Madagascar and other Islands

Madagascar

Imagine an island more than 1,000 miles long in a blue tropical ocean. Forests cover vast areas, interspersed with swamps where crocodiles 8 meters long lie in wait to prey on pygmy hippopotamuses. Thousands of giant tortoises with shells 4 feet across lumber about. In the forests and in dryer parts of the island live some of the strangest primates to have ever existed on Earth. Some 45 species of these lemurs live throughout the island and range in size from the world's smallest primate, weighing about 1 ounce, to a lemur the size of a Gorilla (Tattersall 1993).

Huge white birds plod along forest trails and through savannah grasses. Many kinds of these birds inhabit the island. The largest resembles an Ostrich, but is far more massive in build, weighing 1,000 pounds (Feduccia 1996). It stands 10 feet tall and lays 20-pound eggs, 13 inches long (Feduccia 1996, Greenway 1967). More than 100 other kinds of tropical birds that exist nowhere else fly in forests and deserts and wade in still marshes.

Primitive hedgehog-like mammals, called tenrecs, scurry in forest underbrush. One type of tenrec lives in cold mountain streams, swimming with webbed feet and flattened tail, while another has spines like a porcupine and stripes down its back like a skunk. It communicates with its young by vibrating its spines.

Hundreds of kinds of amphibians and reptiles inhabit forests, aquatic environments, savannahs and drylands. Frogs of every imaginable color and pattern leap in green shadows. Chameleons, some brilliantly colored, and others shades of mottled brown, creep invisibly about. The largest, 2 feet long, can capture mice and birds, while the smallest, measuring only 1.5 inches, feeds on insects (Amos 1980). Tortoises with shells adorned in delicate yellow sunburst patterns inhabit shrub and deserts.

Plants exist in unparalleled variety, a botanical paradise. Relicts of species long-extinct on mainland areas--tall tree ferns, palms, red-flowered flame trees, massive deciduous and rainforest trees, giant tamarinds and aloes, desert oddities, and baobabs of many sizes--grow in even the driest parts of the island. Orchids in a rainbow of colors bloom among the deep green rainforests. Waterfalls abound, cascading down tall cliffs into rivers and lakes. Along the west coast, a dry deciduous forest stretches the length of the island**.** The central highlands are a mosaic of woodland and savannah, while the eastern regions are covered in dense, humid rainforest. In the extreme south, a desert environment prevails, harboring *Didierea*, strange cactus-resembling plants that form long, spiny, twisted shafts rising 30 feet into the air. An impenetrable wilderness of limestone spikes and sharp rocks dominates the far north. Rare birds and lemurs find refuge in this craggy landscape and feed in oases watered by meandering streams.

Flightlessness, fearlessness, gigantism, dwarfism, and survival of ancient species all occurred in this evolutionary laboratory. That such a large land mass went uninhabited by humans for so long is truly remarkable. Nowhere else on the planet has such a large land area remained isolated for such a prolonged period, allowing a flowering of diverse life forms to flourish and adapt to the island's many habitats and terrains in this mild, tropical climate. Such is the history of the island from Madagascar in 400 A.D., a century before the arrival of the Malagasy people of Asia. Had humans reached Madagascar earlier, it might not have evolved its diverse, yet vulnerable, fauna and flora.

How such an extraordinary diversity of animals and plants inhabits Madagascar is tied to its geological history. Some 160 million years ago, when Africa, Australia, New Zealand and South America were united in the super-continent Gondwana, Madagascar was attached to eastern Africa and what is now peninsular India. Dinosaurs, giant turtles, crocodiles, primitive mammals, reptilian birds and lizards roamed on this massive land mass. Gondwana gradually broke apart as a result of movements of tectonic plates covering the Earth's crust. For many millions of years, India and Madagascar formed a mini-continent. Then, about 88 million years ago, they split along Madagascar's east coast, and peninsular India moved northward toward Asia (Garbutt 1999, Tyson 2000).

Paleontologists have only recently discovered that Madagascar was home to dinosaurs and other primitive animals quite unlike those found in other parts of the world. The oldest known species of dinosaur, dating back 227 million years, may be the ancestor of all dinosaurs (Flynn 2000). One dinosaur had teeth that were clove-shaped (Stenzelt and Thiessen 2000). Seven species of crocodiles inhabited Madagascar from the Cretaceous period onward, including a pug-nosed vegetarian species (Flynn 2000). About 65 million years ago, the last dinosaurs died out, concurrent with their extinction throughout the world. Some native plants and animals survived from the time when Madagascar was part of Gondwana. Giant tortoises, crocodiles, boas, tenrec ancestors and possibly an early form of elephant birds may have lived on the super-continent, although most ornithologists are certain that the ancestor of the elephant bird flew to the island and became flightless (Feduccia 1996). Plants of many kinds, virtually unchanged from their ancient forms, grow on the island.

Immigrant animals arrived during the millennia from many sources. Because Madagascar separated from India and Gondwana long before the evolution of the prosimians that were the ancestors of the lemurs, these primates must have come from mainland Africa, where their close relatives, bush babies and galagos, survive today. Some scientists believe they might have traveled over a land connection that existed between Africa and Madagascar at some point (Tyson 2000). Others dispute that there ever was such a land bridge and maintain that they arrived by sea, perhaps sheltering on large mats of floating vegetation or clinging to uprooted tree trunks that swept down mainland rivers to the sea and washed up on Madagascar's shores. Few modern mammals of Africa, whether baboons, monkeys, gazelles, antelope or other hoofed mammals, reached Madagascar. The hippopotamuses must have originated in Africa, but how they came to the island is another mystery.

Over many millennia, a blossoming of evolution occurred in this mild, tropical climate of Gondwandan and immigrant species, radiating into entire new families and creating a flora and fauna of great diversity unlike any in the world. Birds, bats and insects flew or were blown to the island by wind currents and storms from Africa and Asia. No large carnivores arrived, however. The largest mammal predators are relatives of mongooses, primitive viverrids. Grazing and browsing roles were filled by hippopotamuses, land tortoises, lemurs and elephant birds.

Human Settlers Invade Paradise

About 500 A.D., immigrant people from Asia, most probably Indonesia or Malaysia, arrived on Madagascar's shores in hand-hewn canoes, bringing domestic animals with them. They began clearing forests and burning them for farmland, and turned lakes and wetlands into rice paddies. Cleared land produced crops for only a few years until the thin soil became sterile. Farmers then moved on to other parts of the forest, in this slash-and-burn agriculture. At some point, African herdsmen colonized the island, bringing zebu cattle, which crowded out wildlife (Tyson 2000). Gradually, abuse of the land eroded the soil in the central highlands to bare earth, pocketed and gouged by deep gullies and cavernous holes. This region had harbored a great variety of lemurs, along with a wealth of birds, reptiles and unique plants. Throughout the island, wildlife declined as habitats disappeared, isolating animals in smaller and smaller patches of forest and wetlands. The large lemurs, tortoises and elephant birds were avidly hunted.

Within 600 years of the arrival of the Malagasy, extinctions claimed many native animals. Several elephant bird species, the larger lemurs and many native plants vanished. Two kinds of pygmy hippos inhabited the island. The Madagascar Hippopotamuses (*Hippopotamus lemerlei*), an amphibious species, and *Hippopotamus madagascariensis*, a forest species, were both about 6.5 feet long and 2.5 feet tall, smaller than the Common Hippopotamus of Africa, which is about 10 feet long (Tyson 2000). From genetic and anatomical analysis, both seem to have evolved from the latter species (Tyson 2000). The hippos had been widely distributed and very common prior to the arrival of the Malagasy (Dewar 1984). Their bones have been found with marks indicating that they had been butchered (Tyson 2000). Both died out long before Europeans arrived. The native crocodile, whose large bones have been found, is

believed by some scientists to represent large specimens of Nile Crocodiles, the species native today (Tyson 2000). It is thus possible that the crocodile survived. A large mongoose-like viverrid, *Cryptoprocta spelea*, and a very unusual aardvark-like animal, *Plesiorycteropus madagascariensis*, died out at an early date (Dewar 1984).

Prior to the arrival of humans, elephant birds had been abundant in most parts of the island, as attested by the prevalence of their bones. There were two genera, and from six to 12 species of these birds (Tyson 2000). It is likely that the flightless birds fell prey to the primitive weapons of the Malagasy and were crowded out of their habitats by livestock (Tyson 2000). The last to die out was the Great Elephant Bird (*Aepyornis maximus*), which may have survived until recent times by retreating to remote swamps. Dr. Alexander Wetmore of the Smithsonian Institution examined bones of a Great Elephant Bird unearthed in archeological excavations in the 1960s. He was amazed by their size: "The incredible femur, or thighbone, of this ponderous bird is by far the largest I have ever seen" (Wetmore 1967). Estimated to weigh at least 1,000 pounds, more than three times the weight of an Ostrich, it produced eggs larger than any dinosaur's, with a capacity of 2 gallons (equivalent to seven Ostrich eggs), 180 chicken eggs or 12,000 hummingbird eggs (Bradbury 1919, Fuller 1987). When one was X rayed, the bones of an embryo three fourths developed were revealed (Wetmore 1967). Something had interrupted the embryo's growth and frozen it within the eggshell for hundreds and perhaps thousands of years (Wetmore 1967).

Despite its fearsome size, the Great Elephant Bird lacked a hooked beak for tearing prey and was plainly not a predator (Wetmore 1967). Its large, clawed feet may have helped it defend itself against the small native predators but were not enough to protect it from Malagasy arrows. Its short legs prevented it from running as fast as its relative, the Ostrich, but it may have been quite agile when chased. This vegetarian bird browsed and cropped plants, able to reach with its long neck to the lower branches of trees (Wetmore 1967). By the mid-16th century, when Europeans had managed to establish a foothold in Madagascar, the new French Governor, Sieur Etienne de Flacourt, wrote in 1661 that the Great Elephant Bird was still found in the south of the island, "seeking the most deserted places" to avoid human hunters (Tyson 2000). Villagers of Antandroy told of an Ostrich-like bird that was difficult to catch, according to Flacourt (Tyson 2000).

The exact date this giant bird became extinct is not known with certainty. Alan Feduccia (1996), an eminent paleo-ornithologist, asserts that elephant birds of many species were still widespread in the 10th century but gradually disappeared as a result of human activity. He cites an account by a French merchant sailor in 1848, who visited Madagascar and saw the shell of the Great Elephant Bird; he was told that it belonged to the chief and that the bird that produced such eggs "is still more rarely seen" (Feduccia 1996). Some authorities estimate that it died out in the mid-17th century, although there is no proof that any European ever saw one of these birds (Tyson 2000). It has been suggested that Europeans were responsible for the bird s extinction by hunting and destroying its habitat (Quammen 1996). But Thomas Brooks (2000) of the Center for Applied Biodiversity Science, Conservation International, asserted in a list of extinct birds in *Threatened Birds of the World* (BI 2000) that all the elephant birds had disappeared by 1500. In a bizarre footnote to this species' epitaph, an *Aepyornis* egg washed up on Australia's western coast in 1995. No conclusive explanation for this strange event has been put forth, although it is likely that it became unearthed from long interment by rains, and washed out to sea. Much less is known of the other species of elephant birds, which existed in a variety of sizes down to a chicken-sized species.

Lemur-like primates once lived on many continents, but nowhere had they evolved into such a great variety of species. When the Malagasy people arrived some 1,500 years ago, lemurs occupied every habitat, even marshland. A species as tall as a man must have startled the Malagasy immigrants, giving rise to legends that these animals had superhuman powers. The first French naturalists were told by the Malagasy that these primates were thought to be the ghosts of sacred ancestors of man, inspiring the genus name Lemur, the word for ghost in Latin. The Malagasy considered some lemurs sacred and punished anyone who harmed them, but most species were feared as evil demons and were killed on sight.

From their arrival on Madagascar, the Malagasy hunted the larger species of lemurs, almost all of which are now extinct. Archaeological excavations show that they formed a staple in the immigrants' diets. Such diggings have

unearthed the skulls and bones of long extinct lemurs in early Malagasy jars and kitchen middens; their heads had been split by ax-heads made from an extinct flightless bird (Jolly 1980).

In the centuries following colonization by the Malagasy immigrants, some 15 species of lemurs of eight genera became extinct (Mittermeier 1997). These extinct lemurs were, for the most part, far larger than surviving species and had evolved to fill many ecological niches. Three *Megaladapis* lemurs weighed between 90 and 170 pounds and moved slowly through the trees, feeding on foliage (Tattersall 1993). Another species, *Archaeolemur*, was about the size of a female baboon and lived on the ground (Tattersall 1993). Two *Palaeopropithecus* species weighed between 90 and 130 pounds and were sloth like tree dwellers with flexible bodies (Tattersall 1993). These extinct lemurs had evolved many unusual means of movement and locomotion that have no parallels in living species of lemurs.

Largest of all, the massive 400 pound *Archaeoindris* was apparently a ground dweller, moving on all fours; many of its anatomical characteristics are unlike any living primate (Tattersall 1993). One entire lemur family, Archaeolemuridae, was obliterated. In this family were many species of lemurs weighing between 35 and 55 pounds; they were powerfully built and short legged (Tattersall 1993). The heaviest lemur surviving today, the Indri (*Indri indri*), weighs only about 15 pounds (Tattersall 1993). These lemurs had survived for millions of years, and their extinctions were indeed a major biological loss to the planet. According to primatologists, the surviving lemurs resemble the very earliest primates from the Eocene (Tattersall 1993). Like prosimians in Africa and Asia, but to a far greater degree, lemurs have a highly developed sense of smell. Some species have long, fox-like noses (Preston-Mafham 1991). Genetic analysis of their DNA has revealed that all lemurs are descended from a single ancestor that probably arrived from Africa about 60 million years ago (Garbutt 1999).

The Giant Aye-aye (*Daubentonia robusta*) lemur was somewhat larger and 2.5 to 5 times heavier than the surviving Aye-aye (see below), but in other respects was very similar (Garbutt 1999). It is known from subfossil remains found in southwestern Madagascar (Nowak 1999). The date of its disappearance is unknown but may be fairly recent.

Archaeologists have uncovered remains of a massive bird of prey, the Malagasy Crowned Eagle (*Stephanoaetus mahery*), which undoubtedly preyed on lemurs (Feduccia 1996). In fact, at one locality the diet of this eagle, based on the bones of eagles and lemurs found together, contained at least 80 percent primates, including specimens weighing up to 26.5 pounds (Feduccia 1996). Remains of another large eagle of the genus *Aquila* have been discovered, and it, too, preyed on large lemurs and became extinct after the arrival of the Malagasy. These extinct birds preyed on smaller lemurs as well, including some species still surviving (Feduccia 1996). A bird of prey flying overhead still elicits fear in lemurs, causing them to seek cover. Neither of the two remaining species of eagles on Madagascar preys on lemurs, but two hawk species have been seen preying on young lemurs (Garbutt 1999).

In addition to the Giant Elephant Bird, the large Snail-eating Coua (*Coua delalandei*), a member of the cuckoo family, became extinct. The last specimen of this large, slate-blue bird was taken on an islet off the east coast, Ile Sainte-Marie, in 1834 (Morris and Hawkins 1998); reports by observers who claimed to have seen the bird were recorded as late as 1930 (Fuller 1987). The causes of this bird's disappearance, and even its exact range, remain obscure (Langrand 1990). Many specimens of this bird were taken before its extinction and kept in museums in Leiden; London; New York; Paris; Philadelphia; Tananarive (Madagascar); and Cambridge (Massachusetts) (Fuller 1987). The long feathers of this bird were highly valued by the Malagasy, and hunting may have reduced its numbers to a critically low level (Fuller 1987). It is also possible that the many birds killed for zoological specimens may have pushed this already rare bird to extinction, since its distribution may have been limited to the tiny Ile Sainte-Marie. No reliable record exists of its presence on the main island of Madagascar, but there is hope that it might be found in lowland forest near the Bay of Antongil (Morris and Hawkins 1998). Ten closely related species of couas survive, all smaller than the Snail-eating Coua.

