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J. Michael Scott and Cameron B. Kepler

Hawaii is an ecologically isolated archipelago 2,500 miles from the nearest continent. Its isolation resulted in a taxonomically unbalanced flora and fauna with remarkable examples of adaptive radiation among those groups of organisms that won the dispersal sweepstakes. It was one of the last oceanic island groups to be populated by humans, about 900 A.D. by Polynesian travelers and in 1778 by Europeans. Relatively recent colonization by humans did not save it, however, from the biodiversity losses suffered by other isolated archipelagos—it only delayed them (Scott and others, 1988; Pratt and others, 2009a).

The size of those losses and the severity of the threats were formally recognized by the United States in 1964 with the publication of "Rare and Endangered Fish and Wildlife of the United States" by the U.S. Department of the Interior (DOI) Committee on Rare and Endangered Wildlife Species (U.S. Department of the Interior, 1964). Sixteen of the 62 species in that book, vertebrates all, were Hawaiian. That "red book" provided information that was used to compile the first formal list of endangered species under the 1966 Endangered Species Preservation Act, commonly referred to as "the Class of 67" (Wilcove and McMillan, 2006). That first list reinforced the findings of the Committee on Rare and Endangered Wildlife Species that Hawaii was home to some of the most highly endangered species in the United States. Twenty of the first 78 species listed under the Preservation Act (25.6 percent) were from Hawaii.

Dr. Ray Erickson was well aware of the challenges the country faced in recovering endangered species. A biologist in the Division of Research of the Bureau of Sport Fisheries and Wildlife in Washington, D.C., Dr. Erikson was a member of the Committee on Rare and Endangered Wildlife Species. Beginning in 1956, he had been advocating for funding to rear one of America's rarest birds, the whooping crane (*Grus americana*), in captivity and to conduct research on the sandhill crane (*Grus canadensis*) as its surrogate species. In early 1961, responding to a White House call for new ideas from Federal employees, Ray offered a proposal for a captive propagation and research program on rare and endangered species. Although small amounts of funding were received as early as that year to construct pens for sandhill cranes and support studies of their behavior in Colorado, funds sufficient to initiate a multispecies field and laboratory program to study rare and endangered species were not available until March 1966, when the Bureau signed off on $350,000 to support endangered wildlife research. With those funds, the research and captive propagation effort was moved to Patuxent Wildlife Research Center (Patuxent) in Laurel, MD, from Monte Vista National Wildlife Refuge, Alamosa, CO, and Ray was placed in charge of what came to be known as the Endangered Wildlife Research Program. The original focus on captive rearing of whooping cranes and their surrogate the sandhill crane continued, but these efforts were quickly expanded to include other imperiled species and their surrogates, including black-footed ferret (*Mustela nigripes*), California condor (*Gymnogyps californianus*), Puerto Rican parrot (*Amazona vittata*), masked bobwhite quail (*Colinus virginianus ridgwayi*), and Aleutian Canada goose (*Branta canadensis leucopareia*) (U.S. Fish and Wildlife Service, 1976a, b; 1977). Ray Erickson originally envisioned an Endangered Wildlife Research Program that would include a field research component involving 10 field biologists that would complement the laboratory studies and captive propagation efforts at Patuxent. Four field biologists were eventually assigned to Hawaii. The first of these was Winston (Win) Banko. His task, as it was for all of us, was broad—work on the endangered birds of Hawaii. He arrived on Oahu in 1966, but later moved to the "Big Island" of Hawaii. John Sincock, who was assigned to Kauai, joined him in the islands in 1967. In 1974, Mike Scott joined Win Banko on the island of Hawaii, and, in 1977, Cam Kepler was assigned to Maui.

That first cohort of Patuxent's endangered species biologists in Hawaii, Banko, Kepler, Scott, and Sincock, conducted extensive studies on the endangered flora and fauna of the islands (see Selected References). Their studies involved reviews of the literature and museum collections to determine the extent of studies conducted and the historical distribution of each species, their status and distribution in the field (Scott and others, 1977), their natural history and ecology threats, and recovery planning. Simultaneously, they were developing the methods needed to accurately identify and rigorously assess the distribution and abundance of Hawaii's threatened and endangered species under the difficult conditions of complex terrain, adverse weather, and extremely low bird densities.

John Sincock, U.S. Fish and Wildlife Service, after surveying a Kau transect on Hawaii, summer 1976. Photo by U.S. Fish and Wildlife Service.

Jim Jacobi and Mike Scott, U.S. Fish and Wildlife Service, in Hawaii on the Kona side transect, summer 1978. Photo by U.S. Fish and Wildlife Service.

