American Tropics

INTRODUCTION

From Tropicality to Biodiversity

The problems of human beings in the tropics are primarily biological in origin: overpopulation, habitat destruction, soil deterioration, malnutrition, disease, and even, for hundreds of millions, the uncertainty of food and shelter from one day to the next. These problems can be solved in part by making biological diversity a source of economic wealth.

—Edward O. Wilson, 1988

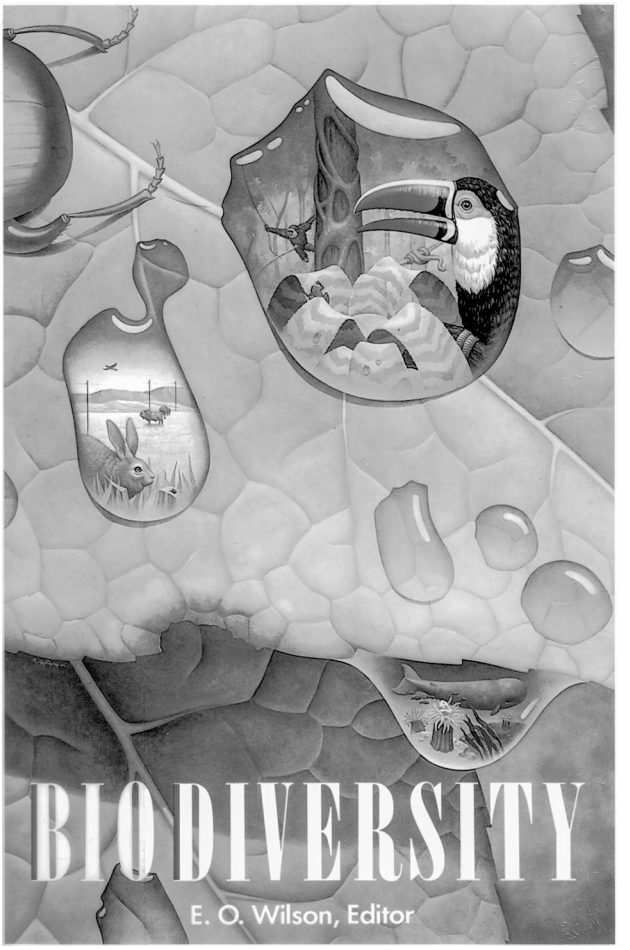
In September 1986, sixty scientists and policy makers convened for the "National Forum on BioDiversity" in Washington, DC. The conference, organized under the auspices of the Smithsonian Institution and the National Academies of Science, included some of the biggest names in the U.S. science and conservation communities, Edward O. Wilson, Thomas Lovejoy, Paul Ehrlich, Peter Raven, Stephen Jay Gould, and Michael Soulé among them. Although it was a U.S. "national" forum, its ambitions were decidedly global. As each speaker came to the podium, a picture of a worldwide extinction crisis emerged. Together, they made a forceful, and very public, case for the need for more scientific research in support of conservation around the globe. Species were being lost, they warned, before they could even be discovered.[1]

To articulate their cause, the conference organizers coined the term *biodiversity*, which quickly became the rallying cry of the emerging field of conservation biology. As the forum was telecast and participants interviewed by news agencies nationwide, it even became a household word. In a narrow sense, *biodiversity* refers to the number and variety of species in a given area. Although most definitions also include variation within species (genetic diversity) and at the level of ecosystems, the term is often used as a synonym for *species diversity*—the number and relative abundance of species in an area. As a scientific measure, biodiversity offered an important tool for making conservation priorities. The discourse surrounding the term *biodiversity*, however, also helped reinforce the global nature of the conservation problem at hand. At stake, conservationists argued, was not just particular wild places or even individual endangered species; the threat was to the diversity of life on Earth itself.[2]

Nevertheless, one global region dominated the dire stories and statistics that the participants cited: the tropics. A whole session of the forum (the only one delimited geographically) focused on tropical problems. Many of the organizers and participants were specialists in tropical biology, and the institutions hosting the forum were among the country's most important supporters of tropical research. Tropical imagery dominated even the poster that loomed onstage beside each speaker, and that afterward became the cover of the forum's proceedings. On it, water droplets cling to a lush background of greenery, each reflecting images that represent Earth's diverse biomes; the largest drop contains a rainforest whose colorful animal inhabitants peer out at the viewer. This tropical emphasis was not accidental. Wilson reminded his audience that, although tropical rainforests "cover only 7% of the Earth's land surface, they contain more than half the species in the entire world biota."[3] It was also the region most in peril, as deforestation and population growth ran rampant "especially in tropical countries."[4] For this reason, Wilson argued, "rain forests serve as the ideal paradigm of the larger global crisis."[5] The biodiversity crisis might be global, but it was both centered on and symbolized by the tropics, particularly tropical forests.

Significantly, Wilson and the other participants cast tropical diversity not only as threatened nature but also as a natural resource. The uncatalogued species of the world, the vast majority of which lay in the tropics, figured as humanity's most irreplaceable and untapped asset. Tropical nature, they suggested, could be transformed into a source of salvation rather than suffering, thus addressing some of the world's most pressing social and economic problems at their root. With biologists' expertise, the diversity of life could be recognized and valued as "a source of economic wealth," thus effecting development in harmony with conservation at a global scale.[6] This move linked a need for basic research in tropical biology—long an obscure and underfunded field—to some of the most politically significant issues of the day. But how had scientists come to connect the abstract and technical concept of species diversity to the problems of international development? And why did a group of biologists from the north temperate zone insist on moving the tropics to the center of global debates at this historical moment?

The suddenness with which *biodiversity* landed on the lips of policy makers and "Save the Rainforest" appeared on bumper stickers belies a deeper intellectual and political history. Consciousness of tropical biodiversity exploded onto the scene in the mid-1980s, but it was not a new concept to biologists. U.S. scientists' engagement with life in the tropics already stretched back a century. During this time, scientists had struggled with questions of



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the biological differences of the tropics—especially its richness in species—and at the same time entangled themselves in U.S. corporate and government efforts to exploit tropical resources. This book argues that both the key scientific concepts and the values embedded in the modern biodiversity discourse had significant precedents in biologists' involvement in U.S. encounters with the tropical world over the course of the twentieth century, centered on the circum-Caribbean region. From the era of the Spanish-American War and the construction of the Panama Canal through the revolutionary 1960s and

1970s, U.S. biologists sought ongoing access to research sites in the tropics. They found it through a complex set of partnerships and the intertwining of intellectual and economic agendas. *American Tropics* argues that the ideas, attitudes, and institutions forged at field sites in the colonies and neocolonies of the circum-Caribbean are crucial for understanding the emergence of this new paradigm in biology and conservation at the end of the century. Long before the 1986 BioDiversity Forum extended such ideas to the globe, U.S. biologists had begun both to articulate fundamental biological questions raised by the diversity of tropical life and to argue for its potential as a resource.

