The Activities and Importance of International Field Stations

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Field stations worldwide are valuable resources for the discovery of natural phenomena, education and enlightenment of students, and training of the next generation of field scientists. Field stations face the pressures of human population expansion, habitat and biodiversity loss, and changing environmental conditions, and hence are sentinels of the state of our precarious Earth. We demonstrate the importance of field stations by describing developments supported by field stations and by examining recent literature. Eleven percent of papers published in Conservation Biology *and 26% of those published in* Ecology *were supported in some way by a field station. We review data supplied by field stations over the last 20 years about stations' ecology, dominant discipline, personnel, and infrastructure. Communication among international field stations is difficult and could be improved by the formation of more regional networks. An international network would help elevate the recognition of the importance of field stations.*

Keywords: field stations, international, ecology, infrastructure, personnel

And it appears to me that doing what little one can to increase the general stock of knowledge is as respectable an object of life as one can in any likelihood pursue.

—Charles Darwin in a letter to his sister while at Maldovado, Uruguay, 22 May 1833 (Keynes 2000)

We believe field stations around the world are important because they are sentinels of our Earth's environment, biodiversity, and climate. Our purpose is to present an overview of the importance of field stations' support of research, conservation, and education; to discuss the activities and operations of marine and terrestrial field stations; and to promote the establishment of more regional field station networks so that a truly international network may emerge. We examine the importance of field stations by highlighting the careers of four researchers who were influenced by field stations earlier in their careers. We also review issues of the journals *Conservation Biology* and *Ecology* to determine what proportion of work was influenced by a field station. We discuss the activities of field stations by reviewing information submitted by stations to the International Organization of Biological Field Stations (IOBFS) over the last 20 years. Finally, we present information on field station networks and call for the formation of more regional networks that may result in a more effective international organization.

Kofoid (1910) reviewed work at dozens of European field stations, a *BioScience* article by Whitesell and colleagues (2002) explored field station activity in tropical regions, and Dolan (2007) discussed the histories of several European stations that Kofoid (1910) had covered. In the United States, Lohr and colleagues (1995) reviewed field station and marine laboratory activity. We present close-up views of four international field stations in the boxes accompanying this article. We chose these stations because they represent the range of activity and habitats of field stations and because they are familiar to us. We intend no slight to any other field station.

Humans have been observing nature since the beginning of recorded history, and, if cave art is any indication, since our species first evolved. Naturalists aboard ships involved in exploration—a young Charles Darwin among them—were the first to begin to document globally the Earth's ecosystems and biodiversity. Their ships were their research stations. Darwin's trip changed forever how we view ourselves and our world (Darwin 1859).

The materials amassed by naturalists on explorations were the foundation for new museum collections. The study of natural history evolved into the scientific disciplines of evolution, ecology, animal behavior, biogeography, and others during the 1900s. Field stations on land became places where hypotheses about these subjects could be tested. Dolan (2007) reported that at marine stations in Europe, earlier descriptive work was

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followed by studies of embryology, physiology, and oceanography, and these were followed by the addition of genomics and remote sensing.

The objectives of international field stations mirror those of US stations, with emphases changing in accordance with the state of the nation's development, climate extremes, age, and population pressures. These shared objectives are research, education, preservation, and community interaction. Field stations attempt to provide an opportunity for free and open inquiry, foster a culture of scientific research, offer a secure outdoor facility with appropriate infrastructure, and present unique educational opportunities. The degree to which field stations afford these opportunities varies, depending on their long-term goals and extrinsic pressures (population, poverty, war).

We have two answers to the question, What is a field station? For membership in the IOBFS, an entity must have expressed interest in the objectives of the organization. We were liberal here because we wanted to be sure to include any entity that considered itself a field station. We included agricultural stations because in many countries those are the only stations present.