The Biological Wealth of an Impoverished Country

The Madagascar of today is still a remarkable place, although about 90 percent of the forests, including almost all lowland rainforests that were richest in wildlife, were destroyed (Mittermeier *et al.* 1999). Some 33 lemur species survive, along with all but one species of tenrec, various mongooses and their relatives, more chameleons than any other country, several hundred kinds of frogs and reptiles, and thousands of endemic invertebrates and plants. Madagascar has no native fish, but many introduced species. Its fauna and flora represent many extremely unusual and unique examples of evolution (Mittermeier *et al.* 1999). This island is considered one of the five most biologically important areas in the world; its primates are the world's highest priority for conservation (Mittermeier *et al.* 1999).

Forests and Plants
Mammals
Birds
Reptiles and Amphibians
Invertebrates

The Biological Wealth of an Impoverished Country: Forests and Plants

Madagascar has one of the richest floras in the world. Eighty percent of its plants are found nowhere else (McNeely *et al.* 1990, Preston-Mafham 1991). The diversity of plants that survived almost 2,000 years of forest destruction continues to astound biologists and conservationists. Tropical trees with fruit growing on their trunks (various species of the genus *Tambourissa*) are native, as is a cactus (*Rhipsalis*), related to American species, that lives in the rainforest. A tree, *Symphonia*, which has leathery leaves and red-and-white striped flowers that look like peppermint candies (Morell 1999), also survives. The Flame Tree (*Delonix regia*), which produces cascades of red flowers, is grown around the world for its beauty, but few realize that it originated in Madagascar (Preston-Mafham 1991). Miraculously, many endemic plants have survived the fires and tree cutting that have destroyed much of the island. One mountain chain has 150 endemic vascular plants, a very high number (Preston-Mafham 1991). They are among the 7,300 to 12,000 species of plants native to Madagascar (Preston-Mafham 1991). Its flowering plants make up 20 percent of all the plants in the African region (McNeely 1990). At least 191 botanical families, a very large number for a relatively small area, evolved from ancestor species (Preston-Mafham 1991).

Some 2,000 years ago, the eastern rainforest stretched in a band 100 miles wide from north to south, covering 27 million acres (Tyson 2000). Ninety percent of the plants were endemic, with a profusion of unusual ferns, some types growing on tree trunks; wild ginger, with delicate purple flowers; bamboos; and far more orchids than in an African rainforest (Preston-Mafham 1991). An early traveler described the woods as so dense that there was a deep gloom: below the canopy at mid-day (Tyson 2000). Rainfall must have been greater and general climate more humid than at present as a result of these extensive rainforests. In the montane ridges, huge tree ferns, mosses and lichens cover the ground and hang from tree branches (Preston-Mafham 1991). Over the centuries, Malagasy burned many portions of the rainforest, especially in the south. Few tall trees remain in the rainforest today, although at one time there must have been many giants. During the 19th century, a palace was built for a woman ruler, centering on a 130-foot tree that had been carried by 5,000 laborers from the eastern rainforest (Tyson 2000). The palace was destroyed by an uprising in the 1850s. About this time, Malagasy dragged a tombstone through the forest, cutting 25,000 trees just to make a path (Tyson 2000). Early decrees banned cutting of virgin forest, with severe penalties, in the 19th century, but these were largely ignored (Tyson 2000).

About half of the island's forests had been cut by the late 19th century, and intensive cutting continued in the 20th century (Tyson 2000). The prime lowland forests throughout the island and three-fourths of the rainforest were cleared by the French for growing coffee and other crops in the first three decades of the century (Tyson 2000). The rainforest was heavily logged between 1950 and 1985, with 275,000 acres cleared and burned each year (Tyson 2000). The northeast Masoala Peninsula still retains sizeable areas of unlogged rainforest, but the southern region has been reduced to fragments of the original unbroken expanses. The remnants tend to be on sharp ridges where soil is poor and access difficult. For example, Ranomafana, a recently declared national park, straddles such an escarpment. Even so, many of its trees had been removed prior to its protection (Tyson 2000). What was once a closed-canopy, humid rainforest is now far dryer and cooler, with many openings among the trees, and some illegal logging continues (Tyson 2000). Still, botanists from the Missouri Botanical Garden, who were conducting a census of the trees in this park, counted 37 families of trees with 105 species in a 1-hectare plot (Tyson 2000). Outside the park's boundaries, rainforest is still being cleared and burned by the Malagasy, many of whom believe that their wealth lies in the amount of land they clear (Morell 1999).

The western dry, deciduous forest lies in the shadow of eastern mountains, which block moist ocean air currents (Preston-Mafham 1991). Trees do not attain heights of more than 80 feet, but many types of plants have adapted to this environment. Liana vines grow among the trees, and dead leaves carpet the forest floor. Large tamarind trees grow along rivers, and baobabs grow in plateaus (Preston-Mafham 1991). Beautiful orange bell flowers of the *Ipomoea carnea* plant burst into bloom during the short rainy season. As with the eastern rainforests, the once continuous stretches of deciduous forests have been largely destroyed, replaced by grasses able to survive in the eroded or bare soil.

Throughout the island, most deforested areas fail to regenerate into second-growth forests, even when left fallow, because Madagascar lacks vigorous colonizing trees that can quickly protect cleared ground and prevent further erosion (Preston-Mafham 2000). Cleared hillsides become covered in non-native grasses and exotic South American trees (*Psidium cattleyanum* and *Psidium guajava*) or plantations of eucalyptus, which inhibit the establishment of native seedlings (Preston-Mafham 1991; Sayer *et al.* 1992). Only if soils are rich and remnants of original forest are nearby will native forests regenerate. Unfortunately, the original forests and their native wildlife are lost permanently, and even regeneration cannot take place without a cessation of the slash-and-burn cycle, known as tavy by the Malagasy (Preston-Mafham 1991). Moreover, foreign logging companies have obtained logging concessions on most of the unprotected remnants of native forest. Tree cutting consumes some 7.8 million cubic meters of wood per year, of which 7 million cubic meters is for fuel and charcoal (Sayer *et al.* 1992). Valuable timber trees have been logged to extinction in most of Madagascar. The two native species of ebony trees of the genus *Diospyros* have been heavily logged for centuries, and few large trees are left (Sayer *et al.* 1992). The understory plants, such as tree ferns, are also exploited, dug up to sell as potted plants (Sayer *et al.* 1992).

The net result of this logging and burning, especially in the barren central highlands, is the loss of "a priceless reservoir of plant and animal species, replaced by one of the most impoverished forms of vegetation on the planet" (Preston-Mafham 1991). Many species of trees and other plants are highly endangered. Madagascar is one of the world's 12 "hot spot" areas of tropical forests, having a high percentage of endemic species which are under great threat (McNeely *et al.* 1990). Since an estimated 94 percent of Madagascar's trees are endemic, and many occupy very restricted ranges, they are highly vulnerable to extinction. Further research will likely reveal even more threatened species. Some authorities believe that even this rich plant diversity must represent only a fraction of the "vast original flora," since 80 percent of the vegetation and forests is gone (Ayensu *et al.* 1984). The *1997 IUCN Red List of Threatened Plants* includes 19 species of plants that may have recently become extinct, and an additional 287 species that are threatened with extinction (Walter and Gillett 1998).

Resident since the days of the dinosaurs, trees of a family of primitive pines, Podocarpaceae, grow on the island. The family is represented by species in other parts of the world that were part of Gondwana, from South America west to Southeast Asia. Madagascar has a number of native Podocarps, of which four endemic species or varieties are listed by the *IUCN Red List* as either Vulnerable or Rare (Walter and Gillett 1998). At least 26 genera of plants are

native to Madagascar and South America, but not to Africa, and are believed to be remnants from Gondwana (Preston-Mafham 1991). Another one of these, Madagascar's national tree, the Traveller's Tree (*Ravenala madagascariensis*), is a palm-like species of the banana family (Musaceae). Its closest relative of the same genus grows in Brazil and Guiana, but not in Africa (Preston-Mafham 1991). This tree has leathery petals covering its pollen and nectar and is a key food source for both bats and lemurs. In return, it depends on lemurs for pollination. Lemurs feed on the nectar, getting their noses covered with pollen in the process. They are so fond of the nectar that they travel miles to find another Traveller's Tree, still carrying the nectar on their noses and, unknowingly, pollinate the next tree they feed on (Attenborough 1995).

A plant of the Winteraceae family that has been growing on the island for 30 million years was recently seen again after a period of 90 years (Hsu 1997). This tree, *Takhtajania perrieri*, has many primitive features, such as a lack of vessels to move water and minerals; like many of Madagascar's relict species, it once grew on much of continental Africa, but long ago disappeared there (Hsu 1997).

Madagascar has more palms (Palmae family) than all of Africa (Preston-Mafham 1991). Many are in danger, however. The *IUCN Red List of Threatened Plants* lists 148 native species in various categories (Walter and Gillett 1998). The Big-leaf Palm (*Marojeya darianii*) was chosen by the Species Survival Committee of the IUCN to be one of 12 critically endangered species highlighted at its 1988 General Assembly in Costa Rica. This species was only discovered in 1982 and is confined to a single swamp in the northeast (Prance 1990). An agricultural program to raise rice cleared half its habitat, and then failed. This huge-leafed palm has been over-harvested as a source of heart-of-palm, a commercially valuable product (Prance 1990). Huge palms are felled for their inner pith to supply this gourmet market. The majority of palms grow in the eastern rainforests in a great diversity of size. Two threatened palms, *Dypsis hildebrandtii* and *Dypsis louvelii*, are miniature delicate-fronded palms only 3 feet high (Preston-Mafham 1991). Others, like the threatened *Ravenea glauca*, are majestic giants with long, straight trunks rising 50 feet or more to a luxuriant crown. Palms do not often survive the fires set by the Malagasy to clear land, disappearing from one area after another (Preston-Mafham 1991).

On the entire continent of Africa, only one species of baobab tree is native, while seven species are found in Madagascar (Preston-Mafham 1991). These strange-looking trees have wide trunks that taper to a narrow crown, looking like upside-down trees. Some baobabs grow to immense size. One famous specimen measures 46 feet around the base of the trunk (Preston-Mafham 1991). Another species, *Alluaudia ascendens*, grows in the southern desert. Although it can reach a maximum height of 16 feet, it is usually far smaller (Preston-Mafham 1991). Each of the seven species has a slightly different shape and size, but all have gray bark that resembles unwrinkled elephant skin. Baobabs are extremely important to both wildlife and humans. The Malagasy cut holes in their massive trunks and hollow out the spongy pith where water accumulates. In the dry south, these trees become wells, and villagers set ladders against the trunks, climb to the hole cut from the trunk, and lower buckets into the pool of water. Natural holes in baobob trunks and branches provide important nesting holes for birds and lemurs. These trees are fire-resistant, and fortunately, they are worthless as timber because of their soft, pulpy cores. For this reason some stands of thousands of huge, very old baobabs remain in parts of the island. Because of the heavy livestock grazing, few young baobab seedlings can survive, however, and botanists believe that the spectacular vistas of these behemoths will gradually disappear (Preston-Mafham 1991).

One very strange group of Madagascan plants native to dry areas has nine species in the same genus, *Pachypodium*. These succulent plants lose their leaves at the onset of the dry season and have evolved into a variety of forms, all with gray, smooth bark. Eight of the nine species are threatened with extinction, according to the *IUCN Red List of Threatened Plants* (Walter and Gillett 1998). One of these, the endangered *Pachypodium decaryi*, is native to Antananarivo, the "tsingy" limestone crags of the northwest. Its smooth, silvery trunk resembles a large inverted turnip, fat at the base and tapering upward, topped by a messy mop of thin, straggly branches (Preston-Mafham 1991). It bears large, white flowers during the dry season. Its main population occurs in the Ankarana Special Reserve, which bans burning (Preston-Mafham 1991), but has recently been invaded by hordes of miners who are clearing vegetation to search for sapphires (Morell 1999). Other Pachypodiums have equally bizarre

shapes, such as the bulbous *Pachypodium rosulatum*, which resembles a huge gourd sprouting long, thin shafts from which its bright yellow flower bloom. The rare *Pachypodium densiflorum*, with the appearance of a domestic jade plant run amok, has a mass of short, gray branches sprouting from a squat gray base. All these plants are highly susceptible to fire. Ken Preston-Mafham, in *Madagascar: A Natural History*, describes the threat of "incessant brush fires which ravage the length and breadth of central Madagascar during the dry season. Within hours, hillsides which had been decorated with colorful rock gardens of rare succulents are converted into graveyards of charred embers." These brush fires have been intentionally set by Malagasy to improve grazing land for their cattle or clear land. Another threat to Pachypodia is collectors who tear specimens, especially bizarre forms, from mountain slopes (Preston-Mafham 1991). Few species are protected in reserves. Without strong conservation programs, these fascinating plants could easily disappear.

Other strange trees of the southern spiny desert include the Octopus Tree (*Didierea madagascariensis*), a member of an endemic family of 11 cactus-like species, Didiereaceae. This tree has no trunk, but a bouquet-like grouping of stems covered in long, needle-sharp spines that branch out in odd, twisted shapes. Although resembling cacti, this family has no close relatives anywhere in the world (Preston-Mafham 1991). Another member of the family, *Alluaudia procera*, has a thick trunk with very long spines that grow in curving rows upward, and small, rounded leaves along its branches. In spite of this, several lemur species are able to leap onto these plants without hurting themselves (Preston-Mafham 1991). Three species in this family, all of the *Alluaudia* genus, are Rare, according to the IUCN (Walter and Gillett 1998). One of these, *Alluaudia montagnacii*, has tall, solitary tapering stems ending in a tuft of flowers.

The discovery of the medicinal effects of the endemic Rosy Periwinkle (*Catharanthus roseus*) has saved thousands of human lives. Two potent alkaloid compounds found in this plant have proven effective in the treatment of Hodgkin s' Disease, producing a 99 percent remission in patients with acute lymphocytic leukemia (Myers 1983). It also contains 75 different alkaloids, which could produce commercial substances (Preston-Mafham 1991). Fortunately, the Rosy Periwinkle is easy to propagate, grown in greenhouses around the world. Ongoing research is uncovering other Madagascan plants of medicinal value. Samples of plants are being tested in laboratories, and elderly Malagasy healers are being consulted. More than 50 species of wild coffee (*Coffea* spp.) grow in the island's eastern rainforests, providing an important genetic base for hybridizing with other strains because of their insect-resistance and low level of caffeine (Preston-Mafham 1991). These plants are symbolic of the great botanical wealth at risk.

The Biological Wealth of an Impoverished Country: Mammals

Home to some of the world's most fascinating, beautiful and curious mammals, Madagascar has approximately 117 native species, 90 percent of which exist nowhere else (Garbutt 1999). Excluding bats, all 88 native terrestrial mammals are endemic to Madagascar. Three-fourths of native mammals, or 66 species, are threatened with extinction; 49 of these are in higher categories of threat listed in the *2000 IUCN Red List of Threatened Species*. This represents 42 percent of all mammals found in Madagascar, by far the greatest percentage of threatened mammals of any country in the world (Hilton-Taylor 2000). As new species of mammals continue to be discovered, the numbers that are threatened continues to rise. A few have not been seen in the wild since their discovery. The majority is made of forest-dwellers, and a few inhabit marshy areas or woodland streams. The loss of forest, predation on them by Malagasy and domestic dogs, and introduction of exotic species of mammals that out-compete native species are combining to push many of the island's mammals toward extinction.

Page 1 (Tenrecs)
Page 2 (Lemurs and Aye-ayes)
Page 3 (Bats)

Page 4 (Viverrids)
Page 5 (Rodents)

The Biological Wealth of an Impoverished Country: Mammals: Page 1
The publication of *Mammals of Madagascar*, by Nick Garbutt, in 1999 filled a void for a complete guide to all native mammals, illustrated with color photos of most species and major habitats. This supplemented *Madascar: A Natural History* in 1991, an important reference on mammals and their environment. Conservation work has focused mainly on lemurs, with many organizations involved, including Earthwatch Institute, which sponsors field research; Conservation International; Jersey Wildlife Preservation Trust (based in England); and CARE. Several of these groups sponsored biodiversity studies and helped establish national parks, benefiting thousands of species, including tenrecs and other native mammals. A growing number of Malagasy zoologists are taking part in studies and conservation work, and new programs have been initiated to help local people while conserving mammals and their environments. Certain mammals have received inadequate attention to date, notably bats, rodents and some viverrids, who will undoubtedly benefit from the swell of interest and enthusiasm for Madagascar fauna that has developed in recent years. Filmmakers have recently produced a number of excellent wildlife documentaries, photographing rare species and spreading knowledge and concern about endangered mammals (see Video section).