John Sincock, U.S. Fish and Wildlife Service, waiting for helicopter in Alaka'i Swamp, Kauai, 1983. Photo by Paul W. Sykes, Jr., U.S. Fish and Wildlife Service.

Several books that provide a synthesis of these and other efforts to save Hawaii's endangered avifauna and document the methods developed to survey and analyze the information from field studies emerged from the work of Patuxent's biologists and others in the islands. These included Ralph and Scott (1981), Scott and others (1986), Scott and others (1993), Scott and others (2002), Stone and Scott (1985), and Stone and Stone (1989). The importance of collaborations with other researchers from Federal and State agencies, nongovernmental organizations, and academia as well as the private landowners of Hawaii to the success of these efforts cannot be overstated. The list of those who worked with us in the field, helped with funding, and collaborated on almost every one of the publications that resulted from the U.S. Fish and Wildlife Service (USFWS) effort in the islands is long. One need only consider the institutional affiliations of the authors of the reports, journal articles, and books we wrote or edited and the individuals we recognized in the acknowledgments sections of each publication to gain an appreciation of the truly interdisciplinary and interinstitutional nature of our work in the islands.

The arrival of the first Patuxent researchers followed shortly after the arrival of Gene Kridler on Oahu in 1965. As the first DOI biologist and manager assigned to Hawaii, Gene played a key role in identifying research needs and obtaining funds to conduct the needed research. The late 1960s and early 1970s saw a great increase in research on the Hawaiian biota. Andrew Berger (ornithologist, American Museum of Natural History, New York) and his students at the University of Hawaii, other academic researchers, and folks at the Hawaii Department of Forestry and Wildlife (HDFW) were conducting life-history studies on many of the endemic birds (Berger and others, 1969; Engilis and Pratt, 1993; Frings, 1969; Shallenberger, 1977; Shallenberger and Vaughn, 1978; Swedberg, 1967). In 1970, the International Biological Program (Mueller-Dombois and others, 1981) initiated studies on island ecosystems and their biological organization. Finally, the U.S. Forest Service initiated studies on feather molting and behavior of Hawaiian birds (Ralph and Fancy, 1994) and the influence of nonnative species on native ecosystems (Scowcroft and Giffin, 1983). The role of Patuxent's four research biologists, working along with others, in that resurgence of interest in Hawaii's endangered biota is documented in the narrative that follows.

Win Banko came to the islands in 1966 and spent his first year on Oahu. He relocated to the island of Hawaii, where he established the Kilauea field station, a year later. Upon finding that little field work had been conducted on birds in Hawaii since the early 1900s (for example, Baldwin, 1945, 1947, 1953; Warner, 1960, 1967, 1968), Banko determined that his contribution to understanding the endangered species of Hawaii would be in examining the literature, long-forgotten field notes, and museum specimens to determine what information was already known and where the gaps in our knowledge lay. Early on, however, Win went into the field to survey the birds of Kipahulu Valley, Maui, where, as a member of The Nature Conservancy's Kipahulu expedition led by Rick Warner, he rediscovered the Maui nukupuu (*Hemignathus lucidus affinis*) (Warner, 1967; Banko, 1968). Banko also detected populations of several endangered forest bird species near Hawaii Volcanoes National Park. This discovery led to the selection of this area for intensive ecological studies by scientists associated with the International Biological Program and the U.S. Forest Service (Mueller-Dombois and others, 1981; Ralph and Fancy, 1994).

The bibliography on Hawaiian birds and the documentation and Banko's summaries of 20,700 status and distribution records were published by the Hawaii Cooperative Ecosystems Study Unit as part of its special reports series from 1980 to 1990. In addition to his library work, Win conducted field studies of Hawaiian crows (*Corvus hawaiiensis*) on the leeward side of Hawaii and searched for the endangered Hawaiian dark-rumped petrel (*Pterodroma sandwichensis*) and other seabirds high on the desolate volcanic slopes of Mauna Kea and Mauna Loa (Banko, 1980). His studies of the crow documented its precarious status and prompted the decision to bring the first Hawaiian crows into captivity for propagation. Those birds were housed in flight cages at Hawaii Volcanoes National Park for a short period, then transferred to State

managers and used to form the nucleus of the Hawaiian crow captive propagation effort (National Research Council, 1992). Win retired from the USFWS in 1977.