To demonstrate the importance of field stations, we used a manifold approach in our review of the literature. First, if an entity referred to itself as a field station, we accepted this at face value. Second, an entity had to conduct research on its property or on property associated with it—for example, a station may have been established to do work in a national park. Third, there had to be some sort of infrastructure, especially for housing researchers; the housing and research site did not have to be on the same property, however. We did not include research conducted in parks, preserves, or reserves unless mention was made of logistical support, which we assumed meant housing. When we were unsure, we did not include the entity in our tally. We are certain our definitions of a field station will not please everyone.

The importance of field stations

We give brief examples of how research conducted at field stations helped the development of four scientists. We then review issues of the journals *Conservation Biology* and *Ecology* to tally work conducted at or supported by field stations. We mention these particular researchers because their work, which had an impact on human understanding, began at field stations and because that work illustrates the role serendipity may play in research at field stations.

Both Eugene Odum (University of Georgia) and Donald Griffin (Harvard University) worked on the Edmund Niles Huyck Preserve and Biological Research Station (Rensselaerville, NY) in 1938. At the preserve, Odum produced an energy budget for overwintering birds (Odum 1942, 1945). Odum's later work built on his interest in energy budgets and applied that concept to entire ecological systems, later called ecosystem ecology (Odum 1989). Griffin, as he told one of the authors of this article (R. L. W.), came to the preserve as a summer researcher with a project already in mind. As often happens with field research, he discovered that his idea was not feasible. While sitting on the back porch of his cabin, he noticed bats emerging from the attic and then flying about in the dark. This serendipitous observation led him to study bats and determine that they produce and hear high-frequency sounds used in echolocation (Griffin and Galambos 1941).

Peter Grant (Princeton University) first went to the Galápagos more than 30 years ago, when the Charles Darwin Research Station was just beginning (see box 1). Grant's work on the Galápagos finches is one of the best demonstrations of evolution in action and of the roles of a variety of selective agents (Grant 1975, Grant et al. 1975, Grant and Grant 2006). He said he chose the Galápagos finches because of their relative tameness and the simplicity of their undisturbed habitat (*www.eeb.princeton.edu/faculty/grant_p*).

Thirty years ago, Nalini Nadkarni (Evergreen College) began work on canopy-dwelling plants at the Mondeverde Field Station in Costa Rica (figure 1), with logistical support from La Selva Field Station (see box 2; Nadkarni 1981, 1984). Her work revealed the importance of forest canopy plants to forests' tree nutrient cycling. She is the cofounder of the International Canopy Network, and recently received a Guggenheim Foundation grant to introduce ecosystem ecology to nontraditional students (Nadkarni 2007). We are sure many other field stations could yield similar stories.

We determined which papers in *Conservation Biology* and *Ecology* were supported in some way by a field station by checking the authors' addresses, the methods section, and the acknowledgments in each paper published in 2005 and 2006. We believe our calculation of the number of papers supported by a field station is an underestimate because many papers in *Conservation Biology* and a few in *Ecology* are reviews of literature, model developments, and meta-analyses that no doubt contain data gathered with the aid of a field station. We did not count reviews and meta-analyses as work done with station support, but they are contained in the total number of papers.

During the two-year period, 417 papers were published in *Conservation Biology,* of which 46 (11%) mentioned a field station or field station–like entity. In *Ecology,* 674 papers were published, and 177 (26.3%) mentioned field station support in 28 countries.

What are field stations like globally?

The following data and summaries have been gathered over the last 20 years as an ongoing activity of the IOBFS (*www.iobfs.org*). The IOBFS began in 1989 with the goal of helping international field stations much as the OBFS does in the United States, that is, by fostering field research and education in the biological sciences (Wyman et al. 1997). To achieve this goal, author R. L. W. asked field station representatives to answer a questionnaire about the station's ecology, programs, infrastructure, and challenges. Over the years, we have gathered information on more than 200 field stations. Tallied examples in this article total between 90 and 201, depending on which questions were answered. We estimate

Box 1. Charles Darwin Research Station, Galápagos, Ecuador.