Among Madagascar's mammals are many primitive forms. The tenrecs' closest relatives are insectivores known as solenodons, native to Cuba, Hispaniola and other vestiges of Gondwana in the Caribbean. Tenrecs and solenodons may have had a common ancestor living on the supercontinent, progenitor of all mammals. The remains of similar species have been found in Africa and South America, indicating that they were once very widespread but died out on all but isolated refuges such as Madagascar and West Indian islands. Tenrecs belong to a family of insectivores, Tenrecidae, related to shrews, moles and hedgehogs, but quite distinct from them. Twenty-seven species of three types of tenrecs make up this family--spiny, furred and otter-shrews (Garbutt 1999). They range in size from the Common Tenrec (*Tenrec ecaudatus*), which resembles the European Hedgehog and weighs more than 5 pounds, to the shrew-like tenrecs, *Microgale* genus, weighing less than 2 ounces (Nowak 1999). Tenrecs have some very unusual physical characteristics placing them far from any close mammalian relative. They have variable body temperatures that change with the ambient temperature and, an even more reptilian or avian trait, a cloaca that combines urinal, rectal and generative canals into one (Garbutt 1999).

A striking tenrec is the Lowland Streaked Tenrec (*Hemicentetes semispinosus*). It and a similar species, the Highland Streaked Tenrec (*Hemicentetes nigriceps*), weigh about 5 to 7 ounces and measure some 6 inches in length. White stripes run down their backs like skunks, and barbed, porcupine-like spines are detachable (Eisenberg 1975). The Highland species has a stiff, white neck ruff rising several inches at the back of its head that can be stabbed into the nose of an unwary predator (Eisenberg 1975). Family groups forage together and communicate by vibrating quills that produce low-frequency sounds like dry grass being rubbed together; tenrecs can detect these sounds from distances of more than 4 meters (Garbutt 1999). They also make a number of sounds that are audible to humans.

The Aquatic Tenrec (*Limnogale mergulus*), listed as Endangered in the *2000 IUCN Red List of Threatened Species*, inhabits streams and lakes, living at altitudes between 600 and 2,000 meters (Nowak 1999). This 8-inch tenrec has clawed, webbed feet, and a long, thin tail for propelling it through the water to feed on small crustaceans and fish. Its habitat in the central highlands has been greatly affected by human disturbance and deforestation. The Aquatic Tenrec has at least one refuge, the new Ranomafana National Park, created for the bamboo lemurs (Preston-Mafham 1991). In 1990, Dr. David Stone managed to lure an Aquatic Tenrec into a live trap, the first one of its kind seen alive in 25 years (Preston-Mafham 1991). Later, four more were taken and studied in captivity for three weeks prior to being returned to the river Namorona in Ranomafana, one of the few clear, unsilted rivers left in Madagascar (Preston-Mafham 1991). This species requires such streams, and only the preservation of forests, such as that in

Ranomafana, will ensure its survival.

Another six species in this family, all shrew-tenrecs of the genus *Microgale*, are listed in the *2000 IUCN Red List of Threatened Species*. These tiny insectivores are found in all parts of Madagascar in areas of heavy vegetation, and have dark, soft fur. They range in size from 1.5 to 5 inches in length, and weigh as little as 1.8 ounces (Nowak 1999). Several of the threatened species are highly restricted in range and habitat, and one, *Microgale dryas*, listed as Critical, occurs only in Ambatovaky Special Reserve in the northeastern rainforest (Garbutt 1999).

The Biological Wealth of an Impoverished Country: Mammals: Page 2

Far better known to the world, the lemurs are the focus of many programs to conserve them, as well as research on their wild behavior and biology. New species continue to be discovered; most recently in 2000, three new species of tiny mouse lemurs. Three more have been rediscovered, an indication that other species may yet be discovered to add to the present total of 33 species (Garbutt 1999)**.** This is the only country with five families of primates, making up more than one-third of all primate families; it is home to 12 percent of all primate species and 21 percent of all primate genera (Mittermeier *et al.* 1999). Unlike Brazil, however, which is another center for endemic mammals, Madagascar is far smaller, the size of Kenya, covering 226,656 square miles, or 0.4 percent of Earth's surface (NYT 2000). The number of lemur species is not an indication of their variety since many subspecies differ so radically from one another that in the future, each may be accorded full species status. One species of sifaka, a long-legged kind of lemur, has one subspecies that is pitch black, and another that is pure white. At least 51 species and subspecies of lemurs are known to exist (Mittermeier *et al.* 1999).

The most gregarious of the lemurs are the Ring tailed Lemurs (*Lemur catta*), who travel about in boisterous, friendly troops, living mainly on the ground. These lemurs have long, fox-like muzzles, large, soft golden-brown eyes, fluffy, gray fur, and black-and-white striped tails. Their body length is 15 to 17 inches, but their rope-like tails are half-again as long, from 21 to 24 inches (Nowak 1999). These 5-pound primates use their boldly patterned tails in a complex language of mutual visual and scent signals. They wave them about to show dominance, as a signal to follow other group members, or rub them on their wrist glands to wave at their rivals in territorial battles (Sleeper 1997). Moving about in troops of up to 25 individuals, they walk rapidly on the ground with the tail held high, waving it about. They wrap their tails around themselves for warmth on chilly nights. Extremely affectionate and playful, their core group is dominated by females (Jolly 1988).

In reserves where they are strictly protected, Ring-tailed Lemurs become very tame, napping on the ground in piles of leaves near tourists. Sometimes they sprawl out on their backs with arms spread wide apart. Females usually have a single young, but when twins are born, one may be "adopted" by a non-pregnant female, who may begin to produce milk in response to her surrogate role (Preston-Mafham 1991). Aunts also help in raising the young, and the daughter born the previous year babysits (Jolly 1988). Lemur babies are a source of great interest to the entire troop, females gathering around the mother and her young, grooming one another and the babies, forming a "grooming pod" (Preston-Mafham 1991). Only half of the infants survive their first year, and only 30 percent reach adulthood (Garbutt 1999). "A Lemur's Tale," shown on PBS in 1996, is a touching film about the death of a young Ring-tailed Lemur. Some fall from high branches, are killed by small carnivores or hawks, die of undiagnosed illness or starve in years of drought in their arid habitat. Ring-tailed Lemurs communicate with one another in a variety of sounds, from soft mewing contact calls to a territorial "bark-howl." Sometimes chasing and cuffing other members of their group, they are mainly peaceful, spending many hours a day in mutual grooming and in "snoozing-huddles," in which several animals form a complicated embrace from which tails and feet stick out in all directions (Preston-Mafham 1991).

In recent years, Ring tailed Lemurs have been classified "high priority" for conservation by the IUCN and the Species Survival Commission (SSC) Primate Specialist Group because their habitat of dry woodlands in southern Madagascar

is disappearing at an alarming rate due to fires, overgrazing by livestock and tree cutting; they are also hunted with dogs in some areas, and captured as pets (Mittermeier *et al.* 1992, Garbutt 1999). Their distribution has become increasingly patchy as forests are cut (Garbutt 1999). The *2000 IUCN Red List of Threatened Species* lists the Ring-tailed Lemur as Vulnerable, or declining toward endangered status.

One of the strangest mammals in the world is the Aye aye (*Daubentonia madagascariensis*), so unique that it is assigned to its own family, Daubentoniidae. When first discovered, scientists classified it as a squirrel because of its long, bushy tail and short legged body. In 1863, however, after anatomical studies, the Aye aye was revealed to be a lemur, in spite of incisor teeth that never stop growing, long, clawed fingers and other unlemur like characteristics. Aye-ayes have a perpetually startled expression: huge, round protruding eyes dominate the face, the pupils completely surrounded by deep golden irises. Dark rings surround their eyes, heightening the eerie appearance. The rest of the face and body are gray to black, with long grizzled guard hairs. Spending the day in their twig and leaf nests, Aye-ayes emerge at night to forage for insects and fruit (Garbutt 1999). The Aye-aye's enormous ears are sensitive to the movements of insects under tree bark. At Duke University Primate Center, which has the world's largest number of captive lemurs, Aye ayes have been filmed using their middle finger, which is twice the length of the other fingers, and skeletally thin, to tap on wood, listening for the movement of insects under the bark. When presented with a block of wood containing insect larvae in holes, the Aye aye taps the wood and, cocking its head, can tell, even in the case of a hidden hole, the location of the insects, which it then extracts almost surgically, with its middle finger. This primate fills the ecological role of a woodpecker. Aye ayes eat fruit as well, biting holes into the hard shells of coconuts and scraping the meat out with their middle fingers (Petter 1965). They have also been seen eating nuts of a native tree, nectar from the Traveller's Tree, fungus and lychee nuts (Garbutt 1999).

Aye-ayes have been heavily persecuted by the Malagasy, who consider them to be the embodiment of evil. In general, they are killed whenever seen. Dr. Ian Tattersall once found a dead Aye aye with a wire pulled tight around its neck (McNulty 1975). In 1990, apparently to dispel the bad luck caused by its having entered a village, local people set an Aye aye tail on a pole next to the road (Simons 1993). At one time, Aye-ayes were considered among the most endangered animals in the world, facing imminent extinction. To prevent their extinction, a few were captured and released on Nosy Mangabe, a small islet off the northeast coast. Fortunately, Aye ayes survived on the main island, perhaps because coconut plantations provided food when their forests were cut. Feeding at night, they remained undetected until recently. The Malagasy continue to persecute them.

Since the early 1980s, field surveys have revealed that Aye-ayes have a larger distribution than was originally thought. In 1991, they were seen for the first time in western Madagascar in the northern mountains (Simons 1993). With confirmed sightings in many eastern and northern forests and a few western localities, Aye-ayes inhabit a variety of forest types (Garbutt 1999). They can survive in secondary forest, coming out of their stick nests only at night. And while once thought solitary, groups of three to four individuals have been seen traveling together and feeding at foraging sites (Garbutt 1999). In spite of the greater distribution, the Aye-aye is an endangered species and almost certainly is declining (Garbutt 1999). Aye-ayes require large tracts of forest to maintain viable populations and to protect them from the persecution that often results in their deaths (Garbutt 1999). Although very rare in captivity, several captive births have occurred in recent years at the Duke University Primate Center and Jersey Wildlife Preservation Society zoo in England.

One lemur has recently been rediscovered in the wild and, in the process, an entirely new species was found. The Greater Bamboo Lemur (*Hapalemur simus*) seemed to have disappeared in the wild some time in the mid-19th century. Not until 1964 was this 5-pound, grizzled, gray-olive lemur seen again in a village market, where it was purchased by a French scientist. Unfortunately, it escaped. A pair captured in 1972 in a southeastern rainforest lived in the zoo in Madagascar's capital city, Antananarivo, until both male and female and their two offspring died (Quammen 1996).

Patricia Wright, an American primatologist, decided to search for this species in 1986 in its supposed range. Fossil evidence indicates that 1,000 years ago, the Greater Bamboo Lemur was widely distributed throughout most of

Madagascar's forests, and European naturalists saw it fairly regularly in the 19th century. When she saw a russet-colored lemur clinging to a trunk, making loud "tonking" calls, Wright assumed that she had rediscovered the Greater Bamboo Lemur. Although a different color, she concluded that these animals probably represented a color variation (Quammen 1996). A German primatologist, Bernhard Meier, made independent studies in this patch of rainforest at the same time, also discovering the reddish-gold lemur. Both scientists had great difficulty making observations because of its extreme shyness (Quammen 1996). Finally one was caught, and in 1987, after chromosomal and anatomical studies were done in France, this lemur was found to be an entirely new species (Jolly 1988). It was named the Golden Bamboo Lemur (*Hapalemur aureus*) in a joint zoological paper by Meier, Wright and three other biologists (Preston-Mafham 1991). After months of unsuccessful attempts, Wright took the first photographs of the Golden Bamboo Lemur in the wild. Its beautiful golden-red face mask and belly contrast with darker brown fur on the rest of its body. (See color photographs in Garbutt 1999, Jolly 1988 and Preston-Mafham 1991). This lemur has been found at another location further north, and it is not known whether these populations are isolated from one another. Its population is apparently very low, as only about 1,000 animals have been estimated in the original location of discovery, and its habitat continues to be cleared (Garbutt 1999). The *2000 IUCN Red List of Threatened Species* has classified the Golden Bamboo Lemur as Critical, the most endangered category. Its limited range places it in great jeopardy, and it has been hunted with slingshots; its long-term survival is not secure (Garbutt 1999).

The Greater Bamboo Lemur, the animal first sought, was later found in the same forest, resembling original descriptions and clearly a separate species from the Golden Bamboo Lemur; a third species of bamboo lemur, the Gray Bamboo Lemur (*Hapalemur griseus*), weighs only 2 pounds. It has smoky gray fur and golden eyes, and lives alongside the latter two species in this same forest. This lemur lives in other parts of Madagascar as well (Preston-Mafham 1991).

Each of these three bamboo lemurs eats different parts or species of bamboo plants. One eats the leaves, another the pith, and the third confines itself to new shoots, leaf bases and pith from narrow stems (Quammen 1996). Amazingly, chemical analyses of the plants eaten by the Golden Bamboo Lemur found them to have high concentrations of cyanide, a chemical usually toxic to mammals. Golden Bamboo Lemurs weigh only about 2.2 pounds, and Wright and her co-workers found that, based on toxicity tests of other mammals, they eat 12 times the amount of cyanide that should kill them (Quammen 1996). This is another example of the biological mysteries of Madagascan wildlife.

The Ranomafana forest, with its rare and endemic lemurs and other unusual fauna and flora, would likely have been cut by the Malagasy for more farmland, but Wright spent five years in a successful effort to protect it in the newly created Ranomafana National Park (Bohlen 1993, Mittermeier *et al.* 1992). This new park covers 108,000 acres of old-growth eastern lowland rainforest. Giant rosewood and other ancient trees tower above a lush understory. It is an extremely important--perhaps the most important--forest for lemurs. Fourteen species of lemurs and 18 other endemic species of mammals live in the park (Jolly 1988). Local people cooperated fully in setting the park s boundaries, aware of the importance of saving forests. They had experienced a major catastrophe when a cyclone caused landslides, burying entire families in their homes, all precipitated by deforestation (Jolly 1988). In spite of these remarkable achievements, some tree cutting still occurs in Ranomafana National Park (Garbutt 1999).

Wright has continued to study lemurs, now specializing in the exquisite Diademed Sifaka (*Propithecus diadema*) (Brody 1998). Sifakas are the most acrobatic lemurs, leaping from tree to tree, but they have a unique means of locomotion to cross open spaces between trees. Standing on their long hind legs in an upright posture, they hop sideways, with their arms raised high above their heads. Sifakas can move very quickly in this amazing, dance-like gait, covering distances of more than 100 yards. They are also able to leap vertically to tree branches from a standing position, even carrying babies on their backs. One of their spectacular leaps, some 30 feet up, is the equivalent of a person jumping to the top of a telephone pole. The Golden-crowned or Tattersall's Sifaka (*Propithecus tattersalli*) is a beautiful, nearly all white species with rich yellow-orange on the crown and tinges of this color on its back, legs and chest. Orange eyes contrast with a furless black face. The smallest of the sifakas, it is confined to a tiny area of only about 15 square miles of forest fragments in northeast Madagascar. The Golden-crowned Sifaka's small population of

fewer than 8,000 animals, fragmented into isolated populations, is threatened by forest cutting, brush fires, loss of habitat to agriculture and hunting (Garbutt 1999). Distributed in discontinuous patches of forest, these sifakas may become inbred if corridors are not acquired to link populations. A core part of their forest had been scheduled for cutting for charcoal when scientists named these sifakas. The PBS Nature program, Madagascar. Island of Ghosts, was the first to film these delicate lemurs (see Video section, Regional - Africa and Indian Ocean Islands). They move about in small groups and feed on a variety of unripe fruits, seeds, shoots, leaves, bark and flowers (Garbutt 1999). No reserve has been set aside for this highly endangered sifaka, although a three-parcel national park covering 20,000 hectares (49,420 acres) has been proposed to protect this species from extinction (Garbutt 1999). The IUCN classifies this species as Critical (Hilton-Taylor 2000).