Soon after his arrival in the islands in 1967, John Sincock conducted wetland surveys to identify possible sites for new wildlife refuges. John also initiated the first statistically rigorous inventories of endangered birds in the forested areas of Kauai (Sincock and others, 1984; Scott and others, 1986) and of the endangered birds of the Leeward Islands (Laysan, Midway, and Nihoa): Laysan finch (*Telospiza cantans*), Nihoa millerbird (*Acrocephalus familiaris kingi*), Nihoa finch (*Telospiza ultima*), and Laysan duck (*Anas laysanensis*). The Leeward Islands transects he established for the land bird inventories have been surveyed for more than 40 years (Conant and Morin, 2002; Morin and Conant, 1997). The wetland surveys of Kauai, conducted collaboratively by John with refuge manager Gene Kridler, provided the information needed to establish Hanalei, Huleia, and Kilauea Point National Wildlife Refuges and complemented the statewide waterfowl surveys by the HDFW (Engilis and Pratt, 1993). John expanded his research efforts to include natural history studies and threats to survival of three seabirds: Newell's shearwater (*Puffinus newelli*), band-rumped storm petrels (*Oceanodroma castro*), and Hawaiian dark-rumped petrels. After documenting the rediscovery of nesting areas for Newell's shearwaters (Sincock and Swedberg, 1969), he translocated eggs of this species under nesting wedge-tailed shearwaters (*Puffinus pacificus*) to secure low-elevation nesting areas at the then Kilauea Point National Administrative site (Byrd and others, 1984). Presumed offspring resulting from those efforts or their young still continue to nest on what is now Kilauea National Wildlife Refuge (http://www.fws.gov/endangered/news/bulletin-spring2009/shearwaters-of-kilauea-point.html).

Recognizing the heavy mortality suffered by Newell's shearwaters and Hawaiian dark-rumped and band-rumped storm petrels from crashing into the ground and other obstacles as a consequence of light pollution, John worked with Tom Telfer (HDFW) and researchers at the University of Wisconsin to develop methods to reduce light pollution by switching and shielding light sources (Reed and others, 1985; Telfer and others, 1987).

Left to right: Dave Marshall, Gene Kridler, and Win Banko, U.S. Fish and Wildlife Service, in Alaka'i Swamp, Kauai, HI, 1966. Photo by U.S. Fish and Wildlife Service.

Sincock and Tom Telfer established the Save Our Shearwaters (SOS) program in the 1970s. This project involved informing the island community of the consequences of the annual "raining of shearwaters" and its causes, and rescuing and then releasing stranded birds. Like almost every one of the Patuxent research studies, it quickly became a family affair when John's wife, Renate, took on many of the day-to-day activities of this effort—helping to enlist volunteers in the rescue effort, picking up birds, coordinating volunteers, and housing and releasing birds. The SOS program continues to this day (2016) under the auspices of the Kauai Humane Society (http://kauaihumane.org/services/saveourshearwaters).

John was the first to propose and then conduct an assisted colonization for the Northwest Islands passerines. Working with folks in the HDFW and with Gene Kridler of the USFWS, he successfully translocated Laysan finches to Pearl and Hermes Reefs. However, their efforts to translocate Nihoa finches to French Frigate Shoals were unsuccessful (Conant and Morin, 2002). One product of John's efforts in the Leeward Islands was a conservation plan for the future protection of the islands' endemic avifauna (Sincock and Kridler, 1977). John was the last of the original cohort of Patuxent research biologists to leave Hawaii. He left the islands and the USFWS in 1988.

Mike Scott arrived fresh from graduate school in the fall of 1974 to work with the endangered birds of Hawaii. Working with John Sincock, USFWS refuge manager Gene Kridler, and State wildlife biologists Ernie Kosaka, David Woodside, and Ronald Walker, he identified the information needs that were most important to recovering the endangered species of Hawaii. It was not the "niche differentiation studies of endemic Hawaiian birds" (MacArthur and Levin, 1961) that Mike had envisioned when he accepted the position of endangered species biologist with the USFWS. The questions to which managers needed answers were far more policy- and management-relevant. The decision-making process for recovery planning and implementation required answers to questions such as: Which species are extant? Where can they be found? How many are there? How do their distribution and density vary geographically? Who owns/manages the land, and what is its conservation status? The information gained from answering these questions could be used by managers to take the first two steps toward conserving Hawaii's endangered forest birds—identifying and securing essential imperiled species habitat. It became clear to Mike and his colleagues that to answer those questions an extensive survey of all remaining forest bird habitat in the islands was needed. The result of their planning was the Hawaiian Forest Bird Survey (HFBS), a program to survey all remaining forest bird habitat in the islands, from the tree line down to the cane fields or the coast, on all the main islands in Hawaii with the exception of Oahu. The forest birds of Oahu were surveyed separately by others (Shallenberger and Vaughn, 1978).

