HISTORY AND STATUS OF SCIENCE PROGRAMS AT THE SMITHSONIAN NATIONAL ZOOLOGICAL PARK'S CONSERVATION AND RESEARCH CENTER

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HISTORY AND STATUS OF SCIENCE PROGRAMS AT THE SMITHSONIAN NATIONAL ZOOLOGICAL PARK'S CONSERVATION AND RESEARCH CENTER

EXECUTIVE SUMMARY

In 1965, Theodore Reed, Director, hired John F. Eisenberg as Resident Scientist, and began a major program in scientific research at the National Zoo. In its modest beginning the program's research concentrated on the comparative ethology of mammals, and relied heavily on an extensive research collection, as well as the zoo's exhibit collection. Under Eisenberg's leadership the program quickly grew in taxonomic breadth to include birds and reptiles. Disciplinary scope also expanded through collaboration within and beyond the Smithsonian and through graduate students, first at the University of Maryland, and later at other academic institutions. Eisenberg and his growing staff initiated a series of long-term field studies that were instrumental in advancing biological exploration in Latin America, Asia, and Africa. These field studies also opened the doors to collaboration with scientists at the National Museum of Natural History, who undertook their own independent studies.

At the beginning of the second decade of science (1975 through 1984) Director Reed acquired the Conservation & Research Center as surplus government land. It was a time when zoos were awakening to their latent ex-situ role in conservation as breeding centers. At first, CRC was used primarily as a satellite facility for research activities on the newly established captive collection there. but it also served as a venue for symposia and workshops convened by National Zoo scientists and their collaborators. In addition, CRC's natural habitats became a site for ecological investigations of native wildlife, particularly birds and mammals. By the 1980s, training of developing country nationals in wildlife conservation and management became a new science-based initiative, and CRC became the initial site for training. This program soon offered training courses and workshops at various locations overseas, including the zoo's long-term field project sites in Venezuela, Nepal, and Ceylon (Sri Lanka). Staff, programs and facilities for science grew against a backdrop of continuous organizational change, but science, in the form of biologically trained staff also overflowed from the research department into other parts of the zoo. By the end of the second decade National Zoo scientists had published numerous syntheses of their work in edited books, monographs, and peer-reviewed journals. Eisenberg was hired by the University of Florida for the Ordway Chair in Wildlife Management. Shortly after, Director Reed retired and Dr. Michael Robinson took the helm as the Director of the National Zoo in the mid-1980s.

In the third decade (1985 through 1994), as a result of new positions and special federal appropriations, the zoo gained new programs in reproductive physiology, molecular genetics, and eventually migratory birds. A program in landscape ecology was also created at CRC through donations and grants. Each of these initiatives grew under their leaders, who secured funding for graduate students, research fellows, and projects, and generated a significant body of published work. An endocrine research laboratory was also established at CRC. Conservation became a recurring theme in many projects. At the end of this period several scientists began to invest their time in translating science into educational initiatives. One of the outcomes was the National Zoo's Amazonia Science Gallery, where zoo visitors can view laboratory science in action, interact with scientists, and browse an extensive menu of projects conducted by National Zoo scientists. The Forest Biodiversity Monitoring Project on the other hand is field-oriented and targets secondary school teachers and their classes in northern Virginia. Finally, ELIPSE demystifies science and brings environmental education to the attention and involvement of Latino audiences in the greater Miami metropolitan community.

At the beginning of the fourth decade the program in reproductive physiology was transferred to

and incorporated within CRC, and scientists in different parts of the organization began to discuss ways of integrating their work better and capitalizing on their collective strength to promote their work and raise funds. At the end of the year 2000, Director Spelman consolidated most of the zoo's research programs within CRC. The Department of Zoological Research became the Department of Conservation Biology, and the Reproductive Physiology Program became the Department of Reproductive Sciences. The Monitoring and Assessment of Biodiversity (MAB) Program, a collaborator of several years situated in the Ripley International Center, was also transferred to the zoo's supervision by Undersecretary O'Connor and placed within CRC. The Molecular Genetics program however was transferred to the National Museum of Natural History though its offices and laboratory will remain at the zoo until new space can be created at the museum.

CRC currently has 86 employees of whom 36 are practicing scientists. Its staff is spread between three facilities, the Research Building at the National Zoo in Washington, D.C., the Ripley International Center on the Washington mall, and CRC property in Front Royal, Virginia. Over the past 35 years the zoo's science activities have generated over 2400 publications including books, and edited volumes. Of these, 68% have been published in peer-reviewed journals. Over 3400 alumni have accrued to formal training courses in the WCMTP and MAB programs, and another 1000 trainees and interns have been individually mentored by scientists in the last two decades. The tradition of conducting long term field projects in the developing world continues today, but perhaps with even greater emphasis on capacity building and cross-disciplinary involvement.

Introduction

In the 2001 Smithsonian "white paper", *Science in the 21st Century*, the role of science within the Institution is reviewed with reference to each of the science units except the Smithsonian National Zoological Park. The single reference to the National Zoo mentions the exhibition of giant pandas. This document suggests that the Zoo is not a science bureau, when in fact its contribution to science through a structured program began nearly four decades ago and continues today. The purpose of this document is to place the National Zoo's science into the broader context out of which it grew and to summarize its history, accomplishments, and current status. This will provide background to help the review committee understand the present status of the Conservation & Research Center (CRC), the administrative unit that now contains most of the Zoo's science programs.

The beginning of the Zoo's science programs was greatly influenced by the popularity of the science of animal behavior or ethology. Ethology reached its zenith in the 1960s and early 1970s when the three co-founders of ethology, Konrad Lorenz, Niko Tinbergen and Karl von Frisch were awarded the Nobel Prize for Medicine. This limelight underscored ethology's important contributions to other disciplines, including: systematics and taxonomy, in which the Smithsonian Institution held a global leadership role then as now; animal health and reproduction (especially of captive populations); ecology, genetics; as well as psychology and anthropology. Furthermore, it became clear that most academic institutions lacked the requisite infrastructure for behavioral research on most animal species. Such research required either costly captive settings, such as only zoos could provide, or wild populations.

Academia and zoos soon developed a mutually beneficial interaction: to wit, scientists were able to study a greater variety of species by working in zoos, and zoos were able to use the results of these studies to improve their husbandry practices. These cooperative efforts began in Europe and initially involved only a few American zoos, e.g., the Bronx, San Diego, Brookfield and National Zoo. The captivation of wildlife commonly seen in zoos and in nature documentaries today results from new knowledge gained through science. Zoos have been transformed from uninspiring collections of caged animals, to centers of learning about and conserving animals and their habitats for future generations. Behavioral research not only enlightened the public, it also improved the management of zoo animals and the design of captive settings, by accounting for differences in the social and nutritional needs

among species. Science has improved the quality of life and survival of captive populations, as well as the public's understanding, enjoyment and attendance.

The National Zoo has been a leader in applying scientific knowledge to animal management in zoos and in making science and conservation biology a standard component of zoo missions. Under the directorship of Dr. Theodore Reed, in 1965 the National Zoo hired Dr. John Eisenberg as Resident Scientist. Eisenberg, then an Associate Professor of Zoology at the University of Maryland, became a full-time employee of the zoo and created the Scientific Research Department. The program started with four positions: a secretary and two keepers, and a full-time biotechnician. A visionary with a brilliant ability to teach and lead, Eisenberg, with the encouragement of Smithsonian Secretary S. D. Ripley and Reed, built a department of zoological research that focused the expertise of leading scientists and graduate students in a variety of disciplines: mammalogy, ornithology, herpetology, nutrition, veterinary medicine, reproduction, population biology, and ecology. Under his leadership the National Zoo set a high academic standard not only for the study and management of captive populations, but also of wild ones. As collaborations with scientists and students from other countries were launched, the scientific activity of the National Zoo extended far beyond its own staff and park boundaries. These enterprises were funded not only by the Smithsonian, but also by the nation's most prestigious scientific institutions, including the National Geographic Society, the National Science Foundation and the National Institutes of Health.

Though Ripley, Reed, and Eisenberg often disagreed with one another on details concerning zoo programs and priorities, their thinking was in harmony when the availability of 3150 acres of surplus government property in Front Royal, Virginia, came to their attention in 1974. The Smithsonian's proposal to acquire the property was approved by the Board of Regents and Congress. The Conservation & Research Center was created in the wake of the passage of the Endangered Species Act, when zoological institutions around the world were awakening to their unique but latent potential in conservation. The New York Zoological Society and San Diego Zoo also acquired additional properties to broaden their respective roles in captive propagation, and research departments were established or expanded in several other zoos.

The role of science in the National Zoo continued to grow with the addition of scientists to the research unit, then known as the Department of Zoological Research (DZR). Professional biologists were added to the curatorial staff, and the programs in pathology and reproductive biology were expanded. However, in the absence of an overall vision for science at the National Zoo by higher administration, DZR, CRC, the Reproductive Physiology Unit, and the Smithsonian Migratory Bird Center (which later merged with DZR) evolved independently under Director Michael Robinson, who succeeded Dr. Reed in 1984. Each unit achieved recognition of its own programs and the zoo's greatest asset came to be its set of highly successful science and conservation programs about wildlife. Its "soft underbelly" was the failure to integrate fully its science assets with its public programs. It can be fairly said that each program vied for identity within Director Robinson's vision of BioPark, and each achieved some success. The Cheetah Station, Elephant House Education exhibit, and Hawaiian Bird Exhibits were all scientist-generated exhibits. However, Amazonia Science Gallery, an exhibit showcasing National Zoo research, is the most significant effort to integrate science into the mainstream of public programs at the zoo. Amazonia Science Gallery was developed because of the combined efforts of Associate Director for Education, David Jenkins and DZR staff, especially Miles Roberts.

When Secretary Small assumed responsibility for the Smithsonian in 2000, he saw the Zoo as "science rich" and "exhibit poor". His avowed priority for the Zoo was public exhibits. Early in his tenure he appointed the Zoo's Chief Veterinarian, Dr. Lucy Spelman, as Director. Spelman has stated that her vision for the zoo is state of the art facilities (for animals and visitors), increased visitation, recognized excellence in reproductive biology and veterinary medicine, and expanded educational outreach. This means that every exhibit includes education and public outreach, research (ideally on site and off site), interactive exhibitry, animal care, facilities support, and horticulture. In an effort to unify SNZP

scientists and to place virtually all scientists in one organizational division, Spelman reorganized the zoo by moving DZR and Migratory Birds under the direction of the Associate Director for CRC, joining reproductive sciences, professional training, and other scientists already within the CRC organization. It was made clear that the move was not intended to physically relocate all scientists to Front Royal, but that the move was designed to encourage NZP scientists to work together to evaluate their scientific programs, animal collections, and educational programs and better define their connections with the animals on public display at the Zoo. In addition, the Monitoring and Assessment of Biodiversity Program (MAB), which had resided at different times in the NMNH and Office of International Programs, was also added. (See organization chart below.) However, the zoo's long history of budgetary decline necessitated solution. As a financial survival strategy Small proposed to close CRC. downsize its staff, and relocate science functions to the zoo in Washington. This would allow the continuation of some scientific functions at the zoo in Washington and eliminate the need for what he saw as costly "property management" at Front Royal. This decision was unpopular with many conservation organizations, universities, and other government agencies, both nationally and internationally, so Small proposed turning the whole of science reorganization over to a commission composed mostly of scholars outside the Smithsonian.



The future of science at the National Zoo and the Smithsonian Institution in general now rests in the hands of a special commission. Regardless of the outcome, the products of National Zoo science are evident not only in an applied sense, as in the transformation of many zoos into centers of biological education and conservation, but also in the numerous scientific publications that provide citizens of the world with new knowledge about man's biological heritage. Science at the National Zoo has fulfilled the Smithsonian Institution's most basic mission: the increase and dissemination of knowledge to humankind.

The Evolution of Science at NZP

To provide a more detailed understanding of the development of the scientific programs now consolidated under CRC, we have divided the period 1965-2001 into four decades. For each decade, we provide a summary, and then review staffing and zoo organization, developments in scientific programs, and major scientific accomplishments. We also attempt to summarize major conceptual themes of each decade. As will be seen, each decade had a distinctive scientific climate or "zeitgeist". Many of the original research themes, such as the behavior and ecology of mammals, avian communication, and the improvement of captive husbandry through a variety of scientific disciplines continue to the present day. However, many new scientific themes and programs were added over the years either by the addition of staff trained in new disciplines or by changes in the research interests of existing staff.

Compiling a thirty-five year history of science is a difficult challenge. Many pre- and postdoctoral scientists have not been mentioned in the interest of being concise. While we believe we have covered all major aspects of the science, other parts have no doubt been abbreviated or overlooked due to limitations of time and records.

THE BEGINNING: 1965-1974

SUMMARY

The first decade legitimized the National Zoo as a science bureau of the Smithsonian Institution. The zoo became a venue for comparative studies of mammalian behavior and the Director allocated funds to construct facilities to advance this goal. The zoo acquired an extensive collection of little known and unusual mammalian taxa, such as tenrec insectivores, dasyurid marsupials, and caviomorph rodents. These and exhibit collections offered subjects for Eisenberg's graduate students at the University of Maryland and attracted collaborations with senior scientists. While the Smithsonian Tropical Research Center (STRI) became a focus of long-term field studies, the National Zoo led all Smithsonian bureaus in initiating international field studies of behavior and ecology. The National Zoo initiated investigations in Madagascar, Ceylon (Sri Lanka), Venezuela and Barro Colorado Island (STRI). These activities broadened the Smithsonian's scope of biological science internationally, and opened the doors to participation by scientists from the National Museum of Natural History and external specialists. Research promoted scientific theory of behavioral evolution, ecology, and mammalian management and husbandry, and several major monographs and numerous publications were the results. In 1970 a new building dedicated to scientific research and veterinary medicine allowed for expanded scientific efforts. By the end of 1974 the research department had a staff of five scientists (Eisenberg, Buechner, Kleiman, Morton, Montgomery), and four support staff (Holden, Maliniak, Deal, Hough).

Staffing and Organization

When Dr. Reed created the science program at the National Zoo, it was an activity confined to the Department of Scientific Research (SRD) under the supervision of the Resident Scientist, Dr. John Eisenberg, who answered to the Director. The Smithsonian created a Deputy Director position in 1974, which was filled by Mr. Ed Kohn, who then supervised the Resident Scientist. Eisenberg was given several positions: a staff secretary, Wyotta Holden, and three keepers (supervisor Gene Maliniak, Mike Deal and John Hough). Larry Collins, a Maryland schoolteacher, was hired as a biotechnician. A small number of scientists joined SRD in the mid-1970s. Hal Buechner, a senior scientist, was transferred to the zoo from the National Museum of Natural History, when the Department of Ecology was disbanded in the mid-1970s. Devra Kleiman, a post-doctoral fellow from Rutgers University was hired as a reproductive biologist, and Gene Montgomery was hired as an ecologist. Gene Morton, then an assistant professor at the University of Maryland, was also hired to expand the taxonomic breadth of the program to include birds.

Science Programs

Comparative Mammalian Ethology: Eisenberg had studied comparative mammalian ethology with Peter Marler at the University of California (Berkeley) and recognized the scientific value of zoological parks for comparative studies. In the 1960s, the National Zoo maintained a remarkably eclectic collection of small mammals that reflected the interests of Ernest P. Walker whose monumental *Mammals of the World* was written during his tenure as National Zoo mammalogist with funding from the National Science Foundation. Eisenberg's taxonomic tastes, on the other hand, favored other groups of mammals, and to accommodate those interests, Zoo Director Reed made a significant amount of animal holding space available exclusively for research. Eisenberg amassed an unrivaled collection of small mammals for phylogenetic studies of mammalian behavior -- including dasyurid marsupials, insectivores (Madagascan tenrecs and Hispaniolan solenodons), caviomorph rodents, as well as viverrid and herpestid carnivores. It is doubtful that the taxonomic scope of such collections will ever be duplicated in a zoo again. Under Eisenberg's leadership, the National Zoo rapidly developed a vigorous research enterprise that revolved around his personal investigations and those of his students at the University of Maryland.

The Zoo's tradition of linking captive and field studies was manifest at the beginning when Eisenberg and Edwin Gould, then of Johns Hopkins University, commenced their comparative studies of Madagascan insectivores. With a two-year grant of \$100,000 from the National Science Foundation, they logged several months of fieldwork in Madagascar, and carried out parallel studies of behavior and reproduction at the zoo. The work culminated in *The Tenrecs: a study in mammalian behavior and evolution* (Eisenberg and Gould, 1970). In addition, several specimens of unusual Madagascan birds and mammals were added to the exhibit collections. At the same time, Eisenberg's interest in neotropical mammals focused on primates and rodents, and capitalized on both the zoo's collections and the field facilities of the Smithsonian's Tropical Research Institute. This resulted in Eisenberg's studies of communication in black spider monkeys (1976). Other projects that combined captive and field studies included Nancy Muckenhirn's master's thesis (1967) on the anti-predator behavior of Geoffroy's marmoset. Nicholas Smythe's Ph. D. (1970) studies of the comparative ethology of agoutis and pacas, and postdoctoral fellow, Devra Kleiman's work on green acouchi behavior (1970, 1971, and 1972). Eisenberg subsequently hired Kleiman as a reproductive biologist and Smythe was hired by STRI.

It is important to recognize that mammalian field studies by zoo scientists frequently focused on species in the National Zoo's collections. It is fair to say that the motive for conducting field studies was often stimulated by interest generated by the species in the collection. However, the reverse was true too. When practical, species such as tenrecs and Tasmanian devils, were added to the exhibit collection as a result of field or captive research studies. Animals moved freely between the captive exhibit and research collections.

Golden Lion Tamarin Project

In 1972, the Wild Animal Preservation Trust sponsored the ground breaking conference "Saving the Lion Marmoset," a meeting at the Smithsonian Institution's National Zoological Park (NZP) that brought together 28 European, American and Brazilian biologists who reviewed and analyzed all available data on the lion tamarins and other callitrichids. Long long-term recommendations were made for husbandry, research and conservation activities, including recommendations to establish an inter-institutional cooperative breeding program, the establishment of a studbook and a data bank to record all aspects of their captive propagation. Following this important meeting, DZR made a major commitment to the captive propagation and conservation of the golden lion tamarin and launched the Golden Lion Tamarin Conservation Program.

Research on Zoo Exhibit Animals

In 1970, when Devra Kleiman joined the research department staff as a reproductive biologist, she immediately initiated research programs on reproduction in white tigers and golden lion tamarins, two high-profile collection species designated by Director Reed as priority candidates for captive breeding. Kleiman's research made use of trained teams of graduate students and volunteers who gathered, analyzed and interpreted information about the social and reproductive behavior of target species to determine how to manage them to promote reproduction.

Kleiman's approach also required something never before seen in zoos: collaboration between researchers and collection management staff to achieve a common goal. As such, her research was a true watershed in integrating research and exhibit collection programs, a process that flourishes today in many zoos around the world. Reed, Eisenberg and Kleiman quickly realized the enormous potential of such a collaborative approach. In fact, its success had already been quietly demonstrated in the off-exhibit basement facilities of the Scientific Research Department where, for several years, Biotechnician Eugene Maliniak, and Eisenberg had been breeding colonies of rare species of small mammals for behavioral research purposes. Eisenberg's experience and vision was that captive studies complemented field studies in many valuable ways and additionally that captive colonies provided unique training opportunities for students and research opportunities for visiting scientists.

After years of experience with a veritable cornucopia of small mammals obtained for the Mammals of the World project, Maliniak was the consummate animal husbandryman able to coax even the most reticent species to thrive and reproduce in captivity. Together Eisenberg and Maliniak became world famous for their audacious and innovative achievements at maintaining and breeding species that few well-traveled and worldly biologists had seen in the flesh.

The off-exhibit colonies at SRD were a unique resource, which provided over the next three decades animal facilities and trained staff, a training ground for many graduate and postdoctoral students, incredible research opportunities for visiting researchers from around the world, and, as a by-product, rare and exotic (even by zoo standards) species for exhibition. During that time, the research collection housed 112 species of mammals, nine species of birds and one species of reptile and supported research in behavior, endocrinology, reproductive physiology, energetics, communication, life history, nutrition, and molecular genetics.

The cross-pollination effect of Kleiman's collection-oriented projects and the thriving small mammal breeding colonies in SRD played a major role in initiating the next era in the evolution of the SNZP, and its hallmark would be no less than the creation of the science of captive animal management.

At about the same time that Director Reed had convinced Congress to fund a major overhaul of the exhibit facilities at NZP, he himself became convinced by Eisenberg's and Kleiman's successes that a scientific approach toward collection management could have major payoffs for the National Zoo and the larger zoo community. Reed directed that the curatorial staff be upgraded and should be made responsible not only for upgrading the quality of animal exhibits, but for professionalizing animal care. The new curators, biologists by training, interacted easily with researchers who, in many ways, became their mentors. The presence in the collection of a veritable army of graduate and postdoctoral students and volunteers conducting research on the collection had a profound effect on researchers, managers and keepers alike. The abrupt mixing of what amounted to two distinctly different "animal cultures" also resulted in profound changes in the way the Zoo managed its animals and how researchers viewed zoo collections. It sparked equally profound changes in the how zoos around the world manage their collections and animal populations.

With the collaboration of curators, there now began a period of intense collection-based research at the Zoo. Almost monthly, new breeding and behavioral research programs were initiated for species as diverse as cheetahs, white-tailed prairie dogs, elephant shrews, tree-kangaroos, Tasmanian devils, white-cheeked gibbons, Barbary lions, South American fruit bats, bongos, Dorcas gazelles and ringtailed mongooses, to name but a few.

The research programs generated mountains of data, publications, and trained students. They also engendered in animal managers a new perspective, one that demanded scientific approaches and an eye on the connection between captive and wild populations. These collaborations also generated observations that aided collection management and posed challenging questions about collection management practices which, in the final analysis, stimulated improvements in animal care and management.

Within a short period of time, research and management at the National Zoo became inexorably and forever entwined. The distinction between job titles began to blur as curators engaged in research, researchers delved into husbandry and management, and students working both with researchers and the collections received a rich cross-disciplinary education that prepared them simultaneously for careers in academia, conservation, and zoo management. The influence of this veritable revolution in how zoos operate soon spread to other institutions through a diaspora of NZP-trained biologists who found jobs as curators, researchers, and directors in zoos throughout the U.S. Many of those who followed a more traditional career path as teachers and professors at universities developed working research and educational relationships with zoos in their local communities and stimulated research

programs in small and medium sized zoos. Suddenly, a new generation of university students around the country began considering zoo work, or "zoo biology" as it was becoming known, as a serious career option. Researchers and curators participated equally and vigorously in the nascent conservation, education, and training programs of the professional zoo association (the American Association of Zoos and Aquariums) and many were elected and appointed to leadership positions in that organization.

In short, the unique amalgam of research and zoo management forged at the National Zoo literally sparked a once-in-a-lifetime revolution in the zoo industry. The echoes of that revolution still reverberate through the industry. To this day zoos around the world strive to emulate our achievements of two and three decades ago and wait expectantly for the next rumblings from one of the few zoological institutions in the world capable of truly revolutionary action.

Veterinary Research

Mitchell Bush, while serving primarily as a clinical veterinarian began to systematically collect information on anesthesia and repair of fractured bones in the wide variety of species offered by work in the zoo. The development of a record keeping system was a vital requirement, and this was pursued at the same time. By the end of the decade he had a respectable database of dosages for a variety of drugs, as well as the expected range of effects, and this provided an indispensable source of information in determining dosages for new species. His work on the surgical repair of fractured bones concentrated on mammals and birds as opportunity allowed, but in addition he conducted experimental study of bone repair in pigeons.

Field Studies

Field studies of single species and communities of mammals were driven by a number of motives, but implicit in these studies was the conviction that the key to understanding the biology of any species required thorough knowledge of the creature in the setting in which it evolved. In other words, the yardstick for assessing the biology of a species in captivity is the nature of the beast *in situ*. The natural setting is a control and a basis for understanding the effects of the artificial context of captivity.

<u>The Ceylon Biological Program</u>: As the tenrec studies were winding down, Eisenberg joined forces with the late Drs. Helmut K. Buechner¹ of the National Museum's Department of Ecology and Raymond Fosberg (Department of Botany). In 1967 they jointly initiated the Ceylon Biological Program in what is now Sri Lanka. This multi-year (1967-1979) program was funded under Public Law 480 with supplemental funds from the National Institutes of Health. Fosberg organized a revision of Henry Trimen's *The Handbook to the Flora of Ceylon*, whereas Buechner conducted an ecological survey of elephants with an eye towards management of wild populations. Eisenberg led the elephant surveys and expanded the program to include studies of Sri Lanka's primates and other mammals. These efforts were in collaboration with the Government of Ceylon.

Drs. Eisenberg and Dietrich Mueller-Dombois (University of Hawaii) taught courses in animal and plant ecology at the University of Peradeniya, and provided highly successful training and research opportunities for Sri Lankan students and colleagues. With the support of Hilary Crusz, Chairman of the Zoology Department, their course syllabus became the reference for the newly formed program there in ecology.

Eisenberg brought a number of collaborators and graduate students into the Ceylon Program. Drs. Marcel and Annette Hladik (from STRI) and Dr Gil Manley (from Oxford) undertook studies of

¹ Buechner was subsequently transferred to the Zoo where he informally mentored the younger staff and graduate students until his death in 1975.

nutritional ecology and behavior of primates. Dr Fred Kurt, a Swiss ethologist, concentrated on the behavior of elephants. Among the student projects were studies on the anti-predator behavior of the axis deer (Nancy Muckenhirn), the ecology of the Asian elephant (George McKay, 1973), and the comparative ecology of gray and purple-faced langurs (Rudy Rudran, a Ceylonese). Rudran, whose project became a masters thesis, subsequently became a Ph. D. student at the University of Maryland and completed his Ph. D. research on primate ecology in the Kibale Forest of Uganda (1976) where he worked in close association with Thomas Struhsaker, then of the New York Zoological Society. Charles Santiapillai, another Ceylonese field assistant became a prominent member of the IUCN Asian Elephant Specialist Group. Both Rudran and John Seidensticker returned to Sri Lanka in the early 1970s to assess the elephant situation for a major World Bank development project.

The Ceylon Program also provided the roots for the Primate Biology Program in Sri Lanka, one of the most comprehensive studies of any wild primate species. It is headed by Dr. Wolfgang Dittus, another Eisenberg student who undertook his studies of the toque macague from 1968-1972. He has continued the project uninterrupted for over 30 years through funding from the National Science Foundation and similar agencies, and has maintained a non-salaried affiliation with the National Zoo. The work has established a substantial empirical resource for cross-fertilization among projects on different aspects of primate biology. It involves an entire population of toque macaques (Macaca sinica) that inhabit natural dry evergreen forest at Polonnaruwa. Over 1,100 macagues (from 34 different social groups) are individually known, with information from all or most individuals on date of birth, death and emigration, matrilineal genealogy, social rank, and history and ecological variables. For many individuals, profiles have been established for growth and development, paternity and other genetic attributes, as well as epidemiology and physiology. Sympatric primates, the langurs (Semnopithecus entellus and Trachypithecus senex) and loris (Loris tardigradus) also have been studied, but less intensively. The program therefore offers not only unique empirical congruity among a diversity of scientific interests, but also the possibility to investigate phenomena in a wild population that heretofore were possible only in well-studied captive colonies.