Biology, Diversity, and the Tropics

Although the word *biodiversity* was new when it appeared in the title and throughout the speeches of the 1986 forum, its organizers did not feel they were doing anything radical by contracting a conventional phrase. *Biological diversity* was already in use, not to mention long-standing formulations like *organic diversity*, or the host of specialized quantifications of species richness and species diversity.[7] Historians and philosophers of biology have referenced such precursors, but their primary focus has been on the use of the term *biodiversity* in conservation circles since the 1980s.[8] In fact, the contemporary conception of biodiversity emerged from much longer-standing scientific efforts to understand the numbers and distribution of species on Earth, and particularly in the tropics. In part, this book argues that tropical biologists played a much more central role in shaping this intellectual history through the twentieth century than scholars have previously acknowledged.

To understand why tropical biology was central to formulating modern concepts of biodiversity, however, we must first understand what constitutes this field of study. What is tropical biology? In one sense, it is simply the study of living things in the tropics—the global region surrounding the equator between 23° 26′ 16″ north and south latitudes. Geographically, the tropics are marked by a near-constant day length throughout the year and climates free from frost (except at high elevations). The nature of biological adaptations to such environmental factors is among the problems that interest tropical biologists. But if tropical biology is a regional specialization, it is also an interdisciplinary field. The biologists who publish in journals like *Biotropica*, *Tropical Ecology*, or *Revista de Biologia Tropical*, who attend the meetings of the Association of Tropical Biology and Conservation or the International Society for Tropical Ecology, or who work at organizations like the Smithsonian Tropical Research Institute or the Organization for Tropical Studies come from the full

range of subdisciplines within biology. They may study particular groups of organisms or focus on biological processes. Their approach may emphasize taxonomy, behavior, physiology, evolution, or ecology—although ecology becomes the touchstone when confronting the complexity of many tropical ecosystems.[9] Tropical biologists are driven by a range of motivations, including curiosity about the puzzles of theoretical biology, a love of fieldwork, or concerns about conservation and resource use. The work that tropical biologists do is nearly as diverse as the ecosystems they study.

Tropical biology is more than a geographic pigeonhole, however. Why are there scientific journals, professional associations, and research institutions devoted to tropical biology while "temperate biology" remains an unmarked category? Historically, the field of tropical biology was demarcated by outsiders. From the European voyages of exploration of the sixteenth century to the overland expeditions of nineteenth-century naturalists, northern visitors to the equatorial regions tended to set the plants, animals, and people they encountered there in comparison with those of their temperate homelands. During the same period, tropical countries developed their own local scientific communities, but whether these chose to designate their research as specifically "tropical" varied. An outsider's perspective thus left its mark on the kinds of questions the emerging community of tropical biologists asked: How does tropical life compare with life elsewhere? Does life in the tropics share qualities that make it unique? Conversely, might the study of living things in the tropics reveal something fundamental about the phenomena of life everywhere?[10]

These are questions with roots that extend far beyond the scientific community. The tropics are loaded with powerful meanings and imagery for outsiders. In the imaginations of Europeans and North Americans, the equatorial regions have figured as an earthly paradise or a green hell. This discourse of tropicality, as identified by cultural geographers and historians, has pictured the tropics as an exotic Other—a place both attractive and dangerous, a realm of unbounded abundance and riotous growth as well as disease and decay.[11] Like Orientalist discourses, this exoticized imaginary geography of the equatorial regions has functioned to justify the colonization and exploitation of its people and environments.[12] In it, tropical people appear backward and lazy, spoiled by the abundance offered by tropical nature, and unable to efficiently develop the resources of their own lands. In popular imaginings, the tropics were—and largely remain—a region of untapped potential. Thus, while *tropical biology* may be defined as "biology in the tropics," the complex, contested cultural meanings of *the tropics* make this far from a simple declaration.

Scientists' views of the tropics have run in tandem with these broader cultural understandings. The narratives of naturalists and explorers like Alexander von Humboldt, Henry Walter Bates, Richard Spruce, Thomas Belt, and Alfred Russel Wallace worked alongside those of other foreign travelers to construct and reproduce the familiar tropes of the tropical. Traveling naturalists saw with "imperial eyes," carrying with them on their journeys prejudices and assumptions shaped by generations of previous visitors.[13] Working within the naturalist tradition, however, they sought to systematize and explain the phenomena they confronted—in ways that often reinforced but sometimes challenged their own preconceptions. Encounters with nature in the tropics sparked some of the most important biological syntheses of the nineteenth century, from Humboldt's plant geography to Darwin and Wallace's theory of evolution by natural selection. To varying degrees, some naturalists were aware of the ways their expectations about life in the tropics were shaped by forerunners' accounts. Darwin acknowledged how Humboldt's descriptions loomed in his mind when he "first saw a Tropical forest in all its sublime grandeur."[14] For others, heightened anticipation of superabundant life led to disappointment when lush vegetation appeared "monotonous" and parrots failed to adorn every tree.[15]

This heavy burden of prior writing led Wallace to open his influential 1878 essay *Tropical Nature* with the admonition, "The luxuriance and beauty of Tropical Nature is a well-worn theme, and there is little new to say about it." What was sorely lacking, he argued, was a serious effort to "give a general view of the phenomena which are *essentially* tropical, [and] to determine the causes and conditions of those phenomena."[16] To replace the "many erroneous ideas" in circulation, Wallace synthesized his own extensive field observations in Malaysia and the Amazon with other reports. As evolutionary theories increasingly provided a framework for such analyses from the late nineteenth century on, this essay became a new starting point for investigations into tropical difference. The basic patterns Wallace described in *Tropical Nature* are still recognized and studied by tropical biologists today; thus, they provide a convenient introduction to the phenomena that would continue to populate the conceptual space of the tropics for biologists during the following century.

First among the general features of tropical vegetation that Wallace recognized was its lushness of growth—in modern terms, the sheer biomass of plant life. In contrast, animal life was inconspicuous and widely dispersed. For both animals and plants in the tropics, however, the "best distinguishing features are the variety of forms and species."[17] He noted the prevalence of

certain types of plant adaptations, including climbing, epiphytic, and parasitic habits; the division of mature forests into layers of canopy and undergrowth forms; and a variety of trunk structures, such as buttressing, that were highly unusual outside of the tropics. Among animals, Wallace found "such a diversity of forms, structures, and habits, as to render any typical characterisation of them impossible," but he did note, for example, some particularly close interrelationships of plants and insects.[18]

Wallace not only enumerated these "peculiar" features of plant and animal adaptation but also described certain broad patterns in the distribution of species at local and global scales that have remained among the central puzzles of tropical biology.[19] Within tropical forests, Wallace contrasted the high number of species with the low abundance of individuals of any one species. This was in no case more evident than among trees: "If the traveller notices a particular species and wishes to find more like it, he may often turn his eyes in vain in every direction. Trees of varied forms, dimensions, and colours are around him, but he rarely sees any one of them repeated. Time after time he goes towards a tree which looks like the one he seeks, but a closer examination proves it to be distinct. He may at length, perhaps, meet with a second specimen half a mile off, or may fail altogether, till on another occasion he stumbles on one by accident."[20] While temperate forests are dominated by one or a few key species, tropical forests are in general characterized by diversity and rarity—no one species dominates. At the same time, Wallace noticed a curious global pattern in species distribution. For most groups of plants and animals, more member species inhabited the tropics than the temperate zone. A genus or family might contain many times more tropical than temperate species. Moreover, the tropics harbored a wide array of groups rarely found or entirely absent in the North—parrots and palms, for example, as well as whole families of insects, reptiles, and amphibians. Oddly, the reverse pattern was extremely uncommon. Whereas pre-Darwinian biogeographers used such regional concentrations of species numbers to posit "centers of creation," Wallace offered evolutionary explanations, notably a "less severe" struggle for existence against "physical conditions" and the historical absence of glaciation in the tropics.[21] This, he argued, had allowed the "comparatively continuous and unchecked development of organic forms" at the equator, leaving the region a "more ancient world."[22] Biologists would continue to debate these proposed evolutionary and ecological causes of tropical diversity over the next century.