The Charles Darwin Research Station (CDRS) is on the equator 1560 kilometers west of Ecuador, in the Galápagos Archipelago. The archipelago, which is a UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage site, consists of 13 main islands, 6 smaller islands, and 107 rocks and islets. The station is run by the Charles Darwin Foundation, established in 1959 by the IUCN (International Union for Conservation of Nature) and UNESCO. The foundation is a nonprofit research organization whose purpose is to provide scientific research, technical assistance, and information to ensure conservation success in the Galápagos. The foundation partners with the Galápagos National Park Service to help preserve this living laboratory of evolution.

The CDRS, located on Santa Cruz Island, was built between 1960 and 1964. More than 100 scientists, educators, volunteers, and staff work at the station. More than 90% of the staff members are Ecuadorian, and the station has a long-term commitment to training Galápagos residents to become leaders in science and conservation. CDRS teams are also based in Puerto Baquerizo Moreno (San Cristóbal Island) and Puerto Villamil (Isabella Island). The objectives of the station are research, education, conservation, and working with the local populations to ensure the conservation of the environment and biodiversity of the archipelago.

Galápagos island iguanas sun bathing near the Charles Darwin Research Station. Photograph: Heidi Snell/ Visual Escapes.

The Galápagos is known for its array of endemic species of plants, invertebrates, and vertebrates. Most land is covered by arid, semi-desert xerophytic vegetation, but a few islands are high enough to support humid tropical vegetation. About 500 endemic plant species are present. Noteworthy vertebrate species include the Galápagos Island iguanas (see the photograph), blue-footed booby, waved albatross, the Galápagos tortoise, sea lions, and a variety of ground finches.

The history of the islands as a port of call for early shipping and exploration and recent human population growth have contributed to the islands' conservation needs. The human population on the five inhabited islands is about 40,000. Early explorers introduced goats, rats, donkeys, cattle, and dogs, among other animals. Some 700 species of plants have been introduced.

Research often focuses on systematics and evolution because the islands are young (< 10 million years old) and much of the fauna and flora have been found to be actively evolving. The work of Peter Grant and B. Rosemary Grant on the ground finches is a notable example of such research (Grant and Grant 2006). Much research focuses on conservation and the control and eradication of aggressive alien species.

The guiding principles to achieve the mission of the conservation of the environment and biodiversity on the Galápagos Islands center on ecosystem management. People are a vital part of the ecosystem and hence the CDRS works to build long-term options for the inhabitants as a critical component of effective management.

there are more than 1000 field stations worldwide, excluding those in the United States. We compare our results where appropriate with those of Whitesell and colleagues (2002), who reviewed activities at tropical field stations.

One surprising fact, also noted by Whitesell and colleagues (2002), is that it is difficult to communicate with international field stations. For example, we mailed more than 450 surveys to field stations for which we had addresses in 1993, and 120 were returned by postal services because the field station could not be located. Another 100 or so of the questionnaires resulted in no response. Since 2000, the field station questionnaire has been available online. Field stations tend to form and then dissolve, depending on the energy and leadership of single individuals, which makes it difficult to know exactly how many field stations exist at any one time (also noted by Dolan [2007] for European stations). There is also a tendency for field stations to change identity, such as when government stations studying forestry change to ecology stations after forests are cleared and forestry activities cease.

The continuum of technology development and the growing complexity of scientific focus at field stations largely depends on the economic circumstances of the country or region and its degree of development (boxes 3, 4). As mentioned earlier, during the 1900s, field station activity evolved from natural history studies and collecting to studies of ecology, evolution, and animal behavior, and then to ecosystem studies, genomics, and conservation biology (Dolan 2007). Much of this diversity in areas of study still exists today among global field stations. For instance, many countries in Africa have only agricultural stations whose work involves crops or other plants and animals of regional importance. In South America, the study of cattle is often the focus of study, and in Saudi Arabia, it is palm trees. The Organization of Tropical Studies, representing three field stations in Central America (box 2), focuses on advanced topics in ecosystem ecology and is well funded; these three stations are exceptions and not the rule.