More than 50 publications have emanated from Ceylon Primate Biology Program. Despite local political constraints twenty graduate students and post-doctoral fellows have benefited from the program. The program takes the lead role locally for conservation issues and environmental education outreach projects. In addition, over 150 short-term volunteers from around the world have participated in the program as Earthwatch volunteers. On a wider scale, knowledge gained from this research has been disseminated through several documentary films that have been broadcast nationally and internationally on the Discovery and other TV channels.

The National Zoo's program in Ceylon paved the way for significant independent efforts by scientists in the National Museum of Natural History (e.g., Dr. Karl Krombein's entomological surveys) and from other specialists around the world. The PL-480 monies were exhausted by 1971, and most Smithsonian activity ceased. Overall, a great number of scientific publications (over 100 papers & two monographs) resulted from this program, and many careers (three Ph.D.s and eight M.Sc.s) were launched in tropical biology.

Ecology of Edentates: The 1970s saw the commencement of several new field programs. The National Zoo had enjoyed an unusual success; for several years two-toed sloths had reproduced in the zoo's old Lion House. This stimulated Eisenberg's scientific interest in the species, and prompted him to contract and subsequently hire wildlife biologist Dr. Gene Montgomery, who was an expert in the use of radio-telemetry, then a new technology of great promise. A major study of sloth ecology commenced on Barro Colorado Island, and Mel Sunquist was contracted to assist in arduous tree climbing necessary to capture the animals for radio-collaring. The studies revealed a number of remarkable findings about the species' life history adaptations, and awakened interest in the unknown biology of this ancient lineage of bizarre mammals. Montgomery's findings and enthusiasm stimulated studies of edentates by scientists beyond the Smithsonian. One of them was Kent Redford, a former intern with Eisenberg and Ralls, who studied myrmecophagy under Holldobler (Harvard University), and focused on the South American rodent genus *Oxymycterus* for his Ph.D. During his postdoctoral fellowship at NZP he began comparative studies and expanded his interests in armadillos. Montgomery transferred to STRI where he continued his studies until retiring in the 1980s. Redford is now a program officer at the Wildlife Conservation Society.

The Venezuela Biological Program: The Venezuela Program (1975-present) grew out of Eisenberg's interest in vertebrate ecology in the neotropics. The mammalian fauna was well documented from extensive collections coordinated by the National Museum's Charles Handley in the 1960s. With funds from the Smithsonian's International Environmental Sciences Program (IESP), and a grant from NIMH for studies of primates, the program took place at Guatopo National Park and Fundo Pequario Masaguaral, a large ranch in the llanos owned by Tomás Blohm. The project was collaborative within and beyond the institution and up to now has provided research opportunities to about 20 Smithsonian biologists and twenty more scientists from eleven other institutions. The red howler monkey (Alouatta seniculus) was a species of major focus. Eisenberg, Rudran, and the National Museum's Don Wilson and Dick Thorington worked closely to capture, age, and mark the population that has served as the research subjects for the past twenty-six years. Carlos Saavedra, Caroline Crockett, David Mack, Rudy Rudran, Ranka Sekulic, Damian Rumiz, Theresa Pope, and G. Agoramoorthy conducted pre- and post-doctoral studies on various aspects of behavioral ecology. Dr. Rudran documented infanticide for the first time in any New World primate (Agoramoorthy and Rudran, 1995), and created the impetus for the discovery of this behavior in numerous other South American monkeys as well.

Besides the red howler project, the Venezuela Program included investigations on several other mammals (Cebus monkey, white-tailed deer, crab-eating fox, rodents, bats, giant ant-eater, tamandua and coendu), birds (hoatzin, snail kite, green rumped parrotlet, white-bearded flycatcher), reptiles (Orinoco crocodile, Spectacled caiman, turtles, green iguana), fish, plants and fungi. These investigations mainly covered aspects of ecology, behavior, taxonomy, nutrition and communication. However, some investigations such as the studies of the Orinoco crocodile and the green-rumped parrotlet conducted by John Thorbjarnarson and Steve Beissinger respectively, also had important conservation implications. The earlier investigations were published in a 1979 volume titled *Vertebrate Ecology in the Northern Neotropics* edited by Eisenberg. Since that time the research supported by the Smithsonian Venezuela Program has contributed nearly 140 scientific articles to various journals. Furthermore, three graduate students obtained their M.Sc. degrees and 15 received their Ph. Ds for research conducted under the aegis of this program. Hato Masaguaral has also been the site for Rudran's international wildlife management courses. The thorough background of studies from this location has enhanced the educational capacity of the course, and the multiplier effect of the teachers and graduate students trained and motivated new generations of researchers in Latin America

Avian Research

When Dr. Gene Morton joined the staff in 1974, the National Zoo expanded the taxonomic scope of the zoo's research programs to include birds. Morton continued his ongoing studies of bird communication and maintained his ties with the University of Maryland. His research interests in vocal communication gave impetus to developing a first-class sound analysis laboratory to support research on communication and mating systems in birds. Morton established projects in Panama, where he did field research as a graduate student of Charles Sibley, and advised a continuing stream of graduate students in his work there. His interest in migratory birds (*Migrant Birds in the Neotropics*, 1982) and tropical avian ecology led to the formation of the Smithsonian Migratory Bird Center.

Research Syntheses through Publications, Symposia, and Books

In the first decade Eisenberg produced eight major papers on management and husbandry of mammals in zoos, and another paper on the use of zoos for individual study. Twelve major papers that synthesized mammalian behavior and evolution appeared in print, ranging from a phylogenesis of

mammalian predatory behavior (with Paul Leyhausen, 1972), and olfactory communication in mammals (with D.G. Kleiman, 1972), to a comparison of ungulate adaptations in the New and Old World (with George McKay, 1974). Eisenberg also co-edited the first *Man and Beast* symposium with Wilton Dillon. He advised three post-doctoral fellows, one master's student, and five Ph.D. students.

Below is a selection of publications/workshops/conferences that synthesized major bodies of knowledge at the time:

Collins, L.R. 1973. Monotremes and marsupials. Smithsonian Institution Press, Washington, DC.

Conference on "Saving the Lion Marmoset". The Conference that started the Golden Lion Tamarin Conservation Program, Washington, DC, 1972.

Eisenberg, J.F. and G.M. McKay. 1974. Comparison of ungulate adaptations in the New World and Old World tropical forests with special reference to Ceylon and the rainforests of Central America. In *The behaviour of ungulates and its relation to management,* ed. V. Geist and F. Walther, 2:585-602. IUCN Publications, n.s. No. 24, Morges, Switzerland.

Eisenberg, J.F. and D.G. Kleiman. 1972. Olfactory communication in mammals. *Ann. Rev. Ecol. System*, 3:1-32.

Eisenberg, J.F. and P. Leyhausen. 1972. The phylogenesis of predatory behaviour in mammals. *Zeitschrift Tierpsychologie*, 30:59-93.

Eisenberg, J.F., Muckenhirn, N.A., and Rudran, R. 1972. The relationship between ecology and social structure in primates. *Science*, 176:863-874.

Kleiman, D. G. and Eisenberg, J. F. 1973. Comparison of canid and felid social systems from an evolutionary perspective. *Animal Behavior* 21: 637-659.

Kleiman, D. G. (ed.). 1977. *The Biology and Conservation of the Callitrichidae*. Smithsonian Institution Press, Washington, D.C.

ADVENT OF CONSERVATION: 1975-1984

SUMMARY

The scope of science at the National Zoo expanded in the second decade. The zoo raised the educational standards for curatorial positions and filled new positions with young Ph.D.s. In addition to their managerial duties, these curators conducted collection and field-based research. The application of science to collections management and exhibit design reaped important insights. The National Zoo's discovery that inbreeding has major deleterious effects in zoo animals awakened zoos, wildlife managers, and conservation biologists around the world to the importance of scientific population management, and it contributed to the evolution of the "small population paradigm" of conservation biology. Animal nutrition research allowed the zoo to scientifically formulate diets for a variety of species, and to design replacements for maternal milk. The Endangered Species Act compelled zoos to scrutinize their role in conservation. The National Zoo advanced captive breeding of threatened species by creating the Conservation & Research Center on surplus government land in Front Royal, Virginia. Field and captive animal research commenced mainly through graduate and post-doctoral researchers. A number of long-term projects began to bear fruit leading to major publications. symposia, and books by zoo scientists. A dominant theme in this work was the synthesis of the evolution of behavior. New field studies were initiated on sea otter population biology and behavioral ecology of pinnipeds, and the Zoo assumed scientific oversight of the SI-Nepal Tiger Ecology Project. At the end of the decade the Zoo started a new program in reproductive physiology. At this point in time, researchers worked in four different parts of the National Zoo, and the earlier cohesion of a small research department became fragmented.

Staffing and Organization

The Scientific Research Department was re-named the Department of Zoological Research around 1975, and in the succeeding years a number of new positions for scientists were added to the Zoo's staff, primarily as curators under the General Curator, Jaren Horsley. CRC was created as a satellite unit of the zoo with line authority to the General Curator for animal programs, to the Director's budget office for administration, and to facilities management for support services. The inevitable conflicts of this arrangement lead Kohn to create a single management unit, and Chris Wemmer, who had been hired in late 1974 was promoted to serve as the Curator-in-Charge, answering directly to the Deputy Director. Larry Collins and Guy Greenwell were transferred to the center as curators of mammals and birds, respectively, and keepers were transferred from the zoo and hired as well.

CRC--Facilities development and staffing

Reed envisioned CRC as a captive breeding center for endangered exotic mammals and birds, and took possession of the property and installed staff nearly a year before the Government Services Administration completed the formalities of transfer. A program committee with representation from the research, animal, veterinary, and facilities departments guided decisions about facilities development and species selection for the next 3 years, at which time a master plan was developed under Reed's guidance.

Facilities development during CRC's first decade occupied much of the staff's time. The center's maintenance staff expanded as a result of temporary hires through federal Renovation and Restoration funds, and the conversion of existing buildings to new functions was done by zoo staff. After a large section of land had been fenced for ungulates, the barns were renovated, and animals transferred. With the exception of Bactrian camels, nearly all species of mammals in the CRC collection originated in the zoo's exhibit collection in Washington. The center also served as a back-up facility for nearly the entire bird collection between 1975 and 1977during the renovation of the bird house at the Zoo. Unlike mammals, many new species of birds were added to the CRC collection

Eisenberg hired Katherine Ralls in 1976 as a full-time researcher in DZR to replace the late Helmut Buechner. In 1978, when Ed Kohn left the National Zoo to become director of the Minnesota Zoo, Reed appointed Eisenberg as Assistant Director for Animal Programs, and created an Assistant Director for Facilities Management. Devra Kleiman was appointed as the new head of DZR. Eisenberg left the Zoo in August 1982 to assume the Catherine Ordway Chair in Wildlife Biology at the University of Florida. Dr. Reed retired from the National Zoo in 1982. Chris Wemmer served as Acting Director for 14 months until Dr. Michael Robinson was hired in 1984.

The Emergence of Scientific Curators

In an effort to model zoo curatorial staff after museum curators, Eisenberg encouraged the hiring of curators with Ph.D.s and research interests even though they were not positions directly under his administrative control in the Department of Zoological Research. This was done by Jaren Horsley, who was then General Curator and a supporter of the idea. The idea was that curators having part-time research responsibilities would also bring a stronger scientific approach to managing the living collections. Several research-oriented curators were hired during this decade including: Dale Marcellini, a herpetologist, to head the Reptile Department, Daryl Boness, a marine mammal biologist, to supervise the aquatic mammal exhibits, Edwin Gould, a small mammal biologist, to head the Mammal Department, and Ben Beck, a primatologist. Director Reed also provided the resources to establish a nutrition lab to support improved diets for the collection. Olav Oftedal was hired in 1978 to develop and run the lab. The lab and position was initially within the curatorial staff of the animal collections. However, within a few years of its inception, Eisenberg convinced Reed to move the lab into DZR and gave it a stronger basic research function, where it continued to support the collection needs as well. One other curatorial transfer out of the Mammal Department to DZR was that of Miles Roberts. Roberts maintained a curatorial position at DZR and was responsible for managing the research collections and supervising the keeper staff there. In 1983 Ballou was made a permanent DZR staff member as a "population manager" and began working on the Golden Lion Tamarin Program with Devra Kleiman.

Dr. Dick Montali was hired as the clinical pathologist in 1976. It was understood that research was a component of his job. His supervision shifted within the organization from the Chief Veterinarian, to the Deputy Director, and finally to the Associate Director for Animal Programs.

These hires broadened the range of scientific disciplines represented at NZP. However, as the range of science expanded, communication and coordination of scientific activities began to diminish.

Science Programs

There were major additions to the science programs in the second decade.

<u>Small Population Biology:</u> Ralls began comparative studies of mother-young interactions in captive ungulates in the exhibit collection. However, concerned about high juvenile mortality rates in several species, she soon began to investigate the relationship between juvenile survival and inbreeding levels. She hired Jon Ballou on "soft money" to assist with this work, and they began a long and fruitful collaboration. Their publications on inbreeding ultimately convinced the zoo community that traditional zoo management practice was adversely affecting many captive populations and that zoo animals required genetic and demographic management at the population level as well as good husbandry at the individual level. Ralls and Ballou also interacted extensively with Michael Soulé, who temporarily joined DZR as a distinguished Regent's Fellow. These interactions contributed to the development of what would later be known as the "small population paradigm" of conservation biology, i.e. that small populations are prone to extinction from random demographic and genetic events.

<u>Bioenergetics</u>: For a period of five years, post-doctoral fellow Steve Thompson conducted a series of bioenergetic investigations on a variety of small mammals. The work complemented the studies of Dr. Ted Grand, a research associate who had been studying mammalian locomotion and mechanics based on carcasses of deceased zoo animals. This metabolic work also had important energetic implications for Oftedal's studies of lactation and milk composition. Thompson also teamed up with Oftedal, Boness and post-doctoral fellow Kathryn Ono in measuring metabolic rates of Californian sea lion pups in the field to test for sex differences (Thompson et al., 1987).

<u>Animal Nutrition</u>: The completion in 1981of a new Nutrition Laboratory, the first of its kind in a US zoo, permitted Oftedal to start research focused on nutritional problems of the animal collection as well as field research, often with an active role for students. Ellen Dierenfeld completed a Masters thesis on bamboo digestion by giant pandas; she would later become nutritionist for the Wildlife Conservation Society. Mary Allen (later clinical nutritionist at SNZP) began Ph.D. research on nutritional consequences of insectivory in reptiles. With a goal of improving zoo animal diets, nutritional studies were conducted on zoo giraffe, red pandas and black-and-white colobus monkeys; the red panda studies ultimately led to major revision of red panda diets at virtually all US zoos, as well as a Masters thesis for Karen Fulton, later nutritionist at the Baltimore Zoo. From the outset the nutritional research program had as a goal the training of nutritionists who could help improve animal husbandry at other zoos.

Lactation Strategies: Oftedal also developed research on the nutritional costs and reproductive strategies associated with lactation in mammals. He initiated field research on California sea lions in 1981 and hooded and harp seals in 1984 (see below), and also began a multi-year study of lactation in hibernating black bears in the Pocono Mountains of Pennsylvania, in collaboration with Gary Alt of the Pennsylvania Game Commission. These lactation studies, as well as others on captive animals such as Bactrian camels, fruit bats and rock cavies, pointed to the tremendous costs associated with lactation, as well as the great species-specificity of lactation strategies. To apply knowledge of milk and lactation to captive animal care, Oftedal established an intensive care program for mammalian neonates in 1981, using a 24 hours per day, 7 days per week staff of volunteers from the Friends of the National Zoo. This program was not only very successful in the rearing of more than 50 neonates of a wide range of species, but allowed testing of new formulas and methods, and collection of detailed data on food intake and development.

Veterinary Research

In the early 1980s Bush had the opportunity to work in South Africa with his colleagues Wildt and O'Brien of the National Cancer Institute. He seized the chance to collaborate with South African veterinarians and wildlife biologists who were themselves pioneers in the anesthesia of free-ranging large mammals. Bush's growing expertise on wildlife anesthesia was a vital link in the studies of cheetahs and African and Asian lions that clarified the relationship between genetic variability and sperm characteristics. Partnerships with pharmaceutical firms and veterinary schools gave access to the latest drugs and physiological monitoring tools, which at times supplied drugs on an emergency basis for field projects such as the Tiger Ecology Project. During this period, Andrew Teare, one of Bush's veterinary interns, developed an upscale veterinary record-keeping system in collaboration with the International Species Inventory System (ISIS). This has become the standard system used by a majority of zoo veterinarians.

Field Studies

In addition to ongoing projects in Ceylon and Venezuela, a number of new projects started.

SI-Nepal Tiger Ecology Project: The purpose of the Tiger Ecology Project, launched at Dillon Ripley's behest in 1973, was to generate biological information for rational long-term management of tiger populations and habitats. The project was carried out in Royal Chitawan National Park in

collaboration with the Department of National Parks and Wildlife Conservation, HMG Nepal, under the auspices of the Smithsonian Institution and the World Wildlife Fund-U.S. Appeal. The field team at any one time consisted of the two Principal Investigators (Nepali and U.S.), two research assistants (undergraduate or baccalaureate students), and ~28 support personnel locally hired on the basis of jungle experience and trained in wildlife research techniques.

Wemmer became the project's scientific coordinator in 1977 after John Seidensticker, Mel Sunquist (University of Minnesota), and Kirti Tamang (Michigan State University) had completed their studies. David Smith (University of Minnesota) and Hemanta Mishra (University of Edinburgh, Scotland) then began their own Ph.D. projects. As with previous studies, Smith's work relied on radio-telemetry, but aerial surveillance was necessary to investigate the dispersal of tigers, and in particular to document the sudden and often long-distance movements of young males. Smith's work remains a seminal study of the population ecology of this large predator (Smith, 1984). Mishra's investigations focussed on the population ecology of four deer species: chital, sambar, hog deer and muntjac, and produced detailed information on annual cycles of reproduction and population levels. Sanat Dhungel (University of Montana) followed with his own study of the ecology of hog deer, which was subsequently published as a Wildlife Monograph.

In the early 1980s, Wemmer and Ross Simons, in consultation with Mishra, decided that if continued, the project should de-emphasize the tiger, and lay greater research emphasis on the ecology of the terai, the lowland jungle habitat characteristic of the region. The project's name was accordingly changed to the *SI-Nepal Terai Ecology Project*, and Eric Dinerstein then began his ecological studies of Greater One-horned Asian rhinoceros (*Rhinoceros unicornis*). A year later, John Lehmkuhl (University of Washington) joined the project to investigate the role of disturbance, namely fire and flood on the ecology of the grassland communities. Dinerstein revealed a number of co-evolved adaptations between rhinos and forage plants, and a summary of his work will soon be published as a book by Columbia University Press.

The project resulted in the completion of five doctoral dissertations on tiger and ungulate ecology, a popular book, publication of over two dozen reports, and recommendations for two park extensions that were implemented by HMG of Nepal. The project also facilitated the establishment of an international trust for conservation in Nepal. (Wemmer, Simons and Mishra, ms). A continuing legacy of this project is a "second-generation effect" by which original project scientists have trained a substantial number of developing country field biologists.

<u>Marine Mammal Studies</u>: Boness began developing a project on the reproductive behavior of California sea lions at the Channel Islands off California in 1980. After discussions with Oftedal early on they agreed to expand the project using blood dilution methodology based on deuterium oxide, developed by Oftedal during his Ph.D. work. Interestingly, despite the popularity of sea lions in zoos there were no systematic studies of this species' breeding behavior. This work focusing on the energetics of lactation was not only the first of its kind for otariid seals, it also happened to incorporate a severe El Niño. This provided a natural experiment allowing an investigation of the effects of El Niño on the sea lion's maternal care pattern.

In 1984, Boness and Oftedal connected with Dr. Don Bowen of the Department of Fisheries and Oceans in Canada for a once in a lifetime trek to the pack ice off Labrador. The three scientists had a 100 m research vessel with a crew of 55 and two helicopters to support a month of studying the hooded and harp seals (*Cystophora cristata* and *Phoca groenlandicus*), which breed on pack ice in March. One of the amazing discoveries from this expedition, and a record among mammals, was the discovery that the hooded seal has a lactation period lasting a mere four days. Seal cows produce an amazingly high milk fat content of 61%, and a neonatal growth rate of over seven kilograms/day (Bowen et al., 1985).

Sara Iverson, a graduate student from the University of Maryland, developed her Ph.D. thesis on fatty acid composition of California sea lion and hooded seal milks and blubbers. She subsequently

was hired on the biology faculty at Dalhousie University in Canada. In three years at Dalhousie, in an unprecedented move for an assistant professor, she was awarded a prestigious Canadian faculty research fellowship given each year to only four professors across the entire Canadian university system. The award was in recognition for her excellence in teaching and her research in developing a technique to use fatty acids to identify prey species of marine mammals.

There were applied benefits for zoos of these pinniped lactation studies. One was the realization that sea lion pups must be fasted every other day to replicate the hauling out and feeding cycles of lactating mothers. More frequent feeding has detrimental effects on development.

In 1984, Katherine Ralls began a collaboration with scientists from the University of Minnesota to study the behavior and population biology of California sea otters (*Enhydra lutris*). As most of this work occurred in the next decade of science at SNZP, we will describe this work more thoroughly in the next section.

<u>Golden Lion Tamarin (GLT) Reintroduction:</u> The GLT Program directed by Kleiman and Beck moved into a new phase that included ecological field studies at the Poço das Antas Biological Reserve near Rio De Janeiro in Brazil (coordinated by post-doc James Dietz at CRC). This work was in preparation for a pending reintroduction program with captive-born GLTs, negotiated by Devra Kleiman with the Brazilian government. The Reintroduction Program has included studies of the structure and composition of preferred habitats of GLT, the process of forest regeneration in deforested areas, mechanisms to develop support for conservation by local communities through education (spearheaded by Lou Ann Dietz), methods for preparing and rehabilitating captive-born GLT for survival in the wild (Beck and Ines Castro), and methods for transplanting wild tamarins to protected areas.

<u>Avian communications, mating systems, and ecological plasticity:</u> Morton's studies of communication in birds were influential in changing the focus of research among fellow avian ethologists. The theory of avian communication based on information theory was being replaced by a new emphasis on the structure of communication signals as emotional indicators and an interpretation that was functional, rather than linguistic. The 1977 conference on migratory birds held at CRC gave way to other avian studies on the behavioral ecology of migrant birds from North America in their tropical habitats. Russ Greenberg and Morton collaborated with Jim Lynch (SERC) to study hooded warblers (*Wilsonia citrina*), Kentucky Warblers (*Oporornis formosus*), and worm-eating warblers (*Helmitheros vermivora*). Studies of neophobia by Greenberg on warblers and the innate basis for sexual differences in habitat choice by hooded warblers by Morton were noteworthy.

Russ Greenberg came to the National Zoo in 1981 and began a decade long investigation into the psychological basis of ecological plasticity. Why some animals are more adaptable than others remains a critical area of behavioral research relevant to both evolutionary ecology and conservation biology. Greenberg began by investigating the psychological differences between different species of tropical wintering warblers. He focused his work on neophobia and other responses to novel stimuli, hypothesizing that species with specialized ecological needs exhibit a greater fear of novelty than generalists. He has examined this hypothesis in a variety of taxa including sparrows, warblers, and ducks. His pioneering work has been cited by ornithologists, primatologists, and others interested in the evolution of innovative behavior.

<u>White-tailed Deer Ecology</u>: Early wildlife projects at CRC focused on white-tailed deer (*Odocoileus virginianus*) as a management issue. Director Reed's decision to fence the zoo and prohibit hunting at CRC created ideal conditions for an irruption of the native deer population, with increased disease transmission to the exotic herds. Wemmer was by now a member of the IUCN's Deer Specialist Group and had promoted studies of CRC's captive Pere David's and Eld's deer, as well as field studies of deer in Nepal. He saw studies of the white-tailed population as a way to prepare visiting students for field studies on endangered deer in Asia.

In 1982 Michael Stuewe, a German pre-doctoral student was the first of a series of graduate students who studied white-tailed deer on CRC. He developed methods of capturing and marking the deer and investigated social organization and behavior of the population at high-density. The center was in the midst of a population irruption, with consequent loss of the alfalfa crop which supplied ungulates at the zoo in Washington with food. At the Director's orders, Wemmer contacted the state Game and Fish Commission to organize a controlled hunt, and 126 deer were removed in the fall of 1982. The next year media publicity castigated the zoo for planning a second hunt, and Representative Sid Yates, Chairman of the Appropriations Subcommittee to the Smithsonian, called for the hunt's cancellation. In 1983 Stefan Holzenbein and Georg Schwede (University of Bielefeld) continued the studies of the marked deer and expanded the sample size, and received masters degrees for their study of rutting behavior.

Sea Turtle Biology, Conservation, and International Policy: Eisenberg invited Jack Frazier to join DZR in 1979 as a Research Associate. For the next 6 years Frazier conducted field surveys of sea turtles in various parts of the world on various sources of low budget "soft money." The resulting publications of these and earlier studies provided basic information on the biology and conservation status of marine turtles in various areas. Frazier routinely wrote these for local publications in Spanish or English to enhance availability for local workers in places such as Argentina and Uruguay (Frazier, 1984a; 1991), Chile (Frazier and Salas, 1984a; 1986; Frazier and Brito, 1990), China (Frazier et al., 1988), Comores (Frazier, 1985a), Egypt (Frazier, 1984b; Frazier et al., 1987), Maldives (Frazier et al., 1988; 2000), Mexico (Frazier, 1984c), Peru (Frazier, 1983; Frazier and Salas, 1983; 1986; 1987), and Seychelles (Frazier, 1982a). These papers are regarded as foundations for research and conservation actions in these nations.

Frazier also developed a technique for estimating age in marine turtles (Frazier, 1985b; 1985c). Staff at the National Museum of Natural History were trained in the method, and since then it has been widely used by Dr. George Zug, Curator of Amphibians and Reptiles. Based on his extensive research in the Indian Ocean Frazier also explored the human dimensions of conservation problems with marine turtles (Frazier, 1980; 1982b). This theme has recently gathered importance in wildlife management and conservation biology.

Conservation & Research Center

Research on Captive Collections

Research on the animal collections was carried out by graduate students and post-doctoral fellows working for scientists at DZR and Wemmer. A Smithsonian Scholarly Studies grant to Devra Kleiman in the late 1970s initiated several years of studies on the comparative behavior of South American canids. Facilities were renovated to house maned wolves (*Chrysocyon brachyurus*), bush dogs (*Speothos venaticus*) and crab-eating foxes (*Dusicyon thous*). Charles Brady, a graduate student at the University of Ohio, investigated the social behavior in these animals as research towards his Ph. D., completed in 1980. Subsequently, Ingrid Porton and Dr. Maxeen Biben studied social and predatory behavior of these species. Several projects focused on the growing ungulate collection, including Richard Yahner's post-doctoral studies of alarm barking in muntjac, and Joel Berger's studies of comparative ethology of onagers and zebras. Wemmer worked with lead mammal keeper James Murtaugh and Curator Collins on reproductive biology of binturong, and social behavior of Pere David's deer.