Prior to launching the HFBS in 1976, a population survey was conducted to determine the distribution and abundance of the palila (*Loxioides bailleui*). That effort was led by University of Hawaii graduate student Charles Van Riper, whereas Mike Scott and David Woodside of the HDFW took the lead on the multiagency effort. They laid transects throughout the dry mamane (*Sophora chrysophylla*) and naio (*Myoporum sandwicense*) forests of the upper elevations of Mauna Kea, where the last remaining palila resided (Van Riper and others, 1978). These surveys, covering the entire geographical, geophysical, and ecological range of the palila, were repeated in 1980, and have been repeated every year since then (Jacobi and others, 1996; Banko and others, 2009). That standard—the surveying of the entire range of a species—was used for the larger HFBS (described below) that followed.

With funding and administrative support from the management side of the USFWS, logistical support from Ernie Koska and others from the HDFW, and leadership from John Sincock and Mike Scott, this historic undertaking (Pratt and others, 2009a) was launched in the Kau Forest on the island of Hawaii in the spring of 1976 (U.S. Fish and Wildlife Service, 1976a, b; 1977) and concluded on the island of Kauai in the summer of 1981 (Scott and others, 1986). Observers were selected from applicants who were screened for birding experience, physical fitness, hearing acuity, birding ability, familiarity with Hawaiian birds, and ability to spend extended periods in remote locations to conduct field studies. All field folks were trained in distance estimation and the audio, behavioral, and visual characteristics of the forest birds of Hawaii, as well as safety and sampling protocols (Kepler and Scott, 1981; Ramsey and Scott, 1981; Scott and others, 1986). Members of that first year's survey team, particularly Jim Jacobi, provided input to the study design that resulted in adding surveys for mapping rare and endangered plants and increased documentation of feral animal presence to the survey protocols. To supplement the quantitative capabilities of the group, Scott asked Fred Ramsey, longtime friend, lifelong birder, and professor in the statistics department at Oregon State University, to join the team to provide the statistical and analytical rigor needed to fully analyze the survey findings (Ramsey and others, 1979, 1987; Ramsey and Scott, 1978, 1979, 1981).

By the time the last sampling station was surveyed, members of the HFBS had recorded 30 native species and 33 nonnative species; counted hundreds of thousands of birds; characterized vegetation (Jacobi, 1983, 1989; Jacobi and Scott, 1985); and documented the occurrence of nonnative plant species (Warshauer and others, 1983), damage from feral animals, the presence of rare plants, and the discovery of new ones (Warshauer and Jacobi, 1982) at 9,940 survey stations during 20,789 count periods along 876 miles of transects (Scott and others, 1986). A dozen or so new species of plants were described and much new information was gained on the distribution and abundance of rare plants from the botanical collections created by James Jacobi, Rick Warshauer, Holly McEldowney, and others. Throughout Mike's tenure in Hawaii, his wife, Sharon, played a key role in his research, making radio checks with field crews; picking up team members at the end of a transect; and serving as professional sounding board, editor, and all-around advisor for Mike.

The results of the HFBS were published in "Forest Bird Communities of the Hawaiian Islands" (Scott and others, 1986) and many other peer-reviewed publications that are described elsewhere. The 1986 synthesis received The Wildlife Society's Best Monograph Award. A review of the book characterized the HFBS as "a biological exploration of a high order and an excellent demonstration of applied statistics and despite my gloomy prediction, ecology of a high order…a model for other federal agencies charged with conservation programs" (Pimm, 1988). The complete electronic records of bird observation and transect locations of the HFBS are archived at the U.S. Geological Survey (USGS) Kilauea field station on the island of Hawaii (R.J. Camp, U.S. Geological Survey, written commun., 2010). The results of the HFBS complemented earlier statewide surveys of waterbirds (Engilis and Pratt, 1993; Reed and others, 2007; Swedberg, 1967) and game birds (Schwartz and Schwartz, 1949). Mike left Hawaii in 1984 to supervise the condor research effort in California.

Cam Kepler arrived in Maui in 1977 and joined the HFBS then underway on the Hamakua coast. Kepler participated in the surveys of Kona, Kohala, and Mauna Kea, including the extensive training sessions each spring (Kepler and Scott, 1981) in the years that followed. In 1980–81, he was coleader of the surveys of Maui, Molokai, Lanai, and Kauai.

During the HFBS, variable circle point counts for birds were conducted only in the first 4 hours of the day, weather permitting. This schedule provided time in the afternoons, after camp was set up, to make incidental observations in the study area. On May 12, 1981, during an incidental bird survey, Cam Kepler discovered the first nest of the small Kauai thrush (*Myadestes palmeri*) in a streamside cliff in one of the many embedded streams in the Alaka'i Swamp, on Kauai (Kepler and Kepler, 1983). All 13 small Kauai thrushes observed in the HFBS counts were also in deep gorges with flowing water, a finding consistent with observations made over 700 days in the Alaka'i by John Sincock (Scott and others, 1986). Knowledge of the microhabitats and nest-site locations of this endangered species allowed for more robust population estimates and management of the small Kauai thrush in subsequent years (Woodworth and others, 2009).