Field stations are facing mounting challenges and pressures on many fronts. Earth's 6.7 billion people, who use about one-half of Earth's primary productivity, affect climate, biodiversity, and ecosystem services; place pressures on field stations; and create a sense of urgency in field stations' activities. Field stations monitor and report on ecological matters such as the effects of climate change, and are sometimes in the midst of the resulting chaos.

Respondents to our questionnaire (n = 201) reported dominant field station interests to be research (46.8%), education (27.8%), and preservation and conservation (24.5%). These interests are not mutually exclusive because stations could list all three interests. Of 194 responses on field stations' research area, freshwater studies dominated, with 22.7% of stations listing their major focus as freshwater, lakes, rivers, and water. Whitesell and colleagues (2002) reported freshwater studies to be the dominant activity at 17.5% of tropical field stations. In our study, ecology was listed by 19.1% of field stations and forest studies by 9.8%; Whitesell and colleagues (2002) found that ecology was the dominant discipline at 37% of tropical stations. Birds were listed as the focus of work by 6.7%, mainly in Europe. Marine studies represent 5.2% of responses (Whitesell et al. 2002 reported 7.5%), followed by mammals (4.2%) and tropical systems (4.1%). Agriculture, animals, soils, and ecosystems each were reported by 3.6% of field stations. Agroforestry represented 2.1% (Whitesell et al. 2002 reported 6.1%) of responses. Studies having to do with people (such as ethnobotany, ethnology, and indigenous people), but excluding agriculture, were mentioned by only 1% of field stations. Including agriculture, cattle, and sheep, 6.7% of field stations mentioned human activities as an area of primary focus. Oddly, only 1.5% of responses listed climate change as an area of study (Whitesell et al. 2002 reported 2%), although that percentage may have grown recently.

Field stations occupy all major ecosystems on Earth (table 1), although we have not had any responses from Antarctica, where there are more than a dozen field stations. The main habitat of field stations was most frequently listed as freshwater (33.1%). Forests were the second most-often mentioned (26.3%; Whitesell et al. 2002 reported 50.5%), and agroecosystems were third (11.6%). Interestingly, 11.6% of field stations were in agroecosystems, but only 2.6% of the respondents mentioned studying agroecosystems.

The amount of land that field stations listed as available for study varied from none to 4.9 million hectares (ha), the latter being a national park. We calculated the average area available (after eliminating parks and reserves) to be 335 ha, and the total, 31,205 ha (n = 93). Twenty-four field stations claimed no land as their own. It is difficult to determine whether field stations actually owned land or simply had access to it, because their institutional affiliation may have precluded actual ownership by the field station entity. One third of field stations listed the government as their main affiliation (34.4%). For 26.1% of the field stations, nongovernmental organizations were their major affiliation, and universities were the main affiliation of 35.4%. The final category of "other" (4.1%) was listed as unknown (n = 4) or the United Nations (n = 1). Kofoid (1910) and Dolan (2007) both remarked that a close association with a university appeared to be a peculiarity of US stations, and that in Europe, the government was often the chief benefactor. Dolan (2007), however, revisited some of Kofoid's field stations and found a growing shift in Europe to field station affiliations with universities.

Figure 1. Nalini Nadkarni, with a mouthful of samples, hanging from her climbing gear in the Mondeverde cloud forest, Costa Rica. Photograph: David Robertson.

Table 1. Habitat types listed as the focus of study by 201 field stations worldwide.

Habitat type	Number listed	Percentage
Agroecosystem	43	11.6
Desert	12	3.2
Estuary	18	4.8
Forest	98	26.3
Grassland	24	6.5
Marine	25	6.7
Shrub	20	5.4
Tundra	9	2.4
Water	123	33.1
Total	372	100.0

Note: Categories are not mutually exclusive.

Box 2. The La Selva Station, Costa Rica.