Research on Native Wildlife

CRC's extensive grounds of old fields and second growth forest were a unique setting for field studies of native wildlife. CRC is contiguous with the Shenandoah National Park along its western border and is therefore part of a much larger Blue Ridge ecosystem. This wildlife habitat has been the focus of research at CRC since the beginning. Within a year of acquiring CRC, Dr. Dale Madison

(University of Toronto) studied the maternal ecology and predation of meadow mice (*Microtus pennsylvanicus*). DZR's Gene Morton also initiated studies of bluebird behavior at CRC utilizing nestboxes, and Kentucky warblers, a project that continues today. In the early 1980s Eisenberg hired John Seidensticker as a temporary employee to develop a program on local ecology and to assist with field studies he hoped to undertake on giant pandas. A wildlife biologist who had studied with the Craigheads and Maurice Hornocker at the University of Montana, Seidensticker had launched the SI-Nepal Tiger Ecology Project in 1973. A radio-tracking laboratory was situated in one of the buildings, and field assistants and equipment were funded by the Friends of the National Zoo. Intensive studies of raccoons, opossums, and other small carnivores lead to the publication of several papers with post-doctoral researchers Jim Hallett and A.J.T Johnsingh. Seidensticker also collaborated with National Zoo Chief Veterinarian, Mitch Bush and Chief Pathologist, Dick Montali to document the rise and fall of a major rabies epidemic in the mid-Atlantic states.

In addition to National Zoo scientists, the center served as a research site for several graduate students of the University of Maryland. Nancy Stamp completed her Ph.D. on the checkerspot butterflies at CRC in 1980, and Keith Berven's studies on metapopulation ecology of Eastern newts was published in 1981.

The property had additional advantages to the zoo. It was a site where visiting researchers could be economically lodged for extended periods. Dr. Mel Sunquist, a recent Ph.D. from the University of Minnesota whose research had been conducted on the Smithsonian-Nepal Tiger Ecology Project, was funded by FONZ to prepare his dissertation for publication. Sunquist also worked with Seidensticker on small carnivore studies at the center. To promote international outreach and advanced training in radio-telemetry, Eisenberg and Kleiman arranged to support A.J.T Johnsingh, an Indian national who had just completed an extensive study of predation by South Indian wild dogs (*Cuon alpinus*). He too prepared his Ph.D. dissertation for publication, while working with Seidensticker on the ecology of raccoons and learning the applications of radio-telemetry.

International Training Programs

The Wildlife Conservation and Management Training Program (WCMTP): The WCMTP was inaugurated in 1981 to help meet the critical need for trained conservation personnel in developing countries. It was the brainchild of Rudy Rudran who had personal experience of the shortage of trained personnel from his long-term field studies in Sri Lanka, Uganda and Venezuela. One of the major objectives of this program was to provide short-term training to mid- and upper-level personnel through various types of courses and workshops. Thus far, the WCMTP has conducted 101 courses and workshops and trained over 1700 resource managers, wildlife biologists and environmental educators from 81 countries. The majority of the courses have dealt with in-situ conservation (conservation biology and wildlife management), while the others have provided training in ex-situ conservation (zoobiology) and environmental education. The workshops were conducted in order to provide intensive training to decision-makers and technical specialists in topics that were specifically requested by them. Besides the short-term training initiatives, the WCMTP includes three long-term initiatives to more fully address the problem of biodiversity conservation in developing countries. These initiatives are: a) career development assistance to course participants, b) training of former trainees as course instructors, and c) the establishment of international centers for conservation biology in selected countries within the program's international network. In essence, the long-term initiatives were incorporated into the program to stimulate interest in protecting the commons through investment in the professional development of individuals and institutions. Using this strategy the WCMTP's goal has been to make developing countries equal partners in the worldwide effort to conserve the earth's biological resources.

Substantial progress has been made so far in achieving the WCMTP's goal. In addition to conducting an average of four courses per year, Rudran has directed financial support to 22 course participants to attend universities for post-graduate studies or conduct conservation oriented field

projects in developing countries. Forty-one former trainees have also undergone training as trainers, and some of them currently participate as fully-fledged instructors in the program's courses. Additionally, International Centers for Conservation Biology have been established in Malaysia and China, and serve as administrative umbrellas for courses conducted by those trained as trainers. Similar centers are currently being established in Brazil, Uganda and Thailand as well. Furthermore, many WCMTP alumni have obtained their doctoral degrees and now occupy highly respected and prestigious positions at universities, government agencies and non-governmental organizations in their home countries. Several have also been hired by international organizations such as the World Bank, Wildlife Conservation Society, Conservation International and World Wildlife Fund to help promote conservation on a global scale. Another remarkable achievement of the WCMTP is that it has served as the progenitor of similar training initiatives within the Smithsonian and at other institutions in the US and Europe.

Reproductive Sciences

In 1983, David Wildt, was hired by SNZP's Chief Veterinarian, Mitchell Bush, to head up a newly-formed Reproductive Physiology Program. Research initially focused on how to use reproductive technologies (e.g., tools such as artificial insemination, *in vitro* fertilization and embryo transfer) for propagating endangered species, but later was expanded to conduct a variety of research in the areas of gamete biology, andrology, embryology, endocrinology, theriogenology and cryobiology. The program focused on four primary functions: 1) increasing basic knowledge of reproductive physiology; 2) providing skills and technologies for assessing reproductive status and offering recommendations for improving reproductive efficiency; 3) implementing strategies for preserving biomaterials (sperm, embryos and tissue products) useful for conserving biological and genetic diversity; and 4) offering unique opportunities for training and education. A relatively small core of four federal scientists (Wildt, Brown, Howard and Monfort) began to recruit what became 20 post-doctoral fellows, 40 graduate students and 100 research interns, and thus professional training has been a core strength of the program.

Although originally based solely at the zoo's Rock Creek facility, Monfort was stationed in Front Royal in 1986 to establish an Endocrine Research Laboratory at the CRC. He was joined by Brown in 1991, and a satellite gamete laboratory was constructed at CRC after Wildt moved his base of operations there in 1994. Reproduction scientists have been instrumental in addressing a variety of conservation issues related to captive animal management, breeding, reintroduction, and conservation of captive and wild populations. Collectively, they have published more than 300 book chapters and manuscripts in peer-reviewed literature, as well as more than 300 abstracts and proceedings papers. The senior reproduction staff has secured more than 9 million dollars in grant, contract and private sector support.

A substantial amount of research on reproduction during the 1980s and 1990s was conducted at the NIH Animal Center in Poolesville, Maryland, where Wildt held an adjunct position. Using the Center's domestic cats as models for endangered felids, several DRS trainees (Karen Goodrowe, JoGayle Howard, Mitch Schiewe) developed assisted reproductive techniques for endangered felid species, including artificial insemination, in vitro fertilization and embryo transfer. Along with applied studies, DRS scientists also conducted multi-disciplinary science to understand the biology of cats, including the endocrine control of the estrous cycle, ovarian follicular dynamics, the control of ovulation, embryo development, and sperm morphology. Mitch Bush, JoGayle Howard, David Wildt and collaborators Carol Platz and Steven Seager also pioneered methods for collecting sperm from numerous felid species (Wildt et al., 1981). A major early discovery was that captive cheetahs produced extremely poor quality ejaculates characterized by a high proportion of abnormal sperm. Field studies conducted in eastern and southern Africa revealed that wild cheetahs also had poor semen quality. Molecular genetics research conducted in collaboration with Stephen O'Brien (National Cancer Institute), confirmed that a population "bottleneck" had resulted in extremely low genetic diversity for all cheetahs, and that this was at least partially responsible for the poor quality of cheetah

sperm (1983). Overall, felid research has helped to improve our understanding of how animal health, genetics, environmental and husbandry-related factors impact breeding success in cats.

Research Syntheses through Publications, Symposia, and Books

By the mid seventies, several National Zoo scientists began to organize symposia on specialized topics of personal research interest. CRC's conference and dormitory facilities again offered an isolated and economical venue. Most of these conferences were published in the Symposia of the National Zoological Park, a now defunct series of the Smithsonian Press. The symposia brought attention to the zoo as an active community of scientific endeavor, and advanced collaborations through numerous resulting contacts.

Eisenberg's scientific contribution at the National Zoo culminated in the publication of *The Mammalian Radiations, An Analysis of Trends in Evolution, Adaptation, and Behavior* (Eisenberg, 1981). Beck and Wemmer's studies of Pere David's deer culminated in *Pere David's Deer, the Biology of an Extinct Species*, (1980) edited by Ben Beck and Wemmer.

Below is a selection of publications/workshops/conferences that synthesized major bodies of knowledge at the time:

- Bowen, W.D., O.T. Oftedal, and D.J. Boness. 1985. Birth to weaning in four days: Remarkable growth in the hooded seal, *Cystophora cristata*. *Canadian Journal of Zoology*, 63: 2841-2846.
- Beck, B. and C. Wemmer. 1983. *The Biology and Management of an Extinct Species: Père David's Deer.* Noyes Publications, Park Ridge, New Jersey, 193 pp.
- Berven, K.A. 1981. Heritable and environmentally induced variation in development and reproduction of the wood frog *Rana sylvatica*. Ph.D. Thesis, University of Maryland.
- Bush, M., Wildt, D. E., Kennedy, S., & Seager, S. W. J. (1978). Laparascopy in zoological medicine. *J. Amer. Vet. Med. Assoc.* 173: 1081-1087.
- Eisenberg, J.F. 1981. *The Mammalian Radiations. An Analysis of Trends in Evolution, Adaptation and Behavior.* The University of Chicago Press, Chicago and London. 610 pp.
- Kleiman, D. G. 1977. Monogamy in mammals. Quarterly Review of Biology. 55: 224-227.
- Oftedal, O.T. 1984. Milk composition, milk yield and energy output at peak lactation. A comparative review. *Symposia of the Zoological Society of London* 51: 33-85.
- Oftedal, O.T. 1980. Milk and mammalian evolution, p. 31-42 In *Comparative Physiology: Primitive Mammals*, K. Schmidt-Nielsen, L. Bolis & C.R. Taylor (eds.). Cambridge, England: Cambridge Univ. Press.
- Ralls, K., and J. D. Ballou. 1983. Extinction: lessons from zoos. In C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde, and L. Thomas (eds): *Genetics and Conservation*. Menlo Park, CA: Benjamin/Cummings, pp. 164-184.
- Ralls, K., K. Brugger, and J. D. Ballou. 1979. Inbreeding and juvenile mortality in small populations of ungulates. *Science* 206: 1101-1103.
- Ralls, K. 1976. Mammals in which females are larger than males. *Quarterly Review of Biology*. 51: 245-276.
- Smith, J.L.D. 1984. Dispersal, communication and conservation strategies for the tiger (Panthera

tigris) in Royal Chitwan National Park, Nepal. Ph.D. thesis, University of Minnesota, St. Paul.

- Stamp, N.E. 1980. Effect of group size on an egg-clustering butterfly. Ph.D. Thesis, University of Maryland.
- Wildt, D. E., Platz, C. C., Seager, S. W. J., & Bush, M. (1981). Induction of ovarian activity in the Cheetah (*Acinonyx jubatus*). *Biol. Reprod.* 24: 217-222.

Genetic Management of Captive Populations. (with K. Ralls). Front Royal Virginia, 1984

Man and the Biosphere International Conference on Genetics and Conservation (with C. Schonewald-Cox). Washington, D.C., 1982

THE RISE OF CONSERVATION BIOLOGY: 1985-1994

SUMMARY

While much research of the previous two decades primarily advanced basic scientific knowledge, the third decade saw a shift towards research that targeted conservation issues, the development of programs to implement conservation actions (including capacity building around the globe), and engagement in more activities that directly informed conservation policymakers. In conjunction with these changes, there was a greater emphasis on field activities, although research on captive collections continued both at the DZR facility and CRC at Front Royal. A series of important scientific expansions occurred that were consistent with and facilitated these changes. The Zoo received funds to build a molecular genetics lab and hire scientific and technician positions. The impact of the decline in tropical and temperate forests on migratory bird populations was recognized as a major conservation concern, resulting in congressional funds to establish a Smithsonian Migratory Bird Center to conduct research, advise policy makers, and inform the public. The Reproductive Physiology unit also expanded, adding the capability for endocrine studies to complement the existing expertise for developing assisted reproductive techniques. Many SNZP scientists saw the importance of being able to go beyond small scale ecological studies, which led to the establishment of a Spatial Analysis Lab at CRC in Front Royal for landscape level assessments. Unlike the other new programs, however, this lab was funded entirely by grants and small donations, and received no federal funding or permanent staff positions.

Staff continued involvement in AZA-related conservation and breeding programs, such as Species Survival Plans and Taxon Advisory Groups, but their involvement in conservation service activities expanded to higher levels that had greater impacts nationally and internationally. Many staff became involved in Endangered Species Recovery teams (e.g., black-footed ferrets, Marianas crows, California condors, sea otters). They also began serving on government and non-government commissions and advisory groups dealing with conservation issues (e.g., National Academy of Sciences committees, Marine Mammal Commission, Captive Breeding Specialist Group). As the small population paradigm, having its roots in small zoo populations, became increasingly more important and useful for the management of endangered and threatened natural populations, CRC scientists became actively involved in this activity.

Unfortunately, this decade saw continued fragmentation among the SNZP science community as a result of its organizational structure and limited resources. Internal resources for science declined throughout the decade, in part because of insufficient funds to support both scientific and major exhibit expansions and the annual unfunded cost-of-living increases mandated by Congress. This produced an underlying atmosphere of competition for resources among the science groups.

Staffing and Organization

Dr. Robinson reorganized the zoo in 1985 by creating 5 assistant directors (Research (DZR), Veterinary Medicine, Conservation (CRC), Animal Programs, and Facilities). In 1987 he elevated Conservation, Animal Programs and Facilities to Associate Director status. DZR and Veterinary Medicine were assigned to Animal Programs under Ben Beck, while the Reproductive Physiology Unit answered to Mitch Bush. Don Jannsen, was hired as an associate veterinarian, and Linda Munson who was hired as an associate pathologist during this period. Also in 1985, Boness was transferred from being a curator to being a full-time researcher in DZR. Seidensticker was hired by Ed Gould as a curator in the Mammal Department when Boness moved to DZR. Mary Allen was hired as a clinical nutritionist under Ben Beck at the same time.

In 1988 and 1989, Congress added base funding to the NZP budget for a molecular genetics program that would support research on behavioral ecology and conservation genetics. This was

largely due to the efforts of Katherine Ralls, who argued successfully to higher SI administrators that the zoo should be included in the plan to establish molecular genetics abilities within the institution. About half of the money provided by Congress was given to the National Museum of Natural History, with the other half split between STRI and SNZP. The Zoo was provided with \$320,000 per year and four new positions, two scientists and two technicians. After subtracting salaries for the four new positions, this left about \$136,000 per year towards operating costs for the new lab. Dr. Robinson assigned the lab within DZR administratively. DZR had several failures in trying to hire a new scientist to head the lab, so it was not until 1991 that Dr. Robert Fleischer was actually hired.

In the interim, National Zoo administrators reallocated two positions and all of the operating budget. This was supposed to be temporary but neither the two positions nor the original operating budget was restored to the molecular genetics program. When he arrived, Fleischer was allowed to hire one technician but not provided with an operating budget. Meanwhile, the molecular genetics laboratories at the National Museum of Natural History and the Smithsonian Tropical Research Institute had been established with the full number of positions and operating budgets originally planned. After protracted negotiations with zoo administrators, he was finally given an operating budget of about \$25,000 per year for the lab in 1993. Despite his protests, the new lab was not constructed in or near the existing DZR facilities but at a distant location within the zoo in a building close to Rock Creek that had previously suffered serious damage from a flood. Fleischer felt that this location inhibited scientific interactions between students working in the genetics lab and staff and students at DZR.

The Global Change Initiative of the Reagan Administration provided the Smithsonian with the opportunity to compete for federal funds to study and mitigate global change. The zoo's initial proposals, prepared by various individual scientists and departments, were unsuccessful. Consequently, the next year Associate Director Ben Beck asked Katherine Ralls to determine the most urgent needs for each of the zoo's fragmented and somewhat competitive science units and prepare a unified, comprehensive proposal for the entire zoo. This approach was successful and the zoo was awarded several scientific positions and some operating funds. As a consequence, Dr. Steve Monfort was hired in 1986 as a research veterinarian with shared supervision by Wildt and Bush and Wemmer; Janine Brown was hired in 1991 as a research endocrinologist under Dave Wildt. Both were assigned to CRC as a duty station. In 1994 Dave Wildt and Mitch Bush were transferred to CRC. Several other global change positions, including a second geneticist, were never filled as zoo administrators reallocated these resources.

In 1985 Marty Fujita was hired by Wemmer as an International Conservation Officer, with a duty station in Jakarta, Indonesia, but took leave without pay to join The Nature Conservancy (TNC) a year and a half later. As a result of an external review in 1987, Rudy Rudran was transferred from DZR to CRC. John Rappole was hired in 1989 as a research coordinator to deal with the increasing number of volunteers and students at CRC.

Science Programs

Despite constraints imposed by National Zoo administration, the new molecular genetics program was an outstanding success. Fleischer proved to be an excellent collaborator, undertaking studies, for example, with Boness on gray seals, Kleiman on golden lion tamarins, and Ralls on kit foxes. He was notably successful in obtaining external funding and the program soon attracted an increasing number of graduate and postdoctoral students through the competitive SI fellowships program.

The Molecular Genetics Laboratory pioneered the use of ancient DNA methods (museum specimens and fossil bones); has developed modern DNA profiling methods to determine the genetic mating systems of numerous birds, mammals and fish; has investigated the interactions of avian disease with their vectors and their host immune systems; and has determined genetic variation,

population structures, evolutionarily significant units and phylogenies for a wide range of endangered and threatened species. Nearly all of these studies have supported the development of management strategies for captive and wild populations and many have provided us with an understanding of the evolution of key traits for survival. Fleischer's own primary projects focus on the evolution and extinction of Hawaiian birds, although his collaborations include studies of Asian elephants, grey and elephant seals, kit foxes, warblers, blue-head wrasse among many others.

Small population biology and management of captive populations: Ballou, who had been appointed keeper of the International Golden Lion Tamarin Studbook, converted the written studbook information into a computer database program. This was one of the first computerized studbooks, and it soon became a model for other studbook keepers in the zoo community. Ballou also began writing a series of programs to analyze the tamarin data. These too were soon adopted by other studbook keepers. This began Ballou's continuing role as scientific advisor and software developer for the North American and International zoo community. His outputs include programs such as PEDDEMO (which calculates life tables from studbook data sets) and CAPACITY (which calculates carrying capacities for captive populations), both of which were published in 1986. He also became genetic adviser for the Black-footed Ferret Recovery Program and published several papers on ferrets beginning in 1989. A year later, Ralls became genetic adviser for the California condor program. While maintaining his full-time position with the National Zoo, Ballou obtained a master's degree in Applied Statistics from George Washington University in 1985, and later became a graduate student in the Ph.D. program at the University of Maryland.

<u>Smithsonian Migratory Bird Center</u>: The Smithsonian Migratory Bird Center was founded by congressional appropriation in November 1990. Initially independent, it was folded into the National Zoo in 1996 and become part of CRC in October 2000. The Migratory Bird Center was established to continue the Smithsonian's strong research program on the ecology and behavior of tropical migratory birds, as well as synthesize information for policy makers and the interested public. It was established as a response to the public awakening to the problems facing migratory birds.

Migratory Bird Center staff have focused their research on the effects of human land use on migratory bird populations. The aim of research, synthesis, and outreach is to be proactive in developing creative conservation solutions. In the tropics, Migratory Bird Center research has been aimed at identifying land uses that are consistent with migratory bird conservation. In particular, the Center has taken lead in developing strategies for promoting the use of diverse shade in raising certain tropical crops, such as coffee and cacao. In addition, Migratory Bird Center scientists are looking at enhancing the conservation value of cattle pastures through the use of native trees.

Migratory Bird Center scientists have investigated temperate zone issues as well. Research has concentrated on the effects of urbanization and fragmentation. Furthermore, staff conducted the first trans-continental study of boreal forest birds, concluding that the forest avifauna of Europe has been completely altered with the advent of agriculture. Recently, a post doc has focused on the role of declines of particular tree species on changes in bird populations, and the program has taken a lead role in the conservation biology of tidal marsh songbirds.

The Migratory Bird Center has had an active program in policy research. Bob Rice, staff geographer, has explored the economic and social issues underlying land use patterns. The program has hosted several symposia on tropical land use (forest patches, coffee, and cacao), bringing together an interdisciplinary group from around the world to address these issues. The Migratory Bird Center has worked with the coffee and cocoa industries to help develop awareness of issues related to biodiversity in the production of these tasty commodities. Today, the staff is consulted by major funding institutions, trade groups, and producers about the relationship between bird conservation and tropical agriculture.

The Smithsonian Migratory Bird Center is also a leader in the development of programs and

materials for outreach concerning migratory birds. The Center has a large portfolio of publications in English and Spanish, in addition to a very active web-site.

Landscape Ecology: In 1991, Dr. John Rappole founded CRC's Spatial Analysis Laboratory. The Lab and its research program are dedicated to employing cutting-edge information technology, such as satellite imagery, Geographic Information Systems (GIS), and Global Positioning Systems (GPS) to evaluate and help mitigate large-scale changes in ecosystems that threaten biodiversity and species survival. Satellite imagery, especially, has proven a powerful tool for the detection of human-induced and natural changes such as fire, flooding, deforestation, and land cover conversion. In combination with their extensive ecological field studies, Peter Leimgruber, Bill McShea, and Rappole have used these tools to spearhead some of CRC's most successful examples of applied conservation research. This includes delineating suitable habitats for creation of protected areas, to ensure survival of endangered golden-cheeked warblers in Guatemala and of Eld's deer in Myanmar.

This integration of field-based conservation research and education with space-age technology for spatial analysis is one of CRC's most compelling stories. Not only does the technology allow conservation analyses over vast areas, it also provides information in the form of maps and computer displays. These have proven extremely powerful for educating decision makers and informing new conservation policy. Leimgruber, McShea and Melissa Songer are now using these tools for conservation assessments of Asian elephants, giant pandas, and pampas deer. All these studies are targeted to identify and locate remaining areas for species conservation and to quantify potential threats from human-induced or natural changes to wild populations. Other research highlights include landscape ecological research on the effects of forest management on biodiversity on the eastern deciduous forests of Virginia, assessing deforestation of Canada's remaining forests, and assessing how biomass changes in Mongolian steppes influence migration by the Mongolian gazelle.

Training wildlife practitioners in the conservation applications of this new spatial technology is an integral part of the laboratory's agenda. It was initiated by John Rappole and Doug Muchoney with the Conservation Technology Support Program (CTSP). CTSP provided major funding and in-kind equipment donations to North American conservation organizations that intended to start their own conservation GIS. Funding corporations for this multi-million dollar program included Hewlett Packard, Environmental Systems Research Institute, Apple, Altek, Trimble and many others. For three years, CRC's Spatial Analysis Lab was the training facility for the program and was equipped with hardware and software worth over US\$ 200,000.

Since 1996, Leimgruber, McShea and Songer have been offering regular introductory and advanced training courses in GIS and satellite remote sensing to wildlife managers and conservation biologists in the U.S. and abroad. Songer and McShea also created training material and a workshop on forest biodiversity monitoring and remote sensing for Virginia K-12 educators.

Black-footed ferret: In 1985, Wemmer became a graduate committee member for Brian Miller's doctoral research on the conservation and ecology of the black-footed ferret (*Mustela nigripes*). At that time, black-footed ferrets existed in only one wild population, located on a few prairie dog colonies just east of Yellowstone National Park. When the wild population crashed due to an epizootic of canine distemper and plague, all black-footed ferrets were captured to prevent extinction of the species. At one point only 10 individuals remained. David Wildt became a member of an advisory team headed by U. S. Seal that recommended strategies for captive reproduction. In 1988, the CRC, along with the Henry Doorly Zoo, received black-footed ferrets for captive breeding.

By 1988, captive propagation was successful enough to begin planning for reintroduction. During that year, Ben Beck and Wemmer sponsored Brian Miller as a Smithsonian Post-doctoral Research Fellow to investigate pre-release programs that could increase survival of captive-born animals when they were reintroduced into the wild. The U.S. Fish and Wildlife Service was an active cooperator in this research. During 1989 and 1990 Miller examined the innate and learned components of ferret predatory behavior and ferret predator avoidance. A field component during the same year released neutered Siberian ferrets (*Mustela eversmanni--*an Asian congeneric of the black-footed ferret) to test different pre-release management techniques to maximize ferret predatory and anti-predator behaviors.

In 1991, captive-raised black-footed ferrets were first released into prairie dog colonies of Wyoming, and Brian Miller and Astrid Vargas (a CRC intern) were part of that team. The pre-release conditioning regimen developed at Front Royal increased survival of captive-born black-footed ferrets. Animals lacking pre-release conditioning had survival rates of 2%. The prerelease conditioning program raised survival to between 20 and 30%. The program developed at the Center is now the standard procedure used by U.S. Fish and Wildlife Service to prepare black-footed ferrets for reintroduction. This and associated work by Miller, Vargas, and Dean Biggins resulted in 13 publications and book chapters, 3 reports, and a book (*Prairie Night: Recovery of black-footed ferrets* Smithsonian Institution Press, 1997).

<u>Reptile Nutrition</u>: Oftedal and Allen initiated studies to identify nutritional deficiencies affecting reptiles in zoos and captive breeding programs, as virtually no sound scientific work had previously been done on reptile nutrition. They studied the effects of calcium and vitamin D on bone development and growth of geckos, and developed "insect gut-loading" diets that are now an important means of preventing nutritional bone disease in insectivorous reptiles. On the invitation of Dr. Dagmar Werner of the Smithsonian Tropical Research Institute in Panama, they also pioneered the use of nutritionally complete diets for green iguanas, making it possible to raise this species en masse (thousands per cohort) for release into the wild, both in Panama and Costa Rica. David Baer and Joni Bernard completed Ph.D. research on fiber digestion and vitamin D requirements of captive green iguanas at SNZP; Mary Allen also conducted research on ultraviolet light and vitamin D in Komodo dragons at SNZP. In 1989, Oftedal began work with the land iguana breeding program of the Charles Darwin Research Station in the Galapagos, and was able to identify nutritional factors underlying high juvenile mortality at the Station. Complete feeds were locally developed and produced, mortality was reduced and the reintroduction program to various islands reinvigorated. A major new initiative to study nutrient needs of the desert tortoise was launched in 1991 (see Field Projects, below).

<u>Nutrition and lactation</u>: The uniquely mammalian feature of milk production was the focus of much research on a broad range of taxa, in an effort by Oftedal and his students and collagues to understand the diversity of lactation patterns and how they relate to nutritional constraints and phylogeny. Particular attention was paid to pinnipeds, primates, and bats, but studies were also conducted on rodents and ungulates. Field projects included studies of harbor seals and gray seals on Sable Island, Nova Scotia, red howler monkeys in Venezuela, mantled howlers in Costa Rica, and 5 bat species in both the United States and Trinidad. These projects supported the thesis research of a Masters student and two Ph.D. students, including Mark Edwards who is now nutritionist at the San Diego Zoo. Two other Ph.D. students worked on lactation in galagos and lemurs (Chris Tilden) and on gum digestion in marmosets and tamarins (Michael Power). A series of postdoctoral fellows in the 1980s and early 90s also studied lactation strategies in different organisms: deer (Susan Crissey, now nutritionist at the Chicago Zoological Society), myomorph rodents (Elissa Derrickson), Juan Fernandez fur seals (John Francis), grey seals and bears (Perry Barboza) and tree shrews (Y. Jhala). More than 30 publications were produced from these studies.