The way that Wallace and subsequent researchers imagined the tropics resonated powerfully with broader ideas about tropical exuberance, excess,

and primitiveness. Nevertheless, biologists' views cannot be reduced to such tropes. Tropical biology emerged around a scientific subdiscourse about the characteristics and qualities of tropical life that was also part of broader currents in ecological and evolutionary thought. The specificity of these concerns distinguished (although never freed) scientists' conceptions from the broader discourse of tropicality. Among their key concerns about tropical life was its diversity—its great numbers and variety of species.

This book argues that the articulation of biological ideas about diversity and tropicality went hand in hand through the twentieth century. It examines this relationship particularly as biologists from the United States began to work in the circum-Caribbean and form a professional community of tropical biologists. Biological concepts of diversity have many roots; those that lie in tropical research are especially significant and have been surprisingly neglected by historians. This neglect has obscured the ideas and institutions that laid the foundations for the explosive rise of *biodiversity* at the end of the century.

A Place-Based Science

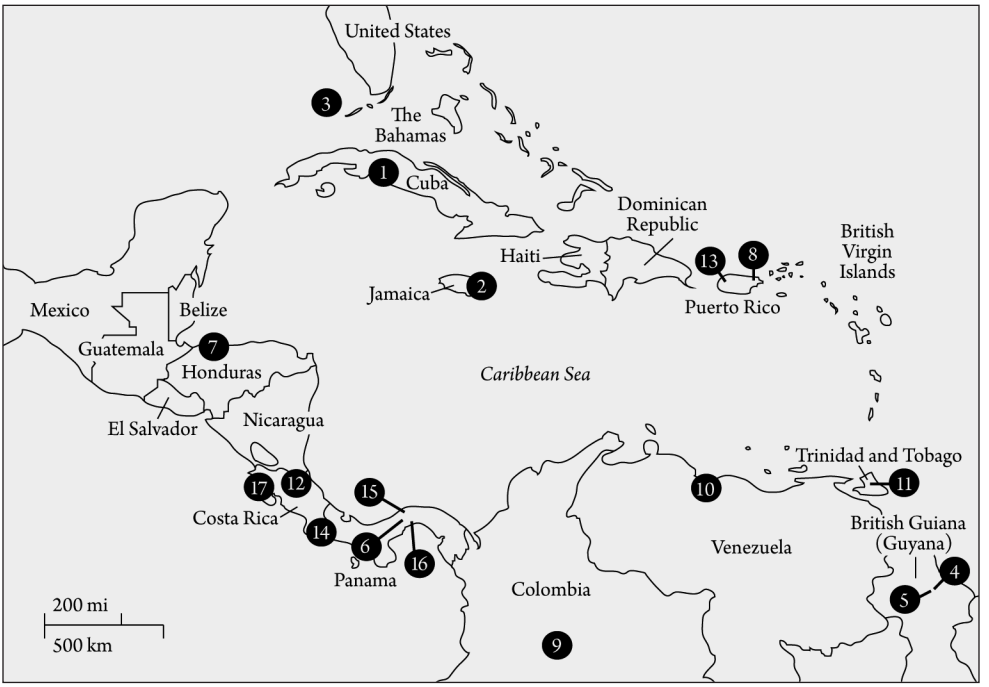
Tropical biology is a place-based science that has historically been practiced by people from outside that place. This central irony has played a profound role in determining the development of the field and its major institutions. For North Americans and Europeans, studying tropical life meant traveling to the tropics. Expeditions allowed northern naturalists to pass through the tropics, bringing back observations and collections of specimens to the metropolitan scientific centers of their home countries. Expeditionary science could reveal the global biogeographic patterns that Humboldt, Wallace, and others commented upon, but it did not permit extended, in situ observations of living tropical organisms and their complex interactions. Understanding the ecological and evolutionary processes that caused the great differences and diversities of tropical life meant not just traveling through but staying in the tropics. It required a more permanent institutional basis, in the form of tropical research stations.[23]

By not only tracing the flow of U.S. scientists into the tropics but also examining how they were sometimes able to take root in place, *American Tropics* contributes to understandings of mobility and knowledge production.[24] Field stations became nodes of scientific migration, giving form to a community of tropical biologists in the United States and shaping its research practices and priorities. As the United States made its first foray into tropical empire at the turn of the twentieth century, so did the nation's biologists,

founding such stations as Harvard's Atkins Institution at Soledad, Cuba (1899); Cinchona Botanical Station in Jamaica (1903); William Beebe's stations in British Guiana (Guyana, 1916 and 1919); and, most notably, the station at Barro Colorado Island (BCI), Panama (1923). While the first professional associations, university programs, and specialty journals in tropical biology did not appear until the 1960s, they emerged directly from a ready-made community centered on stations founded at the beginning of the century. Indeed, we will see in chapter 5 that the final stage in the professionalization of tropical biology was catalyzed by political and environmental threats to long-established research sites.

The U.S. movement to establish tropical stations was part of a larger, international groundswell for stations in the field. The influential marine stations Stazione Zoologica in Naples, Italy, founded in 1872, and Marine Biological Laboratory in Woods Hole, Massachusetts, founded in 1888, have played a significant role in the historiography of biology and American science, signaling the rising prestige of the laboratory and the professionalization of the discipline.[25] Investigations into the relationship between place and practice at field stations were pioneered by Robert Kohler, who approached them as border zones between the scientific cultures of the laboratory and field.[26] Historians of biology have recently begun to examine stations in relation to not only laboratory science but also other institutions and spaces, such as museums, aquaria, parks, and gardens, as well as in the context of a broader set of goals, priorities, and practices.[27]

If, as Raf de Bont notes, field stations have too often been seen primarily as extensions of urban laboratories, then tropical stations have doubly been cast as mere appendages to northern scientific institutions.[28] The Cinchona station, for example, has been discussed as part of the expanding scientific "empire" of the New York Botanical Garden (although its institutional affiliations changed over time), but how the tropical and Jamaican context shaped day-to-day scientific practice there has remained unexamined.[29] Likewise, BCI has been cast as a "failed" attempt to replicate the Naples and Marine Biological Laboratory model, finally saved only by coming under the aegis of the Smithsonian Institution after World War II.[30] Tropical stations have been approached as decidedly peripheral and subordinate to metropolitan, temperate-zone institutions. A significant exception is the pioneering Dutch tropical botanical station known as the Treub Laboratory of the Buitenzorg Gardens, Java, established in 1884, which Eugene Cittadino has argued played a central role in the emergence of Darwinian plant physiology.[31] Buitenzorg, in fact, stood out as the prime exemplar of the possibilities of tropical research



