REPORT IN BRIEF

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE
NATIONAL RESEARCH COUNCIL

BOARD ON LIFE SCIENCES
JULY 2014

Enhancing the Value and Sustainability of Field Stations and Marine Laboratories in the 21st Century

AMID RAPID ENVIRONMENTAL CHANGE, a strong understanding of the natural world is more important than ever. Field stations and marine laboratories place scientists on the front lines of the changing Earth so they can better understand shifting climate and ecosystems and make robust projections of future conditions. Field stations are a critical part of the scientific infrastructure that bring the basic tools of science into the field and connect scientists, educators, and communities to their environments. But to fulfill their vital roles, field stations and their leadership must continue to evolve. This report explores strategies to harness the power and potential of field stations to address complex challenges, by developing stronger networks, establishing more entrepreneurial leadership and planning, and documenting their impacts in science and society.

To understand the workings of our planet—from how a forest responds to wildfire to how climate change is affecting biodiversity—there is no substitute for directly observing the natural world. Field stations and marine laboratories provide the tools to help make those observations possible in almost every environment, from city to mountain, prairie to desert, to forest, river, and ocean.

There are more than 900 field stations and marine labs worldwide.

Although they range in size, scope, and complexity, all field stations are windows into ecosystems that provide unique educational and research opportunities. Field stations engage local communities in observing the natural world and help connect their observations with decision making.

Away from the hustle and bustle of everyday life, field stations foster collaborations among scientists from different disciplines. But the separation that enables focused research and allows creativity to flourish can also mean that field stations are overlooked by their parent institutions and other funding organizations. In challenging economic times, some field stations—especially remote or small ones—are vulnerable to budget cuts and even closure.

If field stations are to thrive in the 21st century and beyond, they will need to become better able to adapt to changing technologies, economic situations, and societal and scientific needs At the request of the National Science Foundation, the National Research Council convened an expert committee to review and assess the roles field stations play in supporting research, education, and public outreach; and to identify strategies to help enhance those vital roles in sustainable ways.

SCIENCE FOR AN UNPREDICTABLE WORLD

In an era of rapid climate change, overexploitation of natural resources, and instabilities in food production, field stations provide vital links to the environment

Box 1 ***An Unexpected Research Opportunity***

Native to South America, red fire ants are invasive pests that cost the United States an estimated $8 billion each year in control, damage mitigation and medical treatment. In 1981, red fire ants invaded the Brackenridge Field Laboratory in Austin, Texas, and inadvertently giving researchers the opportunity to launch an invasive spences research program. Today, the Brackenridge Field Laboratory is an international hub for fire ant research that has generated more than $10 million in research funds and more than 80 publications over 20 years.

Photo credit: John & Kendra Abbott/Abbott Nature Photography

through research, education and community engagement. These connections are more important than ever in understanding, predicting, and modifying the changing relationship of humans with Earth to make them more resilient.

The long-term environmental data gathered at field stations help scientists better understand current changes in ecosystems and climate. Over many years, observations on the timing of leaf budding or the arrival of migratory species allow researchers to document shifting conditions and identify the environmental drivers of change. This historical record allows more robust projections of future change and that can inform policy decisions.

Field stations also foster cross-disciplinary research communities. Field stations stimulate convergence among the various branches of science as well as engineering, humanities, and arts that can help tackle pressing scientific and societal challenges.

PREPARING THE NEXT GENERATION OF SCIENTISTS

Field stations enable hands-on, discovery-based learning for students of all ages and backgrounds. Early research experiences in the field help students build skills such as learning how to develop research questions and gathering data to answer them. Research experiences early in life promote a lifelong interest in science, technology, engineering, and mathematics (STEM) and have been shown influence career choices. Active learning has been shown to help students retain, recall, and apply information. Universities should seek to expand opportunities for student participation in research and active learning programs at field stations, which could boost student interest in science and the environment, and encourage their persistence in STEM fields.

EMPOWERMENT THROUGH PUBLIC ENGAGEMENT

Many field stations have programs that engage the public in science, for example through lectures, workshops, science cafes, citizen science, volunteer opportunities. These engagement activities help connect local communities with their environment and promote stewardship of the natural world.

Technological advances allow citizen scientists to collect field data in unprecedented ways, from relatively simple observational programs, such as eBird or iNaturalist, to coordinated, training-intensive water quality monitoring programs. As well as helping to strengthen public understanding, appreciation, and support of science, citizen science initiatives also contribute much-needed data to researchers. Advances in mobile technologies and geographic information tools allow citizens across the globe to pool data to reveal patterns of change.

Each field station should continue to explore and expand a range of approaches to engage the public in science, tailoring its programs to reflect its unique assets and environmental and societal challenges. Each station should take advantage of empirical knowledge of science communication and informal education research to develop effective public engagement programs. New technologies and networking initiatives provide opportunities to recruit and engage the public in the nation's scientific enterprise as citizen scientists.