Veterinary Research

With the advent of the Zoo Biology Training Course, Bush began to teach the veterinary section of the course in various parts of the world, and this participation continues to the present. Strong collaborations in South Africa allowed Bush to participate in major studies of tuberculosis occasioned by extensive epidemics in Kruger National Park's African buffalo (*Syncerus caffer*) population. At CRC

he began experimental treatments of tuberculosis in Matschie's tree kangaroos (*Dendrolagus matschieii*).

Field Studies

Marine mammals:

Boness continued his collaboration of seal maternal strategies with Oftedal, but also began work on male mating strategies as well. In the late 1980s he established a long-term collaboration with the Bedford Institute of Oceanography and Dalhousie University in Canada, studying the ecology and evolution of reproductive strategies of grey and harbor seals on Sable Island. Sable Island is a 40-km long vegetated sand bar in the Northwest Atlantic Ocean about 200 km off the coast of Nova Scotia. Rob Fleischer became involved in these studies as they required information on paternity and analyses of relatedness. These studies, in which individual animals have been followed for more than a decade, continue today, and have produced a wealth of data on life history traits and long-term fitness. Other seal studies with shorter tenures were developed in Scotland, Wales, Chile, Peru, the sub Antarctic, and Alaska. Like many other programs this one placed a high priority on training students. John Francis, a postdoctoral fellow (1987-1991), developed with Boness a study of the Juan Fernandez fur seal, a species endemic to a small number of islands off Chile and thought to be extinct as recently as the mid-1960s. Little had been published on the reproductive biology of this species and one of the interesting findings of this work, that maternal foraging trips lasted between 11 and 25 days, contradicted a current model of maternal strategies that was well accepted by marine mammalogists.

In 1984 Ralls began field studies of threatened California sea otters in collaboration with Don Siniff from the University of Minnesota. Funded by the Minerals Management Service, the main purpose of this project was to yield data necessary for constructing a population model of California sea otters that could be used to predict probable effects of oil spills within the sea otter range. Because sea otters easily removed radio collars and radios attached to flipper tags yielded data for only a month or two. Ralls and Siniff developed an intraperitoneal transmitter to facilitate long-term radiotelemetry studies of sea otters. This transmitter (Ralls et al. 1989) led to major advances in knowledge of sea otter biology and has been used in virtually all subsequent radiotelemetry studies of sea otters in both Alaska and California. The pioneering study by Ralls and Siniff produced the first estimates of reproductive and survival rates, 24-hour time budgets, and flipper-tag loss in California sea otters. It showed that all previous foraging data on sea otters were seriously biased towards otters feeding close to shore and that average dive lengths had been greatly underestimated. It also revealed that sea otters moved much longer distances then previously suspected, with some individual males repeatedly traveling the entire coastal range then occupied by the population. The study contributed significantly to policy and management decisions regarding sea otters. The finding that sea otters did not remain near coastal kelp beds as then believed but often traveled so far offshore that they could not be seen and sometimes foraged at depths of over 30 m was particularly significant. It led to the passage of new state laws prohibiting set net fisheries (in which sea otters often drowned accidentally) in these offshore areas (Ralls et al. 1995).

By the middle of this decade, the National Zoo had developed a reputation of being one of a small number of "hotspots" for marine mammal work in the country. Along with places like the University of California at Santa Cruz, the National Marine Mammal Lab (NOAA) and Woods Hole Oceanographic Institute, the National Zoo was where students from around the globe were looking to come for graduate or postdoctoral work in the U.S. on marine mammals.

Desert Tortoise project: In 1990, court battles over the status of the Mojave population of the desert tortoise resulted in a call for proposals from a consortium of federal, state and local groups to examine the impact of livestock grazing and urban development on the desert tortoise population. Olav Oftedal responded and was awarded funding for nutritional studies in 1991, and a decade-long

research program was launched that continues today. As part of the court settlement, funding was provided to establish *The Desert Tortoise Conservation Center* (DTCC) outside Las Vegas, Nevada. The center became the repository for tortoises removed from lands undergoing development, and the resulting population of captive tortoises became the object of research and holding for potential translocation. The DTCC became the headquarters for this new program of the National Zoo.

The primary impetus for funding nutritional research was the need to understand the impact of livestock grazing on the nutritional resources of the endangered tortoise. The central theory of Oftedal's research is that tortoises must integrate intake and excretion of two scarce food constituents (protein and water) with that of potassium, which is in excess and potentially toxic. An overall index of plant quality, the Potassium Excretion Potential or PEP index, developed by the Zoo's Nutrition Lab, has been very effective in explaining foraging choices of tortoises. It suggests that a relatively small number of plant species, which grow only in relatively wet years, are of critical importance to tortoise populations. This work identified a clear mechanism for competition between cattle and tortoises when a grazing study by USGS in California, indicated that grazing cattle may remove high PEP plants so they are not available to tortoises.

Future research will hopefully examine the interactions between nutritional stress and susceptibility to infectious disease. It is believed that many of the population crashes of desert tortoises have been associated with infectious disease (especially an upper respiratory tract disease caused by a mycoplasma), but the role of nutrition in making tortoises susceptible to massive disease outbreaks needs further study.

<u>Sea Turtle Biology, Conservation, and International Policy</u>: In the mid-1980s Frazier initiated detailed studies of the epibionts of sea turtle, i.e., the life forms that attach to turtles during their pelagic migrations. This previously little-explored area of study generated unique information on the life history of these complex marine reptiles (Frazier, 1989; Frazier et al., 1985; 1991; 1992; Frazier and Margaritoulis, 1990). Frazier wrote various publications based on extensive field work conducted, often on remote islands, including book chapters and a monograph (1985a). As with many other scientists at NZP, he established a vast international network of colleagues.

<u>Kit Foxes</u>: Ralls began field studies of endangered San Joaquin kit foxes in the newlyestablished Carrizo Plain Natural Area in 1989, with a three-year grant from The Nature Conservancy. TNC was concerned about the possible impact of coyotes on kit foxes in their new reserve. Working with graduate student P. J. White, Ralls radio-collared and tracked both kit foxes and coyotes. Although coyotes indeed proved to be the principal source of mortality for kit foxes and undoubtedly limited kit numbers, the researchers found that annual fluctuations in kit fox population levels were largely driven by the wide variations in annual rainfall in the arid San Joaquin Valley. During severe droughts such as those occurring in 1989 and 1990, annual plants failed to set seeds, levels of seedeating rodents such as kangaroo rats plummeted, and kit foxes failed to reproduce (White and Ralls 1993). Furthermore, Ralls and White discovered that non-native red foxes were present in the reserve in small numbers and that coyotes were probably suppressing the red fox population. Because nonnative red foxes have apparently totally replaced kit foxes in some parts of California and because coyotes tended to exclude red foxes but not kit foxes from their territories (White et al. 1994), Ralls and White concluded that the net effect of coyotes is likely beneficial to kit foxes. They advised TNC not to undertake coyote control efforts to protect kit foxes and TNC agreed.

<u>White-tailed deer</u>: With funding from the German government and FONZ, Stefan Holzenbein: and Georg Schwede began their Ph.D. dissertation research on white-tailed deer ecology in 1981. Both studies relied on radio-collaring fawns. Holzenbein's study of dispersal documented sex and age differences, and showed that female young inherit home ranges from their mothers (1990). Schwede documented the development of mother-young relations (1991).

When Bill McShea arrived at CRC in 1986 as one of Ed Gould's postdoctoral fellows, he joined the deer projects and imparted a new emphasis on the impact of deer populations on forest ecology and other vertebrates. From 1988 to 1992, Salah Hakim, a Sudanese doctoral student from University of Montana, examined deer foraging behavior (Ph.D. 1995). The new approach relied heavily on an experimental method using six 4-hectare deer exclosures and matching control sites within a 30 mile radius of CRC that have been monitored from 1990 to the present. Earthwatch, National Park Service, the US Forest Service, and FONZ funded the work. Annual censuses have been made of small mammal and bird populations and acorn productivity. When John Rappole joined the staff in 1989, a migratory bird component was added to this work to test the hypothesis that high deer densities impact birds that inhabit the forest understory. The project then took advantage of the annual surveys of Kentucky Warbler conducted by Gene Morton and Vickie McDonald. The studies demonstrated a clear detrimental effect of high deer density on certain species of migratory birds, and that a minimum of 5 years is required for deer-free forests to recover sufficient understory before these species resume nesting.

<u>Golden Lion Tamarin Conservation</u>: Between 1985 and 1994 the Golden Lion Tamarin Conservation Program grew significantly under the overall coordination of Kleiman. Under the reintroduction program, coordinated by Ben Beck, groups of golden lion tamarins were reintroduced annually and carefully monitored weekly, which provided a unique database for comparisons of behavior, nutrition, locomotion between wild and captive born animals. Studies on the ecology of the wild populations (coordinated by J. Dietz, now at the University of Maryland) continued to incorporate new habituated wild groups into the study design. The detailed data on the life history of tamarins provided important information on the social system of this species, as well as data that would later be used to model viability of the population. Community education continued to involve the local communities in GLT conservation efforts, and helped recruit land-owners' participation in the reintroduction program. By the end of 1994, 30 local Brazilians were employed by the project.

A Population Viability Analysis Workshop was held in 1990, organized by the Conservation Breeding Specialist Group, to address priorities for GLT conservation. During this meeting, the government of Brazil requested that the International Management Committee for GLTs serve as the official advisors to the Brazilian government on matters relating to the conservation and management of the species. This committee also served as the model for other international conservation programs in Brazil. In 1991, Ballou coordinated the transfer of ownership of almost all captive GLTs to the government of Brazil. This was the first (and perhaps only) example of a species in which the ownership (but not possession) of all but a very few captive animals by numerous international zoos was returned to the jurisdiction of the native country. Ballou continued to manage the International Studbook and what was probably the largest centrally-managed global captive breeding program in existence. He was supported by an assistant Studbook Keeper position, funded by FONZ.

<u>Asian Elephant Studies:</u> In 1990 Wemmer and Ted Stevens received a grant from USAID to investigate population management and genetics of Asian elephants. With matching funds from the Smithsonian Scholarly Studies Program several related initiatives commenced. Dr. Kasinathan Muralidharan began genetic investigations of DNA samples collected by Wemmer and associates during previous Zoo Biology training courses throughout Southeast Asia. V. Krishnamurthy compiled an extensive historical studbook of domestic South Indian elephants, and a body condition index was designed based on morphometric data collected in various range countries. Wasantha Godagama (nee Senenayake) (University of Colombo) studied the elephant culture of Sri Lanka by conducting extensive surveys of mahouts and elephant owners, and was awarded her masters degree in 1996. Sunder Shrestha (University of Texas), a veterinarian who had served on the Tiger Ecology Project, began studies of the reproductive cycles of domestic Nepalese elephants. Unlike South India, the reproductive rate of this northern population had been low. Shrestha monitored the hormones for a full annual cycle in different parts of the terai.

During this period, Prithi Viraj Fernando (University of Oregon), a Sri Lankan alumnus of Rudran's training program began a field study of wild elephant genetics in Sri Lanka. Fernando set aside his career as a medical doctor to pursue doctoral studies under population ecologist Russ Lande, and perfected DNA extraction from feces to circumvent Sri Lankan restriction's on collecting blood and tissue samples. Rudran provided financial support for Fernando's field work, and served on his advisory committee.

Finally, through CRC's long association with the Malaysian Wildlife Department, Michael Stuewe, a Research Associate, initiated a satellite telemetry project to monitor the movements of translocated elephants. For many years the Wildlife Department had successfully captured cropraiding elephants in peninsular Malaysia, and translocated the animals to Taman Negara National Park in northern Malaysia. The "satellite elephants" project made it possible for the Wildlife Department to evaluate their program, and it was soon learned that translocated elephants do not always remain faithful to the boundaries of their new homes(Stuewe et al. 1998). Stuewe developed a web page to promote the project and received additional funding from private individuals as a result.

Reproductive Science

Recognizing the important role that hormones play in regulating reproductive fitness and animal well-being, the Reproductive Physiology Program was expanded through the federal hiring of two endocrinologists, Drs. Steven Monfort and Janine Brown. Monfort, a veterinarian who earned an M.Sc. degree under the guidance of Dr. Bill Lasley (Univ. of California, Davis), had extensive experience using non-invasive urinary steroid monitoring for assessing the reproductive status of wildlife. He came to the CRC in 1986 to set up an Endocrine Research Laboratory (ERL) in CRC's veterinary hospital. One of his first responsibilities was to monitor urinary hormone profiles in the NZP giant panda, Ling Ling, during her pregnancies and/or pseudopregnancies. He began a Ph. D. with Wildt in 1987 to study the reproductive biology of the Eld's deer, and in collaboration with Wemmer conducted one of the most comprehensive, multidisciplinary studies of any cervid species to date. Basic studies of endocrinology in the male and female, coupled with parallel studies of sperm development and function eventually led to the production of the largest number (at that time) of offspring produced by artificial insemination in any wildlife species. In 1989, he was joined by a senior post-doctoral fellow, Samuel Wasser, who had previously pioneered the development of fecal steroid monitoring techniques for primates. Monfort and Brown (who had been collaborating with Wildt since 1987 while working as an assistant professor at the Uniformed Services University in Bethesda, MD) became federal employees in 1990 and 1991, respectively. Together, Monfort, Wasser and Brown teamed up to create the largest wildlife endocrinology laboratory in the world. Wasser departed in 1993 to take a job with the Woodland Park Zoo in Seattle. The ERL became recognized for its pioneering work studying and characterizing the reproductive and stress biology of more than 60 species of captive and free-living mammals and birds including killer whales, elephants, giant pandas, black-footed ferrets, African wild dogs, Spanish Imperial eagles and passerine birds, to name just a few. These endocrine studies had a number of consequences. They helped to understand the relationships between dominance status and reproductive success in social mammals (e.g., mongooses, African wild dogs, sable antelope). They have measured the physiological effects (i.e. stress) of human disturbances on free-living populations (e.g., African wild dogs and big horn sheep), and they have assessed how management practices affect reproductive performance of captive species (e.g., cheetah, clouded leopard, Pallas' cat, numerous South American small felids). Finally, they allowed staff to evaluate the efficacy of hormonal therapies used in conjunction with assisted reproductive techniques (e.g., in numerous felids, Eld's deer, scimitar-horned oryx).

The ERL became one of only a few laboratories devoted to endocrine studies of wildlife, and its services were sought by other research, academic and zoological facilities wanting to do similar studies. As a result, Monfort and Brown established a service lab to handle these requests that now works collaboratively with over 60 zoos and other organizations nationwide.

After earning her Ph. D. in 1989, JoGayle Howard worked closely with Wildt as a post-doctoral fellow until 1993 when she was hired by the NZP as a Theriogenologist. She, along with other gamete biologists, produced numerous "firsts" through the production of offspring using assisted reproductive techniques. These included in vitro-produced domestic cats (Ph.D. student Karen Goodrowe,) and Siberian tigers (Ph.D. student Annie Donoghue), and births following Howard's artificial insemination of cheetah, clouded leopard and black-footed ferret among others.

Many trainees have gone on to leadership positions in zoos and governmental organizations. For example, Goodrowe now heads the reproductive physiology programs at the Toronto Zoo, while Donoghue heads the poultry reproduction program at the U.S. Department of Agriculture Arkansas Experiment Station. Trainees Terri Roth and Bill Swanson (1991-1994) conducted reproductive research in the scimitar-horned oryx and various felid species designed to improve semen freezing and analysis techniques. Both now head the Cincinnati Zoo's Center for Research in Endangered Wildlife. Linda Penfold, a former DRS trainee that specialized in sperm function and cryobiology in ducks, now heads the reproductive biology program at White Oak Conservation Center. Since 1992, Mary Hagedorn's NIH-funded research has focused on pioneering methods for cryopreserving fish embryos, a technique that may eventually revolutionize the preservation of valuable fish lineages. Hagedorn, a senior research associate, continues this research at National Zoo facilities in Rock Creek.

Research Syntheses through Publications, Symposia, and Books

During this period, Ralls and Ballou laid the foundations for the genetic and demographic management of captive populations. One important contribution was the publication of the proceedings of the Workshop on The Genetic Management of Captive Populations in the journal Zoo Biology (Ralls and Ballou 1986). This influential publication was the result of a symposium they organized to obtain consensus recommendations from the population genetics community with regard to several difficult issues facing managers of captive populations. These issues included recommended goals for the genetic management of captive populations, the measurement and preservation of genetic diversity. the role of selection, and the relative merits of various alternative breeding plans. The general recommendations resulting from the workshop were soon adopted by the zoo community and implemented as Species Survival Plans. The symposium also had an important impact on the academic community by alerting a number of noted population geneticists to the need for genetic research on captive populations and conservation genetics in general. Many participants, including Fred Allendorf, Russ Lande, and Alan Templeton went on to make significant contributions in this area. Perhaps the most significant convert was Dick Frankham, who reoriented all of his subsequent scientific efforts to conservation genetics, became a well-known conservation geneticist, and continued to collaborate with Ballou, and to a lesser extent Ralls, in later years.

Another important publication from this period was "*Estimates of lethal equivalents and the cost of inbreeding in mammals*" (Ralls, Ballou and Templeton 1988). Working with pedigrees of captive populations, these authors produced the first estimates of "the cost of inbreeding" (a partial estimate of the "genetic load" that had been used in a variety of theoretical models) for a broad range of mammalian species. Due to the lack of similar estimates in mammals other than humans, this paper has been widely cited, discussed in conservation biology textbooks, and included in many compilations of readings for conservation biology students. It was even translated and re-published in Japanese.

A third significant contribution was the 1989 workshop on *Analytical Methods for Population Survival and Management*. The workshop again brought together many of the leading scientists in conservation biology to address key issues relating to the analyses of population data for aiding in the recovery of small populations. This workshop started the discussions to revamp the methods used by the IUCN Red Data Book to categorize degrees of threat in threatened species (by Mace and Lande). The proceedings of this workshop were published by Columbia University Press in 1995. Continuation of hosting of influential symposia: *Digestive Strategies of Animals* convened by Olav Oftedal, *Forest Remnants in the Tropical Landscape* convened by Russ Greenberg, *Otariid Reproductive Strategies and Conservation* co-convened by Daryl Boness and Patricia Majluf (Wildlife Conservation Society). Elephant results: documentation of historical aspects of elephant culture with Krishnamurthy. Sukumar et al. 1997 on demography of captive elephants. *Population Management for Survival and Recovery (Ballou, Columbia Univ. Press).*

Below is a selection of publications/workshops/conferences that synthesized major bodies of knowledge at the time:

- Allen, M.E. & O.T. Oftedal. 1994. The nutrition of carnivorous reptiles. p. 71-82. In Captive Management and Conservation of Amphibians and Reptiles. Contributions to Herpetology Vol. 11., Murphy, J.B., Adler, K. & Collins, J.T. (eds). Ithaca, N.Y.: Society for the Study of Amphibians and Reptiles.
- Boness, D.J., W.D. Bowen, and J.M. Francis. 1993. Implication of DNA fingerprinting for understanding mating systems and reproductive strategies of pinnipeds. *Symposia of the Zoological Society of London* 66: 61-93.
- Boness, D.J. 1991. The determinants of mating systems in the Otariidae (Pinnipedia). In: *Behaviour of Pinnipeds*, D. Renouf (ed.). Chapman: London, 1-44.
- Brown, J. L., S.K. Wasser, D.E. Wildt, and L.H. Graham. 1994. Steroid metabolism and the effectiveness of fecal analysis for assessing reproductive status in felids. *Biol. Reprod.* 50: 185.
- Creel, S.R., S.L. Monfort, D.E. Wildt, and P.M. Waser. 1991. Spontaneous lactation is an adaptive result of pseudopregnancy. *Nature*, 351: 660-662.
- Freed, L.A., S.C. Conant, and R.C. Fleischer. 1987. Evolutionary ecology and radiation of Hawaiian forest birds. *Trends in Ecology and Evolution* 2:196-203.
- Gittleman, J.G. and O.T. Oftedal. 1987. Comparative growth and lactation energetics in carnivores. *Symposia of the Zoological Society of London* 57: 41-77.
- Miller, B., R.P. Reading, and S. Forrest. 1997. *Prairie Night*. Smithsonian Institution Press, Washington, DC.
- O'Brien, S.J., D.E. Wildt, M. Bush, T.M. Caro, C, Fitzgibbon, and R.E. Leakey. 1987. East African cheetahs: Evidence for two population bottlenecks? *Proc. National Academy of Science* 84: 508-511.
- O'Brien, S.J., M.E. Roelke, L. Marker, A. Newman, C.W. Winkler, D. Meltzer, L. Colly, J. Everman, M. Bush, and D.E. Wildt. 1985. Genetic basis for species vulnerability in the Cheetah. *Science* 227: 1428-1434.
- Oftedal, O.T. 1993. The adaptation of milk secretion to the constraints of fasting in bears, seals and baleen whales. *Journal of Dairy Science* 76: 3234-3246.
- Oftedal, O.T. 1991. Nutritional consequences of foraging in primates: the relationship of nutrient intakes to nutrient requirements. *Philosophical Transactions of the Royal Society*, London B 334:161-170.

- Oftedal, O.T. 1985. Pregnancy and Lactation. Pp. 215-238 In *The Bioenergetics of Wild Herbivores*. R.J. Hudson and R.G. White (eds.), CRC Press, Boca Raton, FL.
- Oftedal, O.T. and J.G. Gittleman. Patterns of energy output during reproduction in carnivores. Pp. 355-378 In *Carnivore Behavior, Ecology and Evolution*, J.G. Gittleman (ed.). Cornell University Press, Ithaca, NY.
- Oftedal, O.T., D.J. Boness, and R. Tedman. 1987. The behavior, physiology and anatomy of lactation in the Pinnipedia, *Current Mammalogy* 1: 175-245.
- Oring, L., R.C Fleischer, M. Reed, and K. Marsden. 1992. Cuckoldry via stored sperm in the polyandrous spotted sandpiper. *Nature* 359:631-633
- Ralls, K., J.D. Ballou, and A.R. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology* 2: 185-193.
- Ralls, K., and J.D. Ballou, editors. 1986. Proceedings of the Workshop on Genetic Management of Captive Populations. *Zoo Biology* (5). New York: Alan R. Liss, Inc.
- Ralls, K., and J.D. Ballou. 1986. Captive breeding programs for populations with a small number of founders. *Trends in Ecology and Evolution* 1: 19-22.
- Seal, U.S., J.D. Ballou and C. Padua, editors. 1990. Leontopithecus: Population Viability Workshop. Captive Breeding Specialist Group, IUCN. Apple Valley, MN.
- Wildt, D.E., U.S. Seal, and W.F. Rall. 1993. Genetic resource banks and reproductive technology for wildlife conservation. In *Genetic Conservation and Salmonid Fishes*: 159-173. Cloud, J. G. & Thorgaard, G.H. (Ed.). New York: Plenum Publishing Corporation.
- Wildt, D.E., J.G. Howard, P.K. Chakraborty, and M. Bush. 1986. The reproductive physiology of the clouded leopard. II. A circannual analysis of adrenal-pituitary-testicular relationships during electroejaculation or after an adrenocorticotropin hormone challenge. *Biology of Reproduction* 34: 949-959.
- Wildt, D.E., J.G. Howard, L.L. Hall, and M. Bush. 1986. The reproductive physiology of the clouded leopard. I. Electroejaculates contain high proportions of pleiomorphic spermatozoa throughout the year. *Biology of Reproduction* 34: 937-947.
- PVA Workshop on the Conservation of Lion Tamarins (with I. Santos, A. Rylands, U. Seal, J. Mallinson). Belo Horizonte, Brasil., 1990
- Analytical Methods for Population Viability Analysis (with M. Gilpin and T. Foose). Front Royal Virginia, 1989
- Small Population Management Advisory Training Workshop, (w/ B. Wiese, R. Lacy and T. Foose). Front Royal, VA., 1991
- Conference on the Conservation of the Giant Panda, Devra Kleiman and Miles Roberts, National Zoo, 1991.
- Symposium on Forest Patches in the Tropical Landscape, Russell Greenberg, 1992 -- Published as an edited volume by Island Press in 1996.
EDUCATION AND COOPERATION: 1995-2001

SUMMARY

The research focus on conservation issues set in motion in the past decade continues to the present. Both DZR and CRC increased efforts to convey their research and conservation programs to a broader public audience. Staff developed Web Sites, established teacher-training programs, and increased their involvement with students at the secondary school level. Through the combined efforts of DZR and the zoo's educational division, an exciting, novel exhibit called the Amazonia Science Gallery was opened to highlight the Zoo's and SI science programs. It includes working laboratories on display with real scientists doing their work. The CRC Spatial Analysis Lab became an expanded classroom for local schools to learn about biodiversity issues and establish their own sites to monitor local biodiversity. The Zoos scientists became leaders within the Institution in building initiatives for Latinos, who are underrepresented at the professional level in the Smithsonian. Director Robinson committed to hiring a temporary position for a Latino Science Initiative coordinator.

Unfortunately, neither the increased public outreach nor the expanded research functions established in the last decade were adequately funded from either federal or internal trust money. Re-allocation of internal funds away from science programs and reduced federal budgets began to put considerable constraints on the ability of science staff to conduct their jobs, which had now expanded to include substantial amounts of public outreach. More was required with less internal support. The retirement of five senior curators during this period reflects the intensity of the budget problems. Administrators placed greater emphasis not only on bringing in external competitive grants, of which there was always some expectation, but also on raising funds through private donors and foundations. This was a realm for which many scientists had not been trained.

Nevertheless, DZR and CRC scientists recognized their common interests, jointly wrote a mission statement for SNZP science, and increased efforts to collaborate and unify science programs, at least conceptually. Upon taking command, the new director Lucy Spelman announced that science programs would concentrate on achieving excellence in reproductive physiology and veterinary medicine, which would represent a drastic narrowing of the zoo's science programs. In 2000, she administratively unified most of the science programs by merging DZR with CRC under Chris Wemmer. A few research and conservation programs remained under the Animal Program Directorate with the curatorial staff. Unfortunately, prior to this event, Rob Fleischer asked to have the molecular genetics lab administratively transferred to the Natural History Museum, due to continued conflicts over the lab's inadequate funding levels. The museum was able to give the lab additional positions and resources that the Zoo could not provide. This transfer was approved by the Undersecretary for Science because a plan to reorganize science units throughout the institution was already under discussion. In 2001, Director Spelman, at the request of Secretary Small, announced that CRC would be closed and science programs, with some reduction in staff, transferred to the zoo in Washington. The future of science at the Smithsonian, including CRC, is now in the hands of a special blue ribbon committee appointed by Secretary Small.

Staffing and Organization

In 1995, Devra Kleiman stepped down as the head of DZR but remained as a senior scientist in the department. For about six months Miles Roberts, who was Deputy Head of the Department under Kleiman, served as Acting Head. Director Robinson then accepted a proposal by the Department to implement a system of management that had a rotating chairperson. Daryl Boness was appointed to be the first in this position for a 5-year period. This shift in personnel brought about a major change in philosophy about science at the National Zoo. Boness believed in working toward greater coordination

and collaboration between the science units within the National Zoo, a goal he worked towards earlier as chair of a group known as the Research Council, which was a grass roots organization of all scientists at the Zoo. Administratively, science in the organization was fragmented and had been for some time. Wemmer, who ran CRC was an Associate Director with direct reporting to the Zoo's Director/Deputy Director. Kleiman, and then Boness, were at a level lower in the organizational structure and reported to Ben Beck, the Associate Director for Animal Programs (which also included DZR, pathology, Migratory Bird Center, all the animal exhibit departments and the commissary).