U.S. tropical biological stations, 1899–1969. This map depicts biological stations operated by U.S.-based institutions. Here, *station* denotes a scientific site with facilities and accommodations for permanent or prolonged and repeated research outdoors—not including temporary camps, parks, or other types of research lands—and *biological* research means basic research on living organisms. This does not include strictly agricultural or forestry experiment stations, botanical gardens, or medical laboratories but does include biological stations that contained or emerged from such institutions. Dates indicate when they were operated by U.S.-based institutions. If a station or other institution exists at this site today, its current name is noted.

for U.S. scientists in the early twentieth century, as explored in chapter 1. This history further complicates narratives centered on the dichotomy of lab versus field, because tropical research stations often emerged in relation to (or even on the grounds of) another distinct and venerable institution: colonial botanical gardens.[32] Thus, *American Tropics* examines U.S.-run stations not only in connection with a variety of U.S. metropolitan institutions but also in context with existing scientific institutions in tropical countries.

MAP KEY U.S. Tropical Biological Stations, 1899–1969

1. Soledad station (Also called Harvard Botanical Station for Tropical Research and Sugarcane Investigation/Atkins Institution of the Arnold Arboretum/Atkins Garden and Research Laboratory), Harvard, 1899–1961. (Today the Jardín Botánico de Cienfuegos.)
2. Cinchona Botanical Station (New York Botanical Garden, 1903–1914; Smithsonian Institution, 1916–1921), 1903–1921. (Today the Cinchona Botanical Gardens.)
3. Dry Tortugas Marine Biology Laboratory at Loggerhead Key, Carnegie Institution, 1903–1939.
4. "Kalacoon" Tropical Research Station, New York Zoological Society, 1916–1917.
5. "Kartabo" Tropical Research Station, New York Zoological Society, 1918–1926.
6. Barro Colorado Island (Institute for Research in Tropical America, 1923–1946; Smithsonian Institution 1946–present. Part of the Canal Zone Biological Area, 1940–1966; STRI 1966–present), 1923–present.
7. Lancetilla Experiment Station, United Fruit Company, 1925–1974. (Today El Jardín Botanico y Centro de Investigacíon Lancetilla.)
8. El Verde Field Station, U.S. Forest Service, 1937–present.
9. Villavicencio Yellow Fever Laboratory, Rockefeller Foundation, 1938–1948. (Today the Estación de Biología Tropical Roberto Franco.)
10. Rancho Grande Station, New York Zoological Society, 1945–1948. (Today the Estación Biológica Fernández Yépez.)
11. "Simla" Tropical Research Station, New York Zoological Society, 1949–1974. (Today William Beebe Tropical Research Station.)
12. La Selva Biological Station (OTS, 1968–present), 1954–present.
13. Institute of Marine Biology Laboratory/Isla Magueyes Laboratories, University of Puerto Rico, 1954–present.
14. Las Cruces Biological Station (OTS, 1973-present), 1962–present.
15. Galeta Marine Laboratory, STRI, 1965–present.
16. Naos Island Laboratories, STRI, 1965–present.
17. Palo Verde Biological Station, OTS, 1969–present.

Although they borrowed from established models, tropical stations were varied and heterogeneous. Some emphasized the study of plants over animals or vice versa. They focused on applied or basic science to varying degrees. They were sponsored by universities, zoos, botanical gardens, government agencies, and corporations, as well as through collaborations among such organizations. They incorporated a variety of scientific spaces on site: Soledad housed experimental plots, botanical gardens, and greenhouses, as well as a biological laboratory, and had access to uncultivated land. BCI comprised a forested island nature reserve, laboratory space, herbarium, dark room, and library, as well as buildings and plots of land that might be turned to a variety of experimental or observational purposes. Depending on the

moment or context, these stations might be elided as *laboratories*, *gardens*, or *institutions* or just denoted by locality—naming practices that suggest their flexibility as scientific sites.[33] Rarely, however, did they appear without the modifier *tropical* close at hand. More than the promotion of any particular institutional model or set of research methods, then, tropical research stations shared a common purpose: to bring northern scientists into contact with nature in the tropics.

Of course, field stations elsewhere were also built to bring scientists "close to nature," but this goal carried very particular meanings for the twentieth-century U.S. scientific community regarding the tropics. During the nineteenth century, U.S. botanists and zoologists were occupied by the project of cataloguing the species of their nation's expanding continental empire.[34] Very few had experience working in the tropics. The new stations gave these temperate-zone scientists a tropical foothold, serving as outposts in the scientific colonization of lands to the south. Research stations removed much of the hardship of organizing a scientific expedition and ameliorated the real and imagined dangers to health and safety of travel in the tropics. By encouraging a much larger number and broader array of biologists to work in the region, stations built up a population of U.S. researchers with experience in tropical fieldwork during the twentieth century. Over time some stayed longer, using stations not just for brief tours but instead as a "home" in the field.[35] By midcentury, these researchers came to identify themselves as "tropical biologists."

Research stations not only offered the ability to access tropical organisms and environments while living in relative comfort, health, and safety, however. They also allowed a wider and qualitatively different set of research practices—practices that this book shows were crucial to the development of the study of species diversity. As discussed in chapter 1, as early as the beginning of the twentieth century scientists realized that the study of the ecologies, life histories, and behavior of tropical organisms lagged far behind those of temperate-zone organisms—comparatively few biologists worked in the tropics where, paradoxically, the greatest numbers of species existed. Whereas expeditions and surveys are best suited for the collection of specimens and measurements from a broad geographic area, permanent stations orient work toward the study of living organisms in place over longer periods of time. They permit repeated or ongoing experimentation and monitoring. Thus, tropical field stations opened up studies in ecology, physiology, and behavior where taxonomic and biogeographic work had long dominated. Taxonomic and distribution studies continued, however, and stations encouraged them

to take place at a much more intensive, fine scale. Indeed, it seemed that the more closely biologists looked, the more species they found.

This concentration of research at stations in the tropics had the side effect of encouraging the accumulation of related studies over time. Biologists themselves have identified this as a significant quality of station work; BCI's Egbert Leigh argues for "the importance of 'unity of place,' " which allows "many different kinds of study, done in one small area [to] cohere into a unified picture."[36] Thus, even without the articulation of a formal research project, studies in a particular locality display increasing integrity, through the complex interconnections of the local ecology itself. For example, research on agouti behavior may provide background data for studies of the trees whose seeds they disperse, which in turn may raise questions about the effect of disease, or soils, or climate change on the diversity of the forest. Stations encourage a deep focus on particular places and organisms, fostering an approach that Ian Billick and Mary V. Price call the "ecology of place": "research that assigns the idiosyncrasies of place, time, and taxon a central and creative role in its design and interpretation, rather than as a problem to be circumvented through replication or statistical control."[37] This form of research shares qualities with the case-study approach of social scientists and is often long term and produced by loose groups of researchers from a variety of disciplines.[38] Such place-based research is not confined to the tropics, but, as Price and Billick argue, it has particular advantages for dealing with highly diverse and complex ecosystems. As we will see, it played a key role in the emergence of species diversity as a core concern of tropical biologists.