Although many Malagasy have become far more aware of the need to protect lemurs, some do not understand their rarity or the importance of conserving them. Many rural people still hunt them for food or kill them because of superstitious beliefs. In some areas, the Malagasy try to sell lemurs to foreign scientists. Visiting zoologists studying lemurs have been approached by Malagasy holding captive, and usually injured or dying lemurs, in hopes of a reward. On one occasion, an endangered species of sifaka was brought to primatologist Dr. Alison Jolly, dragged half choked by a vine around its neck, with one arm dangling loose below the elbow, a jagged bone protruding; blood oozed down its white fur, and it gasped for air through a muzzle smashed by a flung stone (Jolly 1980). Jolly expressed horror at its condition and refused to pay them any reward. She then amazed them by telling them it was a unique sifaka, found only in that small part of Madagascar. They were incredulous . . . not in Antananarivo? . . . Not in France? . . . Not in America? (Jolly 1980). For the majority of people, lemurs are familiar animals, easy to capture and valuable as food. Malagasy schools, established by the French colonial government, taught them only about European animals, encouraging people to assume that their lemurs were unimportant. Fortunately, many Malagasy are becoming concerned about protecting lemurs, and conservation education is taught in an increasing number of schools.

Some lemurs have bred in captivity in zoos and breeding centers, but most, like the endangered Indri (*Indri indri*), have never survived in captivity long enough to breed. In their rainforests, they perch high up, clinging to tree trunks to feed, and suddenly leaping vertically to a neighboring tree, pushing off with their extremely muscular, long legs. Panda-like fur of contrasting black and white--black faces and bodies and white arms and legs--gives them a dramatic appearance. Nearly tailless and heavy--but graceful--their eerie songs, sung at dawn and sometimes during the day, form a loud chorus of high-pitched voices that carries for long distances. Indris were once very common in the eastern rainforest, but much of their habitat has been burned away, making them extremely sensitive to the danger of fires. When a 1992 fire threatened a group in a reserve, they raised such a loud cry that the guards were alerted. They rushed to the scene and put out the fire (Rajaonson 1993).

Although originally found in the far north and central highlands, the Indri is now limited to a narrow strip encompassing only half the rainforests on the island (Garbutt 1999). Indris do not reach sexual maturity until between 7 and 9 years of age, and females are thought to give birth only every second or third year (Garbutt 1999). With such a low reproductive rate, they have been very vulnerable to habitat loss and hunting, especially by immigrants (Garbutt 1999). Moving about in small family groups, they are conspicuous to hunters. The Indri is one of the few lemurs whose killing is considered taboo by the Malagasy, but the old taboos are breaking down, resulting in capture and killing. In some cases, religious leaders encourage such killing. A lemur scientist met a Catholic priest who killed several Indris, roasted them and served them to his congregation, as recorded by Faith McNulty in 1975, and this killing has not ceased. In *Mammals of Madagascar* (Garbutt 1999), two terrified Indris were photographed clinging to poles in a hut, awaiting slaughter for food.

In contrast to the Indri, mouse lemurs (*Microcebus* spp) are so small that it is hard to think of them as primates. The tiniest is the newly discovered Pygmy Mouse Lemur (*Microcebus myoxinus*), with an average weight of only 30 grams, or 1.05 ounces, smaller than any other primate (Garbutt 1999). This tiny mammal is 2.73 inches long, with a tail just under 6 inches in length (Garbutt 1999). The other species are slightly larger, with body lengths ranging up to about 5 inches, and tails of equal or greater length (Garbutt 1999). These nocturnal lemurs have huge dark eyes and are agile and active, resembling African bushbabies. They feed on insects, spiders, and even small frogs and lizards, as

well as fruit, flowers and nectar (Nowak 1999). Females form groups and sleep in a nest together with up to nine individuals, while males usually nest alone or in pairs; occasionally males are found in a group of females (Nowak 1999).

A key to protecting lemurs and their forest homes is educating the people of Madagascar about them. The Jersey Wildlife Preservation Trust has put up posters with pictures of lemurs and their protected status around the island. Habitat protection is obviously key to conserving lemurs, and another recent development is the protection of the largest remaining area of rainforest in Madagascar. The Masoala Peninsula in the northeast is the sole home of the Red Ruffed Lemur (*Varecia variegata rubra*), a 9-pound, reddish subspecies of the Ruffed Lemur, but bearing little resemblance to the latter black-and-white species. With $3 million from USAID (United States Agency for International Development) and three years of planning, the new Masoala National Park, covering 210,000 hectares (518,910 acres or 840 square miles), was announced in June 1996 (Terry 1996). This immense park was formally signed into law on October 18, 1997 (Kremen 1998). Thai and Indonesian timber companies had hoped to log these virgin rainforests, but this new law will prevent clearcutting and slash-and-burn agriculture that would have destroyed the forest within less than 50 years. A coalition of organizations helped establish this park, including the Wildlife Conservation Society, CARE and the Peregrine Fund (Garbutt 1999). It will prevent the extinction of the endangered Red Ruffed Lemur, as well as that of the newly rediscovered Madagascar Serpent Eagle (*Eutriorchis astur*) (see below).

In 1997, five Ruffed Lemurs born and raised in the Duke University Primate Center in North Carolina were released in the Betampona Reserve in the northeast to bolster a small, isolated population of this species (Welch 1997). This reintroduction represented a goal in the captive-breeding program at Duke University, which has long planned such a return of these highly endangered primates to the wild. John Cleese, actor and a member of the 1970s British comedy team, Monty Python's Flying Circus, took an interest in the reintroduction program as an enthusiastic lemur admirer. After contributing to the Ruffed Lemur reintroduction program, he wanted to see how they were faring in the wild, and trekked to their remote release site. A delightful film based on this experience, "Lemurs with John Cleese," was shown on PBS in 1999. These Ruffed Lemurs have been released in an area of dense rainforest and rugged hillsides, a long hike from the nearest road. The biologists and assistants who take part in this reintroduction program show their dedication by living for long periods under extremely primitive conditions. Cleese managed to inject humor into this otherwise arduous situation.

At least six species of lemurs, and perhaps more, serve the ecologically important role of pollinating flowers. Many of Madagascar's plants produce unusually large flowers with strong odors and copious nectars attracting lemurs to feed on them. Should any of these lemurs become extinct, the plants that they pollinate will likely follow. Lemurs also play an important role in dispersing seeds. Research by the German Primate Centre at Hamburg University has found that Brown Lemurs are crucial to the regeneration of the western dry forests. About 10 percent of the island's tree species rely largely or entirely on this species to disperse seeds, which pass through their digestive systems.

The surviving lemurs are in extreme danger of following their relatives into extinction. Conservation organizations accord them extremely high priority among endangered primates, and they are the focus of many programs to preserve them. Twenty-nine of the 33 species are listed in the *2000 IUCN Red List of Threatened Species*, all but seven in higher categories of threat. This is an increase of nine species in the four years since the previous edition of the *IUCN Red List* was published (Baillie and Groombridge 1996). Three species and several more subspecies are in the Critical category of species on the verge of extinction, while seven are Endangered, an increase of four species since 1996. All lemurs are listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the category prohibiting commercial trade, and as Endangered on the U.S. Endangered Species Act.

Although lemurs are protected by Madagascan law, hunting is a major cause of mortality. High fines and even jail sentences may be imposed for killing a lemur, but the severity of the penalties might make officials reluctant to enforce the laws (Peterson 1989). Blowguns, snares, traps, sharpened sticks, slings, stones, guns or even clubs are used to kill them (Peterson 1989). To kill small species of nocturnal lemurs, trees are sometimes cut down, and

hunters seize them from their nest holes (Peterson 1989). In the late 1980s, a "sport" hunter bragged of killing 12 highly endangered Verreaux's Sifakas in one afternoon (Peterson 1989). In spite of education programs launched in the 1990s urging the Malagasy to protect lemurs, and the rise in tourists who come to see them, which provides revenues, few have benefited from tourism. Hunting remains a major threat (Garbutt 1999). The rise in human population has resulted in an increased demand for food, particularly protein, far more than the ailing agricultural system can supply (Garbutt 1999). The larger lemur species are especially affected. Because laws against killing lemurs are not enforced, much more education is needed about their potential value in attracting tourism and research funds that provide new jobs. Already tourism has raised income levels among some Malagasy, but hunger is still widespread (Tyson 2000).

In the late 1980s, a World Bank official studying the extreme and worsening poverty on the island said that there might come a time when the people of the capital city would scale the walls of the city zoo and eat the lemurs: "On the downward spiral, animals are at the bottom" (Peterson 1989). Such a tragedy is not inconceivable considering that hunger and poverty have deepened in the decade since. Conservation programs must involve communities while providing an incentive to conserve lemurs. Otherwise, it may be impossible to persuade the Malagasy not to slaughter them.

Although the status of lemurs is deteriorating along with their forests, much is being done to prevent their extinction. The past two decades have been of critical importance to lemur conservation. These extraordinary animals are receiving worldwide attention, and habitat protection for some species has been achieved. Not too long ago, their extinctions seemed inevitable and imminent. Conservation education programs, including showing slides of lemurs and other wildlife to rural children, have been launched. Wright helped to finance the building of new schools and the renovation of existing schools near Ranomafana National Park (Tyson 2000). A number of international organizations are integrating lemur and biodiversity studies with the economic development of entire communities (Garbutt 1999).

For a growing number of Malagasy, learning how special their lemurs are has made lemurs a source of pride and an important national treasure. In the future, Malagasy children may learn from an early age about lemurs and want to protect them. A few decades ago, few films had been made of these fascinating primates, while today many films show their habitats, biology and conservation work on their behalf. One is Spirits of the Forest, a charming film about many species of lemurs. Others are listed in the Video Section Mammals. Films of lemurs and the island's environment would provide new insights about these animals if shown to the Malagasy people. Lemurs have also been prominently featured in *Madagascar: A Natural History*, by Ken Preston-Mafham, a beautiful and informative book, and the first guide book, *Mammals of Madagascar*, which provides color photos of nearly every species and subspecies, as well as information on habitats, conservation and status (Garbutt 1999).

In some areas of Madagascar, notably on Nosy Be island, lemurs are fully protected by taboo respected by the Malagasy. Here, beautiful Black Lemurs are fed by the villagers and tourists. This island is being developed intensively for tourism, and the strict nature reserve may be made into a national park (Tyson 2000). This will have mixed results, with new income flowing to the local people from park fees--one of the few countries where this occurs--yet with habitat lost and wildlife disturbed as a result of new hotels and a crush of visitors (Tyson 2000).

The gentle, curious gazes and charming behavior of lemurs have left an indelible impression on many people, and their extinction would be tragic, not just for biological reasons, but also because of their unique and delightful qualities.

The Biological Wealth of an Impoverished Country: Mammals: Page 3
Bats, which perform vital ecological roles in controlling insect populations and pollinating plants, tend to be ignored

and often persecuted. Madagascar is no exception. Fifteen species of the 29 species of bats are endemic, living nowhere else (Garbutt 1999). The remaining 14 species live in mainland Africa as well. Fourteen species, or almost half the native bats, are listed by the *2000 IUCN Red List of Threatened Species*. The Yellow Bat (*Scotophilus borbonicus*), the most endangered, is listed as Critical (Hilton-Taylor 2000). This bat has been seen in both eastern and western regions but is extremely rare. A Vulnerable species, the Sucker-footed Bat (*Myzopoda aurita*), is the sole member of its family, Myzopodidae, and an extremely unusual bat. It is able to walk up tree leaves using sucker disks at the bend of its wings and on its feet to adhere to the slippery leaves (Jolly 1988). Only 2 inches long, with a forearm length of 1.9 inches, this tiny bat occurred in East Africa during the Pleistocene, but at present, it is found only in several locations in the eastern rainforest region of Madagascar (Garbutt 1999). It roosts in the Traveller s Tree. It possesses a complex echolocation system and emits very long calls used to hunt insects (Garbutt 1999).

The largest bat, the endemic Madagascar Flying Fox (*Pteropus rufus*), has a 4-foot wing-span. An extremely colorful bat, its crown and nape are yellowish, and its upper chest and shoulders are rufous to golden brown (Garbutt 1999). It feeds on fruit juices by squeezing pieces of fruit pulp in its mouth, swallowing the juice and very soft fruit pulp, especially of figs, papayas, lychees and guavas (Garbutt 1999). Colonies of these bats roost in tall trees in primary forests or plantations (Garbutt 1999). One large roost at the Berenty reserve has decreased, apparently because of daytime disturbance by tourists who come to see them hanging upside down in the tamarind trees (Preston-Mafham 1991). Elsewhere on Madagascar, the species has declined precipitously from hunting for its meat; only on inaccessible offshore islands do these bats survive without persecution (Preston-Mafham 1991). Of Asian origin, this species is related to fruit bats in the Mascarene Islands. Through captive studies, flying foxes have been found to be extremely devoted to one another (see discussion of Rodrigues Flying Fox in Chapter One).

The Biological Wealth of an Impoverished Country: Mammals: Page 4

The Viverrid family is represented in Madagascar by mongooses, civets, and related carnivores that have evolved into eight species of three endemic subfamilies (Preston-Mafham 1991). Their ancestor is thought to have originated in Africa, and may have colonized the island at an early period. The largest carnivore on the island is the Fossa, or Fosa (*Cryptoprocta ferox*). A zoological oddity, it resembles the Jaguarundi, a neotropical cat, but most authorities place it either in the Viverrid family with civets (Preston-Mafham 1991) or the Herpestidae family with mongoose (Nowak 1999). The only member of its genus, it walks flat on its feet, rather than on its toes like cats (Nowak 1999). Sleek and slender, with golden reddish-brown fur, it has a small head with a blunt, dog-like muzzle, and an extremely long tail. Males weigh up to 22 pounds, with a body length of 2.6 feet and a tail of equal length, while the smaller females measure 2.3 feet and weigh about 15 pounds (Garbutt 1999). It has scent glands which discharge a strong odor when the animal is irritated (Nowak 1999). Widespread but rare in forests throughout the island, this nocturnal predator kills small lemurs, rodents and tenrecs, as well as birds, reptiles, amphibians, invertebrates and, reputedly, domestic chickens (Garbutt 1999). The Fossa often excavates animals from their burrows and can pursue fleeing prey by climbing up trees (Nowak 1999).

The first research study of the Fossa is being conducted by zoologist Luke Dollar, funded by the Earthwatch Institute. Helped by volunteers, he is radio-tracking several Fossa to determine their movements, habits and territory size. As the largest predator on the island, the Fossa plays an extremely important role in the evolution, behavior and population dynamics of lemurs and other prey animals. During the research project, several Fossa have shown extreme confidence by raiding the tents of the researchers when unoccupied, ransacking them and even chewing metal objects, leather boots, rucksacks, soap and bottles of malaria tablets (Garbutt 1999). For centuries, Fossas have been persecuted by the Malagasy, believing them to be ferocious and evil.

The Fossa gives birth to a litter of two to four young, which mature very slowly and may not be fully independent until they are about 4 years old (Garbutt 1999). This slow rate of reproduction has made the Fossa vulnerable to

extinction. Along with losses from killing by the Malagasy, its forest home has been steadily whittled away by slash-and-burn agriculture. The Fossa is listed as Endangered in the *2000 IUCN Red List of Threatened Species*, a higher category of threat than it received in the 1996 version of this list.

Gerald Durrell, renowned author and conservationist, traveled in the western forests to capture Aye-ayes for captive breeding. He encountered a Fossa venturing out during the day--an unusual behavior: "A flash of russet red caught my eye in the bushes some six feet in front of the vehicle and, suddenly, from out of the undergrowth, silent as a cloud shadow, came a Fossa which walked languidly to the middle of the road and sat down" (Durrell 1993). Remaining there, the Fossa proceeded to groom himself, apparently unaware of Durrell's presence. Then, with a sigh and a wide yawn, the Fossa crossed the road and disappeared into the forest, "his immense sickle of a tail swinging from side to side like a bellrope behind him. To have spent ten minutes with such a rare and beautiful creature was a privilege" (Durrell 1993).