From 1977 to 1981, Cam and his wife, Kay Kepler, initiated surveys of several offshore islands to assess their seabird populations and plant communities (Kepler and Kepler, 1980; Kepler and others, 1984, 1990; Simons and others, 1985). All four islands hold breeding colonies of wedge-tailed shearwaters and Bulwer's petrels (*Bulweria bulwerii*). The information from the surveys was made available to the Hawaii Department of Land and Natural Resources (DLNR) to inform their management activities on the seabird islands.

In 1978 and 1979, Cam studied the water birds of Kealia and Kanaha Ponds on Maui. Kanaha Pond was protected as a State bird sanctuary, but the much larger Kealia Pond was privately owned. He found that most of the endangered Hawaiian stilts (*Himantopus mexicanus knudseni*) frequently left Kanaha to feed at Kealia, and that the two wetlands were strongly linked, both being essential to the survival of the stilt and Hawaiian coot (*Fulica alai*). In 1984, Cam was asked to provide biological information about Kealia to the Maui County Council, which was considering changing the wetland to a development district (harbor development was a possible use). Because of information provided by Cam and others (Shallenberger, 1977), Kealia was retained in conservation district zoning. Cam also provided his results to Federal and State agencies as well as nongovernmental organizations. After years of deliberation, the USFWS made plans to acquire Kealia Pond (http://www.fws.gov/kealiapond/) as a wildlife refuge.

In 1984, following completion of the HFBS, Cam initiated an expanded research program on the ecology of Hanawi's forest birds, including biological stresses affecting them. In 1986, Cam found the first nest of the po'o-uli (*Melamprosops phaeosoma*), and he, with Andy Engilis and Marie Ecton (USFWS), monitored this and a second (renesting) nest (Kepler and others, 1996; Engilis and others, 1996).

During their studies of the po'o-uli, the team noted a sobering increase in pig activity in the area (Mountainspring and others, 1990; Engilis, 1990). Habitat destruction by pigs resulted in soil loss of as much as 3 inches per year in Maui's primary watershed, far more than previously had been suspected. Cam's studies of the damage being caused by pigs to Hawaii's native ecosystems complemented those of others (Stone, 1985; Stone and Stone, 1989). This information and the briefings by Cam and others to media and public agencies alerted decision makers and the public to the threat pigs posed to endangered species and the public water supply.

During this same period, Haleakala National Park initiated a multimillion-dollar program to fence its entire holdings and expanded its ungulate control program (Pratt and others, 2009a). The Hawaii DLNR created the Hanawi Natural Area Reserve adjacent to The Nature Conservancy's Waikamoi Preserve, and both organizations initiated their own fencing and control programs (Price and others, 2009). Kepler traveled to Athens, GA, in 1987 to study Kirtland's warbler (*Setophaga kirtlandii*).

After Kepler left Hawaii, Patuxent maintained a research staff at the Kilauea field station that continued to study Hawaii's imperiled flora and fauna. That research is summarized in Scott and others (2002) and Pratt and others (2009a).

The Science Policy Discourse: Making a Difference in Policy and on the Ground

In addition to publishing their findings widely in scientific journals, Mike Scott and others made repeated presentations on the conservation implications of the HFBS and their other studies to the Hawaii Department of Forestry and

Wildlife and USFWS managers and biologists, as well as at many meetings of professional societies and conservation groups. By the late 1970s, word of the HFBS was spreading on the mainland and the conservation status of Hawaii's imperiled biota had attracted increased attention from The Nature Conservancy. The Nature Conservancy's Henry Little came to the islands in 1978. After becoming acquainted with the concept of the HFBS and its findings, he used the information from the HFBS to develop the Endangered Forest Bird Project. Working with Henry, Scott presented results of the HFBS and its implications for conservation of Hawaii's endangered biota to The Nature Conservancy's National Board of Directors in 1980. Funding for additional work by the Conservancy in Hawaii quickly became available. Henry used these funds to expand The Nature Conservancy's work in the islands.