The history of tropical research stations is fundamental to understanding the intellectual development of biodiversity and tropical thinking, but it also helps contextualize persistent geographical biases in ecology. Despite the emergence and growth of tropical biology in the twentieth century, documented here, the tropics remain vastly underrepresented in current ecological research.[39] Most tropical research remains concentrated at a few well-established field sites, especially in Panama and Costa Rica, whose origins *American Tropics* examines.[40] Ecologists are only beginning to recognize such biases and assess how they affect understandings of tropical ecosystems and patterns of diversity; through histories of the earliest and most important tropical stations, this book contributes to understanding how and why these particular geographical patterns of tropical research came into being. *American Tropics* also explores how biologists historically attempted to deal with the epistemological problems of extending place-based research into general knowledge. For example, chapter 3 demonstrates how administrators of BCI

at first argued for the representativeness of its tropical forest but later shifted toward encouraging comparative studies with other locations, as shown in chapters 4 and 5. As ecologists today struggle to establish new sites and networks of long-term research, to make data about tropical ecosystems more robust, this book also sheds light on the factors that permitted some stations to survive and thrive to the present day while others closed their doors after a few years or decades.

Just as these stations were founded by U.S. institutions, U.S. researchers themselves remain disproportionately prominent within the field of tropical biology—especially within research in Central America and the Caribbean. The number of tropical biology publications authored by U.S. researchers far exceeds those contributed by scientists from any other nation.[41] The geography of ecological research in the tropics continues to reflect colonial legacies, with U.S. scientists dominating studies in the Americas and Europeans tending to emphasize Africa and Asia.[42] Tropical biologists today recognize a need to increase the national, geographic, and racial diversity of their ranks if their work is to have a broader impact in the places they study; indeed, a common refrain among tropical conservation biologists is the need for more local researchers to catalogue, study, and protect biodiversity.[43] *American Tropics* thus provides important historical context for understanding the ongoing problem of unequal participation in the profession of tropical biology, as well as how it came to be recognized as a problem rather than accepted as a matter of course.

Caribbean Encounters

In the twentieth century, U.S. biologists argued for the need for "tropical" research, not specifically research in the Caribbean. Nevertheless, they focused their attention on a region they called the American tropics. Geographically, this category encompassed the tropical latitudes of the Americas, an area equivalent to the now more often used scientific term *neotropics*. In its historical context, however, the term *American tropics* carried additional connotations of colonial possession.[44] As is clear from the chapters that follow, U.S. biologists used the term not only to denote a particular region but also to strengthen rhetorical connections to U.S. colonial projects and advance the claims of their national professional community over the area. I have chosen this provocative actors' category as this book's title to emphasize these colonial dimensions. Within the text, however, I endeavor to use *U.S.* rather than *American* as an analytic category denoting people and organizations from the

United States, to avoid reinforcing this elision of the United States and the Western hemisphere.

In fact, the geographical frame of this book is the circum-Caribbean—the region including the islands of the West Indies and a broad swath of Central and South American land bordering the Caribbean sea.[45] The fundamental reason for this emphasis is that, historically, the few U.S. research stations that developed an emphasis on basic ecological research in the tropics—including investigations into questions of tropical species diversity—were indeed established in the circum-Caribbean and not elsewhere. U.S. biologists announced ambitions to universal knowledge and territorial claims on the "American tropics," but in practice the region they operated in did not actually encompass the entire neotropics. Research in tropical biology depends on access to tropical land, and the flows and migrations of U.S. scientists were constrained by imperial networks of infrastructure and patronage during the twentieth century.

Especially at first, they tended to work within British colonies, such as Jamaica or Guiana, where, as described in chapters 1 and 2, U.S. biologists found Anglophone populations, established scientific institutions, and existing infrastructure for permanent research stations. Increasingly, however, U.S. biologists accessed land and funding through the growing avenues of their own country's economic, political, and military hegemony. In 1898 Spain ceded Cuba, Puerto Rico, the Philippines, and Guam to the United States, and the United States annexed Hawaii. Following the U.S.-backed secession of Panama from Colombia in 1903, the Panama Canal Zone was created and came under U.S. administration. At the beginning of the twentieth century, the United States had thus acquired an "archipelago" of tropical colonies.[46] In the decades that followed, American agribusinesses—most notoriously the United Fruit Company—became major tropical landholders, exerting influence on economies, politics, and landscapes well beyond the borders of these outright colonies.[47] U.S. biologists could make inroads into tropical environments through these neocolonies—in the Caribbean, Latin America, and the Pacific—far beyond anything possible during the previous century.

For U.S. naturalists and ecologists from East Coast and Midwest universities, museums, zoos, and botanical gardens, however, transportation infrastructure and patronage networks favored research in the circum-Caribbean through most of the century. The tropical Pacific was also a significant area of U.S. tropical research, but for a variety of reasons institutions in the Philippines and Hawaii focused more heavily on agriculture, forestry, and medicine

than on basic ecology.[48] At the same time, although the Amazon rainforest looms large in biodiversity and tropical discourse today, U.S. scientists worked there only sporadically until the latter part of the century—not coincidentally, after U.S. interests in Amazonian rubber burgeoned during World War II.[49] Until the 1970s, U.S. tropical biologists' involvement in South America remained largely expeditionary. Certainly, throughout the century some U.S. researchers accessed the tropics through direct collaboration with local scientists.[50] The oldest and most influential stations for basic ecological research, however, were established in the circum-Caribbean during the early twentieth century.

This book's focus on basic research in tropical biology should not obscure the importance of applied tropical science. In fact, this emphasis is intended to better illuminate the historical evolution of connections between basic biology and efforts to colonize and develop natural resources in the circum-Caribbean. The links between U.S. science and colonial and neocolonial ventures are certainly more obvious in the realm of tropical medicine and agriculture. The large numbers of entomologists, engineers, and medical doctors who worked to control disease-bearing mosquitoes in Cuba and the Panama Canal Zone provided the foundations of U.S. territorial control, as well as humanitarian justifications for invasion.[51] Scientific agriculture, chemistry, economic botany, and entomology also played key roles in enabling vast banana, sugar, and rubber monocultures, mitigating the effects of pests and disease that threatened the profits of corporations throughout the region.[52] Such examples of science, medicine, and agriculture working in the service of empire are relatively well known, although their role in the growth of U.S. hegemony has received far less attention than has been trained on European science and empire.

Nevertheless, the rise of a self-identified community of "pure" or "basic" tropical biologists was also deeply embedded in the expanding networks of U.S. corporate and government influence in the circum-Caribbean. Studies of butterfly mimicry, monkey behavior, or orchid taxonomy may seem rather esoteric, but they, too, depended on access to land, transportation, and patronage. Through much of the twentieth century, these came largely through government agencies and corporations—organizations with strong interests in controlling lands and resources in the region. Proponents of basic research on the natural history and ecology of tropical species often struggled to gain support, but gradually they found a variety of ways to make the case for the relevance of basic tropical biology to regional colonial interests. This book argues that significant among these strategies was the development of the

diversity-as-resource argument, which would become a key component of biodiversity discourse at the end of the century. Indeed, at that time, many long-standing research areas in tropical biology—including questions of species numbers and distribution—that had previously been deemed basic were reframed as applied problems of central importance to conservation biology.