The Falanouc (*Eupleres goudotii*), sole member of its genus and a viverrid, is the size of a domestic cat. It has dense, woolly fur and an extremely pointed and narrow muzzle. Native to humid eastern lowland forests and marsh areas and portions of the northwest, Falanoucs are active at twilight and during the night. Feeding mainly on earthworms and other invertebrates, they use their long snouts and tiny, conical teeth to catch prey in leaf litter (Garbutt 1999). The species is rare or extremely rare over most of its range and is classified as Endangered by the IUCN (Hilton-Taylor 2000). Like the Fossa, it has declined as a result of deforestation, drainage of marshes, hunting by the Malagasy, attacks by feral domestic dogs, and possibly competition with the introduced Small Indian Civet (*Viverricula indica*).

The Malagasy Civet or Fanaloka has the scientific name *Fossa fossana*, which has been confused with the Fossa. Like the Fossa and Falanouc, it is the only member of its genus. Looking more like spotted civets from mainland Africa and Asia, this reddish 3-pound carnivore has rows of black spots on its back, merging into stripes toward its bushy, grayish tail. Its distribution is far more restricted than the Fossa's or the Falanouc's, being confined to eastern rainforests which have been reduced to less than 10 percent of their original size. Sheltering in tree holes or crevices, the Malagasy Civet lives in pairs and feeds on crustaceans, worms, small eels and frogs (Nowak 1999). A pair has a single young, and a captive civet lived 11 years. Hunting and trapping have also threatened the Malagasy Civet, which is listed as Vulnerable by the IUCN (Hilton-Taylor 2000).

Five other viverrids, all mongooses, are native to Madagascar, and all are threatened with extinction from a loss of forest habitat and persecution. A few have very restricted distributions. They tend to be secretive unless in a secure forest reserve, and little attention has been paid to their conservation, biology or habitat requirements. Several are uniform brown or russet, while two have bold black dorsal stripes ending in white, bushy tails. One, the Brown-tailed Mongoose (*Salanoia concolor*), is native to the northeast rainforests, but almost nothing is known of this small carnivore (Garbutt 1999). All of the eight native civets, mongooses and related animals are listed as Vulnerable or Endangered by the *2000 IUCN Red List of Threatened Species*.

The Biological Wealth of an Impoverished Country: Mammals: Page 5

Among Madagascar's 11 species of murid rodents are several extremely bizarre forms. The largest is the Giant Jumping Rat (*Hypogeomys antimena*), the size of a rabbit and weighing 2 pounds, 10 ounces (Preston-Mafham 1991). Restricted to a small area in western dry, deciduous forests north of Morondava, in west-central Madagascar, its entire range is thought to encompass only 39 square miles (Preston-Mafham 1991). Once far more widely distributed, remains have been found in southwest and central Madagascar (Garbutt 1999). These huge rodents search for food, such as fallen fruit, on the forest floor and feed by sitting on their hindquarters and holding food in their forepaws like a rabbit (Garbutt 1999). Giant Jumping Rats build deep burrows and, unlike the vast majority of rodents, a mated pair maintains long bonds with one another and with their young (Garbutt 1999). Male young leave after one year, and

females stay with both parents for two to three years (Garbutt 1999). Only one or two young are born in a litter, and predation by Fossa and the Madagascar Ground Boa (*Acrantophis madagascariensis*) is high (Garbutt 1999). With no reserve and a habitat that continues to decline, this huge-eared rodent is in danger of extinction. A reserve is planned for this species, which is listed as Endangered by the *2000 IUCN Red List of Threatened Species*. Madagascar. Island of Ghosts filmed the Giant Jumping Rat in the wild, one of the only videos of this fast-disappearing species (see Video section).

Eight of Madagascar's native rodents, or 73 percent, are listed by the IUCN in various categories of threat. Two are considered Critical: the Madagascar Mouse (*Macrotarsomys ingens*) and the Madagascar Rat (*Eliurus penicillatus*). The mouse is known only from a single area in northwestern Madagascar, in dry deciduous forests where the type specimen was found, and it is thought to be almost totally arboreal and nocturnal (Garbutt 1999). The Madagascar Rat has not been seen since the type specimen was collected in central-eastern montane rainforest.

The Biological Wealth of an Impoverished Country: Birds

Page 1 (Native birds)
Page 2 (Avain & Terrestrial)
Page 3 (Aquatic)
Page 4 (Bird-watchers)

The Biological Wealth of an Impoverished Country: Birds: Page 1

Until recently, the amazing lemurs and other mammals of Madagascar eclipsed its remarkable bird life. Apart from the extinct elephant birds, 120 species of the 204 native birds are unique to the island (Morris and Hawkins 1998). Like tropical birds of other parts of the world, most are dazzlingly beautiful in brilliant hues. Unlike most tropical birds, however, they represent fascinating examples of evolution, including families of birds that exist nowhere else, having evolved from a single ancestor into many forms, some very bizarre. Most ornithologists recognize five bird families as unique to Madagascar, each with extremely distinctive characteristics. Four of these have some or all species that are threatened. The fifth, a family consisting of a single bird, the Cuckoo-Roller (*Leptosomus discolor*), is secure for the moment (Morris and Hawkins 1998). A few thousand years ago, there may have been far more native bird species that disappeared without a trace as their habitats were destroyed.

Native birds are not thriving, as people and livestock destroy their varied habitats, to which they had adapted over thousands of years. A total of 41 species, all but three of which are endemic, have been listed in the *2000 IUCN Red List of Threatened Species*, based on the research of BirdLife International published in 2000 in *Threatened Birds of the World*. The latter book illustrates each threatened Madagascan bird and describes status, population numbers, distribution and other pertinent information. The three non-endemic birds also breed in the neighboring Comoros or Seychelles (BI 2000). Thus, 20 percent of all native birds and 34 percent of endemic birds are threatened, five species listed as Critical, six as Endangered, 16 as Vulnerable, and 14 as Near-Threatened (BI 2000). Moreover, many native birds that were once widespread have become restricted to isolated forest reserves and parks, not yet endangered but far less numerous than in previous times. While the percentage of threatened birds is less than that of endemic mammals, it is significant, especially considering that 27 species are either Critical, Endangered or Vulnerable in the *2000 IUCN Red List of Threatened Species.* Madagascar has more threatened birds that all of the continental United States (excluding Puerto Rico and Hawaii). Its threatened birds total 41 threatened species, five greater than the United States 36 (BI 2000). Only 4 percent of the 810 breeding birds native to continental US and Canada combined (Sibley 2000) are threatened. If birds in the United States faced the same degree of threat as Madagascar's birds, at

least 162 species would be threatened with extinction.

Fortunately for the future of these unique birds, organizations such as BirdLife International; the Peregrine Fund; Conservation International; the Jersey Wildlife Preservation Trust; and an ad hoc group, The Working Group on Birds in the Madagascar Region, are researching and working to conserve Madagascar's native birds. Malagasy ornithologists and members of the public are participating in surveys, studies and conservation programs. An inventory of the status and taxonomy of all of Madagascar's birds is in progress (Morris and Hawkins 1998).

In spite of Madagascar s many unusual birds, interesting to specialists and amateur birdwatchers alike, no bird guide or text illustrating and describing the island's avifauna existed until 1990, when Olivier Langrand's *Guide to the Birds of Madagascar* was published, providing information on natural history, status, habitats and distribution, as well as color paintings of all native birds. This material supplemented the lengthy descriptions in *Threatened Birds of Africa and Related Islands*, a 1985 publication of the International Council for Bird Preservation, now called BirdLife International (Collar and Stuart 1985). *Madagascar: A Natural History*, by Ken Preston-Mafham (1991), included extensive information on many native birds and their habitats. *Birds of Madagascar, A Photographic Guide* (Morris and Hawkins 1998), published in 1998, updates the latter publications with vivid color photographs illustrating almost all native birds, including many species discovered or rediscovered during the 1990s, such as the two new species, the Cryptic Warbler (*Cryptosylvicola randrianasoloi*) and the Red-shouldered Vanga (*Calicalicus rufocarpalis*), and the rediscovery of several birds thought extinct: the Madagascar Serpent Eagle, Madagascar Red Owl (*Tyto soumagnei*) and Red-tailed or Fanovana Newtonia (*Newtonia fanovanae*). The 1990s also saw the making of many films about the island's wildlife, including its birds (see Video section).

The Biological Wealth of an Impoverished Country: Birds: Page 2

Birds native to aquatic habitats have declined even more dramatically than many forest birds. The largest lake on Madagascar, Lake Alaotra in the northeast, was once a paradise of waterbirds, turtles, frogs and other wildlife. Traditionally, portions of the lake were used by the Malagasy for rice cultivation, without serious damage to the environment or resident wildlife. But as their populations and food requirements grew, people began to destroy more and more of the natural marsh and reed beds that lined the lake, and cleared the surrounding forest for firewood and agriculture. This destroyed the lake's water quality. With no trees to hold back the soil and conserve water, this once-beautiful lake became heavily silted by runoff (Durrell 1993). Added to this, non-native tilapia fish were introduced into the lake as a food source for the local people. The fish eat vegetation needed by dragonflies and other fauna that form the basis of the lake's food chain (Preston-Mafham 1991). This ecological collapse has greatly reduced rice production on the lake, although reeds are still being cleared for rice growing, fragmenting wildlife habitat (Garbutt 1999).

The effects on native aquatic birds have been catastrophic. Lake Alaotra is the only known habitat of the endemic Alaotra Grebe (*Tachybaptus rufolavatus*), which is presumed extinct (BI 2000, Morris and Hawkins 1998). No sightings have been made since 1985, when only two birds were seen. It declined from loss of its habitat, hunting and hybridizing with the Little Grebe (*Podiceps ruficollis*), a recent arrival from Africa (Morris and Hawkins 1998). Many fruitless searches for the species have been carried out in the lake and surrounding area since then (BI 2000, Morris and Hawkins 1998). This small, black-capped grebe was very sedentary and may have been nearly flightless because of its extremely short wings.

Another waterbird restricted to Lake Alaotra, the Madagascar Pochard (*Aythya innotata*), is also probably extinct, having been eliminated by the same threats as the Alaotra Grebe (BI 2000). This duck declined steeply from 1930 on, and the last known bird, a male, was captured in August 1991, having been caught in fishing gear. This bird later died, and intensive searches in 1989 and 1990, and again in 1993 and 1994, failed to discover more Madagascar Pochards

(BI 2000, Collar *et al.* 1994). A handsome bird, the pochard was chestnut-colored, with dark gray bill and yellow eyes (see photograph in Morris and Hawkins 1998). A shy species, its breeding and behavior were studied, but apparently nothing was done during its precipitous decline to prevent its extinction. Classified as Critical, hope remains that a few birds exist in wetland habitats around Lake Alaotra (Morris and Hawkins 1998).

The Jersey Wildlife Preservation Trust has begun education campaigns in the vicinity of Lake Alaotra to teach local people about the presence of the highly endangered Alaotra Reed Lemur or Bandru (*Hapalemur griseus alaotrensis*), a subspecies of the Grey Bamboo Lemur, and the importance of protecting the reed and papyrus beds. This lemur has been classified as Critical by the IUCN. The only lemur to live in an aquatic environment, the Alaotra Reed Lemur is larger than other subspecies of the Grey Gentle Lemur and lives in close, family groups (Garbutt 1999). To move about in the reed beds, they climb up a reed stem until it bends, and then walk along it to reach the next stem; their major food is the endemic papyrus, along with grasses and ferns (Garbutt 1999). Lake Alaotra's reed beds are its sole habitat, and although previously widespread in this and another lake to the north, only two isolated populations of lemurs, one of which numbers fewer than 60 animals and is on the verge of extinction, remain in marsh fragments (Garbutt 1999). This lemur has the most restricted range of any lemur species or subspecies (Garbutt 1999). The film, Madagascar. A World Apart, includes a moving segment on these lemurs feeding among the papyrus when a Malagasy canoe enters the marsh and sets a fire, causing the terrified lemurs to flee. (See Video section). Local village leaders have requested that the government set aside a protected zone in the marshes. There is hope that this lake will be brought back as a functioning ecosystem in the future and that a strict sanctuary will be set aside for this endangered lemur and the highly endangered waterbirds.

While sizeable areas of forest have been protected, few aquatic environments on Madagascar have been preserved, and native waterbird species are declining precipitously. The Madagascar Little Grebe (*Tachybaptus pelzelnii*) was once common and widespread in many parts of the island; with the pollution and destruction of marshes throughout the island for rice farms, this bird has declined greatly. The introduced tilapia was threatening this species by consuming its food supply. This grebe also hybridizes with the introduced Little Grebe (Collar *et al.* 1994). The Little Grebe, an African species which has colonized the island, prefers the habitat created by the tilapia, and is now abundant (Langrand 1990). The Madagascar Little Grebe has also drowned in fish nets, and has lost the vegetation it needed for nesting (BI 2000). It is expected to follow the Alaotra Grebe and Madagascar Pochard into extinction.

Another endemic waterbird, the Sakalava Rail (*Amaurornis olivieri*), native to western wetlands, is also extinct or nearly so. A small, sooty-black bird with yellow beak and pinkish-red legs and feet, it was native to streams and marshes in the western parts of the island. For more than 30 years, this species was not seen at all. In 1995, one was glimpsed at Lake Bemamba, and another in 1999 at the same lake (BI 2000). This species is classified as Critical (BI 2000), and Lake Bemamba and other lakes and wetlands on the west coast may be given protection by the Malagasy government, which has ratified the Ramsar Convention on wetlands preservation (BI 2000).

As a result of extensive habitat destruction and hunting, the Madagascar or Bernier's Teal (*Anas bernieri*) has likewise declined to endangered status in the few sites from which it is known on the west coast. Once widespread on the island, it is now restricted to a few marshes and shallow lakes. Small populations remain on Bemamba Lake and a few other sites (Morris and Hawkins 1998), and a flock of 67 was seen in another area (BI 2000). In 1970, 60 of these birds were seen on a lake, and as soon as this became known, European sportsmen went to the lake and killed more than 25 percent of the population (Curry-Lindahl 1972). In the 1970s, Bernier's Teal inhabited Lake Masama, but heavy hunting by both Europeans and natives with dogs has nearly eliminated them (Todd 1979). In 1993, four birds were captured for captive breeding (Collar *et al.* 1994). The Jersey Wildlife Preservation Trust is working to preserve this beleaguered species and the marshes of the west. The Madagascar Teal has been seen in three protected areas, and a conservation program at one lake has been initiated (BI 2000).

The critically endangered Madagascar Fish Eagle (*Haliaeetus vociferoides*) numbers about 250 pairs in the 600-kilometer stretch of western coastline to which it has become confined (BI 2000). This large eagle resembles the African Fish Eagle, from which it probably evolved, but instead of a snowy white head and upper body, it is streaked

with brown and has shaggy, buff crown feathers. About 35 inches long, with a 6.5-foot-wingspan, it is by far the largest bird on Madagascar. Persecuted by local people, these eagles have been shot and their nests destroyed. On one occasion in the 1990s, ornithologists saw some immigrants cut the tree where an active nest of a Madagascar Fish Eagle was located, and proceed to kill and eat the chicks! The only remaining habitat for this species is the western coast, where mangrove swamps are rapidly being destroyed (Langrand 1990, Preston-Mafham 1991). The Peregrine Fund is sponsoring research on this species, and 10 nests have been located in an area on the west coast in the Three Lakes Complex (BI 2000). The Fund has removed and raised chicks that would have been killed by siblings and released them to augment the population. The fish it feeds on are being depleted, however, by a gill-net fishery that has recently been established. A new Malagasy law allows local communities to control their own resources, and the people in this region are being encouraged to formalize conservation regulations prohibiting gill netting and tree cutting.

The Biological Wealth of an Impoverished Country: Birds: Page 3

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Another endemic waterbird, the Sakalava Rail (*Amaurornis olivieri*), native to western wetlands, is also extinct or nearly so. A small, sooty-black bird with yellow beak and pinkish-red legs and feet, it was native to streams and marshes in the western parts of the island. For more than 30 years, this species was not seen at all. In 1995, one was glimpsed at Lake Bemamba, and another in 1999 at the same lake (BI 2000). This species is classified as Critical (BI 2000), and Lake Bemamba and other lakes and wetlands on the west coast may be given protection by the Malagasy government, which has ratified the Ramsar Convention on wetlands preservation (BI 2000).