The La Selva Biological Station, owned and operated by the Organization for Tropical Studies since 1968, is located in the Caribbean lowlands of Costa Rica. Each year, researchers, students, research assistants, and ecotourists account for approximately 36,000 person-days of station use. The property consists of 1650 hectares (ha) of mainly old-growth rainforest. About 100 university-level courses are offered annually, and 300 scientists work at La Selva on various ecological projects. More than 3000 publications have resulted from work at La Selva, and about 130 more are added each year.

Forty years ago, almost the entire watershed area was forested. Since then, the landscape has undergone considerable fragmentation, particularly north of La Selva, as a result of human population growth and expanding cattle ranching, banana plantations, and, most recently, pineapple fields.

To the south, La Selva borders the 45,000-ha Braulio Carrillo National Park. The area supports a host of plant and animal species including several species of large cats (see the photograph). The La Selva-protected area complex (more than 100,000 ha) spans an elevation gradient from 40 to almost 2900 meters above sea level. This is the largest elevation gradient with strict protection status in Central America.

*A panther (*Panthera onca*), possibly on the trail of a tapir, which also tripped the camera trap. Photograph provided by the Voplcan Barva TEAM Project–Costa Rica as part of the TEAM Network of Conservation International, funded by the Gordon and Betty Moore Foundation.*

La Selva is within a two-hour drive of the San José International Airport. The station has 150 beds, wireless Internet access, digital databases, air-conditioned offices, 60 kilometers of trails, as well as a library, geographic information system (GIS) lab, shade houses, and various other laboratory facilities. There is a full-time lab manager, transportation and purchasing services personnel, informatics and GIS managers, and full-time nature guides and taxonomic experts. The station's development into a premier facility owes much to the financial support of the Andrew W. Mellon Foundation and the National Science Foundation.

An important asset of La Selva is the long-term nature of its projects and data records. La Selva has 45 years of weather records and a history of scientific research beginning in the days when the property was the private reserve of Leslie Holdridge. La Selva is one of the very few places in the tropics where scientists can find reliable data on changes in the system. For example, the minimum nighttime temperatures are higher now than they were 45 years ago, and there are fewer leaf litter frogs, lizards, and forest-interior insectivorous birds.

Another of La Selva's valuable assets is the well-trained corps of parabiologists—local field technicians with highly specialized skills in data collection and field identification of plants and animals. The approximately 40 field technicians who are employed at the station help the scientists in the field or manage projects for visiting investigators. Any new scientist can hire a talented assistant who knows the forest, Excel databases, and basic English. La Selva is an important training ground for the next generation of tropical scientists because dozens of graduate students from around the world base their thesis work at the station.

The challenges of operating La Selva result in part from the long-term nature of research and data collection done there. Maintaining a consistent and reliable meteorological record through funding shortages, lightning strikes, and personnel changes has been no easy task. Although the scientific productivity of the station owes much to large ongoing projects, it is extremely difficult for researchers to maintain long-term funding in a system of short funding cycles. In a world increasingly concerned with global-scale ecological changes, La Selva must be a player on an international scale; the International Organization of Biological Field Stations may be helpful here.

We asked about scientific and technical staff at field stations. The size of the scientific staff varied from 0 to 67 people (the latter at a government institution in Europe). Technicians varied between 0 and 235 (the latter at an agricultural station in Africa). The average was 8.3 scientists and 10.1 technicians. Twenty field stations had no scientists and 15 had no technicians. For all field stations for which we have data, there were 799 scientists and 970 technicians, for a total of 1769. Even considering that we know about only a small percentage of international field stations, the total number of people at field stations is small.

Visiting scientists at field stations come and go erratically, and hence we could not generate statistics. Field stations reported no visitors, a few, dozens, and hundreds (box 2); the exact number depended on grants and changing circumstances (e.g., the death of a key figure). The trend in colleges and universities is shifting from field studies of whole organisms, ecology, and animal behavior toward molecular

Box 3. Kioloa Field Station, New South Wales, Australia.

