisingly, many field-based

programs take place where undisturbed nature has to some degree been conserved. Many scientists—ourselves included—were inspired by such field experiences and therefore tend to automatically equate “the field” with remote, comparatively untouched locations. However, overly narrow interpretations of what constitutes “the field” may lead to missed opportunities to engage students in outdoor experiences (Hale 1986, McCleery et al. 2005), particularly when access to more remote settings is precluded by some of the challenges outlined above. Furthermore, because contact with more (sub)urban landscapes often includes interactions with park rangers, land managers, and other conservation professionals, these experiences can be particularly valuable for revealing potential career opportunities. In summary, the benefits of interacting with nature can be realized in a wide range of accessible settings, a realization that can help make field study part of the pedagogy of all undergraduate programs.

Providing students with field experiences in more human-influenced habitats may require particular creativity. For example, for instructors at large, urban campuses, the classic weekend trip spent capturing mammals or reptiles can be replaced by observations of peregrine falcons foraging in urban canyons, surveys of pollinators in urban gardens, analyses of ants foraging in a local park, recordings of the dawn chorus of birds in a day-use area, or camera trapping of urbanized wildlife. These activities may not provide the deep immersion in nature that more extended or remote field experiences do, but they are often sufficient to pique the interest of students and awaken them to the processes of observation, interpretation, and exploration of nature (McCleery et al. 2005, Barnett et al. 2006).

Even among educators who embrace the importance of field studies, some may hesitate to provide these experiences if they do not feel capable of designing and leading such activities. Challenges include not just pedagogical techniques but also the necessary logistics and demands associated with managing student group dynamics in often-unpredictable physical settings. Teachers, like students, need role models and mentors. Checklists or instruction manuals that summarize the basic considerations associated with overseeing field experiences provide valuable support to faculty. Furthermore, the use of established field stations and marine laboratories can be invaluable for alleviating logistical and academic concerns (Billick et al. 2013, NRC 2014, Scubel 2015). For instructors, field stations provide opportunities to tap into existing networks of supportive colleagues; for students, such locations provide exposure to a wide range of scientific studies conducted in natural settings. Although relevant materials exist on how to lead field courses (e.g., Farnsworth and Beatty 2012, Baldwin 2013, Fleischner et al. 2013, Greene 2013, Tal et al. 2014), more are needed. Tangible resources that experienced field instructors can provide include lesson plans, logistic suggestions, and, in particular, person-to-person mentoring of less experienced colleagues.

## Solutions

Despite the sometimes-significant challenges outlined here, field courses continue to be offered and enthusiastically embraced by dedicated faculty and avid students. Faculty who lead such courses do so because they understand the profound benefits to student learning, to personal and professional development, and to the development of an ecologically literate society. There is no replacement for direct interaction with the living world. Eschewing the field in favor of the classroom, lab, museum, book, or computer is to favor the abstract over the real. We contend that all learners need to experience the real in order to be able to think critically about the abstract, let alone contribute to the development of new conceptual constructs. At the same time, however, we assert that field studies and, specifically, the instruction of field courses need to change to become more available, inclusive, and relevant to the rapidly changing world. We offer the following suggestions to ensure that field experiences contribute to the preparation of future generations of excited and creative biologists, as well as the creation of a more nature-literate society (figure 3).

**Proactive steps.** Although many of us who lead field courses extol the benefits of teaching outdoors, we need more effective means of conveying the necessity of field studies to others. When communicating with those who may perceive field studies as curricular “extras,” the essential nature of field experiences must be put into context so that their core importance relative to other courses is readily apparent. Analogy may help. Field study is how ecologists, conservationists, and taxonomists hone their craft; it is the opportunity to put acquired information, theories, and skills into practice. A music student may be immersed in theory and history, listening to the works of others, but it is when she puts fingers to the keyboard, practicing for hours on end, that she perfects the integration of motor skills and emotion that culminates in a stunning performance. Describing such equivalencies between biological field studies and other disciplines that engage in practice-based, transformative education should strengthen understanding and support among academic colleagues.