As a result of extensive habitat destruction and hunting, the Madagascar or Bernier's Teal (*Anas bernieri*) has likewise declined to endangered status in the few sites from which it is known on the west coast. Once widespread on the island, it is now restricted to a few marshes and shallow lakes. Small populations remain on Bemamba Lake and a few other sites (Morris and Hawkins 1998), and a flock of 67 was seen in another area (BI 2000). In 1970, 60 of these birds were seen on a lake, and as soon as this became known, European sportsmen went to the lake and killed more than 25 percent of the population (Curry-Lindahl 1972). In the 1970s, Bernier's Teal inhabited Lake Masama, but heavy hunting by both Europeans and natives with dogs has nearly eliminated them (Todd 1979). In 1993, four birds were captured for captive breeding (Collar *et al.* 1994). The Jersey Wildlife Preservation Trust is working to preserve this beleaguered species and the marshes of the west. The Madagascar Teal has been seen in three protected areas, and a conservation program at one lake has been initiated (BI 2000).

The critically endangered Madagascar Fish Eagle (*Haliaeetus vociferoides*) numbers about 250 pairs in the 600-kilometer stretch of western coastline to which it has become confined (BI 2000). This large eagle resembles the African Fish Eagle, from which it probably evolved, but instead of a snowy white head and upper body, it is streaked with brown and has shaggy, buff crown feathers. About 35 inches long, with a 6.5-foot-wingspan, it is by far the largest bird on Madagascar. Persecuted by local people, these eagles have been shot and their nests destroyed. On one occasion in the 1990s, ornithologists saw some immigrants cut the tree where an active nest of a Madagascar Fish Eagle was located, and proceed to kill and eat the chicks! The only remaining habitat for this species is the western coast, where mangrove swamps are rapidly being destroyed (Langrand 1990, Preston-Mafham 1991). The Peregrine Fund is sponsoring research on this species, and 10 nests have been located in an area on the west coast in the Three Lakes Complex (BI 2000). The Fund has removed and raised chicks that would have been killed by siblings and released them to augment the population. The fish it feeds on are being depleted, however, by a gill-net fishery that has recently been established. A new Malagasy law allows local communities to control their own resources, and the people in this region are being encouraged to formalize conservation regulations prohibiting gill netting and tree

cutting.

The Biological Wealth of an Impoverished Country: Birds: Page 4

As more and more bird-watchers come to Madagascar, the government may place a higher priority on bird conservation. A special fund to which bird-watchers could contribute might be established to purchase and maintain refuges and to conduct conservation education and other projects for local people, especially in aquatic habitats. The preservation of threatened Madagascan birds has reached a critical point. The most endangered habitats, the last of the western forests, aquatic environments, and many parts of the eastern lowland rainforests, continue to decline. The fragmentation of forests that forces animals into islands of isolation needs to be studied and remedied by establishing habitat corridors between them. One Malagasy ornithologist, Aristide Andrianarimisa, is researching the effects of forest fragmentation on birds.

Pete Morris and Frank Hawkins, authors of *Birds of Madagascar. A Photographic Guide*, state that their purpose in writing their book was to inspire people to visit Madagascar and take an interest in its avifauna and the plight of so many threatened birds, as well as to promote greater interest in wildlife and conservation among the Malagasy people. Ecotourists bring revenue to the island and, thereby, help to preserve natural areas and wildlife (Morris and Hawkins 1998). The discovery of a new species of songbird, the Cryptic Warbler, by bird-watchers in Ranomafana National Park, is an exciting byproduct of ecotourism and an indication that the study of Madagascar's birds has just begun. It also proves that amateurs play an important role in bird observation. *Birds of Madagascar* establishes a good precedent by identifying, on a species-by-species basis, the avian habitats and those birds lacking reserves within their ranges. The authors request that people coming to see the wildlife of the island let the government know why they have come in order to convince decision makers that biodiversity conservation represents a worthy investment (Morris and Hawkins 1998).

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians

The distribution and diversity of Madagascar's reptiles and amphibians have not been carefully researched until the present. Chris Raxworthy, a British herpetologist, is in the process of carrying out the first methodical survey of the estimated 500 non-marine species, all of which are endemic (Holmes 1997). To date, at least 300 reptile and about 200 frog species have been identified (Tyson 2000). This would make it one of the top five countries in the world for diversity of reptiles and amphibians. The British Isles, by contrast, with about half the land area of Madagascar, have only six species of reptiles (Preston Mafham 1991). Even the ranges of newly described lizards and frogs will not be delineated precisely for some time. Some areas remain unexplored by herpetologists, and Raxworthy finds new species of lizards and frogs on each expedition into the tangled swamps and forest fragments. On one day when accompanied by a journalist, he and fellow researchers, including Malagasy biologists, found a bright green day gecko, a strikingly beautiful yellow-and-black snake, tiny frogs resembling lichens, a leaf-tailed gecko and 4-inch chameleons with upper legs the colors of Rainbow Trout, and lower legs like toothpicks (Holmes 1997). In a reserve on Nosy Be island, he and some Earthwatch Institute volunteers rediscovered a 10-inch green lizard that had been lost to science since the 1890s, when last collected (Tyson 2000). Raxworthy is doing inventories in reserves as part of an island-wide biodiversity program, and hopes that in some impenetrable area, giant tortoises long considered extinct will be rediscovered (Holmes 1997).

Page 1 (Threatened)
Page 2 (Tortoises and Turtles)
Page 3 (Lizards)

Page 4 (Snakes)
Page 5 (Amphibians)

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians: Page 1
Of these native reptiles and amphibians, at least 19 are known to be threatened with extinction. A preliminary list includes 17 species of reptiles (four tortoises, a freshwater turtle, four sea turtles, a gecko, four chameleons and three boa snakes) and two amphibians, both frogs. All are in higher categories of threat: Endangered or Vulnerable by the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor 2000). All but the sea turtles are endemic to Madagascar.

The arid regions at the northern and southern ends of Madagascar are home to two intricately patterned tortoises, both in danger of extinction. In the north is a species considered by many to be the world's most endangered tortoise: the 18-inch Madagascar or Plowshare Tortoise (*Geochelone yniphora*), whose tan, domed shell is marked with narrow black lines in delicate hexagonal patterns. The Plowshare name came about because of a protuberance on the tortoise s lower shell that turns up, a kind of knob that remotely resembles a plowshare. This knob is used by males in sparring contests. From the 17th century onward, thousands of these tortoises, which were once abundant and widespread, were shipped every year to the nearby Comoro Islands to use as meat for settlers, driving the species to the edge of extinction before the trade finally ended in the 19th century (Juvic *et al.* 1981). Their populations never recovered, due to the continued take by villagers for pets and the massive destruction of their habitat. Known to the Malagasy as the "Angonoka," this tortoise was headed for extinction until 1985 when the Jersey Wildlife Preservation Trust was requested by the IUCN to work with the Malagasy government in formulating a rescue plan, Project Angonoka (Reid 1995). Research on the tortoise s wild status and behavior began immediately, and a captive-breeding program was established at a government forestry station (Reid 1995).

By 1986, eight adult tortoises had been gathered from the wild and placed in an enclosure which had ample vegetation and conditions natural enough that two male Angonokas immediately began their fights of strength (Reid 1995). Gerald Durrell, founder of the Jersey Wildlife Preservation Trust, in his book, *The Aye-aye and I* (1993), described lone males showing no interest in breeding, even if surrounded by females. But when another male is present, they face each other prepared for combat: "The two males, rotund as Tweedledum and Tweedledee dressed for battle, approach each other at what, for a tortoise, is a smart trot. The shells clash together, and then the plowshare comes into use. Each male struggles to get this projection beneath his opponent and overturn him to win a victory in this bloodless duel" (Durrell 1993). Finally, when one is able to overturn his opponent, he lumbers over to mate with the female while the vanquished male "wanders dispiritedly away" (Durrell 1993).

Project Angonoka has shown success both in captive breeding these tortoises, which may number only between 300 and 1,000 in the wild, and in working with local people to conserve remaining wild populations (Durbin *et al.* 1996). In fact, by 1995, a total of 140 captive-bred juveniles, ranging in age from 10 months to 6 years, had been produced at the breeding center. The breeding program was described in an illustrated article entitled "Observations on Hatchling and Juvenile Captive-bred Angonoka in Madagascar," published in the Jersey Wildlife Preservation Trust's annual journal, *The Dodo,* issued early in 1996. Within months, the captive-breeding program was devastated by the theft of 76 animals--two adult females and 74 hatchlings. On May 6, 1996, someone cut through the flimsy chain-link fence and the wire of the enclosure and took half the animals that were the fruit of a decade's work. Not until a female is 20 years old does she begin breeding, so the loss of two breeding females and their hatchlings dealt the program a devastating setback (McNeil 1996a). The burglary may have been an inside job, since the dog on the premises did not bark to alert the personnel who were sleeping close by (Tyson 2000). It is unlikely that these adult females will breed in captivity, as there are almost no adult male Plowshare Tortoises in breeding programs, and without more than one, no breeding occurs.

Animal smugglers care little about the effect of their actions on the survival of endangered species. Reptile collectors will pay thousands of dollars for rare specimens, and this break-in had been planned. A Dutch rare animal dealer had advertised Plowshare hatchlings for sale the month before, at $3,000 apiece, saying they would be "available soon" (McNeil 1996a). Ten of the hatchlings were traced to Prague, where wildlife law enforcement is weak, and others were suspected to be in the Netherlands, where they would be sold to collectors in the United States, Spain, Germany and Japan (McNeil 1996a). The loss of these tortoises cost the breeding program years of work. Don Reid, the Conservation Field Officer in charge of the Plowshare Tortoise captive-breeding program, had experimented for years to achieve a proper diet for the tortoises, arranged male combats, and conducted lengthy experiments to learn proper conditions for the eggs to hatch (Reid 1995). These tortoises became so tame that they would stretch their necks out to be scratched (McNeil 1996a). Although discouraged by the theft, he continued the breeding program; 40 new tortoise hatchlings were produced in late 1996, bringing the total to 130 juveniles. In 1998, several of the smuggled tortoises were seized from a Malaysian animal dealer in Mexico City who had been the subject of a long-term U.S. Fish and Wildlife Service undercover investigation. The same year, three more Plowshare Tortoises were seized in Belgium as they were being imported (TRAFFIC 1999a). The species is listed by the *2000 IUCN Red List of Threatened Species* as Vulnerable, and is protected by the Malagasy government, which bans trade.

Officials from the Jersey Wildlife Preservation Trust and other conservationists have sponsored education programs aimed at informing local people about the tortoises and their rarity. This has resulted in their cooperation in helping to guard wild tortoises from poachers and control brush fires (Durbin *et al.* 1996). This region in northwestern Madagascar has lost most of its forest cover; Arab residents cut trees and burn them to clear the land for agriculture, and feral pigs kill the young wild tortoises (Durbin *et al.* 1996). So much clearance of natural vegetation has taken place that the climate has become increasingly more arid, causing ponds to dry up. Tree cutters are now turning to the mangroves, causing siltation of the inlets, which affects prawn harvests (Durbin *et al.* 1996) and destroys a key aquatic environment on the island.

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians: Page 2

The Plowshare Tortoises have been reduced to a few forest sites, and in spite of the urgent need for a reserve, none has been set aside. The area is getting conservation help with the formation of a new organization by conservation biologists, the Association to Safeguard the Environment. Its purpose is to involve local people in environmental projects, such as planting cashew trees, learning fire suppression methods, and trapping bush pigs; they are also giving conservation lessons to children and conducting literacy classes (Durbin *et al.* 1996).

The Radiated Tortoise (*Geochelone radiata*) inhabits the drylands of the extreme south, where the strange Didierea plants and other desert vegetation grow in open shrubland. Many people consider this tortoise to be the most beautiful in the world. Delicate yellow sunburst patterns adorn the top of its 16-inch-long black shell, and the underside is marked with diamond patterns. These tortoises also declined after tens of thousands were killed to supply local villagers with meat, or exported to the Comoro Islands from the 17th century on for meat markets abroad. In 1922 alone, 22,000 of these tortoises were exported (Jolly 1980). The legal trade did not cease until 1930. The tortoise populations have not rebounded, and illegal capture for collectors and zoos may be the explanation. The slow reproduction of this species means that it cannot quickly make up for losses in its population. An extremely long-lived species, it has evolved with low natural mortality and has few young. As an example of its longevity, a Radiated Tortoise of unknown age presented to the Queen of Tonga by Captain Cook in the 1770s, lived until 1966, making it almost 190 years old at its death (Jackson 1993).

The lovely patterns on this tortoise's shell, which vary from individual to individual, have placed it in great demand around the world, encouraging poverty-stricken Malagasy to risk jail to earn the money that these tortoises bring.

Thousands of Radiated Tortoises have been collected for the international market, sold in Europe, North America and elsewhere for $2,000 or more per animal. In spite of having a range that is far larger than that of the Plowshare Tortoise, the Radiated Tortoise is declining rapidly toward extinction. The species is listed by the *2000 IUCN Red List of Threatened Species* as Vulnerable. Export and collection of Radiated Tortoises are prohibited by the Malagasy government, with severe penalties for violations including prison sentences. The United States lists both the Radiated and Plowshare Tortoises on the Endangered Species Act, which prohibits commercial importation. International commercial trade is banned by their listing on Appendix I of CITES. Still, the smuggling continues, fed by the many wealthy collectors who have no conscience about the effect their purchase has on wild populations, and the zoos that knowingly purchase smuggled animals. Malagasy authorities have failed to put an end to the poaching, especially of the Radiated Tortoise and other southern species.

Donovan Webster, a journalist, researched the rampant smuggling of Radiated Tortoises and other wildlife from the island for *The New York Times Magazine*, which published his lengthy article on February 16, 1997. The magazine cover featured the article and read: "I was caught in Madagascar. Peddled for 30 cents. Smuggled to Orlando. Sold for $10,000. I'm a rare, coveted tortoise--coldblooded contraband." Webster found that Madagascar was a "pirate's paradise," with little or no local enforcement of conservation laws. Its long and unpatrolled coastline is used by smugglers, who load tortoises onto small boats at night, with little fear of arrest (Webster 1997). Although some enforcement of capture bans takes place in the range of the Radiated Tortoise, local people have learned to avoid arrest.

The contrast between the attitudes of local people toward the Plowshare Tortoise in the north, where education programs have been carried out by the Jersey Wildlife Preservation Trust, and the south, where no strong program exists to protect the Radiated Tortoise and other wildlife, could not be more dramatic. In the south, poaching Radiated Tortoises and other reptiles is considered an accepted form of revenue by the extremely poor people of the region. At local bars and restaurants, Webster was approached by people who offered to produce a rare snake within 24 hours. Snakes are a favorite animal for smugglers because they can be secreted in small bags and placed in luggage or, if they are small enough, in pockets. He refused a boa, which was offered at $300 and could be sold for $2,000 in the United States (Webster 1997).

Webster exposed a large-scale and fairly open trade in Radiated Tortoises in local markets within the range of these tortoises. He visited a woman who was reputed to have many of these tortoises for sale. She showed him 24 Radiated Tortoises which she kept ready for sale to anyone who would pay the right price; they were crowded into a make-shift pen in her living room, stacked two and three deep in filthy conditions (Webster 1997). They grunted and made hissing sounds when disturbed, scratching and scrabbling against one another and the pen sides; their shells were covered with dust, and most appeared to be sickly (Webster 1997). The woman tossed the tortoises back into the pile after handling them. She claimed that she sold them to local people for $1.35, and to outsiders for $4 or more, depending on how many tortoises she had at the time (Webster 1997). She also admitted supplying a smuggler who arrived once a week in a canoe at a remote beach with any Radiated Tortoises she had in stock (Webster 1997).