The Kioloa Field Station, on the campus of the Australian National University (ANU), is located on the southern coast of New South Wales between the villages of Kioloa and Bawley Point (see the photograph). The station is funded by the university and with revenue raised through its business activities, which cover all operational costs. The staff of the station includes an executive officer who is based on the main campus in Canberra and a station manager, a caretaker, and a half-time administrator based at Kioloa. The Kioloa village was built to house foresters early in the 20th century, and many of the buildings now at the field station are refurbished mill cottages.

The station's 1.2 kilometers of surf beach and dunes occupy a complete drainage basin. The Murramarang Range is the western boundary, and sclerophyll forest dominated by eucalypt species with rainforest remnants cover this part of the field station. The casuarina species, coastal heath, and mangroves that grow closer to the coastline provide habitat for more than 140 species of birds, including the endangered glossy black cockatoo and powerful, masked, and sooty owls. Many marsupial species reside in the forests on the upper portion of the field station, including greater and feathertail gliders and ringtail, brushtail, and pygmy possums. The station contains a range of archeological sites, including coastal middens, that date back more than 25,000 years.

*View of the main drive at the Kioloa Field Station, Australia, with newly planted bottlebrush bushes (*Callistemon *sp.), visitors' housing on the left and the Pacific Ocean in the background. Photograph: Richard L. Wyman.*

The Kioloa Field Station offers cottage and dormitory accommodations for 90 people, and two community buildings with kitchens and dining and meeting spaces for up to 90 people, in addition to a laboratory with research and meeting space. All the buildings, including the cottages, have Internet access.

The Kioloa Field Station's objectives are to offer undergraduate field courses, research and monitoring programs, workshops, and small conferences. The facilities are also used to stage local concerts and celebrations, and they become the command center during bush fire emergencies in the district.

Kioloa is representative of many stations the world over: it is set in a beautiful, pristine environment, and it is an ideal locale for teaching and research activities in the natural sciences. The opportunities for long-term monitoring programs and conservation initiatives are abundant. The existence and evolution of both the Oceanic Research Station Network and the International Organization of Biological Field Stations have been beneficial for field stations, allowing tried and tested solutions to a host of logistical and operational issues to be shared among all field stations, an outcome that is both efficient and practical.

biology and genetics, and this same trend affects the types of visiting scientists at field stations (Dolan 2007).

We queried field station representatives about the infrastructure at their stations—including laboratory and sleeping space (beds)—and their ability to support visiting scientists and students. We found the number of beds available to be particularly informative, because most respondents said a laboratory was available but they provided little detail. Available beds ranged from 0 to 150. Institutions with large numbers of beds were invariably associated with universities, and the beds were predominantly for students (i.e., dorm-style accommodations). The total number of beds for 96 field stations was 2800, for an average of 29.1 beds per station. Infrastructure also reflects the age of the field station. The total infrastructure of one of the newest field stations, begun in 2005, consisted of three tents.

Wishes and needs of field stations

Field stations are often located in important, unique habitats, and thus are well placed to monitor those habitats. They may provide data and knowledge on the functioning of natural systems and on threats to those systems. Because threats to habitats around field stations are representative of threats to habitats globally, field stations are of strategic importance to governments globally. To perform their strategically important roles of monitoring, research, and education, field stations require support that is stable and as independent as possible of the erratic whims of governments.

Box 4. Motupore Island Research Centre, Papua New Guinea.

The Motupore Island Research Centre (MIRC), established in 1970, is the University of Papua New Guinea's dedicated marine and coastal research unit. The MIRC is on Motupore Island in Bootless Bay, off the eastern Hiri coast about 15 kilometers (km) southeast of Port Moresby, the capital and international port of entry to Papua New Guinea. Motupore Island is within the Papuan Barrier Reef, the lagoon of which is a submerged ancient coastal plain whose outer margin is defined by an impressive reef some 5 km offshore, paralleling Papua New Guinea's coast to the southeast, a reef system hosting up to 3000 species of fish and 3000 species of corals.