As well as capturing the sites of the most significant institutions for basic research in tropical biology, the circum-Caribbean also offers analytical advantages. As a linguistically, politically, and environmentally heterogeneous category, the Caribbean demands attention to movements across national and imperial boundaries. Caribbean historians have increasingly defined the region not by drawing sharp boundaries around it but through reference to material and cultural circulations—movements of people, commodities, and practices, mediated through shared histories of colonialism and plantation slavery.[53] The history of science in the region mirrors these flows. This book traces U.S. scientists' travels through and sojourns within the circum-Caribbean, which were highly determined by existing and developing networks of commerce. At the same time, concentrating on the Caribbean rather than on formal U.S. territories across the tropics helps more closely weave together a wider array of sites—including neocolonies, European colonial territories, and independent nations.

This regional and local focus brings to light the ways that experiences in place reshaped ideas about tropical environments and organisms and, ultimately, the diversity of life. U.S. scientists never simply went to "the tropics"; they worked at specific Caribbean localities that they framed as tropical. The view of tropical nature that each research site presented was quite distinct; scientists' consciousness of human-environment interactions, for example, could be influenced by the prevalence of agricultural land (as at Soledad) or forest (as at BCI) surrounding a station. Local conditions—of infrastructure, labor relations, environment, politics—shaped what science was done and how it could be done. At the same time, local conditions were often significantly structured by regional relationships and changes. Even as broader trajectories of the history of U.S. science played out, the specificity of locality and region—including and especially colonial contexts—made U.S. biology in the circum-Caribbean significantly different from research at coastal marine, agricultural, or montane biological stations in the continental United States. U.S. tropical field research has long been treated as peripheral in the historiography of twentieth-century science. This is in part because of the dominance of studies of European colonial science and in part because of a long-standing tradition of exceptionalism in the historiography of American

science, and also due to a broader neglect of twentieth-century sciences of natural history and exploration.[54] At the same time, the discourse of biodiversity itself is highly globalizing—its nesting scales situate local species as part of a global biological heritage.[55] Biodiversity has been so successfully framed as a world resource that it is tempting to see its intellectual history as abstracted from place—or as the product of discussions in a Washington, DC, conference room. Countering this tendency, *American Tropics* argues that Caribbean contexts strongly shaped the emergence of biodiversity as a central paradigm in theoretical and conservation biology.

Overview

Centered on U.S.-Caribbean encounters, the following chapters examine the interconnected development of understandings of the tropics and the diversity of life. Each chapter pays special attention to the cultural and institutional contexts of this intellectual history. U.S. researchers' dependence on access to tropical land, however, means that this narrative also traces the outlines of the growth and transformation of U.S. political and economic hegemony in the region—an era bookended by the lead-up to the Spanish-American War at the close of the nineteenth century and the rise of nationalist and anticolonial movements during the Cold War era.

During this period, a growing trade and transportation infrastructure made tropical environments increasingly accessible to U.S. scientists. At the same time, both the interest in tropical agriculture and the rise of the "new botany"—which emphasized studying plants in their natural habitats—gave impetus to botanists to work in the tropics. U.S. botanists pointed with envy to the progress of European scientists, who had access to tropical colonies. Even before the Spanish-American War, as we will see in chapter 1, they pushed for the creation of an "American tropical laboratory" to study plants in their tropical home.

Early efforts to create institutions for ecological research were far more difficult to sustain financially than stations with agricultural goals, however. In the 1910s and 1920s, rival zoologists Thomas Barbour and William Beebe each drew on their wealth, corporate and political connections, and larger-than-life personalities to transform the landscape of basic tropical research. While differing in their spatial practices and relative emphases on taxonomy or ecology, both men argued that the study of life in the tropics was fundamental to a broad understanding of biology. Barbour argued furthermore that "tropical biology" was essential to solving the nation's growing practical

problems in tropical agriculture and medicine. Chapter 2 examines the stations they developed—Beebe in British Guiana, Barbour at Soledad, Cuba, and Barro Colorado Island (BCI) in the Panama Canal Zone—and how they leveraged U.S. economic interests in the tropics to further basic science.

These new stations drew hundreds of U.S. biologists, few of whom would have attempted a rigorous tropical expedition on their own. BCI in particular, however, became a model tropical forest. Chapter 3 demonstrates how the station's location on an island nature reserve within the Panama Canal Zone enabled unprecedented control over space and scientific labor. There, biologists were able to develop practices to study living tropical organisms as part of a complex, dynamic ecological community. Moreover, the monitoring and censusing of BCI's ecology in the 1920s through 1940s allowed researchers like Frank Chapman, Robert Enders, Clarence Ray Carpenter, Warder C. Allee, and Orlando Park to investigate ecological change over time, planting the seeds of a challenge to the old idea of the primeval, changeless tropics.

Tracing the fieldwork and ideas of Robert H. MacArthur, Howard T. Odum, and Theodosius Dobzhansky, chapter 4 examines the post–World War II rise of efforts to capture the complexity of tropical nature using a simplified quantitative measure: species diversity. The new approaches were abstract but were shaped by U.S. biologists' experiences in an increasingly wide array of sites within and beyond the circum-Caribbean—facilitated by the U.S. government's interest in tropical warfare, demand for tropical products, and the growth in air travel. The rise of mathematical and systems approaches in ecology, along with the population perspective of the modern evolutionary synthesis, recast the old question of the biological difference of the tropics. The need for tropical data to solve biology's core theoretical problems was now unquestionable.

The 1960s and 1970s saw a wave of highly influential publications on problems of the distribution and ecological controls on species diversity, which drew heavily on data from key tropical field sites. Yet, at this same moment U.S. scientists' future in the tropics was thrown into question. Revolution swept Cuba and protests erupted in Panama against the U.S. occupation of the Canal Zone. U.S. tropical biologists confronted the loss of access to their most important tropical stations. They responded by realigning themselves, creating professional organizations, and taking new steps toward international collaboration. As chapter 5 explains, they also recast their justifications for the support of basic research. Tropical research was not merely in the U.S. national interest, they began to argue; understanding the biological diversity of the tropics was essential for sustainable global development.

American Tropics closes with an examination of the postcolonial situation of tropical research in the circum-Caribbean. Today, the institutions that are the most important and heavily used by U.S. biologists for tropical research and teaching are located in independent republics: the Organization for Tropical Studies (OTS) in Costa Rica and the Smithsonian Tropical Research Institute (STRI)—since the 1979 dissolution of the Canal Zone—in Panama. Key players in the move to bring "biodiversity" to the public stage in the 1980s were tropical biologists who had deep connections to OTS and STRI during the previous two decades of transition. The emergence of the modern biodiversity discourse, this book argues, is a direct product of the intellectual and political ferment of tropical biology during that revolutionary period. The significance of that moment, in turn, can be understood only in the context of the full twentieth century and its mixed legacies for tropical biology—the development of place-based research practices and a long-standing dependence on institutions supported by U.S. corporations and government agencies.