In addition to finding better ways to communicate the values of field study in biology, field instructors must actively participate in creating assessment-based curricula. Most universities use assessment tools based on course content and skill acquisition to evaluate student learning. Numbers matter. Recent analyses indicate that content and skills are better retained following field experiences than following lab-based exercises (Scott et al. 2012) and that field studies elicit positive affective responses (Boyle et al. 2007). That is, feelings and values matter to students. Because tools for assessing affective impacts are less familiar to most bioscientists and often include qualitative elements that are more challenging to analyze and interpret, the development of mixed-measure assessment tools (i.e., quantitative *and* qualitative) may provide the common language needed to

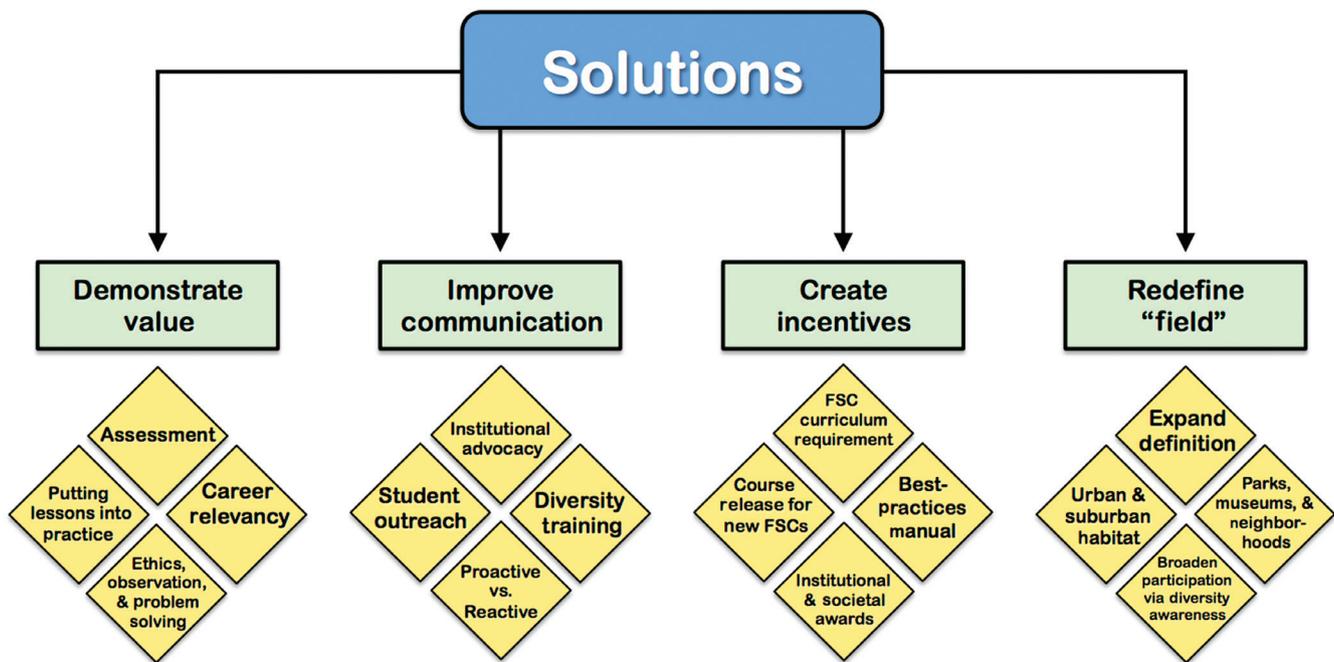


Figure 3. Potential solutions for offering field studies at colleges and universities. (FSC, Field Studies Course).

demonstrate the impacts of field studies on student learning. Such measures could also serve to improve student experiences and to identify (and rectify) inequities in access to field opportunities.

To meet compliance challenges, we encourage field instructors to join local conversations regarding the regulatory environment at their institutions. Constructive steps include (a) pushing for risk-management training for instructors and students, (b) advocating for training to avoid sexual harassment and cultural intolerance, and (c) placing field course instructors on IACUCs, where they can help educate colleagues about the nature of field studies. These efforts will require time and energy that most of us would prefer to spend in the field, but these actions are essential to the larger goal of promoting field instruction in biology.

At the same time, educational institutions need to be more proactive in offering solutions to regulatory challenges. For example, university administrators tend to be leery of the potential liabilities associated with field courses but may not make the effort to discover that considerable expertise and numerous “best practices” exist in the world of experiential adventure education (e.g., Hirsh and Sugerman 2008, Pace 2014). Institutions would make huge strides by providing risk-management training that enables, rather than obstructs, field studies. Toward this end, we have compiled a manual of relevant protocols based on adventure education programs that include extended student exposure to field conditions (Pace et al. 2017; [www.naturalhistoryinstitute.org](http://www.naturalhistoryinstitute.org)).