NETWORKING FOR DISCOVERY AND INNOVATION

Linking field stations and other organizations to enable data pooling could greatly enhance our understanding of the impacts of a regional drought, an extreme storm, or longer-term environmental change resulting from human activities. More expansive and robust networks would make it easier to share these data in a timely way and transform them into information and knowledge that could aid decision-making. In a time of budget constraints, networking could help field stations share resources to make investments in expensive infrastructure such as tools for data storage and analysis. Networking also promotes the coordination of research and education programs to enhance effectiveness and reduce redundancies.

By providing incentives for networking, universities and funding organizations could encourage collaborations that make scientific, educational, and business

sense. For example, funding agencies could state in program announcements and in requests for proposals that they will give preference to proposals that link multiple field stations.

Networking of field stations can also help build convergence among scholars from different scientific disciplines to foster creativity and innovation, and to fuel more rapid scientific and societal advances. Field-station leaders can facilitate this convergence by organizing research around common scientific and societal challenges, and by embracing the social sciences, the arts and the humanities.

MEASURING PERFORMANCE AND IMPACT

The value of field stations is documented unevenly and, for the most part, anecdotally. There is a dearth of empirical evidence on the contributions that field stations make to research, education, and community engagement. In the absence of aggregated and empirical documentation of their value, field stations are vulnerable to budget cuts. Field stations need to document the roles they play in science and society with better metrics individually and as a community. One way of doing this could be to track the publications based on research from a particular field station using a field-station–specific digital object identifier, or DOI. A digital object identifier is a character string (a "digital identifier") that is used to uniquely identify content and provide a persistent link to its location on the Web. If each future publication based on research at a particular field station cited this DOI, publications from the field station could be easily tracked. In times of shrinking budgets and increased demands for accountability, demonstrating outputs and outcomes is essential to securing long-term funding.

Field stations should work together to develop a common set of metrics of performance and impact that can be aggregated across regions and the entire nation. New mechanisms and funding are needed to collect, aggregate, and synthesize these data.

MODERN INFRASTRUCTURE FOR A NETWORKED WORLD

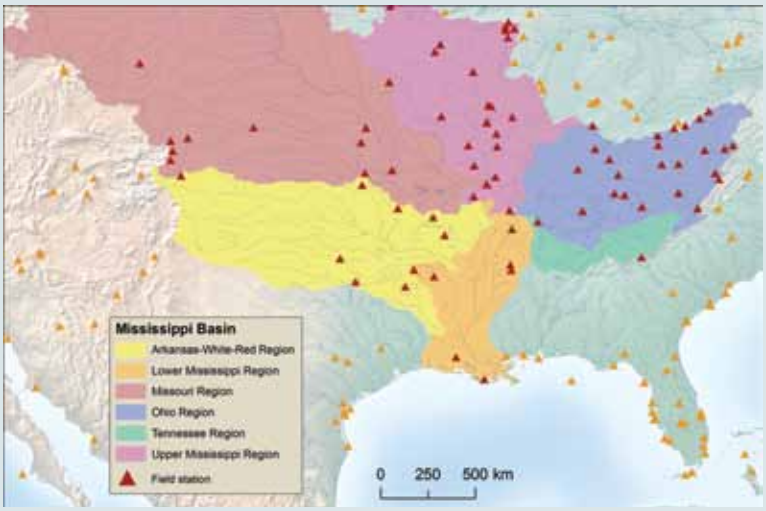
Maintaining and upgrading field station infrastructure—from laboratory space to scientific equipment—is essential to ensuring field stations are equipped to provide scientists with the tools needed for research and education in the 21st century.

Field stations vary greatly in size, scope, complexity, and mission, and therefore each field station needs to assess and define its own infrastructure needs. However the infrastructure needed for data management and internet connectivity, known as cyber-infrastructure, is essential to allow all field stations to build networks and more easily share data. In particular, the process of archiving "dark data"—data that are not currently stored in digitally accessible formats—is critical.

FINANCIAL SECURITY FOR A MODERN INFRASTRUCTURE

Aging infrastructure, the need for current technology and cyber-infrastructure, and evolving safety regulations place increased financial demands on field stations. To be sustainable, many field stations will need to place greater emphasis on good business practices. A business plan that includes a clear, compelling, and comprehensive value proposition is crucial both to secure continuing support from host institutions