Although the global change funds included a position for a second geneticist, it was never filled. When Daryl Boness became chairman of DZR, he succeeded in having the lab's operating budget raised to between \$30,000 and \$60,000 per year. When funds became available for enhancing opportunities for Latinos within the Smithsonian in 1995, DZR was able to obtain funds to hire Jesus Maldonado as a second geneticist for a five-year term. His duties included training Latino students as well as genetic research.

In 2000, Fleischer almost accepted a position in England but decided to remain with the Smithsonian when the Director of the Natural History Museum offered to support his program at the level originally specified in the 1988 appropriation from Congress. This included a permanent position for Jesus Maldonado as the second geneticist, the long-awaited second technician, and a significantly enlarged operating budget. Although his lab will remain physically located in the zoo until a new lab can be constructed at the museum and he will continue to collaborate with many of his former colleagues in DCB, Dr. Fleischer and the entire molecular genetics program will be administratively part of the Natural History Museum as of 1 October 2001.

During this fourth decade there had been a gradually increasing desire and effort to think of National Zoo science in a unified manner. Indeed, when the new Secretary came on board the Research Council was drafting an all-encompassing document that would describe a single mission for the zoo's science rather than several separate ones. As National Zoo scientists talked more it became obvious that the unifying theme was advancing the conservation of the earth's biodiversity through scientific research, professional training, and environmental education. Shortly thereafter, near the end of 2000, Director Spelman made the decision to combine CRC and DZR into a single science unit under Wemmer and CRC.

A second important change that took shape in the previous decade flourished in this fourth one: the recognition that National Zoo scientists needed to commit more strongly to getting their science out to a broader public audience.

Science Programs

Small population biology and management of captive populations

In 1995, Ballou completed his thesis *Genetic management, inbreeding depression, and outbreeding depression in captive populations* and received his Ph.D. in population genetics from the University of Maryland. He introduced the concept of managing captive populations so as to minimize mean kinship, which was generally adopted by the international zoo community. As an extension of his studies on inbreeding, he developed computational models to analyse the effects of purging in pedigreed inbred populations, and collaborated with Bob Lacy of the Brookfield Zoo. They applied these models to Lacy's experimental studies of inbreeding and out-breeding in captive *Peromyscus* mice. Together with various collaborators, he continued developing software for the zoo community, such as PM2000, which integrates several demographic and genetic management routines into a Windows interface. He also advised on the genetic management of numerous captive species in addition to the golden lion tamarins and black-footed ferrets and assisted the Conservation Breeding Specialist Group in conducting Population Viability Assessment workshops in the Philippines, Brazil, China, and India. He began to collaborate extensively with Dick Frankham and, together with D. Briscoe, they completed the first textbook on conservation genetics -- *Introduction to Conservation Genetics* (now in press with Cambridge University Press). He began work on a shorter version of this textbook, titled *A Primer of Conservation Genetics*.

Although most of Ralls' research was no longer concentrated on small population biology, she, together with Ballou and Frankham, identified a probable autosomal recessive lethal gene for chondrodystrophy -- a form of dwarfism -- in the California condor population and advised regarding its management. She also wrote two reviews on population viability analysis. In 1996, Ralls received the LaRoe Award from the Society for Conservation Biology for her sustained achievements in applying science to real-world conservation problems.

Lactation studies: As more and more of the effort in the Nutrition Laboratory is now devoted to nutritional ecology and clinical nutrition, the number of lactation studies has declined. However, Oftedal remains committed to milk studies; to date milk samples from more than 60 institutions and 150 species have been assayed, and the SNZP data base on milk is matched by no other lab in the world. The discovery and validation of new instrumental micro-methods for milk analysis, requiring only 20 ul milk, has made it possible to conduct detailed studies of small species such as bats and rodents. This was essential to Wendy Hood's Ph.D. work on nutritional constraints on lactation in big brown bats, and to Mary Beth Voltura's postdoctoral research on the effect of enriched atomospheric CO2 on nutrition and lactation in voles. A Ph.D .student from New Zealand (Regina Eisert) came to SNZP to assay milk samples from Weddell seals in the Antarctic, and giant panda milk has been collected from both wild and captive animals as part of collaborative research.

Veterinary Research

By the late 1990s Bush's work on anesthesia had reaped major dividends for zoo animal medicine by reducing anesthesia related mortality at the National Zoo from 20% to less than 1%. The zoo's animal collection in Washington and Front Royal has provided the subjects for over 20,000 anesthesias, and field testing has taken place around the world. Bush's collaborations in South Africa and Thailand strengthened, with a focus on bovine TB in Kruger National Park where the disease is considered the major health problem in the ecosystem. He and his colleagues discovered that where 100% of the buffalo population is infected, more than a third of the lion population is also infected, through predation. Major effort is now being made to develop diagnostic tools for each ungulate species at risk, and in particular to develop a vaccine for the buffalo. Bush also lead veterinary training courses in Thailand with Michael Stoskopf of the University of North Carolina's Veterinary School, and worked closely with Miles Roberts to address captive animal management in Papua New Guinea where he delivered veterinary modules in zoo biology training courses.

Field Studies

<u>White-tailed deer</u>: Deer and forest management issues continued to interest the staff, and in 1995/96 Bill McShea and Steve Monfort studied the behavioral and physiological effects of immunocontraception on captive white-tailed deer within CRC. The present focus is to test whether forest biodiversity measures can be increased through deer management, either culls or contraception. In 1996 they tested the efficacy of a new immuno-contraceptive, PZP, as a deer control agent. In 2001 they have almost completed negotiations with Garfield Foundation to test this contraceptive on the CRC deer herd in conjunction with a deer reduction program. They would examine rates of population growth and biodiversity measures on 3 deer sub-populations; cull only, cull followed by contraceptive, no management. This project would use all forested sections of CRC.

<u>Marine Mammals</u>: The culmination of over a decade of emphasis on the adaptiveness of pinniped maternal strategies came with a publication in BioScience (1996) by Boness and colleague, Don Bowen, on the *Evolution of maternal care in pinnipeds*. Oftedal also published a major literature review (1997) on lactation strategies of Cetacea, but as Oftedal is now focusing on nutritional ecology

(especially of the desert tortoise), his marine mammal work is currently limited to collaborative research on Weddell seals and to the development and evaluation of new biomarkers for the assessment of foraging. In the mean time Boness has shifted emphasis to studying male mating strategies of pinniped species focusing on harbor seals and grey seals on Sable Island, the former having an aquatic mating system and the latter a terrestrial system.

In 2001, Ralls began a new radiotelemetry study of threatened California sea otters in collaboration with Jim Estes and other scientists at UC Santa Cruz as well as Don Siniff. Like the earlier sea otter project, this one is also funded by the Minerals Management Service (MMS), due to renewed concern over the deleterious effects of oil spills on sea otters. The California sea otter population has expanded its range into southern areas where the MMS hopes for additional oil development. However, the dynamics of the population have changed for unknown reasons and it is no longer increasing. The main objectives of the current study are to better understand the current population dynamics, behavior, and seasonal movement patterns of sea otters at the southern end of their range and to determine why the population is declining so that appropriate management measures can be taken. Current knowledge of sea otter population dynamics is largely based on the earlier study are being designed to yield data that can be directly compared with the results of that earlier study, so that researchers can identify what factors have changed.

<u>Kit Fox Project</u>: Ralls expanded the kit fox research beyond the confines of the Carrizo Plain and began to collaborate with Fleischer on kit fox genetics. Their first project was undertaken at the request of the U.S. Fish and Wildlife Service, which wanted a way to definitively identify kit fox feces (scats). Working with graduate student Eleni Paxinos, the researchers developed a method to distinguish kit fox scats from those of other canids present in California including domestic dogs, gray foxes, non-native red foxes, and coyotes. The method is based on the mitochondrial DNA extracted from the sloughed intestinal cells contained in canid feces. With graduate student Michael Schwartz, and using nuclear microsatellite markers, Ralls and Fleischer estimated levels of genetic variation and levels of gene flow among the various semi-isolated populations of kit foxes in the San Joaquin Valley. This information was badly needed by both U.S. Fish and Wildlife Service and California Department of Fish and Game personnel managing kit foxes. Ralls and Fleischer also used microsatellites to estimate levels of kinship among individual foxes on the Carrizo Plain and combined this information with radiotelemetry data to discover that mated pairs of this socially monogamous species were not closely related but that adult relatives, especially mothers and daughters, often shared adjacent home ranges and occasionally shared the same dens (Ralls et al. 2001).

After Maldonado was hired, Ralls began to collaborate with him rather than Fleischer. Maldonado's primary interest was in mammals, and he had even done genetic work on Mexican kit foxes while a graduate student, whereas Fleischer's primary interest was in birds. Using kit foxes as a model system for other small carnivores, Ralls and Maldonado are concentrating on developing the use of non-invasive techniques based on DNA from scats to develop improved survey techniques, estimate population size, and compare the results of the new non-invasive DNA techniques to the results of traditional radiotelemetry work. Working with graduate student Debbie Smith, who trained her German shepherd Rio to detect kit fox scats and ignore those of other species, Ralls and Maldonado determined that the dog was 100% accurate in distinguishing kit fox scats from those of other species and much more effective than humans at finding kit fox scats (Smith et al. 2001).

Desert Tortoise Program: Nutritional research on the desert tortoise has remained an important priority for two agencies managing the future of this threatened species in southern Nevada: the US Bureau of Land Management and the Clark County Desert Conservation Plan (the long-term habitat conservation plan for the desert tortoise in this area). Nearly a million dollars was provided by these agencies to SNZP to support research for another five year period (1997-2002), with particular focus on nutritional evaluation of tortoise habitat. A study conducted by Oftedal and colleagues in 1998 at a relatively undisturbed site at Fort Irwin, California confirmed the highly selective foraging of this

species in years of good rainfall, and led to the prediction that a small set of plants are of particular nutritional importance. This study was repeated in 2001 over a broader period of the spring-summer, and preliminary data indicate that tortoises match foraging choices to changes in nutritional composition of plants as they mature and senesce. Foraging choice in this species appears to be more predictable than in other herbivores that have been studied, because it is under tight nutritional constraints. Oftedal hypothesizes that differences in nutritional constraints may explain why tortoises are threatened with extinction in the Mojave and western Sonoran deserts, but not in the eastern and southern Sonoran desert. Additional research has focused on the effects of protein intake on reproductive output (postdoctoral researcher Brian Henen), on the importance of dietary calcium and phosphorus (funded by Morris Animal Foundation), and on the potential impact of elevated CO₂ on desert tortoise nutrition. The success of the nutritional studies of the desert tortoise and the strong public programs of the Smithsonian have led desert tortoise conservation agencies to seek a more formalized role for the Institution in developing a combined long-term research and public outreach program for desert tortoises in the Mojave desert. As planned, the University of Nevada (Las Vegas) and the Bureau of Land Management will be partners, and graduate student research opportunities will be increased. However, Oftedal realized the need for greater communication among scientists working on the nutrition of non-domestic animals, and spearheaded the formation in 1996 of a new professional society with about 200 members worldwide, the Comparative Nutrition Society. He was elected the first President (1996-1998), as well as the third Honorary Life Member (2000).

<u>Sea Turtle Biology, Conservation, and International Policy</u>: After returning to CRC in 1997 as a Research Associate, following a decade based in Latin American institutions, teaching, advising students, and developing graduate programs, Frazier focused on providing scientific information and advice directly into the policy arena, and thereby facilitated the application of scientific knowledge in decision-making and conservation initiatives. He was solicited to produce technical reports for the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) (Frazier, 2001), the Convention on Conservation of Migratory Species of Wild Animals (CMS) (Frazier, 1998a) and also the World Trade Organization (WTO) (1998b) and the European Union (EU) (Frazier, 2000). Advice has also been provided to a major NGO on the development of a hemispheric strategy for the conservation of marine turtles (WWF, 2000). In addition, considerable effort has been invested in active participation in the development of international treaties and other instruments to promote conservation of marine turtles (Al-Ghais and Frazier, 2001).

<u>Golden Lion Tamarin Conservation Program</u>: A major new focus of the GLT Conservation program took place when Cecilia Keirulff, a Brazilian masters student, conducted a survey of all existing forests in the GLT historical range, and discovered numerous small populations of GLTs outside the Poço das Antas Biological Reserve. The rescue of animals in highly threatened forest patches, and their placement in suitable but unoccupied GLT habitat initiated the *GLT Translocation Program*. Thus began a series ongoing studies that explored how tamarins react to unfamiliar environment, and allowed comparisons of reintroduced, translocated and wild tamarin populations. This initial translocation also resulted in the designation of a new Biological Reserve for GLTs. A second Population and Habitat Viability Analysis held in 1997 reinforced the notion that the priority for GLT conservation now depended on strengthening ties between ongoing conservation and research work with efforts in the local community and national conservation groups. An external review of the GLT Conservation Program also recommended that most of the coordination and administration of the project be based on-site in Brazil. As a result the *Golden Lion Tamarin Association* was formed in Brazil to take the leadership role of the GLT Conservation Program. With Kleiman's departure from NZP in 2001, the coordination of the GLT program at NZP was transferred to Beck and Ballou.

<u>Monitoring and Assessment of Biodiversity Program (MAB)</u>: In 1986, the Smithsonian Monitoring and Assessment of Biodiversity Program (MAB) was created as a joint initiative between then Secretary Adams and the Director General of UNESCO. Francisco Dallmeier was hired to head the program, and in the first decade he expanded his staff through two federal positions and four trust fund employees. The program's goal was to promote biodiversity research and conservation through an international network of global protected areas. The MAB Program has conducted research projects, biodiversity assessments and monitoring programs to understand ecosystems, while education and training courses complement the core research and conservation activities. Like Rudran's Wildlife Conservation and Management Training Program, MAB reaches a diverse international audience in order to build in-country professional capacity. MAB was initially under the National Museum of Natural History and the Assistant Secretary for Research, but in 2000 Undersecretary Dennis O'Connor transferred MAB to the National Zoo as part of the Conservation and Research Center.

Research by MAB scientists and collaborators has targeted geographic areas where biodiversity is poorly known and biological data are needed to make sound decisions about conservation and development of natural resources. The research component has produced standard protocols and methodologies for assessing and monitoring biodiversity in a growing global network of research sites. Those long-term monitoring areas provide a basis for comparing information among sites and for detecting changes in biodiversity resulting from natural and human activities. The staff and collaborators publish the results of their research independently, but also in periodically edited volumes (e.g., the SIMAB series).

MAB's evolving education and training component complements this work by transferring information and technologies to scientists, resource managers, and decision-makers around the world. As part of the curriculum, the *Environmental Leadership* course emphasizes influential communication skills to facilitate interactions among scientists, decision makers, and resource personnel. The *Biodiversity Monitoring and Assessment for Adaptive Management* course guides participants in designing and carrying out full-scale local and regional biodiversity programs. The program also conducts *Regional Training* courses throughout the world. MAB's unique internationally known biodiversity curricula boasts more than forty well-recognized environmental leaders as instructors and lecturers.

The principles of adaptive management have underpinned MAB's conservation partnerships with the Shell Foundation, Rio Tinto, and the Ministry of Energy in Ecuador. This component has allowed participating scientists, decision-makers and environmental leaders to find common ground related to collaborative projects in Peru, Gabon, and Canada. The practice of adaptive management is particularly well suited to the process of devising reliable strategies for long-term sustainable use, and reduces the risks of species extinctions. The four steps in the adaptive management cycle--setting the objectives of the project, conducting resource assessment and monitoring programs, evaluating the findings, and using that information to make needed changes in the project plan—have been key to MABs successful partnerships among national and international organizations and the private sector. Within the framework of these three components, Dallmeier and his staff have assembled teams of national and international experts to generate biological and ecological information on numerous ecosystems. Participants have been trained in standard protocols, management recommendations have been generated, and long-term monitoring programs have been implemented. Biodiversity assessments have provided the first picture of the abundance and distribution of flora and fauna, whereas long-term monitoring is "the movie" that shows the dynamics of the system.

In 1996, MAB formed partnerships with the Shell Foundation and associates for the Camisea Project in the Amazon of southeastern Peru. One million dollars of support was generated for biodiversity surveys and monitoring, and the Camisea area was designated as a protected area when petroleum exploration was complete. The scientific results of the project were published by MAB in a three volume series – *Biodiversity Assessment and Monitoring of the Lower Urubamba Region, Peru*. In 2000, the Shell Foundation awarded a \$2.8 million grant to MAB for a five-year biodiversity monitoring project in the pristine Gamba complex of Gabon, West Africa.

<u>Thamin Ecology Project</u>: Wemmer, Monfort and McShea initiated an ecological investigation of the Eld's deer or thamin (*Cervus eldi thamin*) in Burma (Myanmar) in 1995. *Chatthin Wildlife Sanctuary* was targeted for field work because it represents the last stronghold of the species in

Southeast Asia. The survival of this endemic deer and other life forms depends upon a unique but threatened ecosystem--the *indaing* forest of Upper Burma. The goal of the project was to assist the protected area staff and Wildlife Division to integrate knowledge of the deer's ecology with the management of the park and surrounding communities (Wemmer, 1996). Wemmer worked with U Myint Aung, the warden of the park to select a field team of Burmese protected area staff. McShea, Monfort, Leimgruber and other scientists trained the staff as field ecologists. During the next 7 years, over 30 CRC, SI staff, and associates also trained wildlife division staff as field biologists and parataxonomists, instituted long-term ecological research, and fostered community-based conservation. They trained over 140 wildlife staff in over a dozen training courses in biodiversity subjects. The project strengthened the skills of the Burmese staff, and generated data for the first ecological studies of the Eld's deer (McShea et al. 2001, and Aung 2001). The work has also spawned sister programs with strong counterpart collaboration, such as the taxonomic surveys by CRC's John Rappole, George Zug (National Museum of Natural History), David Rentz (CSIRO, Canberra), and Steve Kinyon (NMNH).

<u>Asian Elephant Studies</u>: By the mid-1990s a number of elephant projects came to completion. Wasantha Godagama (nee Senenayake) finished her masters thesis and published a series of papers in the *Ceylon Journal of Science* (Godagama, 1998a, 1998b). Muralidharan's efforts were passed on to Rob Fleischer, who orchestrated the DNA and data analyses and coordinated inputs for the final report on elephant genetics, which was published in the journal *Evolution* (Fleischer et al. in press). Priti Viraj Fernando completed his Ph. D. in 1999 and received a post-doctoral fellowship to work with Don Melnick at Columbia University.

Wemmer and Leimgruber proposed a new elephant project to the U.S. Fish & Wildlife Service in 1999. This project of wild elephant populations focuses on conserving and managing two critical ranges in the western hills. It grew out of a familiarity with Burma's protected area system gained by Wemmer and his staff earlier in the decade. The objective of the project is to foster research skills, policies, and practices that will allow park staff in Alaungdaw Kathapa National Park and Htamanthi Wildlife Sanctuary to effectively manage their parks and respond to the conflicts between elephants and the villagers who live on the park boundaries. Following preparations in 2000 and an attitude survey of villagers, the project officially commenced in January 2001 with a training course on elephant survey methodology and radio telemetry.

In October, 2002, CRC will convene a workshop elucidating the central ethical issues for national and international policies regarding captive, domesticated, and wild elephants. Social and natural scientists and wildlife practitioners will critically examine pressing ethical issues associated with elephant welfare in zoos and circuses, elephant labor practices, international policies for ivory and elephant trade, wild elephant protection and management, and human-elephant conflicts. With participation of renowned elephant experts from Asia, Africa, Europe and the United States, the workshop and subsequent edited volume will play a role in elephant-related conservation and international policy. Wemmer and Dr. Catherine Christen are the workshop's organizers, in cooperation with representatives of the American Zoo and Aquarium Association and with partial funding from the Disney Conservation Fund.

Reproductive Sciences

In the mid-1990's Brown's emphasis began to switch from felids to elephants, and as Reproductive Advisor to the Elephant SSP (since 1995), she has since operated a service for assessing reproductive activity of elephants. She found that captive elephants have numerous reproductive problems and that the demographic consequence for captive populations of Asian and African elephants will be extinction within a few decades. Brown launched a comprehensive effort to monitor the reproductive status of captive elephants and to determine possible physiological and psychological causes of reproductive failure (e.g, acyclicity due to ovarian cysts, hyperprolactinemia, or social suppression) so that mitigating treatments can be developed. In the 1990s, DRS scientists began intensive efforts to establish genome resource banks (GRBs) -- systematic collections of frozen germ plasm (sperm, embryos), blood, tissue and DNA to preserve biodiversity. The staff also played an increasingly important role in zoo and conservation programs such as the AZA's SSP and TAG programs, as well as IUCN Specialist Groups. Wildt has served as co-chairman of the Felid Taxon Advisory Group since 1990 and helped create one of the most organized and effective TAG groups within the AZA. He also worked closely with Ulysses Seal and the Conservation Breeding Specialist Group (CBSG), helping to facilitate working groups on husbandry, genetics, reproduction, management and Population and Habitat Viability Assessments (PHVAs) of a variety of species (e.g., cheetah, lion, clouded leopard, monk seal). Several DRS staff continue to serve as reproductive advisors to the CBSG and SSPs (e.g., cheetah, clouded leopard – Howard; elephant, cheetah – Brown). Monfort also served on the IUCN Cervid and Antelope Specialist Groups.

The application of artificial insemination played an increasing role in the USFWS recovery program for the black footed ferret (*Mustela nigripes*). Howard became a central figure in artificially inseminating brood ferrets whose offspring were destined for reintroduction in the western United States. She and her co-workers also discovered that poor fertility among one-year-old male ferrets in breeding programs was a major cause of false pregnancy among females. By evaluating semen quality of such males prior to mating she was able to increase the pregnancy and birth rate. At the time of writing CRC has produced nearly 200 ferret kits using both artificial and natural breeding.

With the arrival of the National Zoo's two giant pandas, the reproductive scientists have become intensively involved in developing a strategy to maximize the reproductive potential of this pair of pandas. This will include non-invasive (urine and feces) endocrine assessments of reproductive and stress hormones, use of vaginal cytology to confirm breeding readiness, and use of assisted reproductive techniques to ensure reproduction (if necessary). Wildt also was very active in promoting reproductive and veterinary research of captive giant pandas in China where he and colleagues Susie Ellis, JoGayle Howard and Rebecca Spindler, among others, conducted several workshops and training courses for Chinese biologists. The result was an extensive database characterizing the physical, reproductive, and health characteristics of each panda in the Chinese panda studbook. The outcome of the relationships and activities is an edited volume on panda biology which is currently under preparation.

In 1996, Buddha Pukazhenthi joined the Department as a post-doctoral fellow and working with Howard continued research designed to understand the biology of teratospermia in domestic and nondomestic felids. Using molecular techniques, they have identified differences in membrane structure, metabolism and enzyme function that help explain the inability of morphologically abnormal sperm to fertilize eggs in vitro. Rebecca Spindler joined the DRS in 1997 and expanded the gamete biology program to include investigations into the metabolism of domestic cat oocytes and embryos. She has pioneered new techniques to enhance the development of embryos through co-culture with companion embryos, as well as methods to assess the competence of oocytes and embryos through analysis of metabolic markers. This work has received NIH funding and currently is being viewed as a possible means of improving IVF technology in humans. Working together with other DRS staff, Pukazhenthi and Spindler have pioneered a "gamete rescue" program that permits sperm and eggs to be retrieved from animals that die unexpectedly, but whose genetic contributions to the population are critical. Although in its infancy, this program shows great promise for preserving the genetic representation of valuable individuals, perhaps even producing offspring after their death.

The ERL saw a tremendous increase in activities related to the non-invasive monitoring of wildlife species, including new studies in the killer whale, Alaskan moose, Imperial eagle, Bali mynah, golden-breasted starling, meerkat, black and white rhinoceros, porcupine and mountain gorilla. In 1997, Dr. Nadja Wielebnowski joined Brown's laboratory to begin a series of studies integrating behavioral observations with endocrine assessments to better understand the physiological and psychological control of reproduction in the cheetah and clouded leopard. One of the most important

outcomes of this work was the development of non-invasive fecal monitoring techniques to evaluate adrenal activity as a measure of stress. At the same time, Monfort was using this technology to evaluate the potential stress of capture and radio-collaring procedures in African wild dogs.

A major milestone of this decade was the development of a successful artificial insemination technique for elephants. This was done as a collaborative effort between Brown and German colleagues, Drs. Thomas Hildebrandt and Frank Goeritz of the Institute of Zoo and Wildlife Research in Berlin. Hildebrandt and Goeritz developed a new method for depositing sperm into the female reproductive tract using ultra-sonography and endoscopy, while Brown discovered a new way to estimate the time of ovulation based on the analysis of luteinizing hormone, which characterizes ovulation. Several pregnancies in African elephants were achieved, and in 1998 the Asian elephant at the National Zoo was successfully artificially inseminated.

Wildt's activities with the CBSG increased. He facilitated workshops associated with Meso-American felids, Iberian lynx, bottle-nosed dolphin, Florida panther and cheetah. He also participated in the coordination of a comprehensive multi-disciplinary biomedical survey of the giant panda in China. Monfort has become increasingly involved with antelope conservation efforts and helped to establish the Sahelo-Saharan Interest Group, consisting of conservation partners from 15 countries focused on conserving arid lands antelope species of North Africa.

Translating Science for Public Audiences

The National Zoo has a long-history of educating the public through its exhibits, with emphasis on trying to inspire the public to understand and support nature, and ultimately increase biological literacy of the zoo's visitors. National Zoo scientists have been at the forefront of new science-based initiatives designed to engage and educate the lay public. One of the best known science outreach initiatives at National Zoo (and within the zoological community) has been its Amazonia Science Gallery (ASG), which opened in 1997 under the leadership of former National Zoo Director, Michael Robinson. This unique experimental science education center brings visitors into the day-to-day world of scientific research and the people who do it. ASG is a unique working science facility, where visitors can see scientists at work in nutrition, genetics, behavior and scanning electron microscopy laboratories and can engage themselves with research artifacts, computer interactives, videos, hands-on interactives, and demonstrations that tell the stories of our research.

Since the late 1990s, National Zoo scientists have also helped to develop and implement innovative environmental education programming to convey National Zoo science to under-served audiences, particularly those in minority and rural communities. Environmental education is frequently cited as a cornerstone activity of biological conservation, and zoos are particularly well-placed to serve as focal points for engaging the students, teachers and other community members about biodiversity conservation. One example of such a program is the Miami-based ELIPSE (Environmental Latino Initiative Promoting Science Education) program. This CRC program uses middle school teachers as educational multipliers and targets school-age children and their families. ELIPSE seeks to demystify science, create first-person relationships between scientists and teachers, and inspire students to learn more about the environment in which they live. Another similar National Zoo program is the NSFfunded "Community Science Workshop" that targets elementary and middle school children in the Latino communities of Washington, D.C. Working with the Latin American Youth Center, National Zoo scientists provide materials and supplies, mentors for interns, and facilitate the involvement of scientific staff and resources from other Smithsonian bureaus. The "Bridging the Americas" program is another cross-cultural environmental education program that links elementary school classes in the state of Maryland with classes in Latin America and the Caribbean through an exchange of art work and letters that focus on Neotropical migratory birds. The National Zoo's Migratory Bird Center provides teachers with teaching aids and information on migratory birds, including posters, bilingual vocabulary lists, and

suggested activities. Children from Latin America and the USA exchange drawings and letters, sharing what they have learned about migratory birds.