The small hilly island of Motupore is about 800 meters (m) by 280 m (20 hectares). Most tropical marine nearshore habitats are present between Motupore Island and the barrier reef, including a variety of reef types (fringing, patch and barrier), seagrass and algae beds, mangroves, and extensive intertidal and sublittoral carbonate and mud areas (see the photograph). The terrestrial vegetation on the island is mainly eucalypt savannah. Work at the MIRC includes marine sciences, archaeology, geology, anthropology, botany, and entomology. In the past two decades, research has included studies of marine biodiversity, giant clam culture, seagrass and mangrove ecosystems, the medicinal properties of coral, prehistoric trade, botany, atmospheric science and climatology, as well as marine and coastal resource management. With the recent establishment of the Motupore Island Marine Biodiversity Unit, supported by the David and Lucile Packard Foundation, the MIRC's present focus is on marine biodiversity.

*Poisonous scorpionfish (*Scorpaena *sp.) on a reef near the Motuore Island Research Center, Papua New Guinea. Photograph: David Harasti.*

The objectives of the MIRC are to support and develop research conducted by staff and visitors, and education, academic, and research conferences and meetings. The MIRC's facilities include staff housing, a self-catering hostel with sleeping quarters for 24 people (4 to a room), a conference and lecture room, a marine studies library, study hall and staff office space, and a dry and wet laboratory. The station also has four fiberglass boats, a diving unit with nine full sets of diving gear, and underwater video and photography equipment.

A number of improvements to MIRC would boost the efficiency of its staff as well as its attractiveness to a global research audience. For instance, Papua New Guinea must struggle at times to be heard in the modern age—for example, broadband was introduced only recently into the country. Access to modern technology haunt institutions such as MIRC, which operate under harsh economic conditions, exacerbated further by remoteness. It is extremely difficult to spread the word, engage with peers, and promote a center when your gateway to the information superhighway peaks at 16 kilobytes per second for 15 minutes at a time. Several operational problems affect small, remote field stations, including lack of access to freshwater, a constant and efficient power supply, scientific equipment and supplies, and specialized technical expertise. In a sense, field stations such as MIRC soldier on, at times relying heavily on technical ingenuity (which is considerable, if sometimes flawed), crossed fingers, and going without.

The existence of a body such as the International Organization of Biological Field Stations and the Oceanic Research Station Network can do much to help solve some of these problems. In a practical sense, networks are a forum for discussing common technical problems and providing innovative solutions: they enable the exchange of information on new technologies and access to cheap or secondhand equipment, and they can lead to programs of personnel exchange to augment experience and improve skills. Above all, networks make it possible to speak with others who truly understand the issues that remote field stations face.

Among field station needs, representatives told us, are funding, library resources, geographic positioning technology, and the ability to attract students and researchers (box 4). One of the most compelling requests for help we received came from personnel at a poor African field station who needed writing paper. Most field stations say they would be pleased to have outside scientists visit them. Funding of field station operations (outside of grants) is very difficult to sustain. Often a single wealthy benefactor is (or has been) responsible for keeping the field station viable. Field stations funded by governments or universities often exist at the whim of current administrations and government policy, even when such policies seem nonsensical.

Establishing an international organization of field stations

After 20 years of endeavoring to formalize an international organization of biological field stations, we are able to list problems and impediments. Fair representation leads the list. The number of field stations in countries varies, from one to many hundreds (the United States has more than 300 field stations). Therefore, asking all field stations to be represented as individual entities in an international organization would unfairly bias representation toward countries with large numbers of stations. One solution would be to form regional organizations, such as the OBFS in the United States and the Oceania Research Station Network in the Pacific. Representatives of these regional organizations would then hold membership in the international organization (discussed below).

The fee structure for membership presents another quandary. Field stations occur in the poorest countries on Earth and in the richest. Perhaps a prorated system based on a country's per capita income could be developed, or regional organizations of field stations could provide funding for their stations' membership. To date, the IOBFS has been funded by grants from the National Science Foundation and the Organization of Biological Field Stations, and by support from the E. N. Huyck Preserve and Biological Research Station.