In 1980, Henry hired Kelvin Taketa and Hardy Spoehr, and together they launched the Endangered Forest Bird Project (The Nature Conservancy, 1982). The objective of this project was to use the results of the HFBS and other research efforts in the islands to identify the areas critical to for the conservation of Hawaii's imperiled biota. The project's steering committee was composed of community leaders. Sincock, Scott, and Kepler served on the project's science advisory team along with National Park Service biologists and scientists from academia. In the fall of 1982, the Hawaii chapter of The Nature Conservancy was established. Henry Little quickly assembled a first-class board of trustees for the chapter, consisting of leaders in business, the nonprofit sector, and government. Realizing the importance of science-driven decision making, Henry Little tied the trustees to the science by using the Endangered Forest Bird Project's science advisory board and Cam Kepler's appointment to the Board of Trustees (1982–87) to bring science to the board's conservation actions decision-making process. This organizational structure ensured a powerful flow of ideas between formerly disparate parts of the Hawaiian conservation community and the scientific community. The science board identified and ranked important factors that were essential to the survival of Hawaii imperiled species (The Nature Conservancy, 1982, 1983, 1985), and gave that information to the Board of Trustees of the Hawaii chapter of The Nature Conservancy. The trustees quickly approved several areas for acquisition as nature reserves. The management challenges faced by the managers of those lands were identified in a "Save an Acre" commentary that was published in "Science" (Scott and Kepler, 1983). The response was phenomenal. By 1984, more than $4 million for conservation of endangered forest bird habitat had been brought into Hawaii, mostly in response to the information provided by the HFBS. Henry and Kelvin received the DOI Conservation Service Award in 1984 for their conservation efforts in Hawaii.

While The Nature Conservancy was conducting its conservation activities, Hawaii's Natural Area Reserve System was identifying possible areas for designation as Natural Areas and the USFWS was screening areas for possible new wildlife refuges. The conservation efforts of these three groups were not entirely independent of each other, and each used shared resources to inform its decisions regarding establishment and design of new ecological reserves. Those decisions, made with the benefit of information from the HFBS and other sources, led to the designation of 12 protected areas, including the USFWS Hakalau Forest National Wildlife Refuge (http://www.fws.gov/refuge/hakalau_forest) and an area in Kipahulu Valley on Maui that later became part of Haleakala National Park. Other Natural Area Reserves were established both independently and collaboratively by the Hawaii DLNR and The Nature Conservancy. These areas include Pu'u Maka'ala (http://dlnr.hawaii.gov/ecosystems/nars/hawaii-island/puu-makaala/) and Pu'u O Umi Natural Area Reserves (http://dlnr.hawaii.gov/ecosystems/nars/hawaii-island/puu-o-umi-3/) on the island of Hawaii (Scott and others, 1987b). The Nature Conservancy and the State established Waikamoi Preserve (http://www.nature.org/about-us/index.htm?intc=nature.tnav.about) and the 7,500-acre Hanawi Natural Area Reserve (http://dlnr.hawaii.gov/ecosystems/files/2013/07/Hanawi-Management-Plan.pdf) on Maui. The Nature Conservancy established Kamakou Preserve (http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/hawaii/placeswe-protect/kamakou.xml) and Pelekunu (http://dlnr.hawaii.gov/ecosystems/files/2013/09/Pelekunu-LRP-DRAFT-FINAL.pdf), Olokui (http://dlnr.hawaii.gov/ecosystems/nars/reserves/molokai/olokui/), and the 1,330-acre Puu Ali'i Natural Area Reserves (http://dlnr.hawaii.gov/ecosystems/nars/reserves/molokai/puu-alii/) on Molokai.

On the island of Kauai, the 213-acre Kaluahonu Preserve easement to protect nesting sites of Newell's shearwater (http://www.abcbirds.org/conservationissues/habitats/BCR/hawaii.html) and the 3,579-acre Hono O Na Pali Natural Area Reserve (http://hawaii.gov/dlnr/dofaw/nars/reserves/kauai/honoonapali) to conserve forest birds and rare plants were established. These and several other previously mentioned nature reserves on Kauai were established, in part, because of information provided by the work of Patuxent's research biologists and their conservation partners.

The key to the quick application of information from the survey to the establishment of new protected areas for forest birds was the collaborative development of management- and policy-relevant research questions with managers and the continued involvement of the managers in conducting the survey, making the information available to decision makers in a user-friendly way (The Nature Conservancy, 1982, 1983, 1985; Scott and others, 1986). The use of graphics showing the lack of overlap in the areas established and managed for their conservation value and the distribution of the birds of conservation interest was a particularly powerful tool (Scott and others, 1987b, 1993).