Through the twentieth century, tropical biologists developed ways to cast problems of deforestation, food and population growth, and species loss as justifications for the support of basic research on tropical species and the investigation of the ecological relationships that sustain them. With the emergence of biodiversity, the problems of the tropics became the problems of the world.

Notes

Abbreviations Used in the Notes

Acc	Accession
AHS	Arizona Historical Society
DU	Duke University David M. Rubenstein Rare Book and Manuscript Library
FTG	Fairchild Tropical Botanic Garden Special Collections
HUA	Harvard University Archives
IRTA	Institute for Research in Tropical America
JHU	Johns Hopkins University, Ferdinand Hamburger Archives
NARA	National Archives and Records Administration
NAS	National Academy of Sciences Archives
NYBG	New York Botanical Garden Mertz Library Archives
OTS	Organization for Tropical Studies
PUA	Princeton University Library's Manuscripts Division
RAC	Rockefeller Archive Center
RG	Record Group
RU	Record Unit
SIA	Smithsonian Institution Archives
STRI	Smithsonian Tropical Research Institute, Earl S. Tupper Tropical Sciences Library
WCS	Wildlife Conservation Society Library and Archives

Introduction

1. Conference details come from Acc92-030, SIA. See also Wilson, *Naturalist*, 359–60.

2. On the concept of biodiversity and the emergence of conservation biology, see Takacs, *Idea of Biodiversity*; Lévêque and Mounolou, *Biodiversity*; Oksanen and Pietarinen, *Philosophy and Biodiversity*; Sarkar, *Biodiversity and Environmental Philosophy*; Meine, Soulé, and Noss, "'Mission-Driven Discipline'"; Farnham, *Saving Nature's Legacy*; Barrow, *Nature's Ghosts*, 353–59; Robin, "Rise of the Idea of Biodiversity"; Vadrot, *Politics of Knowledge and Global Biodiversity*.

3. Wilson, *BioDiversity*, 8.

4. Ibid., 3.

5. Ibid., 8.

6. Ibid., 14.

7. Coiner Walter Rosen states that he intended to suggest a less cumbersome word for a well-established scientific concept. Rosen, "What's in a Name?" On the first appearances of *biological diversity* and *biodiversity*, see Farnham, *Saving Nature's Legacy*.

8. Libby Robin has critiqued scholars' concentration on this constricted time frame for "promulgat[ing] an 'origins' story rather than a nuanced sense of what drives the global concept of biodiversity, and its uses today. While there is no doubt that a 'global environmentalist story' accelerates from the 1980s, it is useful to document its roots in actual places, in case histories." Robin, "Biological Diversity as a Political Force," 40.

9. Ecology is so central to the study of biology in the tropics that *tropical ecology* is often used interchangeably with *tropical biology*. I use *tropical biology* to refer to the general field of study and *tropical ecology* only when referring specifically to ecological research.

10. For example, see Zuk, "Temperate Assumptions"; Robinson, "Is Tropical Biology Real?"

11. On tropicality, see Arnold, *Problem of Nature*, 141–68; Slater, "Amazonia as Edenic Narrative"; Arnold, "'Illusory Riches'"; Stepan, *Picturing Tropical Nature*; Sheller, *Consuming the Caribbean*; Driver, "Imagining the Tropics"; Driver and Martins, *Tropical Visions in an Age of Empire*; Tobin, *Colonizing Nature*; Thompson, *Eye for the Tropics*; Carey, "Inventing Caribbean Climates"; Sutter, "The Tropics."

12. Voices from within nations in the tropics have historically challenged aspects of this discourse but have also deployed it in their own campaigns for internal reforms. For example, see Peard, *Race, Place, and Medicine*.

13. Pratt, *Imperial Eyes*.

14. Darwin to J. S. Henslow, 18 May 1832, in Burkhardt and Smith, *Correspondence of Charles Darwin*, 237.

15. Enright, *Maximum of Wilderness*, 22. See also Slater, *In Search of the Rain Forest*, 288–89. Nancy Stepan addresses this phenomenon of disappointment in *Picturing Tropical Nature*, 45–66.

16. Wallace, *Tropical Nature*, vii.

17. Ibid., 65. Wallace here refers only to plants, but he uses nearly identical language in his chapter on tropical animals.

18. Ibid., 69–70.

19. Ibid., 27, 65.

20. Ibid., 65.

21. Ibid., 122–23.

22. Ibid., 123.

23. On station science compared with expeditionary science, see Vetter, *Field Life*; de Bont, *Stations in the Field*; Kingsland, "Role of Place in the History of Ecology"; Kohler, *All Creatures*.

24. On this literature, see Wright and Finnegan, *Spaces of Global Knowledge*; McCook, "Global Currents in National Histories of Science"; Rosenberg, "Transnational Currents in a Shrinking World"; Safier, "Global Knowledge on the Move"; Roberts, "Situating Science in Global History"; Raj, *Relocating Modern Science*.

25. Pauly, "Summer Resort and Scientific Discipline"; Benson, "From Museum Research to Laboratory Research"; Benson, "Naples Stazione Zoologica"; Maienschein, *One Hundred Years Exploring Life*; Maienschein, *Transforming Traditions*; Pauly, *Biologists and the Promise of American Life*, 94–96, 145–64.

26. Kohler, *Landscapes and Labscapes*. See also Gieryn, "City as Truth-Spot"; Kingsland, "Frits Went's Atomic Age Greenhouse."

27. Vetter, *Field Life*; Muka, "Right Tool and the Right Place"; de Bont, *Stations in the Field*; Raby, "Ark and Archive"; Wille, "Coproduction of Station Morphology"; Alagona, "Sanctuary for Science."

28. De Bont, *Stations in the Field*, 3.

29. Mickulas, *Britton's Botanical Empire*, 130–33; Kohler, *Landscapes and Labscapes*, 128–29; Kingsland, *Evolution of American Ecology*, 82–83.

30. Hagen, "Problems in the Institutionalization of Tropical Biology."

31. Cittadino, *Nature as the Laboratory*. Robert-Jan Wille in "De Stationisten" also argues for the station's importance in expanding European botanists' professional prospects.

32. Jack, "Biological Field Stations"; Brockway, *Science and Colonial Expansion*; Drayton, *Nature's Government*; Osborne, "Acclimatizing the World"; Schiebinger and Swan, *Colonial Botany*; Schiebinger, *Plants and Empire*; McCook, "Neo-Columbian Exchange."

33. De Bont notes comparable heterogeneity, excepting gardens, in European zoological stations. De Bont, *Stations in the Field*, 4.

34. For example, see Goetzmann, *Exploration and Empire*; Carter, *Surveying the Record*; Vetter, "Science along the Railroad"; Kohler, *All Creatures*.

35. As Catherine Christen notes, tropical biologists themselves remark on the importance of this shift. Christen, "At Home in the Field," 558–59. Kohler and de Bont have also explored phenomena of "residential" field science. Kohler, "Paul Errington, Aldo Leopold, and Wildlife Ecology"; de Bont, *Stations in the Field*, 199–208.