Finally, the CRC-based "Forest Biodiversity Monitoring Project", which has become the cornerstone of CRC's conservation education programming, focuses on secondary school teachers of students in the rural communities surrounding Front Royal, Virginia. This program provides teachers and their students access to CRC's cutting-edge research protocols in forest biodiversity monitoring and remote sensing and encourages teachers and their students to "become-the-scientists". Teachers and students receive new skills that allow them to promote sound principles of scientific investigation and a clear understanding of their natural environment. Other CRC-based science education programs includes tours of CRC by Friends of the National Zoo staff and an Autumn Conservation Festival that collectively reach several thousand citizens annually. Additionally, FONZ summer camp and Earthwatch Expeditions annually provide public participation in National Zoo scientific activities for more than 300 individuals.

Jack Frazier's more recent research activities have been designed to provide vehicles for enhancing public awareness and promoting the use of scientific information in policy. Marine turtles are classic flagship species, large, attractive and charismatic, and recognized worldwide as endangered. Their complex life histories create enormous challenges to both research and conservation. They are dependent on terrestrial, coastal and pelagic environments for survival. They have delayed maturity requiring decades just to begin reproduction. Finally, they disperse and migrate across vast ocean basins. Satellite tracking is now providing unique information on movements and distribution while the animals are at sea – where they spend most of their lives, and where it is extraordinarily expensive to do research. This approach relies on modern, "cutting edge" technology, and is a seductive means to draw attention to the conservation challenges, as well as an effective tool for educating the general public, particularly decision makers. Work is presently ongoing in the Philippines, Brazil, and India involving different partners, species of marine turtles, and conservation problems. In each case the partners are critically placed within their respective governments to be able to influence policy efficiently. In all cases unique web sites have been designed to disseminate the information widely. See <http://www.oneocean.org/ambassadors/index.html>. <http://tamar.org.br/satelite.htm>. <http://kachhapa.org/telemetry>).

One encouraging result has been increased awareness and interest in the fate of marine turtles and their habitats, as seen in responses from both the general public and policy makers. Recent media coverage in both Brazil and India featured the work on national prime time, reaching millions of people in both countries. Public education and conservation measures that focus on marine turtles must address complex issues that are routinely omitted or underplayed in many conservation initiatives. The conservation requirements of marine turtles encompass a wide variety of environments, vast geographic areas and must be taken into account for decades. There are also a tremendous number of interest groups and "stakeholders" involved, from local, marginalized communities to powerful fishing industries and governments. Hence, appropriate conservation actions for these animals will have lasting and profound benefits for countless other species, various environments, and diverse human societies.

Research Syntheses through Publications, Symposia, and Books

Below is a selection of publications/workshops/conferences that synthesized major bodies of knowledge at the time:

Allen, M.E. & Oftedal, O.T. 1996. Essential nutrients in mammalian diets. Pp. 117-128 in Wild Mammals in Captivity, Kleiman, D.G., Allen, M.E., Thompson, K.V. & Lumpkin, S. (eds). Chicago: University of Chicago Press.

- Allen, M.E., Oftedal, O.T. & Baer, D.J. 1996. The feeding and nutrition of carnivores. Pp. 139-147 in Wild Mammals in Captivity, Kleiman, D.G., Allen, M.E., Thompson, K.V. & Lumpkin, S. (eds). Chicago: University of Chicago Press.
- Ballou, J. D. 1983 2001. International Studbook for Golden Lion Tamains, Leontopithecus rosalia. National Zoological Park, Washington, D.C. (The Studbook has been published annually since 1983).
- Ballou, J. D., R. C. Lacy, S. Ellis, D. Kleiman and A. Rylands (eds). 1998. Leontopithecus II: The Second Population and Habitat Viability Analysis for Lion Tamarins. Apple Valley, MN: Conservation Specialist Breeding Group/ IUCN/SSC.
- Ballou, J. D., and T. J. Foose. 1996. Demographic and genetic management of captive populations. In: Wild Mammals in Captivity, Kleiman, D., M. E. Allen, K. V. Thompson, S. Lumpkin. pp. 263-283. Univ. of Chicago Press.Boness, D.J., Clapham, P.J. and Mesnick, S.L. 2001. Life history and reproductive strategies of marine mammals. In: Marine Mammal Biology: An Evolutionary Approach. R. Hoelzel (ed.). Blackwell Science, Oxford.
- Ballou, J. D.; Gilpin, M.; Foose, T. J. (eds.) 1995. *Population Management for Survival and Recovery*. Columbia Univ. Press.
- Boness, D.J. 1996. Water quality management in aquatic mammal exhibits, Pages 231-242 In: *Wild Mammals in Captivity*, D.G. Kleiman, M.E. Allen S. Lumpkin, and H. Harris (eds.), Chicago: University of Chicago Press.
- Boness, D.J. and Bowen, W.D. 1996. The evolution of maternal care in pinnipeds. *Bioscience* 46: 1-10.
- Cooper, A. C., J. Rhymer, H. James, S. Olson, C. McIntosh, M. Sorenson and R. C. Fleischer. 1996. Ancient DNA and island endemics. *Nature* 381: 484.
- Creel, S., Marusha-Creel, N., & Monfort, S. L. (1998). Birth order, estrogens, and sex ratio adaptation in African wild dogs (*Lycaon pictus*). *Animal Reproductive Science*.
- Dumbacher, J. P. and R. C. Fleischer. 2001. Phylogenetic evidence for Mullerian mimicry in toxic pitohui birds. *Proceedings of the Royal Society, Series B*, in press.
- Fleischer, R. C., E. A. Perry, K. Muralidharan, E. Stevens, and C. M. Wemmer. 2001. Phylogeography of the Asian elephant (*Elephas maximus*) based on mitochondrial DNA. *Evolution*, in press.
- Fleischer, R. C., C. E. McIntosh and C. L. Tarr. 1998. Evolution on a volcanic conveyor belt: using phylogeographic reconstructions and K-Ar based ages of the Hawaiian Islands to estimate molecular evolutionary rates. *Molecular Ecology* 7:533-545.
- Fleischer, R. C. 1998. Genetics and avian conservation. Pp. 29-47 in (J. Marzluff and R. Sallabanks, eds.) *Avian Conservation: Research and Management.* Island Press, Washington, DC.
- Fleischer, R. C. 1996. Application of molecular methods to the assessment of genetic mating systems in vertebrates. Pp. 133-161 in (Ferraris, J. D. and S. R. Palumbi, eds.) *Molecular Zoology: Advances, Strategies and Protocols.* Wiley-Liss.
- Fonseca, D. M., D. A. LaPointe and R. C. Fleischer. 2000. Bottlenecks and multiple introductions: population genetics of the vector of avian malaria in Hawaii. *Molecular Ecology* 9:1803-1814.

- Frankham, R., J. D. Ballou and D. Briscoe. In press (2001). *Introduction to Conservation Genetics*. Cambridge Univ. Press.
- Goldsworthy, S., D. Boness, and R. Fleischer. 1998. Mate choice among sympatric fur seals: female preference for conphenotypic males. *Behavioural Ecology and Sociobiology* 45:253-267.
- Hamilton, M. B. 1999. Tropical tree gene flow and seed dispersal. Nature 401:129-130.
- Howard, J. G., Marinari, P. E., & Wildt, D. E. (2001). Black-footed ferret: Model for assisted Reproductive Technologies contributing to *in situ* conservation. In *Reproductive Sciences and Integrated Conservation*: Holt, W. V., Pickard, A., Rodger, J. & Wildt, D. E. (Ed.). Cambridge: Cambridge University Press.
- Howard, J. G. Sperm function in endangered species. Proceedings of the Pacific Coast Fertilization Society. 21-23. 1998.
- Kleiman, D. G. and J. J. C. Mallinson. 1998. Recovery and Management Committees for lion tamarins: partnerships in conservation planning and implementation. *Conservation Biology* 12(1): 1-13.
- Kleiman, D., M. E. Allen, K. V. Thompson, S. Lumpkin. 1995. *Wild Mammals in Captivity*, Univ. of Chicago Press.
- McShea, W. J., Leimgruber, P., Aung, M., Monfort, S., & Wemmer, C. (1999). The range collapse of thamin (*Cervus eldi*) and the extent of remaining habitat in central Myanmar. *Animal Conservation* **2:** 173-183.
- Oftedal, O.T. 2000. Use of maternal reserves as a lactation strategy in large mammals. *Proceedings of the Nutrition Society*, 59:99-106.
- Oftedal, O.T. 1997. Lactation in whales and dolphins: evidence of divergence between baleen and toothed whales. *Journal of Mammary Gland Biology and Neoplasia*. 2: 205-230.
- Oftedal, O.T. & Allen, M.E. 1996. Nutrition and dietary evaluation in zoos. Pp. 109-116 in *Wild Mammals in Captivity*. Kleiman, D.G., Allen, M.E., Thompson, K.V. & Lumpkin, S. (eds). Chicago: University of Chicago Press.
- Oftedal, O.T. & Allen, M.E. 1996. The feeding and nutrition of omnivores, with emphasis on primates. Pp. 148-157 in *Wild Mammals in Captivity*. Kleiman, D.G., Allen, M.E., Thompson, K.V. & Lumpkin, S. (eds). Chicago: University of Chicago Press.
- Oftedal, O.T. and Iverson, S.J. 1995. Phylogenetic variation in the gross composition of milks. Pp. 749-789 In *Handbook of Milk Composition*, Jensen, R. (ed.) New York: Academic Press.
- Ryder, O. A. and R. C. Fleischer. 1996. Genetics research and its application in zoos. Pp. 255-262 in (Kleiman, D. G., M. E. Allen, K. V. Thompson, S. Lumpkin, eds.) Wild Mammals in Captivity. University of Chicago Press, Chicago, IL.
- Sorenson, M. D., A. Cooper, E. E. Paxinos, T. W. Quinn, H. F. James, S. L. Olson and R. C. Fleischer. 1999. Relationships of the extinct moa-nalos, flightless Hawaiian waterfowl, based on ancient DNA. *Proceedings of the Royal Society, Series B*, 266:2187-2194.
- Sorenson, M. D. and R. C. Fleischer. 1996. Multiple independent transpositions of mitochondrial DNA control region sequences to the nucleus. *Proceedings of the National Academy of Sciences*, 93:15239-15243.

- Tarr, C. L., S. Conant and R. C. Fleischer. 1998. Founder events and variation at microsatellite loci in an insular passerine bird, the Laysan finch (*Telespiza cantans*). *Molecular Ecology* 7:719-731.
- Thompson, K. V. & Monfort, S. L. (1999). Synchronization of estrous cycles in sable antelope. *Animal Reproduction Science* **57**: 185-197.
- Wells, R.S., Boness, D.J., and Rathbun, G. 1999. Behavior. Pages 324-422 In: *The Biology of Marine Mammals*, J.E. Reynolds, III and J.R. Twiss, Jr. (eds.). Smithsonian Institution Press: Washington, D.C.
- Wildt, D. E. & Wemmer, C. (1999). Sex and wildlife: the role of reproductive science in conservation. *Biodiversity and Conservation* **8:** 965-976.
- Wooninck, L. M., R. R. Warner and R. C. Fleischer. 2000. Relative fitness components measured with competitive PCR. *Molecular Ecology* 9:1409-1414.
- History, management and conservation role of the captive lion tamarin populations. In: Kleiman, D. G. and A. B. Rylands (eds). *The Conservation Program of the Lion Tamarins*. Smithsonian Institution Press.
- International Symposium on the Reproductive Strategies and Conservation of Otariids, Washington, DC, (Convenors: Daryl Boness, National Zoo and Patricia Majluf, Wildlife Conservation Society). 1996
- First Sustainaible Coffee Congress, Russ Greenberg and Robert Rice, National Zoo 1996 -- proceeding published in house
- Workshop on Demographic Analyses of Captive Populations, Fort Worth Zoo, (W/ R. Wiese), 1998
- Population and Habitat Viability Assessment Workshop for Lion Tamarins. Belo Horizonte, Brazil (w/ Biodiversity Foundation), 1997
- Sustainable Cocoa Workshop (held in conjunction with STRI in Panama), 1998. Proceedings published on Smithsonian Migratory Bird Center website.
- Birds of Two Worlds: ecology and evolution of migratoryy birds, Smithsonian Migratory Bird Center. To be held in March 2002 (tentatively to be published by SI press)
- Tidal Marsh Vertebrates: Ecology, Evolution, and Conservation, Smithsonian Migratory Bird Center. To be held at Patuxent Wildlife Research Center Nov. 2002.

REFERENCES

Agoramoorthy, G. and R. Rudran. 1995. Infanticide by adult and subadult males in free-ranging red howler monkeys, *Alouatta seniculus*, of Venezuela. *Ethology*, 99:75-88.

Al-Ghais, S. and J. Frazier. 2001. Workshop on Marine Turtles in the Western Indian Ocean. *Marine Turtle Newsletter*. 92: 17-25.

Beck, B. and C. Wemmer. 1983. *The Biology and Management of an Extinct Species: Père David's Deer.* Noyes Publications, Park Ridge, New Jersey, 193 pp.

Berven, K.A. 1981. Heritable and environmentally induced variation in development and reproduction of the wood frog *Rana sylvatica*. Ph.D. Thesis, University of Maryland.

Boness, D.J. and Bowen, W.D. 1996. The evolution of maternal care in pinnipeds. *Bioscience* 46: 1-10.

Bowen, W.D., O.T. Oftedal, and D.J. Boness. 1985. Birth to weaning in four days: Remarkable growth in the hooded seal, *Cystophora cristata*. *Canadian Journal of Zoology*, 63: 2841-2846.

Eisenberg, J.F. 1981. *The Mammalian Radiations. An Analysis of Trends in Evolution, Adaptation and Behavior.* The University of Chicago Press, Chicago and London. 610 pp.

Eisenberg, J.F. 1976. Communication and social integration in the black spider monkey, *Ateles fusciceps robustus*, and related species. *Smithsonian Contribution to Zoology*, 213:1-108.

Eisenberg, J.F. and G.M. McKay. 1974. Comparison of ungulate adaptations in the New World and Old World tropical forests with special reference to Ceylon and the rainforests of Central America. In *The behaviour of ungulates and its relation to management,* ed. V. Geist and F. Walther, 2:585-602. IUCN Publications, n.s. No. 24, Morges, Switzerland.

Eisenberg, J.F. and D.G. Kleiman. 1972. Olfactory communication in mammals. *Ann. Rev. Ecol. System*, 3:1-32.

Eisenberg, J.F. and P. Leyhausen. 1972. The phylogenesis of predatory behaviour in mammals. *Zeitschrift Tierpsychologie*, 30:59-93.

Eisenberg, J.F. and E. Gould. 1970. The tenrecs. A study in mammalian behavior and evolution. *Smithsonian Contribution to Zoology*. 27:1-137.

Fleischer, R. C., E. A. Perry, K. Muralidharan, E. Stevens, and C. M. Wemmer. 2001. Phylogeography of the Asian elephant (*Elephas maximus*) based on mitochondrial DNA. *Evolution*, in press.

Frazier, J. 2001. Basic biological characteristics of hawksbill turtles: The importance of overlapping scales. Convention on International Trade in Endangered Species of Wild Fauna and Flora. First CITES wider Caribbean hawksbill turtle dialogue meeting, Mexico City (Mexico), 15-17 May 2001 (Doc. 6). 30 pp.

Frazier, J. 2000. Evaluation of: Conservation of Sea Turtles and Sustainable Development in the State of Espirito Santo. Projecto TAMAR, Brasil - European Community. 38 pp.

Frazier, J. 1998a. Recommendations on future CMS activities for marine turtle conservation and review of implementation in member states. Convention for the Conservation of Migratory Species of Wild

Animals. 24 + 25 + 4 + 13 pp. 9 April 1998. (Recommendations on future CMS activities for marine turtle conservation. Convention on the Conservation of Migratory Species of Wild Animals (CMS). Eighth meeting of the CMS Scientific Council, Wageningen, The Netherlands, 3-5 June, 1998. CMS/ScC.8/Doc.10 16 pp + 3 Annexes.)

Frazier, J. 1998b. Report to the Panel, World Trade Organization; Dispute 58: United States-Import Prohibition of Certain Shrimp and Shrimp Products. 33 + 26 + 8 + 25 pp. 11 January 1998.

Frazier, J. 1991. La Presencia de la Tortuga Marina *Lepidochelys olivacea* (Eschscholtz), en la Republica Oriental del Uruguay. *Revista de la Facultad de Humanidades y Ciencias*. Serie Ciencias Biológicas, 3a época 2(6):1-4, 1 fig.

Frazier, J. 1989. Are marine turtles free from parasitic copepods? Marine Turtle Newsletter. 47:10-11.

Frazier, J. 1985a. Marine Turtles in the Comoro Archipelago. *Koninklijke Nederlandse Akademie van Wetenschappen.* 84: 177 pp. 18 pls.

Frazier, J. 1985b. A Review of in Vivo Labels for Studies of Age Determination and Growth in Amphibians and Reptiles. *Herpetologica*. 41 (2): 222- 227.

Frazier, J. 1985c. Tetracycline as an in Vivo Label in Bones of Green Turtles, *Chelonia mydas* (L.). *Herpetologica*. 41 (2): 228-234.

Frazier, J. 1984a. Tortugas Marinas en el Océano Atlántico Suroccidental. *Boletín de la Asociación Herpetológica Argentina*. Serie Divulgación. 2: 1-22.

Frazier, J. 1984b. Conservation of Sea Turtles in the Red Sea. *In*: Thompson, M.- F., A.F.A. Latif and A.R. Bayoumi (eds.) *Proceedings of the International Conference on Marine Science in the Red Sea. Bulletin of the Institute of Oceanography and Fisheries*. (1983) 9: 443-449.

Frazier, J. 1982a. Status of Marine Turtles in the Central Western Indian Ocean. *In*: Bjorndal, K. (ed.). *Biology and Conservation of Sea Turtles.* Smithsonian Institution Press, Washington, D.C. pp. 385-389.

Frazier, J. 1982b. Subsistence Hunting in the Indian Ocean. *In*: Bjorndal, K. (ed.) *Biology and Conservation of Sea Turtles*. Smithsonian Institution Press, Washington, D.C. pp. 391-396.

Frazier, J. 1980. Exploitation of Marine Turtles in the Indian Ocean. *Human Ecology*. 8(4): 329-370.

Frazier, J., S. Salas and H. Didi. 2000. Marine Turtles In The Maldive Archipelago. *Maldives Marine Research Bulletin No.* 4: 5-41.

Frazier, J., J.E. Winston and C.A. Ruckdeschel. 1992. Epizoan communities on marine turtles. III. Bryozoa. *Bulletin of Marine Science* 51(1): 1-8.

Frazier, J., I. Goodbody and C.A. Ruckdeschel. 1991. Epizoan communities on marine turtles. II. Tunicates. *Bulletin of Marine Science* 48(3):763-765.

Frazier, J. and J.L. Brito M. 1990. Incidental capture of marine turtles by the Swordfish fishery at San Antonio, Chile. *Marine Turtle Newsletter* 49:8-13.

Frazier, J. and D. Margaritoulis 1990. The Occurrence of the Barnacle, *Chelonia patula* (Ranzani, 1881) on an inanimate substratum. *Crustaceana* (Cirripedia, Thoracia) 59(2):213-218.

Frazier, J., S. Frazier, D. Hanbo, H. Zhujian, Z. Ji, and L. Ling. 1988. Sea Turtles in Fujian and Guangdong Provinces. *Acta Herpetologica Sinica*. 6 (1):16-46.

Frazier, J., S. Salas, and H. Didi. 1988. Marine Turtles in the Maldive Archipelago. *Proceedings Symposium on Endangered Marine Animals and Marine Parks*. Cochin, India. 1985. 304-326.

Frazier, J., G.C. Bertram and P.G.H. Evans. 1987. Turtles and marine mammals: Chapter 14. *In*: Edwards, A. J. and S. M. Hind (eds.) *Key Environments: Red Sea*. Pergamon Press, Oxford. pp. 288-314.

Frazier, J. and S. Salas. 1987. La Situación de las Tortugas Marinas en el Pacífico Este. *In*: S. G. Aguirre (ed.) *VII Simposio Latinoamericano Sobre Oceanografía Biológica*. 15-19 Nov. 1981, Acapulco, Mexico. pp. 615-624.

Frazier, J. and S. Salas. 1986. Tortugas Marinas en el Pacífico Oriental: ¿El Recurso que Nunca Acabrá? *Symposio Conservación y Manejo de Fauna Silvestre Neotropical (IX Congreso Latinoamericano de Zoología PERU)* (1983), pp. 87-98.

Frazier, J., D. Margaritoulis, K. Moldoon, C. . Potter, J. Rosewater, C. Ruckdeschel and S. Salas. 1985. Epizoan Communities on Marine Turtles. I. Bivalve and Gastropod Mollusks. *Marine Ecology*. 6 (2): 127-140.

Frazier, J. and S. Salas. 1984a. Tortugas Marinas en Chile. *Boletin del Museo Nacional de Historia Natural de Santiago, Chile*. (1982) 39: 63-73.

Frazier, J. and S. Salas. 1983. Tortugas Marinas en la Costa Peruana. *Boletin de Lima* 5(30): 13. Hakim, S., W.J. McShea, and J.R. Mason. 1996. The attractiveness of a liquid bait to white-tailed deer in the Central Appalachian Mountains, Virginia, USA. *Journal of Wildlife Diseases* 32:395-398.

Godagama, W.K., C. Wemmer, and W.D. Ratnasooriya. 1998a. The Body Condition of Sri Lankan Domestical Elephants (*Elephas maximus maximus*). *Ceylon Journal of Science*, 26:1-6.

Godagama, W.K., C. Wemmer, and W.D. Ratnasooriya. 1998b. Spinal Conformation of Domesticated Sri Lankan Elephants (*Elephas maximus maximus*). *Ceylon Journal of Science*, 26:7-11..

Godagama, W.K. 1996. An ethnozoological study of domesticated elephants in Sri Lanka. M.Phil. Thesis, University of Colombo, Colombo, Sri Lanka.

Hakim, Salah. 1995. Seasonal variation in habitat selection by white-tailed deer (*Odocoileus virginianus*). Ph.D. thesis, University of Montana.

Healy, W.M., and W.J. McShea. 2001. Goals and guidelines for ecosystem management of oak forests. Pages 333-340 <u>In</u> Oak Forest Ecosystems: ecology and management for wildlife. Edited by William J. McShea and W. M. Healy. Johns Hopkins University Press.

Holzenbein, S. 1992. Expandable PVC collar for marking and transmitter support. *Journal of Wildlife Management*_56: 473-476.

Holzenbein, S. 1990. Integration of maturing white-tailed deer (*Odocoileus virginianus*) into the adult population. Ph.D. thesis, University of Georgia.

Holzenbein, S. and R.L. Marchinton. 1992. Spatial integration of maturing male white-tailed deer into the adult population. *Journal of Mammalogy* 73: 326-334.

Holzenbein, S. and R.L. Marchinton. 1991. Emigration and mortality in orphaned male white-tailed deer. *Journal of Wildlife Management* 56: 147-153.

Holzenbein, S. and G. Schwede. 1989. Activity and movements of female white-tailed deer during the rut. *Journal of Wildlife Management* 53: 219-223.

Holzenbein, S., C.M. Wemmer, and R.L. Marchinton. 1989. Radio-controlled mechanical drop-net trigger. *Proc. Annual Conf. SE Assoc. Fish and Wildl. Agencies* 43: 492-496.

Kleiman, D.G. 1970. Reproduction in the female green acouchi, Myoprocta pratti. *Journal of Reproduction and Fertility*, 23:55-65.

Kleiman, D.G. 1971. The courtship and copulatory behaviour of the green acouchi, *Myoprocta pratti. Zeitschrift Tierpsychologie*, 29:259-78.

Kleiman, D.G. 1972. Maternal behaviour of the green acouchi. (*Myoprocta pratti* Pocock), a South American caviomorph rodent. *Behaviour*, 43(1-4:48-84.

Krishnamurthy, V. and C. Wemmer. 1995. Veterinary care of Asian timber elephants in India: historical accounts and current observations. *Zoo Biology* 14:123-133

Krishnamurthy, V. and C. Wemmer. 1995. Timber elephant management in the Madras Presidency of India (1844-1947). Pp. 456-472 in "A Week of Elephants", J.C. Daniel and H. Datye, eds., Bombay Natural History Society and Oxford University Press.

McKay, G.M. 1973. The ecology and behavior of the Asiatic elephant in southeastern Ceylon. *Smithsonian Contribution to Zoology*, 125:1-113.

McShea, W.J., and W.M. Healy. editors. 2001. *Oak Forest Ecosystems: Ecology and Management for Wildlife*. John Hopkins University Press.

McShea, W.J. and J.H. Rappole. 2000. Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. *Conservation Biology* 14:1161-1170.

McShea, W. J., Leimgruber, P., Aung, M., Monfort, S., & Wemmer, C. (1999). The range collapse of thamin (*Cervus eldi*) and the extent of remaining habitat in central Myanmar. *Animal Conservation* **2**: 173-183.

McShea, W.J., H.B. Underwood, and J.H. Rappole. editors. 1997. *The Science of Overabundance: Deer ecology and population management*. Smithsonian Institution Press. Washington DC.

McShea, W.J. and J.H. Rappole. 1997. The science and politics of managing deer within a protected area. *Wildlife Society Bulletin* 25:443-446.

McShea, W.J., S.L. Monfort, S. Hakim, J. Kirkpatrick, I. Liu, J.W. Turner, Jr., L. Chassey, and L. Munson. 1997. The effect of immunocontraception on the behavior and reproduction of white-tailed deer. *Journal of Wildlife Management* 41:560-569.

McShea, W.J., H.B. Underwood and J.H. Rappole. 1997. Deer management and the concept of overabundance. pp. 1-7 In *The Science of Overabundance: Deer ecology and population management.* W. J. McShea, H. B. Underwood, and J. H. Rappole, eds. Smithsonian Institution Press.

McShea, W.J. and J.H. Rappole. 1997. Herbivores and the ecology of forest understory birds. pp. 298-309 <u>In</u> The Science of Overabundance: Deer ecology and population management, W. J. McShea, H. B. Underwood, and J. H. Rappole, eds. Smithsonian Institution Press.

McShea, W. J. and G. Schwede. 1993. Variable acorn crops, and the response of white-tailed deer and other mast consumers. *Journal of Mammalogy* 74:999-1006.

McShea, W.J., C. Wemmer, and M. Stuwe. 1993. Conflict of interests: A public hunt at the National Zoo's Conservation and Research Center. *Wildlife Society Bulletin* 21:492-497.

McShea, W.J. and J. H. Rappole. 1992. White-tailed deer as keystone species within forest habitats of Virginia. *Virginia Journal of Science* 43:177-186.

Miller, B., R.P. Reading, and S. Forrest. 1997. *Prairie Night*. Smithsonian Institution Press, Washington, DC.