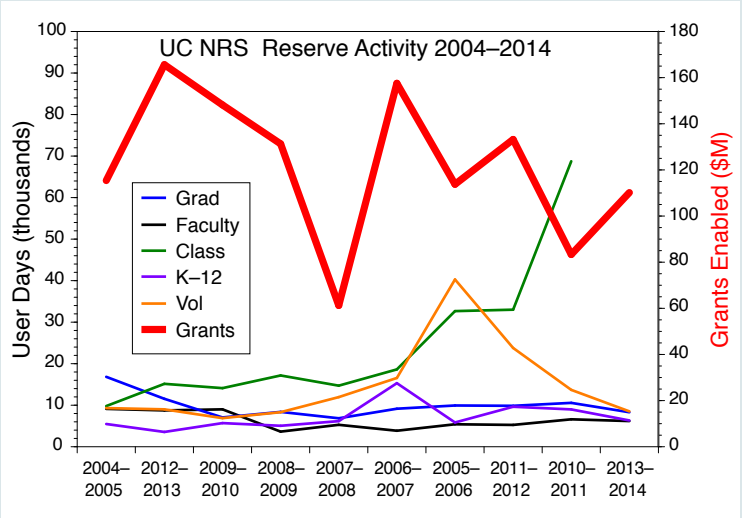
Box 2 ***A Network to Study the "Dead Zone" in the Gulf of Mexico***



In the Gulf of Mexico there lurks a "dead zone"—an area of water so low in oxygen that it is lethal to many of the organisms that live on or beneath the ocean floor. This dead zone is caused by excess nutrients from agricultural lands that runoff into the Mississippi River and are carried to the Gulf, where they cause algal blooms. As the algae decompose, they remove oxygen from the water column. Runoff from agricultural land is exacerbated by the loss of forests and wetlands that help retain sediments and absorb nutrients. Building a network among the many field stations located in the Mississippi River Basin and along the coast could help scientists gather and share data to better understand the connections between the region's freshwater and marine systems.

Box 3 ***University of California Natural Reserve System: Gathering Metrics***

Created in 2000, the Reserve Application Management System (RAMS) helps track the use of the University of California Natural Reserve System's 39 field stations for easier reporting to funders such as campus administrators, and private sector, state, and federal agencies. Before they are granted access to the reserves, researchers are asked to provide information such as the project, an abstract, and funding amounts. Data from the RAMS system show that from January 2010 to January 2013, 26,600 people used the reserves, generating 683 peer-reviewed journal articles, books, and book chapters and $386.4 million. in research grants. These metrics could, when combined with outcome metrics, more effectively demonstrate field stations' contribution to research and education.



and to develop new and diverse sources of funding. Furthermore, station leaders should be recruited and evaluated not only for their scientific credentials, but also for their leadership, management and entrepreneurial skills. Mentoring of field-station leaders would help them develop and hone management, business planning, and fundraising skills.

LOOKING FORWARD

Field stations play a critical role in science and society by connecting researchers, students, and communities with each other and with the environment. These valuable resources are poised to help scientists better understand the shifting climate and nature's responses, and to create the information and knowledge we need to conserve our ecosystems and quality of life. But in an era of budget constraints, reaching these goals will take business acumen as well as scientific expertise. Through networking, incorporating more entrepreneurial leadership and developing new metrics of performance and impacts, field stations can meet the challenges of a rapidly changing world.

Locate additional information, including related reports, at http://dels.nas.edu/bls
Read, purchase, or download a free PDF of this report at http://www.nap.edu

Committee on Value and Sustainability of Biological Field Stations, Marine Laboratories, and Nature Reserves in 21st Century Science, Education, and Public Outreach: Jerry R. Schubel (*Chair*), Aquarium of the Pacific, Long Beach, CA; **Felicia C. Coleman,** Florida State University Coastal and Marine Laboratory, St. Teresa; **Cathy Conrad,** Saint Mary's University, Halifax, Nova Scotia, Canada; **Diane Debinski,** Iowa State University, Ames; **Peter M. Kareiva,** The Nature Conservancy, Seattle, WA; **George I. Matsumoto,** Monterey Bay Aquarium Research Institute, Moss Landing, CA; **Diane M. McKnight,** University of Colorado Boulder; **Camille Parmesan,** Plymouth University, Plymouth, UK, and University of Texas, Austin; **Robert Plowes,** University of Texas Brackenridge Field Laboratory, Austin; **Alison G. Power,** Cornell University, Ithaca, NY; **Mary E. Power,** Angelo Coast Range Reserve, University of California, Berkeley; **Mark R. Stromberg,** University of California Natural Reserve System (*retired*), Sonora, AZ; **Keegan Sawyer** (*Study Director and Program Officer*), **Claudia Mengelt** (*Senior Program Officer*), **Laurence Yeung** (*Christine Mirzayan Science & Technology Policy Fellow, until April 2014*), **Lauren Soni** (*Senior Program Assistant*), **Norman Grossblatt** (*Senior Editor*), National Research Council

The National Academies appointed the above committee of experts to address the specific task requested by the National Science Foundation. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

For more information, contact the Board on Life Sciences at (202) 334-3514 or visit http://dels.nas.edu/bls. Copies of *Enhancing the Value and Sustainability of Field Stations and Marine Laboratories in the 21st Century* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.