These tortoises are absurdly easy to collect in the wild, living in open shrubland and moving so slowly that they can be picked up as easily as rocks. Webster witnessed the capture of one mature tortoise which Benjamin, one of the collectors, located in the shadow of a boulder. When he approached, the tortoise hissed and tried to crawl beneath bushes, but it was easily grabbed, and he flipped it on its back; soon he caught two other adult tortoises who had a baby the size of a small stone wedged beneath them in an apparent attempt to protect it (Webster 1997). Collectors wrap string around the tortoises shells to form handles for carrying them. When they met at the end of the day, they had taken 54 mature tortoises and many young ones, making it a "banner day" (Webster 1997). The occasional presence of enforcement officers and World Wildlife Fund (WWF) representatives did not seem to present any anxiety of threat of arrest to the collectors (Webster 1997).

Each Radiated Tortoise is worth at least $2,000 once smuggled out of Madagascar, and those with unusually exquisite patterns bring as much as $10,000 (Webster 1997). Benjamin later admitted that he was aware that the tortoises were

becoming rarer and that their range had shrunk in recent years; he also knew that many were very old, probably older than his own 53 years. It was obvious that the tortoises would soon be gone, but he believed this was his only potential income source; he was uncertain about how he would make a living when there were no more Radiated Tortoises (Webster 1997).

Some of the smuggled Radiated Tortoises leaving Madagascar have been seized by importing countries. In May 1992, for example, a Dutch citizen arriving from Madagascar was stopped by Customs at Roissy Airport in the Netherlands in possession of 46 Radiated Tortoises as well as 14 bamboo lemurs of several species and seven endangered Madagascar Boas (*Acrantophis madagascariensis*); the animals were confiscated and returned to Madagascar (TRAFFIC 1992). In 1998, a Radiated Tortoise was among many rare tortoises seized in Belgium as they were being imported, and U.S. authorities, under Operation Chameleon, an undercover investigation of trafficking in illegal Madagascar reptiles, seized Radiated Tortoises from an American reptile dealer in Miami. In May 1999, French Customs officers seized 450 tortoises smuggled by three Malagasy citizens living in Paris (TRAFFIC 1999b). Among them were 120 Radiated Tortoises; the suspects were not arrested (TRAFFIC 1999b).

Most ecotourism on the island has been developed for viewing lemurs, chameleons and birds, but the Radiated Tortoise and its extraordinary habitat of endemic plants have the potential of attracting many tourists. Also living in this tortoise's habitat are spectacular sifakas, many unusual birds, and other reptiles. In Beza-Mahafaly Reserve, scientists are studying the ecology and longevity of these tortoises, as well as searching for a permanent form of marking that would make them unattractive to collectors. The Radiated Tortoise could be conserved while helping local people like Benjamin. Grants from international organizations could finance jobs held by local people, such as ex-poachers, to protect the tortoises and serve as wardens. Former collectors could help educate schoolchildren and local people about protecting Radiated Tortoises and other wildlife. Organizations, such as Earthwatch Institute, might sponsor research to study the status of these tortoises. The presence of scientists would pose a deterrent to poachers.

Two other endemic tortoises, the Spider Tortoise (*Pyxis archnoides*) and the highly endangered Flat shelled Tortoise (*Pyxis planicauda*), are much smaller, about 5 or 6 inches long (Preston Mafham 1991). The latter tortoise is restricted to a forest of only 40 square miles, and a captive breeding program is attempting to prevent its extinction. Both these tortoises lay only a single, large egg (Preston Mafham 1991). These tortoises are also in demand by reptile collectors. In August 1996, six men were indicted after being arrested with four Spider Tortoises in their luggage at the Orlando International Airport in Florida. They were part of a smuggling ring supplying rare reptiles to collectors. In 1999, 330 Spider Tortoises were seized along with Radiated Tortoises in the case cited above (TRAFFIC 1999b).

The Madagascar Big-headed Turtle (*Erymnochelys madagascariensis*), is an endangered freshwater species listed in the *2000 IUCN Red List of Threatened Species* and on Appendix II of CITES. This turtle is related to South American river turtles, another link that may date back to the time before Madagascar drifted away from Gondwana. The Jersey Wildlife Preservation Trust began a breeding program for these turtles in 1999 with the objective of releasing young turtles back into the wild after educating local people.

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Madagascar is home to two thirds of the world's chameleons--at least 62 species--more than any other country (Tyson 2000). Among the island's endemic chameleons are the world's smallest and largest species. The smallest, *Brookesia minima*, is only 1.3 inches long, while the largest, *Furcifer oustaleti*, measures 27 inches in length (Preston Mafham 1991). Their conical eyes, moving independently, can look forward and backward at the same time, swiveling almost 180 degrees in either direction (Preston-Mafham 1991). This adaptation, processing totally divergent information spontaneously, would confuse most vertebrates, but chameleons, even very young ones, are adept at using these dual periscopes to locate insects and other prey. They hold onto the thinnest branch with their prehensile tails, and with

long, thin legs bent at the knees, they walk in an odd back-and-forth swaying motion that resembles leaves moving in the wind. Their chunky bodies and spindly legs give them an awkward appearance, but they are superbly adapted to catching their prey by unfurling a long, sticky tongue--curled upside their mouth--with lightning speed, nailing an unaware insect with astonishing accuracy.

Their camouflage coloration, which varies greatly from bright greens, mottled browns, reds and blues, helps protect them from avian and mammal predators. Contrary to general opinion, chameleons do not change colors as they move about in the trees or on the ground to match their background. When they suddenly change colors, it is as a territorial or sexual display meant for other chameleons (Preston-Mafham 1991). Some species have horns and other protuberances, giving them the appearance of miniature dinosaurs. A few species show sexual dimorphism, or a physical difference between the sexes. The contrast can be so striking that some were considered separate species when first identified (Burger and Price 1996). In one species, for example, the female is black and yellow, and the male a mottled brown and white (Burger and Price 1996).

Chameleons are heavily exploited by collectors who capture them for sale in pet stores around the world, threatening them. Collectors will pay $1,000 or more per animal for rare species. This trade, which involves thousands of individuals, has caused declines in many species. The Malagasy government has banned trade in most species, but enforcement is not strong. One chameleon, *Chamaeleo brevicornis*, of which 795 were exported in the first six months of 1990, is restricted to only a few areas of primary forest (Behra 1993). An ongoing study will evaluate whether to allow trade in the commoner species. Chameleons captured and shipped abroad for the pet trade suffer very high mortality as a result of inhumane transport conditions and inadequate care in pet stores and people's homes. They require special conditions of temperature and humidity, and many have specialized diets. In short, they are not suited to being house pets. In the care of specialists, they can be kept alive, but most captive breeding has been unsuccessful. Some of the rarer species, such as the beautiful blue-green Parson's Chameleon (*Chamaeleo parsonii*), which can reach lengths of more than 20 inches, have not been bred to the second generation**,** and mortality is high. All chameleons are on Appendix II of CITES, which requires export permits, but none has been listed on Appendix I of CITES, which would ban commercial trade.

Although some chameleons have adapted to disturbed habitats, such as weedy fields and shrub landscape, the majority favor natural habitats. The small *Brookesia* chameleons, of which one species is listed by IUCN as Vulnerable (Hilton-Taylor 2000), require undisturbed, primary old-growth forest. Three other chameleons, all *Furcifer* genus, are listed as Vulnerable by IUCN. All are in decline, approaching endangered status.

Although many Malagasy regard chameleons as ugly porters of bad luck (Burger and Price 1996), for tourists, they are the second most popular animals, after lemurs. Some Malagasy, aware of the fascination with which chameleons are held by tourists, capture them and offer them for viewing or sale.

Another lizard being captured for the pet trade is the extraordinary 4-inch-long Leaf tailed Gecko, *Uroplatus fimbriatus*, a true master of camouflage. Resting during the day with its head tight against a tree trunk, an elaborate lacy fringe along the underside of the body allows it to melt into the tree, while its skin is patterned to resemble tree bark. Even its golden eyes are streaked with tiny dark lines that imitate bark. With broad, flattened front feet splayed out against the bark and hind legs held vertically under a spatula like tail, it becomes virtually invisible (Preston Mafham 1991). If discovered, however, it has a defense. Opening its mouth wide to reveal a crimson red tongue, it raises its tail vertically and emits an ear-splitting screech, no doubt intended to be a fearsome display (Preston Mafham 1991, Tyson 1994). Malagasy boys have discovered the haunts of the Leaf-tailed Geckos, and capture hundreds--thousands by their accounting--for sale to foreign middlemen who pay them less than $1. They are sold in the United States for $250 a pair (Tyson 1994, Tyson 2000). On Nosy Be island off the northern coast, schoolboys claim to have captured 40,000 over the past six years (Tyson 2000). A threatened gecko, Standing's Day Gecko (*Phelsuma standingi*), is native to the spiny forests of the south and is one of the most coveted by collectors (Tyson 2000). It is hunted out of many areas because Malagasy have captured hundreds, receiving $1.20 per gecko, while reporting only a few to authorities (Tyson 2000). It is on CITES Appendix II, and sells in the United States for

$80 to $200 apiece (Tyson 2000). Most species of geckos bring the village collectors only about 3 U.S. cents, while the exporter receives $9 to $13 and U.S. retailers get $75 or more (Burger and Price 1996). In most cases, these pet reptiles live a very short time, and represent a mere toy to the consumer.

The export trade in live lizards involves an enormous number of animals. One gecko, *Phelsuma serraticauda*, was known only from a few museum specimens until 1,360 specimens were chronicled as exported during the first six months of 1990 for the pet trade (Behra 1993). During this same period, 22,837 lizards--geckos, *Phelsuma* genus, and chameleons, *Chamaeleo* genus--were exported from Madagascar (Behra 1993). Between 1986 and 1991, almost 145,000 lizards of 17 species were exported; of these at least 38,325 were chameleons of 21 species (Burger and Price 1996). Many of these are species that are endemic to restricted areas, or threatened in the wild. The U.S. Fish and Wildlife Service s Operation Chameleon succeeded in arresting 19 people in 1998, among whom was a major Malaysian smuggler and an American, Tommy Crutchfield, who was arrested at Miami International Airport with suitcases full of rare snakes, tortoises and lizards. In another case, a Canadian and a Dutchman were arrested at Chiang Kai-shek International Airport in Taiwan with numerous chameleons and geckos, including some threatened Standing's Day Geckos.

Several gecko species have extremely limited ranges. A newly described leaf gecko, *Uroplatus malama*, is known from a single specimen taken in a remnant of lowland rainforest in southeastern Madagascar (Burger and Price 1996). Only two specimens of a closely related species, *Uroplatus malahelo*, exist, native to a small patch of forest in the south (Burger and Price 1996). When discovered, its habitat was being logged, and the species may already be extinct (Burger and Price 1996). An extremely rare lizard, *Zonosaurus boettgeri*, known from two specimens that were taken in the 1890s and subsequently disappeared, has been rediscovered on the island of Nosy Be by herpetologist Chris Raxworthy and volunteers from Earthwatch Institute (Tyson 2000). The two individual lizards were killed as specimens upon rediscovery (Tyson 2000).

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Among Madagascar's 80 types of snakes--all non-poisonous--are three boas, whose closest relatives are found in South America (Burger and Price 1996). They are thought to be among the island's most ancient inhabitants, resident since the early breakup of Gondwana (Preston Mafham 1991). All are considered Vulnerable by the IUCN (Hilton-Taylor 2000): Dumeril's Boa (*Acrantophis dumerili*), Madagascar Boa (*Acrantophis madagascariensis)*, and the Madagascar Tree Boa (*Sanzinia madagascariensis*). The first two are Madagascar's largest snakes, reaching almost 6 feet in length; Dumeril's Boa is restricted to the south and southwest, while the Madagascar Boa is found in the north and northeast (Preston Mafham 1991). Both species require humid habitats along streams and watercourses. Placid and slow moving, they are often killed or captured by local people. The Madagascar Tree Boa is smaller and more common, shaded in delicate grayish-green with a purplish blue tinge. Little is known of any of these species' life histories and diets (Preston Mafham 1994). A very rare and possibly extinct snake, *Pararhadinea albignaci*, is known only from a single specimen picked up, dead, off the road in eastern Madagascar in 1970. This species has never been seen alive in its forest home (Preston-Mafham 1991).

One of the most extraordinary snakes in the world, *Langaha nasuta*, mimics a dry, pencil-thin twig to camouflage itself among the leaves. The female's nose is extended into a leaf shaped structure adorned with scales and small tooth like projections, while the nose of the male is elongated, tapering into a sharp point to resemble a thorn (photo in Preston Mafham 1991 and Lamar 1997).

A smuggling operation involving hundreds of Madagascar reptiles was exposed in August 1996, when six men were charged with conspiracy to smuggle rare Madagascar reptiles into the United States and Canada. According to the U.S. Justice Department, two men were arrested at Orlando International Airport in Florida with 61 Madagascan tree

snakes in their suitcases that were to be sold at a large reptile breeders show in Orlando (Reuters 1996). Four Germans, one Canadian and one South African were indicted. Simon Harris, the South African, had $100,000 worth of rare reptiles in his luggage; he cooperated to implicate the other suspects, who are still being sought (Reuters 1996). These smugglers shipped snakes and tortoises, concealed in suitcases, from Europe to Canada and the United States and received payment by international wire transfers. Most of the snakes and tortoises were listed on CITES. In 1998, 26 Madagascan Tree Boas were seized in Belgium, and an American reptile dealer was caught by the U.S. Fish and Wildlife Service with the latter species and Dumeril's Ground Boas in his luggage at Miami International Airport (TRAFFIC 1999a).

The sea turtles inhabiting Madagascar's coastal waters are heavily exploited in spite of their listing on Appendix I of CITES. A survey in 1971 estimated that 13,000 were killed along the west coast alone (Burger and Price 1996). Little is known of their present populations.

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians: Page 5

Some 176 species of amphibians, all frogs, have been named and described (Mittermeier *et al.* 1999). Raxworthy estimates that there are another 124, many of which have already been found but not yet described scientifically (Tyson 2000). Salamanders and toads are absent from Madagascar. All but two frogs are endemic, one of which was introduced from Asia by French colonialists as a gourmet food source (Burger and Price 1996). The majority are native to rainforest environments, the most endangered type of habitat on the island. In one such area, a montane rainforest in the Andasibe region, 90 species are native--the highest diversity of frogs in the world (Burger and Price 1996). Since 1990, 13 new species of a single, colorful genus, *Boophis*, have been described, and others await naming by scientists (Burger and Price 1996). A candidate for the world's smallest frog--and perhaps the world's smallest vertebrate--is a minute frog, *Stumpffia pygmaea*, which measures less than 3 millimeters in length (0.117 inches) (Burger and Price 1996). This frog lays its eggs in foam nests hidden among leaves on the forest floor, and the tadpoles grow into froglets without ever feeding (Burger and Price 1996).

The most spectacular Malagasy frog may be the bright red Tomato Frog (*Dyscophus antongili*), which secretes poisonous white mucous when threatened. Some authorities consider the species to be endangered (Bauer 1995), while the *2000 IUCN Red List of Threatened Species* lists it as Vulnerable. To protect it from trade, it is listed on Appendix I of CITES. Fat and squat, this toad-like frog is large enough to cover the palm of a hand (Preston-Mafham 1991). Tomato Frogs have a very restricted range in the region of Tamatave on the east coast; some live in plantations, where pools of water gather, and even in garden ponds (Preston-Mafham 1991). Collectors, pet dealers and zoos have offered thousands of dollars for these frogs, and illegal shipments containing 40 or more Tomato Frogs have been confiscated.

One study entitled "The Export of Reptiles and Amphibians from Madagascar," by Olivier Behra (1993), chronicled the extent of exploitation of frogs. In 1988, 230 frogs of the genus *Mantella*, endemic to Madagascar, were exported. The demand increased, causing exports to rise astronomically to 11,058 in 1989; in the first six months of 1990 alone, almost 11,000 were exported, mainly to Denmark and other European countries, the United States and Japan (Behra 1993). These brightly colored little frogs are sold as pets and to decorate terrariums. The most popular Madagascar frog in this trade is the tiny Golden Mantella (*Mantella aurantiaca*), of which 3,237 were exported in the first six months of 1990 (Behra 1993). This frog is restricted to eastern Madagascar, and is apparently rare and declining (IUCN 1994). It lives in pandanus swamps in rainforests, which are rapidly disappearing, and no part of its habitat has been set aside in a reserve (IUCN 1994). Unlike most frogs, the Golden Mantella is slow-reproducing (IUCN 1994). In the 1990s, 3,000 to 6,000 were exported annually from Madagascar, and in 1994, two proposals sought to list this species on CITES, one on Appendix I and the other on Appendix II. The latter proposal succeeded, which is unfortunate, since it allows the trade to continue. The *2000 IUCN Red List of Threatened Species* lists the Golden

Mantella as Vulnerable (see photos of gold and red phases of this species in Lamar 1997).