Mishra, H.R. 1982. The ecology and behavior of Chital (*Axis axis*) in the Royal Chitawan National Park, Nepal (dissertation). Ph.D. dissertation, University of Edinburgh.

Muckenhirn, N.A. 1972. Leaf-eaters and their predator in Ceylon: Ecological roles of gray langurs, *Presbytis entellus*, and leopards. Ph.D. dissertation, University of Maryland.

Muckenhirn, N.A. 1967. The Behavior and Vocal Repetoire of *Sanguinus Oedipus* (Hershkovitz 1966) Callithricidae, Primates). Master's thesis, University of Maryland.

Murray, S., S. L. Monfort, L. Ware, W. J. McShea and M. Bush. 2000. Anesthesia in female white-tailed deer using Telazol and Xylazine. *Journal of Wildlife Diseases*. 36:670-675.

O'Brien, S.J., D.E. Wildt, D. Goldman, C.R. Merril and M. Bush. 1983. The cheetah is depauperate in genetic variation. *Science* 221:459-462.

Oring, L., R.C Fleischer, M. Reed, and K. Marsden. 1992. Cuckoldry via stored sperm in the polyandrous spotted sandpiper. *Nature* 359:631-633.

Ralls, K., K. L. Pilgrim, P. J. White, E. E. Paxinos, M. K. Schwartz, and R. C. Fleischer. 2001. Kinship, social relationships, and den-sharing in kit foxes. *Journal of Mammalogy* 82: 858-866.

Ralls, K., B. Hatfield, and D. B. Siniff. 1995. Forging patterns of California sea otters based on radiotelemetry. *Canadian Journal of Zoology* 73: 523-531.

Ralls, K., T. W. Williams, D. B. Siniff, and V. B. Kuechle. 1989. An intraperitoneal radio transmitter for sea otters. *Marine Mammal Science* 5: 376-381.

Ralls, K., J. D. Ballou, and A. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. *Conservation Biology* 2: 185-192.

Ralls, K. and J. Ballou, eds. 1986. Proceedings of the Workshop on the Genetic Management of Captive Populations. *Zoo Biology* 5: 81-238.

Rudran, R. 1976. Socio-ecology of the Blue Monkeys (*Cercopithecus mitis stuhlmanni*) of the Kibale Forest, Uganda. Ph.D. dissertation, University of Maryland.

Schwede, G. 1991. Some behavioral aspects of the fawning season in white-tailed deer (*Odocoileus virginianus*). PhD thesis, University of Kiel, Germany

Schwede, G. 1989. A fawn's life. Zoogoer 18, 26-27.

Schwede, G. 1987. Weissedelhirsche sind vorsichtige Mutter. Das Tier 24-25.

Schwede, G., H. Hendrichs, and C. Wemmer. 1994. Early mother-young relationships in white-tailed deer. *Journal of Mammalogy* 75: 438-445.

Schwede, G., H. Hendrichs, and C. Wemmer. 1994. Sibling relations in young white-tailed deer fawns *Odocoileus virginianus*. *Mammalia* 58: 175-181.

Schwede, G., H. Hendrichs, and W. McShea. 1993. Social and spatial organization of female whitetailed deer, *Odocoileus virginianus*, during the fawning season. *Animal Behaviour* 45:1007-1017

Schwede, G., H. Hendrichs, and C. Wemmer. 1991. Activity and movement patterns of young whitetailed deer fawns. *The Biology of Deer*. Pp. 56-62.

Schwede, G., S. Holzenbein, and H. Hendrichs. 1990. Sparring in white-tailed deer (*Odocoilleus virginianus*). *Z. Saugetierkunde* 55: 331-339.

Schwede, G. and S. Holzenbein. 1985. Activitatsmuter von Weisswedelhirshen (Odocoileus virginianus) wahrend der Brunft. MS thesis, University of Beilefeld, Germany

Shrestha, S., D.E. Ullrey, J. Bernard, C. Wemmer, and D. Kraemer. 1998. Plasma vitamin E and other analyte levels in Nepalese camp elephants (*Elephas maximus*). *Journal of Zoo and Wildlife Medicine* 29(3):269-278.

Smith, D.A., K. Ralls, B. Davenport, B. Adams, and J. E. Maldonado. 2001. Canine assistants for conservationists. *Science* 291: 435.

Smith, J.L.D. 1984. Dispersal, communication and conservation strategies for the tiger (*Panthera tigris*) in Royal Chitwan National Park, Nepal. Ph.D. thesis, University of Minnesota, St. Paul.

Smythe, N. 1970. Ecology and Behavior of the Agouti (*Dasyprocta punctata*) and Relates Species on Barro Colorado Island, Panama. Ph.D. dissertation, University of Maryland.

Stamp, N.E. 1980. Effect of group size on an egg-clustering butterfly. Ph.D. Thesis, University of Maryland.

Stüwe, M. 1985. Aspects of structure and reproduction of white-tailed deer populations, *Odocoileus virginianus*, in Venezuela and Virginia. *Saugetierkundliche Mitteilungen* 32: 137-141.

Stüwe, M. and C. Wemmer. 1985. Dynamik einer Weisswedelhirsch - Population (*Odocoileus virginianus*) hoher Dichte. *Zeitschrift fur Jagdwissenschaft* 31: 221-229.

Stuewe, M. 1986. Behavior and ecology of a white-tailed deer population (*Odocoileus virginianus*) at high density. Dissertation, Universitat Bielefeld, West Germany 154 p.

Stüwe, M. 1986. Flight order and its development in white-tailed deer. *Journal of Wildlife Management* 50: 699-701.

Stuewe, Michael. 1986. Behavior and ecology of white-tailed deer (*Odocoileus virginianus*) at high density. PhD thesis, University of Beilefeld, Germany.

Stüwe, M., J. B. Abdul, B. M. Nor, and C. M. Wemmer. 1998. Tracking the movements of translocated elephants in Malaysia using satellite telemetry. *Oryx* 32(1):68-74

Stüwe, M. & Blohowiak, C. McPaal: micro-computer programs for the analysis of animal locations (Manual for Version 1.2). 1986.

Sukumar, R., V. Krishnamurthy, C. Wemmer, and M. Rodden. 1997. Demography of captive Asian elephants (Elephas maximus) in southern India. *Zoo Biology* 16:263-272

Thompson, S.D., K.A. Ono, O.T. Oftedal, and D.J. Boness. 1987. Thermoregulation and resting metabolic rates in the California sea lion, *Zalophus californianus*. *Physiological Zoology*, 60:730-736.

Wemmer, C. 1996. Integrating Deer Specialist Group Activities with Biodiversity Research and Protected Area Conservation in Myanmar. *Species* : 48-49.

Wemmer, C. and M. Stuwe. 1985. Reducing deer populations in large enclosures with drives. *Wildlife Society Bulletin* 13: 245-248.

White, P. J. and K. Ralls. 1993. Reproduction and spacing patterns of kit foxes relative to changing prey availability. *Journal of Wildlife Management* 57: 861-867.

White, P. J., K. Ralls, and R. A. Garrott. 1994. Coyote-kit fox spatial interactions based on radiotelemetry. *Canadian Journal of Zoology* 72:1831-1836.

Wildt, D.E., C.C. Platz, S.W.J. Seager, & M. Bush. 1981. Induction of ovarian activity in the Cheetah (*Acinonyx jubatus*). *Biol. Reprod.* 24: 217-222.

WWF (World Wildlife Fund) 2000. A WWF Marine Turtle Action Plan for Latin American and the Caribbean. Summary Report. pag var.

APPENDIX 1

ANIMAL COLLECTIONS

Department of Zoological Research

Between 1967 and mid-1990s, NZP's Department of Zoological Research maintained a large and diverse animal collection for basic research on life history, behavior, and nutrition. DZR staff also initiated and managed successful conservation programs for several "core" species, including the golden-lion tamarin (*Leontopithecus rosalia*)(i.e., captive breeding and reintroduction) and red panda (*Ailurus fulgens*)(i.e., management of AZA SSP program). Over the 23 year period from 1967 to January 2001, a total of 6710 specimens were maintained by DZR staff, including mammals (6 orders, 43 families, 132 species, 5367 specimens), birds (2 orders, 7 families, 12 species, 168 specimens), reptiles (2 orders, 3 families, 3 species, 84 specimens), and fish (2 orders, 2 families, 2 species, 1091 specimens)(Table 1.3). Animal "loans" into the DZR collection peaked in 1991 at 23, and "loans" to other institutions peaked in 1990 at 452.

Collections-based research in DZR focused exclusively on mammalian species between 1967 and the mid-1980s. As shown in the figure below, Dr. Eugene Morton and his students added a number of avian species to the collection between 1985 and 1992 for behavioral studies, and Dr. Olav Oftedal and his students added three species reptiles between 1986 and 1996 for nutritional studies. Two fish species (not shown) were also added to the collection in 1995 and 1998, respectively, to accommodate studies by Research Fellow Dr. Mary Hagedorn. As shown in the figure below, the number of species in DZR collection has waxed and waned largely in response to the initiatives and needs of individual researchers.



As shown in the next figure, the number of specimens in the DZR collection has waxed and waned similarly in response to the requirements of individual projects and researchers [e.g., the high number of mammal specimens, 1994-1997, reflects the studies of Research Fellow Dr. Lucy Roberts on meadow and prairie voles (*Microtus pennsylvaticus and M. ochrogaster*)].



National Zoo administration decided to eliminate the DZR research collection in 1996 as a result of increasing financial constraints and the need to reallocate keeper positions to the exhibits departments within the zoo. As a result, the collection was progressively reduced from 1996 through 2000. By 31 December 2000, it had been reduced to several red pandas on breeding loan and 3 iguanas. Responsibility for the red panda breeding loans was transferred to the Conservation and Research Center, and the iguanas were accessioned into the collection of NZP's Department of Herpetology.

CRC Mammal Collection

As noted earlier, NZP secured the Front Royal property for off-exhibit breeding, holding, and conservation research. The modification and development of animal facilities began as soon as NZP assumed control of the property in 1974. Due to the minimal requirements of modifying barns and pastures for hoofed stock, the first species to be acquired were 4 species of ungulates [i.e., Persian onager (*Equus onager onager*), Bactrian camel (*Camelus bactrianus*), Pere David's deer (*Cervus davidianus*), and Scimitar-horned oryx (*Oryx dammah*)]. Other species soon followed as appropriate indoor and outdoor facilities were modified and/or constructed. CRC presently has 6 major barn complexes, 4 outdoor breeding complexes, and 4 buildings (indoor/outdoor complexes) suitable for small mammals, including carnivores and small primates.

Since 1974, 2766 mammals (7 orders, 16 families, 42 species) have been accommodated at CRC (Table 1.4). Species selection has been based on a variety of factors, including: (1) availability; (2) suitability of facilities; (3) research opportunities; (4) conservation potential; (5) availability of cooperators; (6) veterinary considerations; and (7) accommodating surplus animals from NZP. As shown in the figure below, the number of species in the CRC mammal collection increased steadily from 4 to 24 species from 1974 to 1981. Since 1981 there has been a slow, but relatively steady reduction in the number of species. In many cases, species were deaccessioned because research, husbandry, or management objectives were completed.



Although the number of species in the CRC mammal collection began to decline slowly after 1981, the number of specimens in the CRC collection did not actually peak until 1993 after the number of species had been reduced to 19 (see figure below). To a large extent, this reflects the continued expansion of a number of ungulate herds that reached carrying capacity at about this time.



The number of specimens in the collection has continued to decline since 1993 as a result of the judicious deaccessioning of specimens and species, and the deliberate re-directing of space and resources to high priority species (i.e., black-footed ferret, *Mustela nigripes*). As of 31 August 2001, the CRC mammal collection included 218 specimens of 12 species (Table 1.1). Of these 12 species, 8 are managed under the American Zoo and Aquarium Associations's (AZA) Species Survival Plan program, and two species are managed under AZA-managed Regional Studbooks and Population Management Plans (PMPs). CRC acquired black-tailed prairie dogs (*Cynomys ludovicianus*) for the pre-release conditioning of black-footed ferrets, and is the only participating institution providing this vital training at this time. The single specimen of Pere David's deer (*Elaphodurus c. cephalophus*) is an aged, imperfect specimen that cannot be deaccessioned. At present, 78 specimens in the CRC collection are on loan from other institutions, and 13 specimens are on loan to other institutions.

Table 1.1.	CRC mammal	collection as	of 31	August 2001.
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Order	Family	Common Name	Scientific Name	Specimens
Marsupalia	Macropodidae	Matschei's tree kangaroo ¹	Dendrolagus matschiei	9
Rodentia	Sciuridae	Black-tailed prairie dog	Cynomys ludovicianus	30
Carnivora	Canidae	Maned wolf ¹	Chrysocyon brachyurus	10
	Procyonidae	Red panda ¹	Ailurus fulgens	4
	Mustelidae	Black-footed ferret ¹	Mustela nigripes	60
	Felidae	Clouded leopard ¹	Neofilis nebulosa	12
Perrisodactyla	Equidae	Przewalski's wild horse ¹	Equus caballus przewalskii	18
Artiodactyla	Cervidae	Eld's deer ²	Cerus eldii thamin	29
		Pere David's deer	Elaphurus davidianus	1
		Tufted deer ²	Elaphodus c. cephalophus	8
	Bovidae	Scimitar-horned oryx ¹	Oryx dammah	34
		Arabian orxy ¹	Oryx leucoryx	3
			Total Specimens	218

¹ Species managed under the AZA SSP program.

² Regional Studbook and Population Management Plan for captive population under auspices of AZA.

CRC Bird Collection

As in the case with mammals, birds were moved to CRC as soon as facilities were appropriately modified for their housing in 1974. The first two species were the common rhea (*Rhea americana*) and common peafowl (*Pavo cristatus*), although neither species warranted either research or conservation attention. Additionally, approximately 80% of the entire NZP Department of Ornithology's bird collection was also moved to CRC in late 1974 to accommodate the renovation of the Bird House. Unfortunately, because the collection was housed in inappropriate and makeshift facilities, avian tuberculosis spread throughout the collection and subsequently became a major source of mortality in both the NZP and CRC bird collections due to the frequent exchanges of specimens between facilities. The disease was not brought under control (<0.05% mortality per annum) until 1988, following an extensive program entailing improved husbandry, judicious euthanasia, extensive substrate replacement, and intensive pest control at both NZP and CRC. CRC bird facilities currently include portions of 3 buildings with indoor/outdoor aviaries, two outdoor complexes for "hardy birds", an outdoor complex, were constructed before 1986.



Since 1974, 6518 birds (15 orders, 39 families, 126 species) have been held at CRC, excluding the specimens and species accommodated during the NZP Bird House renovation in 1974-1975 (Table 1.5).

As shown in the figures above, between 1974 and 1984 the number of species in the collection increased from 2 to 46, and the number of specimens increased from 13 to 505. The rapid expansion of the collection during this 10-year period, resulted from a combination of factors involving (1) acquisitions from other zoological institutions, and (2) acquisitions from NZP (i.e., many eggs were transferred from NZP to CRC for hatching and rearing). By 1984, many species were being held in overcrowded conditions that prevented breeding, exacerbated the incidence of avian tuberculosis, and, with few exceptions, minimized research opportunities. As a consequence, over the next 4-5 years, the number of species was reduced, the number of species was increased, improved

husbandry was emphasized, and breeding loans to other institutions were eliminated. Since 1989, the number of species in the collection has remained relatively constant (i.e., 14-21), and variations in specimen numbers have been related primarily to specific research or conservation projects. For example, from 1990 to 1996, we maintained large numbers of northern (*Anas acuta*) and Bahama (*A. bahamensis*) pintails and redheads (*Aythya americana*) and canvasbacks (*A. valisineria*) for experimental studies of mate choice (Research Fellow Dr. Lisa Sorenson) and nest parasitism (Research Fellow Dr. Mike Sorenson), respectively. Similarly, we are presently maintaining large numbers of mallards (*A. platyrhynchos*) and black ducks (*A. rubripes*) for comparative studies of neophobia by Drs. Russ Greenberg and Eugene Morton.

As of 31 August 2001, the CRC bird collection included 245 specimens of 18 species (Table 2). Of this number, 5 species are managed under the auspices of the AZA SSP program, 1 species is managed under an AZA Regional Studbook, 3 are cooperatively managed with the U.S. Fish and Wildlife Service and zoological institutions, and 6 species are being maintained for specific research projects. Of the remaining 3 species, Florida sandhill cranes (*Grus canadensis pratensis*) are maintained in the collection to provide foster-rearing opportunities for our endangered cranes, and the Laysan teal (*Anas laysanensis*) and Mariana Crow (*Corvus kubaryi*) are each represented by single specimens. We are presently deaccessioning two species (i.e., Darwin's rhea and Mariana crow), and expect to accession a new species [i.e., the toxic hooded pitohui (*Pitohui dichrous*) for research purposes within the next 6 months. There are currently 21 specimens of endangered species that are on loan to CRC from the Government of Guam and the Commonwealth of the Northern Mariana Islands.

Order	Family	Common Name	Scientific Name	Specimens
Struthioniformes	Rheidae	Darwin's rhea ²	Pterocnemia penata	3
Anseriformes	Anatidae	Northern pintail ⁴	Anas acuta	30
		Mallard ⁴	Anas platyrhynchos	47
		N. American black duck ⁴	Anas rubripes	50
		Laysan teal	Anas laysanensis	1
		Muscovy duck ⁴	Cairina moschata	24
Gruiformes	Gruidae	Florida sandhill crane	Grus canadensis pratensis	7
		Red-crowned crane ¹	Grus japonensis	5
		White-naped crane ¹	Grus vipio	3
	Rallidae	Guam rail ¹	Gallirallus owstoni	4
Coraciiformes	Alcedinidae	Micronesian kingfisher ¹	Halcyon. C. cinnamomina	6
Passeriformes	Zosteropidae	Rota bridled white-eye ³	Zosterops rotensis	11
	Drepanididae	Amakihi ³	Hemignathous virens	15
		l'iwi ³	Vestiaria coccinea	1
	Sternidae	Golden-breasted starling ⁴	Cosmopsarus regius	6
		Bali mynah ¹	Leucopsar rothschildi	15
		Superb Starling ⁴	Spreo superbus	16
	Corvidae	Mariana crow	Corvus kubaryi	1
			Total Specimens	245

Table 1.2. CRC bird collection as of 31 August 2001.

¹ Species managed under the AZA SSP program.

² Regional Studbook and Population Management Plan for captive population under auspices of AZA.

³ Cooperative management program between U.S. Fish and Wildlife Service and zoological institutions.

⁴ Species involved in ongoing research project.

Table 1.3. Research Collection, Department of Zoological Research, NZP, 1967-2000.

			No.	Yr. In	Yr. Out
MAMMALS:					
Marsupalia					
Dasyuridae	Australian native cat	Dasyurus viverrinus	2	1969	1971
	Broad-footed marsupial mouse	Antechinus melanurus	1	1972	1972
	Crest-tailed marsupial mouse	Dasycereus cristicaudata	3	1967	1972
	Narrow-footed marsupial	Sminthopsis macrura	36	1967	1972
	New Guinea tiger cat	Dasyurus albopunctatus	1	1972	1974
	Spooted-tailed native cat	Dasyurops maculatus	3	1969	1972
	Yellow-footed marsupial	Antechinus stuarti (flavines)	5	1967	1969
	Kultarr	Antechinomys laniger	4	1967	1968
	Long-legged jumping marsupial	Antechinomys spenceri	3	1969	1972
	Tasmanian devil	Sarcophilus harissii	4	1969	1976
Dasyuroidae	Kowari	Dasyuroides byrnei	14	1967	1986
Didelphidae	Black-shouldered	Caluromysiops irrupta	2	1969	1971
	Grey four-eyed opossum	Philander opossum	8	1982	1988
	Grey short bare-tailed opossum	Monodelphis domestica	289	1978	1987
	Murine opossum	Marmosa elegans	27	1965	1976
	Scaly-tailed possum	Wyulda squamicaudata	2	1971	1972
	South American opossum	Didelphis marsupialis	2	1973	1978
	Wooly opossum	Caluromys lanatus	4	1966	1970
	Yapok (water opossum)	Chironectes minimus	6	1970	1986
Macropodidae	Matschie's tree kangaroo	Dendrolagus matsheii	3	1986	1987
	Southern potoroo	Potorous apicalis	11	1986	1988
	Swamp wallaby	Wallbia bicolor	1	1967	1967
Microbiotheriidae	Monito-del-monte	Dromiciops australis	2	1985	1986
Peramelidae	New Guinean spiny bandicoot	Echymipera rufescens	4	1971	1972
	Short nosed bandicoot	Isoodon macrourus	12	1982	1985
Petauridae	Common ringtail possum	Pseudocheirus peregrinus	44	1982	1992
	Sugar glider	Petaurus breviceps	47	1970	1993
Phalangeridae	Brush-tailed possum	Trichosurus vulpecula	2	1971	1972
	Cuscus	Phalanger gymnotis	2	1970	1972
	Grey Cuscus	Phalanger orientalis	2	1969	1972
Insectivora					
Macroscelididae	Checkered elephant shrew	Rhyncocyon chrysopygus	1	1976	1976
	East African elephant shrew	Elephantulus rufescens	402	1976	1987
	Forest elephant shrew	Petrodromus tetradactylus	9	1976	1983
Solenodontidae	Hispaniolan solenodon	Solenodon paradoxurus	9	1966	1976
Soricidae	House shrew	Suncus murinus	24	1985	1986
Talpidae	Eastern mole	Scalopus aquaticus	1	1967	1969
Tenrecidae	Common tenrec	Tenrec ecaudatus	33	1966	1971
	Large Madagascar tenrec	Setifer setosus	15	1966	1970
	Long-nosed tenrec	Microgale longirostris	1	1966	1971
	Long-tailed tenrec	Microgale thomasi	7	1966	1971
	Long-tailed tenrec	Microgale talazaci	10	1973	1978
	Long-tailed tenrec	Microgale dobsoni	11	1966	1971

Table 1.3. Research Collection, Department of Zoological Research, NZP, 1967-2000.

			No.	Yr. In	Yr. Out
	Moon rat	Echinosorex gymnura	3	1967	1987
	Pygmy hedgehog tenrec	Echinops telfairi	59	1965	1983
	Short-tailed shrew	Blarina brevicauda	1	1967	1968
	Streaked tenrec	Hemicentetes	56	1965	1971
		semispinosus		1000	4000
	Streaked tenrec		4	1966	1968
lupalidae	Common tree shrew	l upaia glis	27	1989	1995
	Lesser tree shrew	l upaia minor	41	1989	1999
	Long-nosed tree shrew	Tupala tana	60	1989	1999
Primate					
Lorisidae	Common potto	Perodictus potto	1	1966	1967
Lemuridae	Mouse lemur	Microcebus murinus	1	1967	1967
Tarsiidae	Western tarsier	Tarsius bancanus	16	1983	1992
Callitrichidae	Common marmoset	Saguinus oedipus	4	?	?
	Goeldi's marmoset	Callimico goeldii	12	1980	1994
	Golden lion tamarin	Leontopithecus rosalia	984	?	?
	Golden-headed lion	Leontopithecus	16	1986	1995
	tamarin	chrysomelas			
	Pygmy marmoset	Callithrix pygmaea	4	1989	1989
Cebidae	Orabussu titi monkey	Callicebus molloch	13	1978	1984
	Spider monkey	Ateles fusciceps	2	?	?
Chiroptera					
Phyllostomatidae	Geoffroys' long-nosed bat	Anoura geoffroyi	9	1972	1973
	Long-tongued bat	Glossophaga soricina	8	1972	1978
	Mexican fruit bat	Artibeus jamaicensis	149	1975	1982
	Neotropical fruit bat	Artibeus lituratus	4	1975	1975
	Short-tailed leaf-nosed	Carollia castanea	6	1975	1978
	bat				
	Short-tailed leaf-nosed	Carollia perspicillata	133	1972	1979
	bat Creater Spear Need Bet	Bhyllostomus hostotus	100	1002	1000
Edentata	Greater Spear-Noseu Bat	Phyliosionius nasialus	109	1993	1990
Edentata	True to ad alath	Obele en el de state		4007	4000
Bradypodidae	I wo-toed sloth	Choloepus aldactylus	11	1967	1983
Dasypodidae	Long-nosed armadillo	Dasypus novemcinctus	1	1967	1967
	Naked-tailed armadillo	Cabassous centralis	2	1975	1976
Manidae	Malayan pangolin	Manis javanica	1	1966	1967
Capromyidae	Bahaman hutia	Geocapromys ingrahami	6	1969	1971
	Cuban hutia	Capromys pilorides	14	1970	1981
	Cuvier's hutia	Plagiodontia aedium	24	1969	1985
Cavidae	Lesser patagonian cavy	Dolichoitis salanicola	24	1972	1979
	Patagonian cavy	Dolichotis patagonum	3	1966	1972
	Rock cavy	Kerodon rupestris	141	1978	1984
	Yellow-toothed cavy	Galea spixii	5	1978	1982
Rodential					
Chinchillidae	Chinchilla	Chinchilla laniger	24	1971	1983
	Mountain viscacha	Lagidium peruanum	7	1971	1976
Crecitidae	Alston's (Mexican) brown	Scotinomys tequina	11	1975	1976
	mouse				
	Northern grasshopper	Onychomys leucogaster	3	1985	1986
	mouse			1005	4000
	Southern grasshopper	Onycnomys torridus	11	1985	1989
	Mied's red-nose mouse	Wiedomys pyrrhorhinus	20	1078	1082
	Moodow Vola	Microtus penneuluoniaus	23 110	100/	1002
			449	1004	1000
			10	1901	1983
	Egyptian spiny mouse	Acomys aimiaiatus	59	19/9	1984

Table 1.3. Research Collection, Department of Zoological Research, NZP, 1967-2000.