Many of the tools used in the HFBS have been used by others. The gap analysis process, first used as a means to identify gaps in the protected areas network for endangered

Hawaiian birds (Scott and others, 1987a; Scott and others, 1993), is used worldwide to assess the conservation status of species and ecosystems (Rodrigues and others, 2004a, b; see also http://gapanalysis.usgs.gov/about-gap/our-history/). Every signatory to the Convention on Biological Diversity Treaty (http://en.wikipedia.org/wiki/Convention_on_Biological_Diversity) uses gap analysis to identify gaps in protection of their biological resources (http://www.cbd.int/doc/publications/cbd-ts-24.pdf), and GAP is an established program in the USGS (http://gapanalysis.usgs.gov/). Variable circular plots are widely used to estimate bird numbers (Estades and Temple, 1999). The 1980s rare bird surveys of the Micronesian Islands by John Engbring (USFWS), Fred Ramsey, and others used the methods and protocols of the HFBS to census the imperiled birds of Rota, Tinian, Aguijan, and Saipan (Engbring and others, 1986).

The translocation of Nihoa finches to new locations in the Leeward Islands by John Sincock and others was unsuccessful, but a population of Laysan finches persists today (2016) on Pearl and Hermes Atoll because of a 1967 introduction by John and Gene Kridler (Morin and Conant, 1997; Conant and Morin, 2002). Newell's shearwater can be found today at Kilauea Point National Wildlife Refuge on Kauai (http://www.fws.gov/endangered/news/bulletin-spring2009/shearwaters-of-kilauea-point.html) because of the translocation efforts of John and others. Those early translocation efforts in the Leeward Islands and Kauai demonstrated the results that could be achieved, and provided a model for the recent translocation efforts to decrease the risk of extinction for Laysan ducks (*Anas laysanensis*) and Nihoa millerbirds (*Acrocephalus familiaris kingi*) (Reynolds and others, 2008; U.S. Fish and Wildlife Service, 2014).

Finally, the Hawaiian crow is known to occur only in captivity (Banko, 2009; Lieberman and Kuehler, 2009). Its future as a wild bird lies with the captive flock made possible through the early efforts of Ernie Kosaka, Ah Fat Lee, Fern Duvall, and others in the HDFW and Win Banko to ensure that there would be options for the Hawaiian crow's survival (http://blogs.sandiegozoo.org/2009/04/21/hawaii-bird-program-open-house).

Our work in Hawaii differed in several ways from that done elsewhere in Patuxent's Endangered Species Program. First, we were tasked with studying an entire avifauna, whose life histories, distribution and ecology, and indeed very existence were undocumented, whereas other programs focused only on a single species. In response to this challenge, we pioneered the development of ecosystem recovery plans for Hawaii's birds (Kepler and others, 1984; Scott and others, 1984; Sincock and others, 1984) rather than the single-species plans that were the standard in the 1970s and 1980s. We also developed new approaches for detecting and monitoring rare birds (Reynolds and others, 1980; Ramsey and others, 1979); however, the clinical interventions and captive propagation of individual animals that were a major component of many of Patuxent's other endangered species field research efforts were only a minor part of ours.

Where Do We Go From Here?

Nearly 50 years after the first endangered species research biologists arrived in the islands, what have we learned? As a result of the work of Patuxent's biologists and other researchers from State and Federal agencies, nongovernmental organizations, and academia in the islands, we learned a lot about the rare things. We learned where they are and where they are not; new sampling methods for rare species; distribution, abundance, habitat associations, and biology of rare species; the nature of threats to survival of Hawaii's endangered birds and plants; and the management actions needed to mitigate those threats. The take-away lessons from those early research efforts are sobering: recovery is slow and asking conservation-relevant research questions is a difficult process, but using the results of that research in a timely manner in the field to implement management actions at scales that increase the survival chances of a species is much more so. Our most important lesson may have been that the consequences of delaying or not implementing management actions are often irreversible.

The birds of Hawaii are still highly endangered (Gorresen and others, 2009; Pratt and others, 2009b). None of the birds unrecorded or insufficiently documented during the HFBS was reliably reported after the survey (Gorresen and others, 2009). The chances that the unreported birds—for example, Kauai nukupuu (*Hemignathus lucidus hanapepe*) and Kauai akialoa (*Hemignathus ellisianus stejengeri*)—escaped detection are vanishingly small (Elphick and others, 2010; Gorresen and others, 2009; Reynolds and others, 2002; Scott and others, 1986, 2008; Sykes and others, 2000). Several birds observed during the HFBS—for example,ʻo'u (*Psittirostra psittacea*) (Kauai and Hawaii), Kauai ʻo'o (*Moho braccatus*), large Kauai thrush (*Myadestes myadestinus*), Molokai thrush (*Myadestes lanaiensis rutha*), Maui akepa (*Loxops coccineus ochraceus*), Maui nukupuu, and po'o-uli—as well as the Oahu creeper (*Paroreomyza maculata*) observed on Oahu during surveys by Shallenberger and Vaughn (1978) have not been seen for 10 or more years. As mentioned above, one species, the Hawaiian crow, is known to occur only in captivity.