Academic reward systems should also be modified to create incentives for teaching field-based courses, beginning with recognition of the often-extensive instructor effort

required to organize and run such classes. At the same time, curricular budgets should explicitly include a mixture of classroom, laboratory, and field experiences, thereby reducing perceived financial constraints on offering field courses. Finally, curricula could be revised to require that all students engage in field learning. Geology and archeology programs, which typically require a summer field camp, offer one potential model for such curricular changes.

To help set these changes in motion, we challenge all biology faculty to teach (or coteach) at least one field course during their academic career, similar to the expectation at many institutions that faculty rotate through the teaching of introductory biology or other foundational courses. Furthermore, we suggest that junior faculty with field-oriented research programs be granted a term to develop or revamp a field course, thereby strengthening ties between teaching efforts and the research methods, questions, and study systems with which they are most familiar. Similarly, midlevel and senior faculty could be provided with teaching release or leave time to develop new field-based courses that build on their research expertise and provide opportunities to mentor less-experienced colleagues in field-based instruction. Post-tenure faculty are better positioned to play a role in institutional conversations regarding regulations, risk management, and training needs, thereby helping to pave the way for junior faculty who wish to offer field courses.

At the campus level, we suggest institutions create distinguished teaching awards specifically for faculty who offer courses that include field-based instruction. Similarly, we urge professional societies to establish awards that recognize creative and innovative efforts to engage students in

field studies. As examples, the development of the *Journal of Natural History Education and Experience*, the establishment of the Ecological Society of America's student natural-history awards, and the inclusion of a field-natural-history column in *Ecology* are positive steps toward professional validation of field study.

**Redefining “the field.”** Opportunities for discovery and learning exist wherever an individual's attention is captured by nature (Dijkstra 2016). Therefore, igniting a resurgence in field-based teaching may require expanding the concept of “the field” to include the anthropogenically altered landscapes that are most accessible to instructors. The use of urban neighborhoods, farms, zoos, or botanical gardens for field-based instruction offers several benefits. For example, by acknowledging that such landscapes harbor complex natural ecosystems that can serve to answer important biological questions, instructors help students who have grown up in these environments to re-envision them as “natural.” This counters the notion that nature and wildness are beyond the reach of urban students and promotes connections for all with the natural world (McCleery et al. 2005).

On a more practical level, urban field experiences may often be the only option. The concept of course-based undergraduate research experiences speaks to the feasibility and value of integrating the (urban) field into large classroom settings (Corwin et al. 2015). For example, establishing a series of long-term observational and experimental plots on or near campus may facilitate field-research opportunities for hundreds of students while creating long-term data sets that can be used to enrich classroom teaching and connect students more directly to their urban backyards (Mauchline et al. 2013). Expanding the field to include the entire urban-wilderness continuum should facilitate concept-based field courses that examine a wide range of biological topics and that allow the exploration of numerous emergent human-environment themes, such as urban geomorphology (Thornbush 2015), biophilic design (Hartig and Kahn 2016), trophic rewilding (Svenning et al. 2016), and ecosystem novelty (Radeloff et al. 2015). To realize this potential, we urge biologists to redefine “field study” to include all educational experiences that incorporate direct experience with elements of the natural environment.

**Invitational learning.** One of the most powerful experiences a student can have is the transformational moment when an instructor's passion for the natural world becomes their own. These pivotal events are *invitational* in that an experienced individual with a deep sense of place invites a newcomer to adopt that same landscape. A field instructor plays multiple roles: natural historian, observer, experimentalist, theoretician, translator, teacher, mentor, and risk manager. The challenge is to fulfill these roles while extending a broad invitation to students. Topics that entice some students may be distasteful to others. Even the language used to name a place may influence the breadth of the invitation if it evokes

a particular cultural history that is not shared by all students (Savoy 2015). Therefore, to increase participation in field experiences, instructors must ensure that their invitations to students are as inclusive as possible.

Contemporary field biologists stand on the shoulders of intellectual giants, including Darwin, Wallace, Leopold, MacArthur, Wilson, and Paine. Making field biology an invitational experience for all students requires attention to who teaches field courses and how they are taught; both are critical to translating the ideas of these consummate but primarily white male scientists into experiences that are of interest to a wide range of students. Field educators, even as they effectively share passion, knowledge, and their approach to learning, need to be receptive to change and to new strategies for broadening and deepening participation in field science. For students with little experience of the theory or reality of nature, building initial exposures around issues that are directly relevant to their culture and worldview can increase interest and motivation (Barnett et al. 2006). Efforts to recast traditional academic perspectives through other geographic and cultural lenses have the potential to pay huge dividends in terms of increasing undergraduate interest in and commitment to field study and its many benefits (Mogk and Goodwin 2012, Robertson et al. 2015).

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