			No.	Yr. In	Yr. Out
	Peter's climbing rat	Tylomys nudicaudatus	76	1971	1978
	Prairie Vole	Microtus ochrogaster	705	1994	1997
Cuniculidae	Paca	Cuniculus paca	8	1967	1972
Dasyproctidae	Acouchi	Myoprocta pratti	55	1970	1980
	Hairy-rumped agouti	Dasyprocta punctata	2	1966	1967
Dinomyidae	Pacarana	Dinomys branickii	8	1968	1975
Echimyidae	Armored rat	Hoplomys gymnurus	6	1982	1988
	Punare	Trichomys aperioides	246	1978	1987
	Spiny rat	Proechimys semispinosus	60	1967	1971
Erethizontidae	North American Porcupine	Erethizon dorsatum	6	1987	1991
	Prehensile-tailed porcupine	Coendou prehensilis	20	1972	1987
Heteromyidae	Least pocket mouse	Perognathus parvus	2	1966	1968
	Lompoc kangaroo rat	Dipodomys heermanni arenae	20	1990	1994
	Morro Bay kangaroo rat	Dipodomys h. morroensis	7	1990	1994
Jerbilidae	Desert jerboa	Jaculus blanfordi	1	1965	1965
	Four-toed jerboa	Allactaga elater	3	1965	1966
	Northern pygmy gerbil	Gerbillus gerbillus	1	1965	1967
Muridae	Australian jumping mouse	Notomys sp.	12	1971	1972
	Four-striped grass mouse	Rhabdomys pumilio	29	1976	1979
	Malagasy Rat	Nesomys rufusa	1	1967	1968
	Spiny mouse	Jaculus orientalis	4	1965	1967
Octodontidae	Chinchilla rat	Abrocoma benntti	1	1971	1973
	Chinchilla rat	Abrocoma cinerea	16	1969	1971
	Coruro	Spalacopus cyanus	4	1973	1976
	Degu	Octodon degus	222	1970	1978
	Pencil-tailed degu	Octodontomys gliroides	56	1971	1979
Rhisomyidae	Lesser bamboo rat	Cannomys badius	18	1967	1972
Sciuridae	Prevost's squirrel	Callosciurus prevosti	5	1987	1987
Carnivora					
Herpestidae	African water civet	Atilax paludinosus	1	1968	1969
	Kusimanse	Crossarchus obscurus	5	1997	1998
Mustelidae	Common ferret	Mustela putorius	1	1972	1974
	Short-tailed weasel	Mustela erminea	1	1966	1968
Procyonidae	Raccoon	Procyon lotor	2	1984	1986
	Red panda	Ailurus fulgens	104	1987	1992
	Ringtail	Bassariscus astutus	2	1971	1971
Viverridae	African civet	Civettictis civetta	2	1969	1971
	Dwarf mongoose	Helogale parvula	3	1984	1984
	Fanaloka	Fossa fossa	2	1966	1968
	Fossa	Cryptoprocta ferox	1	1981	1982
	Genet	Genetta genetta	6	1967	1971
	Lesser oriental civet	Viverricula indica	1	1966	1966
	Oriental civet	Viverra zibetha	2	1969	1971
	Palm civet	Paradoxurus hermaphroditus	2	1971	1971
	Ring-tailed mongoose	Galidia elegans	3	1974	1976
	Two-spotted palm civet	Nandinia binotata	1	1967	1967
Artiodactyla					
Bovidae	Dik-dik	Madoqua kirki	2	1979	1980

BIRDS:					
Apodiformes					
Trochilidae	Ruby-throated Hummingbird	Archilochus colubris	7	1992	1993
Passeriformes	-				
Hirudinidae	Purple martin	Progne subis	13	1992	1992
Mimidae	Northern Mockingbird	Mimus polyglottos	30	1986	1994
Turdidae	Veery	Catharus fuscescens	1	1985	1986
Trogloytidae	Carolina Wren	Thryothorus ludovicianus	2	1991	1992
Parulidae	Chestnut-sided warbler	Dendroica pensylvanica	1	1982	1986
	Hooded warbler	Wilsonia citrinia	11	1984	1987
	Worm-eating warbler	Helmintheros vermivorus	1	1984	1986
Emberizidae	Song sparrow	Zonotrichia melodia	38	1986	1990
	Swamp sparrow	Zonotrichia georgiana	36	1986	1990
	White-throated sparrow	Zonotrichia albicollis	13	1992	1992
	Slate-colored junco	Junco hyemalis	15	1992	1992
REPTILES:					
Squamata Sauria					
Iguanidae	Green Iguana	Iguana Iguana	65	1986	2000
Varanidae	Savannah Monitor	Varanus exanthematicus	17	1994	1999
Chelonia					
Cryptodira					
Testudinidae	African Spurred Tortoise	Geochelone sulcata	2	1996	1998
FISH:					
Perciformes					
Cichlidae	Tiger Oscar	Astronotus ocellatus	401	1995	1996
Cypriniformes					
Cyprinidae	Zebra Fish	Brachydanio rerio	690	1998	2001

Order/Family	Common Name	Scientific Name	No.	Yr. In	Yr. Out
Monotremata					
Tachygolssidae	Short-nosed echidna	Tachyglossus aculeatus	3	1979	1984
Marsupalia				4000	4007
Didephidae	Yapok	Chironectes minimus	4	1986	1987
Dasyuridae	l iger quoii	Dasyurus maculatus	60	1984	1998
Macropodidae	Southern potoroo	Potorius tridactylus apicalis	4	1980	
	Matschie's tree kangaroo	Dendolagus matschlei	116	1977	4075
Duimente	Red kangaroo	Macropus rutus	4	1975	1975
Tarsiidae	Tarsier	Tarsius banacus	Q	1088	1002
Callitrichidae	Coeldi's marmoset	Callimico goeldii	38	1081	1008
Califfictidae	Golden-lion tamarin	Leontonithicus rosalia	146	1901	1004
Cebidae	Dusky titi	Callicebus molloch	5	1970	1081
Rodentia	Dusky III	Califeebus molioen	5	1900	1901
Rodentia	Black-tailed prairie dog	Cynomyc ludovivianus	61	1999	
Carnivora	Diack-tailed plaine dog	Cynoniye iddowiands	01	1333	
Canidae	Crab-eating fox	Cerdocyon brachyurus	35	1975	1982
Canadae	Maned wolf	Chrysocyon brachyurus	83	1975	1002
	Bush dog	Specthos venaticus	86	1975	1988
	Fennec fox	Vulnes zerda	4	1980	1983
Procyonidae	Red panda		120	1977	1000
Mustelidae	European polecat	Mustela e, eversmannii	157	1989	1990
Masteriade	Black-footed ferret	Mustela nigrines	324	1988	1000
Viverridae	Malagasy civet	Fossa fossana	1	1980	1990
viveindae	Binturong	Arctictis binturong	27	1976	1985
	Ring-tailed mongoose	Galidia elegans	3	1980	1982
	Slender-tailed meerkat	Suricata suricatta	5	1980	1983
Felidae	Pallas' cat	Otocolobus m. manul	2	1993	1995
i onddo	Clouded leopard	Neofelis nebulosa	96	1978	1000
Perissodactvla	clouded loopard		00	1010	
Equidae	Common zebra	Fauus burchellii	65	1974	1990
	Przewalski's wild horse	E. caballus przewalskii	44	1983	
	Grevv's zebra	Equus arevvi	3	1997	2000
	Persian onager	Equus o, onager	54	1974	2000
Artiodactyla		got			
Camelidae	Bactrian camel	Camelus bactrianus	45	1974	1985
Cervidae	Eld's deer	Cervus eldii thamin	167	1975	
	Pere David's deer	Cervus davidianus	327	1974	
	Tufted deer	Elaphodus c. cephalophus	10	1994	
	Chinese muntjac	Muntiacus reevesi	122	1976	1994
	White-tailed deer	Oedocoeleus virginianus	78	1992	1994
	Chilean pudu	Pudu pudu	5	1991	2001
	Reindeer	Rangifer tarandus	33	1981	1985
Bovidae	Kirk's dik-dik	Madoqua kirkii	7	1985	1988
	European wisent	Bison bonasus	17	1976	1987
	Eastern bongo	Tragelaphus eurycerus isaaci	2	1975	1975
	Sable antelope	Hippotragus niger	125	1982	2001
	Scimitar-horned oryx	Oryx dammah	195	1974	
	Arabian oryx	Oryx leucoryx	35	1987	

Table 1.4. Mammal Collection, Conservation and Research Center, NZP, 1974-2001.

Order/Family	Common Name	Scientific Name	No.	Yr. In	Yr. Out
Struthioniformes					
Struthionidae	Ostrich	Stuthio camelus	12	1978	1978
Rheidae	Darwin's rhea	Pterocnemia pennata	161	1976	
	Greater rhea	Rhea americana	34	1974	1981
Casuariidae	Double-wattled cassowary	Casuarius c. bicarunculatus	7	1981	1985
Dromiceiidae	Emu	Dromaius novaehollandia	93	1977	1983
Pelecaniformes					
Phalacrocoracidae	Double-crested cormorant	Phalacrocorax auritus	1	1979	1980
Ardeidae	Reef heron	Egretta sacra	З	108/	108/
Threskiornithidae	Poseate spoonbill		1	1904	1084
	Roseate spoolibili		1	1900	1904
Anatidae	Pacific white-fronted goose	Anser albifrons frontalis	2	1983	1985
/	Tule goose	Anser albiforns gambelli	10	1979	1985
	Bar-headed goose	Anser indicus	16	1979	1985
	Aleutian Canada goose	Branta c. leucopareia	14	1981	1986
	Red-breated goose	Branta ruficollis	14	1981	1985
	Ne-ne	Branta sandvicensis	15	1978	1985
	Coscaroba swan	Coscaroba coscaroba	2	1979	1979
	Black swan	Cyanus atratus	2	1978	1978
	Black-necked swan	Cygnus melanoconynhus	2	1082	1082
	Mute swan	Cygnus melanocoryphus	5	1082	1083
	Mandarin duck	Aix calericulata	346	1902	1905
	N Amorican wood duck	Aix galericulata	00	1970	1900
	Creater Brazilian Tool	Aix sporisa	90 25	1977	1904
	Greater Draziliari Tear	Amazonella brasmensis	200	1970	1970
		Anas acula	300	1970/1909	1979/
	Banama pintai	Anas banamensis	217	1989	1996
	American widgeon	Anas americana	1	1981	1981
	Green-winged teal	Anas crecca carolinensis	4	1981/1990	1982/1990
	Cinnamon teal	Anas cyanoptera	117	1978/1991	1981/1997
	Blue-winged teal	Anas discors	33	1978	1981
	Red-billed pintali	Anas erythrornyncha	16	1978	1978
	Brown pintail	Anas georgica	28	1979	1984
	Grey teal	Anas gracilis	11	1979	1979
	Philippine duck	Anas iuzonica	3	1978	1978
	Mallard	Anas platyrhynchos	254	1990/1999	1991/
	Laysan teal	Anas laysanensis	395	1981	
	Hawalian duck	Anas wyvilliana	19	1979	1979
	Indian spot-billed duck	Anas p. poecilorhyncha	28	1978	1982
	American black duck	Anas rubripes	1140	1982/1999	1989/
	Chloe wigeon	Anas siblatrix	12	1978	1979
	Patagonian crested duck	Anas s. specularoides	10	1978	1979
	Gadwall	Anas strepera	27	1978	1979
	Yellow-billed duck	Anas undulata	1	1979	1982
	Redhead	Aythya americana	653	1978/1989	1979/1997
	Common white-eye	Aythya nyroca	2	1982	1982
	Canvasback duck	Aythya valisineria	195	1989	1995
	Bufflehead	Bucephala albeola	2	1995	1996
	American goldeneye	Bucephala clangula	12	1979/1983	1979/1984
	Barrow's goldeneye	Bucephala islandica	3	1982	1983
	Muscovy duck	Cairina moschata	26	2000	
	White-winged woodduck	Cairina scutulata	42	1978	1988
	Ringed teal	Calonetta leucophrys	9	1975	1979
	Ashy-headed goose	Chloephaga poliocephala	1	1979	1979
	Smew	Megus albellus	33	1989	1990
	Hooded merganser	Mergus cucullatus	45	1982/1984	1982/1985
	American merganser	Mergus merganser	4	1979	1979
	Rosybill	Netta peposaca	20	1980/1984	1980/1984
	Red-crested pochard	Netta rufina	10	1978/1981	1978/1981
	N. American ruddy duck	Oxyura jamaicensis	354	1978/1982	1979/1988

Table 1.5. Bird Collection, Conservation and Research Center, 1974-2001.

Table 1.5. Bird Collection, Conservation and Research Center, 1974-2001.

Order/Family	Common Name	Scientific Name	No.	Yr. In	Yr. Out
	American eider	Somateria mollisima	62	1982	1982
	S. African shelduck	Tadorna cana	1	1978	1978
	Common shelduck	Tadorna tadorna	1	1981	1981
Falconiformes				1075	1077
Cathartidae		Corygyps atratus	1	1975	1977
Societtariidaa	Crested serpent eagle	Spilonis cheela Sadittarius serpentarius	5	1980	1980
Falconidae	Common caracara	Sayillarius serperilarius Polyborus plancus	0 1	1903	1990
Galliformes	Common Caracara	i oryborus planeus	1	1900	1900
Megapodiidae	Brush turkev	Alectura lathami	2	1987	1987
Cracidae	Common piping quan	Aburria pipile	8	1978	1983
Phasianidae	Ocellated turkey	Agriocharis ocellata	1	1975	1977
	Bornean great argus	Argusianus argus grayi	18	1975	1986
	Tibetan white-ear pheasant	Crossoptilon c. drouynii	2	1988	1990
	Himalayan impeyan	Lophophorus impeyanus	19	1981	1989
	Swinhoe's pheasant	Lophura swinhoii	11	1978	1984
	Common peafowl	Pavo cristatus	67	1974	1985
	Java green peafowl	Pavo m. muticus	1	1975	1977
	Palawan peacock pheasant	Polyplectron emphanum	3	1981	1984
	Koklass	Pucrasia macrolopha	13	1983	1986
	Crested wood partridge	Rollulus roulroul	21	1980	1984
	Hume's bar-tailed pheasant	Syrmaticus n. numiae	1	1970	1976
	Temminck's tragonan	Tragopan satyra Tragopan temminckii	9 /1	1903	1990
	Kenva crested quineafowl	Guttera nucherani	8	1980	1992
Gruiformes	Kenya erestea guineaiowi	Guilera pucherani	0	1300	1905
Gruidae	Stanley crane	Anthropoides paradisea	54	1977	1987
	Indian sarus crane	Grus a, antigone	72	1977	1987
	Florida sandhill crane	Grus canadensis pratensis	65	1975	
	Mississippi sandhill crane	Ġ. c. pulla	4	1980	1997
	Greater sandhill crane	G. c. tabida	5	1976	1979
	Red-crowned crane	Grus japonensis	13	1980	
	Hooded crane	Grus monachaGrus vipio	2	1991	1993
	White-naped crane	Grus vipio	34	1981	
Dellidee	S. African crowned crane	Balearica r. regulorim	1	1978	1979
Railidae	Common gailinule	Gallinula chioropus	1	1988	1988
	Black Clake	Dorphyria prophyria	2 1	1979	1901
	Cuam rail	Callirallus owstoni	205	1901	1901
	Giant coot	Eulicula gigantea	205	1982	1983
Furvovoidae	Sunbittern	Eurvpvaa helias	14	1978	1991
Cariamidae	Red-legged seriema	Cariama cristata	2	1983	1995
Charadriiformes					
Laridae	Silver gull	Larus novaehollandiae	23	1978	1981
Sternidae	Inca tern	Larosterna inca	23	1978	1981
Columbiformes					
Columbidae	Nicobar pigeon	Caloenas nicobarica	3	1975	1978
	White-breasted ground dove	Gallicolumba jobiensis	8	1982	1984
	Crested quail dove	Geotrygon versicolor	23	1977	1986
	Common crowned pigeon	Goura cristata	28	1979	1986
Peittaciformos	Magnificent ground pigeon	Olidiphaps hobilis	3	1907	1990
Psittacidae	Red collared lorikeet	Trichoglossus haematodus	2	1080	1080
i sillaciuae	Palm cockatoo	Probosciaer aterrimus	7	1982	1995
	Cuban amazon	Amazona leucocenhala	8	1977	1985
	Black-headed caigue	Pionites melanocephala	4	1975	1977
	Blue-headed parrot	Pionus menstuus	12	1975	1992
	Derbyan parakeet	Psittacula derbiana	20	1982	1988
Cuculiformes					
Musophagidae	Schalow's turaco	Tuaraco corythais schalowi	19	1978	1986
Cuculidae Strigiformes	Renauld's ground cuckoo	Carpococcyx renauldi	2	1982	1984

Table 1.5. Bird Collection, Conservation and F	Research Center, 1974-2001.
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Order/Family	Common Name	Scientific Name	No.	Yr. In	Yr. Out
Strigidae	Burrowing owl	Athene cunicularia	3	1978	1981
-	Great horned owl	Bubo virginianus	1	1993	1993
	Common screech owl	Otus asio	3	1978	1985
	Striped owl	Rhinoptynx clamator	1	1981	1981
	Barred owl	Strix varia	2	1993	1993
Coraciiformes					
Alcedinidae	Micronesian kingfisher	Halcyon cinnamomina	40	1984	
Coraciidae	Lilac-breasted roller	Coracias caudata	2	1983	1985
Upupidae	Common hoopoe	Upupa epops	66	1984	1987
Bucerotidae	Rufous hornbill	Buceros hydrocorax	2	1979	1981
	Abyssinian ground hornbill	Bucorvus abyssinicus	2	1980	1081
Piciformes		-			
Ramphastidae	Keel-billed toucan	Ramphastos sulfuratus	1	1979	1979
Picidae	Common flicker	Colaptes auratus	1	1983	1983
	Pileated woodpecker	Drycopus pileatus	1	1983	1983
Passeriformes					
Mimidae	White-breated thrasher	Ramphocinclus brachyurus	1	1977	1996
Muscicapidae	Hawaiian thrush	Myadestes obscurus	1	1991	1991
·	Eastern bluebird	Sialia sialis	13	1982	1987
	Rufous-bellied niltava	Niltava sundara	2	1997	1997
Zosteropidae	Rota bridled white-eye	Zosterops rotensis	27	1993	
Emberizidae	Scarlet tanager	Piranga olivacea	1	1983	1983
Drepanididae	Amakihi	Hemignathus virens	42	1988	
·	l'iwi	Vestiaria coccinea	15	1991	
Sternidae	Golden-breasted starling	Cosmopsarus regius	21	1994	
	Rothschild's (Bali) mynah	Leucopsar rothschildi	360	1975	
	Superb starling	Spreo superbus	35	1979/1999	1980/
Paradisaeidae	Satin bower bird	Ptilorhynchus violaceus	6	1980	1985
Corvidae	Mariana crow	Corvus kubaryi	8	1993	

APPENDIX 2

CRC BUDGET AND FINANCES

In order to justify the acquisition of CRC to Congress in a benign manner, officials within the SI decided to limit the annual budget of CRC to no more than 10% of the zoo's federal budget. This decision has influenced key organizational and resource decisions within the zoo, and has retarded CRC's development as a major force within the zoo, the institution, and the international conservation community.

Table 2.1 summarizes CRC's current revenue base, and includes federal, trust, and private finances over the past 4 fiscal years. Due to the reorganization of CRC to include NZP's Department of Zoological Research and the SI/MAB program in 2001, we deliberately have combined the budgets of all three units for clarity. This has not been an easy process, given the difficulties imposed by the institution's financial system and by the varied record keeping procedures of the individual units. While this summary undoubtedly includes some inaccuracies, we believe that this presentation provides a more concise and meaningful overview of CRC's financial circumstances than would be obtained by providing historical summaries for the individual units.

As shown in the table, as CRC's federal allocation for salaries and benefits has increased, the funds available for equipment and supplies has decreased. This trend is widespread throughout the federal government and reflects the continuing failure of Congress to increase funding while mandating pay increases.

CRC's federal allocations for facility renovation and repair (R+R) have varied considerably over the past 25 years, and have ranged anywhere from \$350K to \$1.2M per year. R+R funds are used to purchase supplies and materials for our maintenance staff or secure the services of independent contractors. As our maintenance staff has decreased, we have had to rely more heavily on R+R funds to meet routine maintenance needs via contract. Contract R+R projects and costs from FY 1998 to the present are summarized in Table 2.2).

The recent declines in CRC's R+R funding reflect the increased priority that is being given to improving the "public face" of the zoo. These declines also reflect the fact that CRC was scheduled to receive significant building funds over three years (FY 2000 - 2003) for the construction of a maintenance facility that was designed in 1996. This building was designated as a priority in CRC's 1979 Masterplan, because it would consolidate all maintenance personnel and operations in a single building, and allow for the development of research offices and laboratories in the vacated buildings. Although funds were allocated for construction in FY2000 (\$1.0M) and FY 2001 (\$2.0M), the funds were subsequently withdrawn and redirected in both years. The last major facilities constructed at CRC were the Veterinary Hospital (1983-84) and the Small Animal Facility (1984-85).

As noted in Table 2.1, SI pays for a number of CRC's basic utilities, including water and sewer services (Town of Front Royal), electricity (Potomic Edison), and fuel oil (various contractors). CRC pays for gasoline and diesel fuels and telephone service out of its annual federal "other objects" budget. It should also be noted that while NZP provides CRC with a variety of animal foods from its commissary budget, CRC produces and provides various types of hay to NZP. CRC also regularly pays the extra costs associated with the production of medicated feed for its hoofed stock.

Revenue from the SI Research Equipment Pool is an important source of monies for the replacement of scientific equipment. These trust funds have varied from \$51 to \$147K per year (Table 2.1). Historically, the annual allocations that SI provides NZP have varied considerably.

CRC generates revenue from employee residence rentals and fees charged for the use of its conference and training facilities (Table 2.1). These rents and fees are placed in a reimbursable "housing fund" and a used for housing repair and upkeep, laundry bills, cleaning, etc. Housing funds are also used to support a fulltime office assistant, a fulltime contract janitor, and 2-3 temporary summer laborers. The decreasing "net" income in the housing fund over the last 4 years reflects both an increase in annual costs, and a concerted effort to improve and maintain the condition CRC's residences.

As shown in Table 2.1, the funds acquired from SI grants and endowments has declined considerably over the past 4 years. Unfortunately, the future of several internal SI grant programs that we have relied upon - including the Scholarly Studies and Fellowship Programs - remains uncertain. The annual allocations of FONZ grant and awards depend heavily on the revenues generated by the public activities of FONZ. The increasing redirection of FONZ resources to the "public face" of the zoo suggests that these funds too may decrease in the future.

CRC scientists and education staff have been extremely successful in obtaining external grants and awards from foundations, corporations, and non-profit organizations, through inter-agency agreements, and through donations. If federal allocations and internal SI Trust funds continued to decline, CRC will be forced to rely increasingly on external grants, awards, and donations to sustain its programs in the future. The formation of the CRC Foundation will certainly assist our entrepreneurial efforts.
Federal Allocations:				
Salaries and Benefits ¹	4,241,273	4,395,102	4,554,510	4,509,172
Equipment and Supplies	793,166	628,503	583,336	499,600
Subtotal	5,034,439	5,023,605	5,137,846	5,008,772
Facility Renovation and Repair ²				
In-house Maintenance	225,000	429,000	262,500	319,000
Contract Renovations	735,000	451,000	377,500	181,000
Subtotal	960,000	880,000	640,000	500,000
Facility Construction (New) ³	0	0	0	0
Facility Support (SI Funded) ⁴	166,108	174,850	184,053	193,740
SI Research Equipment Pool:	147,241	159,901	107,700	51,769
Residence/Facility Rental:⁵	127,925	101,953	72,505	54,184
SI/NZP Grants and Awards:				
SI Grants	640,698	596,820	274,202	376,700
SI Research Endowments	114,057	114,032	137,214	131,065
FONZ Conservation/Non-grant Awards	49,297	43,367	75,000	272,000
FONZ Education/Research Awards	262,173	317,553	306,431	195,878
Subtotal	1,066,225	1,071,772	792,847	879,699
External Grants and Awards:				
CRC Foundation	0	0	99,441	204,650
Other Foundations	329,275	174,615	361,274	2,119,026
Corporations	740,000	266,000	982,714	382,714
Non-profit Organizations	138,428	50,000	129,597	80,777

FY 1998

FY 1999

FY 2000

FY2001(est)

873,303

365,100

9,513,734

2,460,470

Table 2.1. CRC BUDGET SUMMARY, FY 1998-2000

Revenues

Donations:

¹Salaries and benefits estimated to reflect current (FY01) organizational structure.

Inter-agency

Subtotal

²Annual allocations do not include \$120K paid annually for HVAC maintenance. Unspent R+R

TOTALS 9,051,531

funds are carried into the next year, but are not included in the annual allocations shown here.

³Allocations of \$1M (FY00) and \$2M (FY01) for the Consolidated Maintenance Facility were withdrawn.

92,860

1,300,563

249,030

240,000

730,615

255,206

8,397,902

646,049

131,156

9,285,182

2,219,075

⁴Costs for water/sewer, electricity and fuel oil are covered by SI. We assume a 5% increase/year.

⁵Represents net income; annual expenditures for facility maintenance and contract staff have increased.

Table 2.2. Contract repair and renovation projects at CRC, FY 1998-2001.

Year	Cost	Project Desription
FY 1998	\$448,121	Renovate equipmetn storage builfding; replace shingle roof on
		Rivinus Barn; replace gutters and paint on 5 buildings
	\$258,588	Install structural supports in 5 barns
	\$62,175	Install new oil-fired boilers in 5 buildings
	\$2,500	Paint interiors of Veterinary Hospital and Dormitory
	\$2,499	Remove dead trees and trim live trees in central post area
	\$1,990	Repair damaged siding on Commissary tower
	\$965	Install protective post covers at Church, Waller and Slatehill Barns
FY 1999	\$447,670	Replace waterline to Slatehill Barn; renovate Buildings #34 an #40;
		demolish 4 failing structure; install replacement windows in 8
		residences; paint exteriors of 5 buildings; instll new roofing on
		Longfield hoofed stock sheds; install epoxy flooring in Small
		Animal Facility and kitchens in Buildings #4 and #9; install ceiling
		tiles in 2 buildings.
	\$135,423	Install pad-mounted transformer at Training Center; Install box
		culvert over creek a Church Barn; repair and treat exterior of Mule
		Barn; install roof exhaust fan in equipment storage facility.
	\$2,499	Trim trees in central post area.
	\$2,439	Install new boiler in Aministration Building
	\$1,615	Clean gutters on various buildings
	\$812	Monitor settlment cracks in Veterinary Hospital
FY 2000	\$331,845	Renovate Building #159 and construct addition to GIS laboratory
	\$2,499	Tree maintenance in central post area.
	\$2,480	Interior painting of Training Center rooms and hallways
	\$1,846	Obtain additional drawings and specification for Consolidated
	_	Maintenance Facility from architectural firm
	\$400	Repair base of road leading to Building #159
FY 2001	\$122,453	Replace roofing on Veterinary Hospital and 5 other buildings
	\$72,837	Complete closure of oold landfill site to Virginia Department of
		Environmental Quality standards
	\$28,459	Replace medical air compressor at Veterinary Hospital
	\$9,964	Obtain updated construction estimates and pre-bid services from
		architectural firm for Consolidated Maintenance Facility

APPENDIX 3

LIST OF ACRONYMS USED IN REVIEW DOCUMENT

ASG	Amazonia Science Gallery
AZA	American Zoos and Aquarium Association
CBSG	Captive (later Conservation) Breeding Specialist Group
CITES	Convention on International Trade of Endangered Species
CTSP	Conservation Technology Support Program
DRS	Dpeartment of Reproductive Sciences
DTCC	Desert Tortoise Conservation Center
DZR	Department of Zoological Research
ELIPSE	Envuironmental Latino Initiative Promoting Science Education
FONZ	Friends of the National Zoo
GIS	Geographic Information System
GLT	golden lion tamarin
GPS	Geographic Positioning System
GRB	Genome Resource Bank
IESP	International Environmental Sciences Program
IUCN	International Union for the Conservation of Nature
IVF	in-vitro fertilization
MMS	Mineral Management Service
NGO	non-government organization
NIH	National Institutes of Health
NMNH	National Museum of Natural History
SERC	Smithsonian Environmental Research Center
SI	Smithsonian Institution
SNZP	Smithsonian National Zoological Park
SRD	Scientific Research Department
SSP	Species Survival Plan (of the AZA)
STRI	Smithsonian Tropical Research Center
TNC	The Nature Conservancy
USAID	United States Agency for International Development
USGS	United States Geological Survey
WCMTP	Wildlife Conservation and Management Training Program
WTO	World Trade Organization