36. Leigh, "Barro Colorado," 90–91.

37. Billick and Price, "Ecology of Place," 5.

38. Ibid., 5–6.

39. On the underrepresentation of tropical research, see Amano and Sutherland, "Four Barriers to the Global Understanding of Biodiversity Conservation"; Martin, Blossey, and Ellis, "Mapping Where Ecologists Work"; Collen et al., "Tropical Biodiversity Data Gap"; Kier et al., "Global Patterns of Plant Diversity and Floristic Knowledge"; Janzen, "Impact of Tropical Studies."

40. Surveying publications between 2004 and 2009, Laura Martin and colleagues found that nine of the seventy-three countries represented had significantly more sites than expected based on size. Only two were tropical: Costa Rica (with forty-nine times more studies than expected) and Panama (thirty-three times more studies). This made Central America—despite the general underrepresentation of the global tropics—the region "most overstudied by a factor of 8." Martin, Blossey, and Ellis, "Mapping Where Ecologists Work," 198, web tables 7 and 8.

41. In a study by Gabriela Stocks and colleagues, U.S. scientists comprised 35–45 percent of authors of papers on tropical ecology. All other countries were represented by 12 percent or fewer authors. However, scientists from Brazil and Mexico had a much larger share of lead authorship compared with scientists from other developing countries. Stocks et al., "Geographical and Institutional Distribution of Ecological Research." See also Wilson et al., "Conservation Research Is Not Happening Where It Is Most Needed"; Livingston et al., "Perspectives on the Global Disparity"; Malhado et al., "Geographic and Temporal Trends in Amazonian Knowledge Production"; Braker, "Changing Face of Tropical Biology?"; Gálvez et al., "Scientific Publication Trends and the Developing World."

42. Chazdon and Whitmore, *Foundations of Tropical Forest Biology*, 2–3.

43. See, for example, Watkins and Donnelly, "Biodiversity Research in the Neotropics"; Malhado, "Amazon Science Needs Brazilian Leadership"; Amano and Sutherland, "Four Barriers to the Global Understanding of Biodiversity Conservation"; Theobald et al., "Global Change and Local Solutions."

44. See Bemis, " 'America' and Americans"; Renda, *Taking Haiti*, xvii. Philip J. Pauly specifically discusses the expansionist use of *American* in nineteenth-century natural history in *Biologists and the Promise of American Life*, 7–8.

45. This region is also referred to as the Greater Caribbean or Caribbean Basin. For historical and geographical perspectives on this region, see Mintz and Price, *Caribbean Contours*; Knight and Palmer, *Modern Caribbean*; Gaspar and Geggus, *Turbulent Time*; Randall and Mount, *Caribbean Basin*; Hillman and D'Agostino, *Understanding the Contemporary Caribbean*.

46. For perspectives on this imperial transition, see the essays in part 1 of McCoy and Scarano, *Colonial Crucible*.

47. See, for example, Colby, *Business of Empire*; Bucheli, *Bananas and Business*; Soluri, *Banana Cultures*; Tucker, *Insatiable Appetite*; Striffler, *Shadows of State and Capital*; Harrison, *King Sugar*; Ayala, *American Sugar Kingdom*; LeGrand, "Living in Macondo."

48. Overfield, "Agricultural Experiment Station and Americanization"; Overfield, "Science Follows the Flag"; Kramer, *Blood of Government*; Anderson, *Colonial Pathologies*; Okihiro, *Pineapple Culture*; Bankoff, "First Impressions"; Anderson, "Science in the Philippines"; Manganaro, "Assimilating Hawai'i."

49. Garfield, *In Search of the Amazon*.

50. On such collaborations and colonial power dynamics, see Henson, "Invading Arcadia"; Quintero Toro, "¿En Qué Anda la Historia de la Ciencia y el Imperialismo?"; Quintero Toro, *Birds of Empire, Birds of Nation*; Rodriguez, "Beyond Prejudice and Pride."

51. Sutter, "Nature's Agents or Agents of Empire?"; McNeill, *Mosquito Empires*; Espinosa, *Epidemic Invasions*.

52. Overfield, "Science Follows the Flag"; Bankoff, "Breaking New Ground?"; Fitzgerald, "Exporting American Agriculture"; McCook, *States of Nature*; Soluri, *Banana Cultures*.

53. Mintz and Price, *Caribbean Contours*, 5. See also Gowricharn, *Caribbean Transnationalism*.

54. Heggie, "Why Isn't Exploration a Science?"

55. On biodiversity as a globalizing discourse, see Taylor, "How Do We Know We Have Global Environmental Problems?"; Castree, "Geopolitics of Nature"; Zimmerer, "Biodiversity."

Chapter One

1. "American Tropical Laboratory," 415.

2. Kingsland, "Battling Botanist"; Magnus, "Down the Primrose Path"; Kohler, *Landscapes and Labscapes*, 53, 88, 93, 206, 221–24.

3. "American Tropical Laboratory," 415.

4. On laboratory "placelessness," see Livingstone, *Putting Science in Its Place*, 3; Kohler, *Landscapes and Labscapes*, 7–11, 213; Gieryn, "City as Truth-Spot"; Gooday, "Placing or Replacing the Laboratory."

5. "American Tropical Laboratory," 415.

6. McCook, " 'World Was My Garden,' " 499.

7. Coulter's close friendship with Arthur likely later helped bend his ear to MacDougal's proposal for a tropical station. Cittadino, "Ecology and the Professionalization of Botany"; Rodgers, *John Merle Coulter*.

8. Darwin and Darwin, *Power of Movement in Plants*; de Chadarevian, "Laboratory Science versus Country-House Experiments"; Ayres, *Aliveness of Plants*; Whippo and Hangarter, " 'Sensational' Power of Movement."

9. MacDougal, "Tendrils of Passiflora caerulea."

10. MacDougal, "Mechanism of Movement and Transmission of Impulses."

11. MacDougal, "Mimosa," 48.

12. Cittadino, *Nature as the Laboratory*.

13. Nicolson, "Humboldtian Plant Geography after Humboldt."

14. MacDougal, "Plant Zones"; MacDougal, "Recent Botanical Explorations." On C. Hart Merriam's life zones, see Kohler, *All Creatures*, 97–98, 151–54; Nicolson, "Humboldtian Plant Geography after Humboldt."

15. Worster, *Nature's Economy*, 190–93, 198; Coleman, "Evolution into Ecology?"

16. Warming and Knoblauch, *Ökologischen Pflanzengeographie*; Warming, *Plantesamfund*.

17. Schimper, *Pflanzen-Geographie*; Schimper, *Plant-Geography*.

18. See, for example, Cittadino, *Nature as the Laboratory*; Goodland, "Tropical Origin of Ecology."

19. The Indonesian government continues to operate this garden, now known as the Bogor Botanical Gardens.

20. MacDougal, "Botanic Gardens I," 181; "American Tropical Laboratory," 415.

21. Dammerman, "History of the Visitors' Laboratory." For the site's significance in German, Indonesian, and Dutch science, see Pyenson, *Empire of Reason*, 10–13; Cittadino, *Nature as the Laboratory*; Moon, *Technology and Ethical Idealism*, 29, 32–34; Goss, *Floracrats*; Wille, "Coproduction of Station Morphology."