Communication among field stations is another vexing problem. Some field stations appear to exist—they have been mentioned in the literature—but their fate is unknown because posts to them have been returned. Some field stations do not have reliable electricity, making electronic communication erratic or impossible. One goal of the IOBFS is to provide those field stations with alternative electrical-generating capacity.

The lack of a common language at field stations is another impediment to clear and open communication, although most field stations have at least one staff member who can speak some English. We encountered problems earlier when we tried to find volunteers who would, without charge, translate our newsletters into other languages. Web-based translation programs offer some help, but they are inadequate for presenting technical matters.

Last, cultural practices and religious beliefs have been an obstacle both within and among field stations. Long-established cultural practices (hunting, fishing, forestry) may conflict with field station objectives, which could give rise to dangerous situations when the people living near the field station are starving or at war. The town and gown phenomenon (*http://en.wikipedia.org/wiki/Town_and_gown*) appears to be universal. Local inhabitants may be resentful and suspicious of field station motivations, especially when the field station's major affiliation is with the government. Three of the field stations highlighted in the boxes accompanying this article (boxes 1, 2, 4) recognize these kinds of problems and actively strive to help indigenous people through education and employment. These field stations have come to recognize the local residents as important components of the ecosystem. Eugene Odum would be proud.

Other attempts to form international networks that involve research stations include, in the United States, the International Long Term Ecological Research (ILTER) Station network, an offshoot of the Long Term Ecological Research (LTER) Station initiative. The LTER was established by the National Science Foundation so that broad (continental-scale) ecological questions could be addressed. There are 26 sites and more than 1800 scientists involved in the LTER, although most of these scientists are formally associated with a college or university. These stations, all in the United States, tend to be large and well funded. Researchers investigate global change effects, patterns and processes in primary production, decomposition, and population dynamics. So far, the LTER network is responsible for more than 11,000 publications, 9600 of them journal articles.

The ILTER describes itself as a network of networks (*www.ilter.org*). Individual country networks occur in 4 countries in Central and South America, 2 in African countries, 7 in East Asia and the Pacific, and 16 in Europe. In many cases, the Web pages describing these networks are still under development. The Chinese Ecological Research Network (*www.cern.ac.cn*), a centralized field station network comprising 36 stations in China, operates within both the State Environmental Protection Administration and the Chinese Academy of Sciences. Nonetheless, regional organizations do not exist in South America, Africa, or Asia (except for China). Conservation International has received a grant of $40 million from the Moore Foundation for a 10-year period to support the development and operations of 50 field stations in the tropics. This undertaking is just getting under way. Other networks include the Global Terrestrial Observing System (*www.fao.org/gtos*) for terrestrial ecosystem monitoring, the International Canopy Network (*http://academic.evergreen.edu/projects/ican/ican/*), and the International Geosphere-Biosphere Program (*www.igbp.net*). These networks represent the scientific studies around which they were formulated, however, and not the field stations themselves. Among other goals, regional organizations that represent field stations have the potential to raise the prestige of field stations and their work in the eyes of individual countries' governments and populations.

Summary

Field stations worldwide continue to be places where significant advances are made in ecology, ecosystem ecology, animal behavior, evolution, genomics, and conservation biology. Field stations are generally unrecognized for their importance, except by the relatively few scientists who use them. Field stations serve as the training grounds for the next generation of scientists who will deal with the environment in an increasingly stressed world. They also serve as a home for researchers when they are in the field.

In the United States, the OBFS is recognized as the leading advocate for field stations, and it has proved useful in helping the National Science Foundation develop programs to assist field stations with infrastructure development. For the developing world, this kind of help is not currently available. Regional networks of field stations are needed to promote field stations in a particular area. Once these are established, a truly international organization of field stations may emerge and help bring the work of field stations to a broader audience.

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