Why are these birds still endangered? For many of the species we were tasked with saving, we failed to eliminate or mitigate threats and restore habitat at temporal and spatial scales consistent with achieving recovery goals. The consequence of our failure to act at the necessary scales and speed to reduce threats was often extinction. None of the putatively "extinct" species, save possibly the po'o-uli (Groombridge, 2009; Woodworth and others, 2009), benefited from the well-funded and intensive rescue efforts mounted for species like the California condor or peregrine falcon (*Falco peregrinus*). The work forces involved in several of those mainland conservation efforts commonly were larger than the population of the endangered species they were attempting to save. Unfortunately, for many other endangered Hawaiian birds, the resources to implement needed conservation efforts were not available and many of the management actions identified in

the first recovery plans were not implemented or were implemented at scales that were not conservation-relevant.

For example, the first Kauai Forest Bird Recovery Plan (Sincock and others, 1984) called for removal of feral ungulates from the Alaka'i Swamp, the heart of the last remaining habitat for Kauai's endangered forest birds, but the first ungulate fences were not built until 27 years later (http://dlnr.hawaii.gov/ecosystems/files/2013/08/Proposal-Extension-of-Hono-o-Na-Pali-NAR.pdf). In the intervening three decades, three species on Kauai—Kauai 'o'o, the 'o'u, and the large Kauai thrush—have become extinct and two new species have been listed.

Similarly, the 1986 recovery plan for the palila called for removal of feral ungulates from critical habitat of the palila, a recommendation that was supported by two court decisions (Juvik and Juvik, 1984; Meltz, 1994). Twenty-six years later, although our knowledge of the ecology and biology of the palila has increased substantially (Banko and others, 2009), mouflon (*Ovis gmelini musimon*) are still found in critical habitat of the palila in large numbers and are being managed as a recreationally sustainable population for hunters, in part with Federal funds provided under the Pittman-Robertson Act (https://www.fws.gov/laws/lawsdigest/FAWILD.HTML).

Why was there a failure to implement management actions that were known to prevent extinction and promote recovery (Kepler and others, 1983; Scott and others, 1984; Sincock and others, 1984)? Current recovery efforts in Hawaii, the state with the highest density of endangered species per acre in the country, lag far behind those in other states in terms of conservation funds received. Hawaiian terrestrial vertebrates, 30 species, received $1.7 million, with 5 species (the Hawaiian crow, Hawaiian common moorhen [*Gallinula chloropus sandvicensis*], Newell's shearwater, po'o-uli, and Hawaiian stilt) receiving 78 percent of those funds spent on Hawaii's terrestrial vertebrates (U.S. Fish and Wildlife Service, 1996).

The situation is more complex than a lack of funds, however. In a thoughtful treatment of this question, David Leonard and others have suggested that lack of funding (Leonard, 2008; Restani and Marzluff, 2002), lack of understanding of the plight of endangered birds in the islands, and failure to convince folks of the plight have contributed to an urgent need for conservation action. Additionally, there are substantial sociopolitical barriers to implementing conservation actions to benefit endangered forest birds related to conflicting management objectives for areas where endangered species occur (for example, sustaining a recreationally viable population of mouflon for hunters as opposed to maintaining the integrity, diversity, and health of palila habitat [Banko and others, 2009]).

Where do we go from here? We have the advantage of nearly 50 years of research and the wisdom and insights gained from four decades of management actions, successful and unsuccessful; revised recovery plans for all but the northwestern passerine species; and a larger and more diverse conservation constituency with thousands of interested citizens and new citizen conservation groups (the Hawaii Conservation Alliance [http://hawaiiconservation.org/], Hawaii Association of Watershed Partnerships [http://hawp.org/], and Hawaiian Wetland Joint Venture [http://pcjv.org/hawaii/]) with which to work. These new institutional structures focused on maintaining the integrity of native ecosystems and their ecological processes will provide new perspectives on what actions are needed to save the remainder of Hawaii's endangered ecosystems and species (Pratt and others, 2009b). Fortunately, working with the broader conservation perspectives offers new hope for the future of Hawaii's endemic flora and fauna.

The ability of these conservation efforts to prevent extinction of additional species has been made more difficult, however, because of climate change, the increase in human population, and the need to act at landscape scales (Price and others, 2009). Finally, success will require more bridge building and collaboration among different constituencies, and major new commitments of collaboration and financial resources.

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Aloha from Hawaii—John Sincock and his assistant, Mike Scott, U.S. Fish and Wildlife Service, in their truck at the end of several days' work, summer 1976. Photo by U.S. Fish and Wildlife Service.

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