In 1998, two people were arrested in Taiwan trying to smuggle frogs of two *Mantella* species (*Mantella madagascariensis* and *Mantella aurantiaca*), along with some Madagascar lizards. Another seizure of 50 Mantella frogs occurred at Zaventem Airport in Belgium in 1998 as they were being smuggled from Madagascar (TRAFFIC 1999a). Such seizures involved shipments without the proper export permits. Appendix I listing under CITES would provide greater protection.

The Biological Wealth of an Impoverished Country: Invertebrates

Like the rest of its fauna, Madagascar's invertebrates are extraordinary. One insect from the age of the dinosaurs, the Giraffe-necked Weevil (*Trachelophorus giraffa*), has an elongated neck which rises vertically, then makes a right-angle turn and extends horizontally, and ends in a tiny head with furry antennae. Amazingly, this insect has counterparts in New Zealand known as giraffe weevils (Molloy 1994). This may be explained by the fact that New Zealand was also part of Gondwana prior to its breakup (Molloy 1994). Other ancient species include the 100 species of hissing cockroaches. Some are far larger than any other cockroach species in the world; their heavy bodies resemble long-extinct trilobites. The largest species measure up to four inches long, and thousands are exported for the novelty pet trade and for zoos. When touched, they hiss loudly, and males aggressively charge one another with their armored, knobbed shields (Preston-Mafham 1991).

One of the richest land-snail faunas in the world is native, with more than 380 species named so far, 361 of which are endemic and differ greatly from land snails in Africa (Preston-Mafham 1991). Many are threatened, however, by introduced African Giant Snails (*Achatina fulica*) and several other non-native snails introduced to control the African Giant Snail, but threatening native species instead. One native snail, *Tropidophora deburghiae*, is considered endangered by some authorities. Brilliantly colored slugs, or shell-less snails up to 6 inches long, striped in black-and-red or yellow-and-brown, live on the damp rainforest floor (Preston-Mafham 1991). Many have limited distributions and can be easily eliminated by habitat destruction (Preston-Mafham 1991).

An extremely ancient family of spiders, Archaeidae, first described from a specimen frozen in amber several million years old, has seven species on Madagascar, one in South Africa, three in Australia, five in New Zealand and one at the tip of South America; these species appear to be vestiges from the ancient supercontinent (Preston-Mafham 1991). The Archaeidae spiders have strange, grotesquely shaped bodies, visible only through a microscope since they are only 0.14 inches long; they live among leaf litter on the ground (Preston-Mafham 1991). Some Madagascar spiders are extremely bizarre, with shapes that resemble bat-winged leaves, bright red thorns, or mottled brown lumps on logs (Preston-Mafham 1991).

Millipedes on Madagascar reach 6 inches and exude droplets of poison when attacked; Brown Lemurs have found ways of avoiding this toxin and feed on them (Preston-Mafham 1991). Shield-bugs, or stink-bugs, of the family Pentatomidae, have 220 species on Madagascar, many of which are brightly colored in reds, oranges and blacks; 120 species of water bugs, of which 80 percent are endemic, and a variety of assassin bugs add to the rich insect fauna (Preston-Mafham 1991). About 20,000 beetle species, including 500 species of endemic jewel-beetles, are native to Madagascar. Jewel-beetles, with their colorful, metallic bodies, appear during the rainy season in southern and western forests (Preston-Mafham 1991). Many species of scarab beetles, among which are dung beetles, are also native to Madagascar; one endemic genus, *Helictopleurus*, roll the dung balls into their nests and lay their eggs in them (Preston-Mafham 1991).

Madagascar's butterflies, totaling 300 species, are not as diverse as in some parts of the world, such as the Tambopata Natural Reserve in Peru, which has 1,300 species. This may be because they colonized the island fairly recently.

Another possibility is that many species have faded into extinction, leaving no trace, when the plant species upon which they depended were driven to extinction by habitat destruction. Since 80 percent of the island's forests have been cut, hundreds or thousands of species may have disappeared without a trace millennia ago. One Madagascar butterfly, a pale cream-and-black Swallowtail, *Papilio mangoura*, is hotly pursued by collectors because of its rarity (Preston-Mafham 1991). Several butterflies of the Nymphalidae family, or Fritillaries, are threatened, as are two species of the family Acraeidae.

In the 19th century, Charles Darwin learned of a spectacular, white Madagascar orchid (*Angraecum sesquipedale*) that had an extremely long, nectar-bearing tube dangling down from the flower. He reasoned that it could be pollinated only by an insect that could reach its nectar. He guessed that it might be "some huge moth, with a wonderfully long proboscis." Entomologists verified his belief with the 1903 discovery of the hawkmoth, *Xanthopan morgani praedicta*. This moth has a 9-inch tongue that it keeps wound in a spiral in its mouth, unfurling it to reach the nectar of this particular orchid. In a similar arrangement, another orchid (*Angraecum arachnites*), exudes a strange odor that attracts only one pollinator, the rainforest hawkmoth, *Panogena lingens* (Preston-Mafham 1991). The nectar at the base of this orchid's long, twisted tube can be reached only by this single species of moth--and not even every individual, but only one race of this moth which has a long, tapered proboscis (Preston-Mafham 1991). These species co-evolved, and should the moths become extinct, the orchids would have no pollinators and would follow them into extinction. Another unusual moth, the huge Comet Moth (*Argema mittrei*), is one of the largest moths in the world (Preston-Mafham 1991).

Preserving Madagascar's Natural Wonders

This fourth largest island in the world is, in many respects, a minicontinent. This evolutionary treasure-house is of great importance from a worldwide perspective. Madagascar's diversity of life forms is so great that as many as 200,000 species, most of them undescribed, may be native, of which an estimated 150,000 are endemic species (Daley 1997). The habitat loss is proceeding so rapidly, however, that the underfunded biological assessment studies will be unable to appraise this biological wealth before it disappears before their very eyes. Logging and burning have reduced the forested area from 120,000 to 20,000 square miles; this destruction still consumes vast areas each year (Daley 1997). It is estimated that all the remaining accessible forests will disappear within the next 35 years (Sayer *et al.* 1992). With the impending loss of these treasures, many conservationists and scientists consider Madagascar the world's most threatened natural area (Sayer *et al.* 1992).

Less than 5 percent of Madagascar is protected in reserves and parks. Even if these lands remain intact, they represent too small a percentage of forest to preserve the island's genetic heritage. Other than Masoala National Park, which encompasses most of an entire peninsula, some 840 square miles, most reserves are relatively small--islands of forest surrounded by denuded land. Should all surrounding forest be leveled, these isolated fragments would not be sufficient to prevent genetic impoverishment, inbreeding, and eventual extinction of the very species the reserves were meant to protect. Recent research in the Amazon has shown that forest fragmentation results in extinctions, in direct relation to the size of the reserve (Peters and Lovejoy 1990). The larger the reserve, the fewer extinctions. For this reason, Masoala National Park is receiving special attention from scientists. Stanford University's Center for Conservation Biology is analyzing a Geographic Information System (Kremen 1998). So far, this research has revealed that forests on the eastern border of the park are the most threatened, with a likelihood that they will be completely burned away within 25 years (Kremen 1998). The borders of the park were delineated according to the results of biological surveys, a method that is so new that it has not even been used in the United States. Claire Kremen of the Wildlife Conservation Society, with additional support from the National Geographic Society, worked with a Malagasy entomologist and two American ornithologists to conduct detailed biological species diversity studies in this rugged terrain (Kremen 1998). Five new species of butterflies and many other insects were discovered. Each had its own micro-habitat, endemic to that area. Habitats included in the national park are lowland rainforest; cloud

forest and montane heath; coastal and seasonally flooded forest; mangrove; marsh; estuary; bay; lagoon; and coral reef. Lemurs and a vast array of wildlife and plants will benefit from this new park.

Masoala National Park will not displace villages but will conduct education programs and involve them in the conservation of local wildlife. The Missouri Botanical Garden is also involved in the management of Masoala National Park, helping to inventory its rare plants and working with local people for non-destructive agricultural and fisheries industries. Work is also proceeding to stop the cutting of forests for firewood on Masoala and to provide public education on land use (Sayer *et al.* 1992). Some 300 or so villages exist within or nearby Masoala National Park, and the cooperation of the local people is crucial to the success of this park. The final plan for the park involved a compromise in which some cutting of four relatively fast-growing trees, including rosewood, would be allowed. Local communities, which will profit from the products, will be allowed to harvest palm seeds and butterflies. This will prevent the slash-and-burn destruction that was eating rapidly away at this forest (Kremen 1998). This park's endemic plants and animals, including the Red Ruffed Lemur, which exists only in the park, rely for their survival on the protection of this last sizeable rainforest. It will represent an experiment in conservation management that will have serious consequences should it fail. It is, however, one of the first times that ecological rules are being worked out with large numbers of local people to help protect such a large area. Elsewhere in Madagascar, similar projects are in the works.

Many of Madagascar's rarest species are not protected in any reserves, however, and may soon be lost. Reserves and parks, the last refuge for many species, are regularly pillaged for trees, and wildlife is killed or captured. A herpetologist surveying in Bemaraha Reserve, in the western part of the island, discovered a pile of illegally cut trees that had been marked with red paint as part of a botanist's study by the trail in 1996 (Holmes 1997). This is not an isolated occurrence. The native wildlife and plants are among the most endangered in the world. More than 124 vertebrate species are listed in the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor 2000), as well as 306 species of plants (Walter and Gillett 1998). While this crisis is occurring, new species of lemurs, reptiles, invertebrates and plants are being discovered, making the preservation of the environment all the more urgent. Obviously, the amazing biological diversity of Madagascar has not been fully assessed and may be far greater than previously thought.

Several species thought long-extinct are rumored to survive, adding even more mystery to the picture. Many Malagasy have told scientists of having seen an animal that might be a pygmy hippopotamus. Shown a picture of an African Common Hippopotamus, they have said that it was similar, but had floppy ears, uncloven hooves, dark skin, except for pinkish areas around the eyes and mouth, and was the size of a calf or small cow (Tyson 2000). As recently as 1976, a man told biologists of having seen and heard one grunting; many unsolicited, independent accounts from Malagasy have agreed on these details (Tyson 2000). They call the animal "kilopilopitsofy," and many are afraid of being chased by it (Tyson 2000). The Common Hippopotamus of Africa also grunts and kills more people than any other animal on the continent.

A long-lost primate, ground-dwelling and the size of a 7-year-old child, has also been reported by several Malagasy (Tyson 2000). This may be the same animal that was described to primatologist Alison Jolly (1980). A Malagasy told her that he had been given a young lemur of a type he had never seen before. This lemur had very dark fur, walked on its hind legs, one foot after the other, rather than hopping like a sifaka, and had a flat face different from the pointed muzzles of living lemurs. After only two months, this lemur died, and its skeleton was buried in an unknown place (Jolly 1980). An old man recently told a similar story of having seen such an animal in 1952. Called the "kidoky" by others who have seen it, it has a dark coat with white spots above and below a flat, round face. When alarmed, it flees by leaping forward in short hops like a baboon. Its call was described as a long, single whoop, and other villagers who had seen the animal said it was solitary (Tyson 2000). Scientists have said that if it exists, it might be an *Archaeolemur* or *Hadropithecus* (Tyson 2000). The fact that their descriptions seem so similar to species known to have existed makes them all the more intriguing.

Alarm calls about the impending demise of Madagascar's natural world have been sounded for decades (Jolly 1980,

1988; McNulty 1975; Preston Mafham 1991; Tyson 2000). Visitors to the island are united in their descriptions of a ravaged, eroded and deforested land. Jacques Yves Cousteau and his team visited the island for a television special aired in 1995. As they sailed toward Madagascar, they were stunned to see huge, wide, red stains of eroded soil in the water, emanating from the island's rivers, and wisps of smoke from burning forests. These red rivers are bleeding the island's life blood, its topsoil. They are so pronounced that they are among the few natural phenomena on Earth visible from orbiting space craft. Cousteau's helicopter flights over the central plateau revealed a landscape among the most devastated on the planet. A research team sponsored by Earthwatch Institute described the island from the air, "Two features of the landscape stood out even from 10 kilometers up: barrenness and smoke" (Tyson 1994).

Although erosion remains a major problem, some progress has been made to stop it (Morell 1999). Erosion costs Madagascar between $100 million and $290 million per year, caused mainly by the continued slash-and-burn agriculture (Tyson 2000). It has been extremely difficult to convince many Malagasy that the last of the forests will disappear within a generation if they do not seek alternative means of growing crops. To that end, Cornell University's International Institute for Food, Agriculture and Development, run by Norman Uphoff, has been helping farmers in the vicinity of Ranomafana National Park (Tyson 2000). These desperately poor farmers have no electricity or plumbing and struggle to feed large families on soil that is leaching its nutrients. Norman Uphoff discovered that the native Wild Ginger plant had high concentrations of phosphate, and he encouraged its use as fertilizer (Tyson 2000). By supplying seedlings and information, the Cornell program also has helped establish fish farms. Their agronomists have advised farmers to mix crops and to plant certain species in order to keep the soil rich and retard erosion; they have supplied seedlings (Tyson 2000). This agricultural advice has been helpful, but because some rural people have so many children, many are unable to produce enough crops to feed their families (Tyson 2000). Other projects involve encouraging rice cultivation with more suitable seed varieties, improved irrigation systems and application of fertilizer (Garbutt 1999). Using native bees in honey-making is also being taught to the Malagasy, who often fell old-growth trees to obtain honey (Garbutt 1999). The Kew Botanical Gardens in London and Britain's Royal Palm Society are researching the marketing of seeds from some native palm trees (Terry 1996).

International aid organizations could help preserve forests by donating fertilizer so the Malagasy would not need to practice slash-and-burn when forest soil ceases to produce crops. The urgent task of supplying the Malagasy people with methods of producing food and fuel in environmentally non-destructive ways has just begun. Villagers would be more likely to preserve trees now cut for firewood if they were provided with solar cookers or given propane tanks for fuel. Bio-gas, or methane, produced by animal dung and sewage, could be used to provide fuel and fertilizer. Such projects have been launched by international agencies in some countries of Central Asia.

Madagascar's human population is growing at a rate of 3.1 percent per year and reached 12,596,000 in 1992 (55 persons per square mile) (Anon. 1994). By 1995, it had grown to 13.9 million (61 persons per square mile) (McNeil 1996b). Another increase to 14,462,509 people (64 persons per square mile) was registered in the 1999 *World Almanac*. The *2001 New York Times Almanac* noted a population of 15,506,472, based on a July 2000 estimate. Thus, 3 million people were added to the population in just eight years. Along with the original Asians, more recent immigrants from Africa, India, Pakistan, China, Europe, and Arab countries add to the diversity. They have long since passed the carrying capacity of the land, and rice must be imported to feed the people. As one of the world's 12 poorest countries, Madagascar's external debt is approximately $4.25 billion. Average annual income is only $780 (NYT 2000). The unemployment rate is about 33 percent, and 51 percent of children are malnourished, according to a study by USAID (Tyson 2000). The literacy rate is 46 percent, and only 42 percent of children attend schools; 70 percent of children ages 6 to 9 have had no formal education (Tyson 2000). Jacques Cousteau's team filmed hordes of desperately poor people as they combed dumps for scraps of metal and food. Some people even live in these dumps in holes they have dug in the soil. Such scenes are symptoms of extreme overpopulation and rampant poverty that can also be seen in parts of Brazil and Asia.

One of the reasons that illiteracy is so high in Madagascar is that millions of people must spend their days searching for food, water and firewood, requiring the help of their children, who are then unable to attend school. In general, foreign corporations have looted the island's resources, leaving no economic base that would help the people as a

whole. One U.S. company, the Esso Corporation, is owed $25 million by the Madagascan government and demanded payment in spite of the country's cash reserves of less than $2 million (McNeil 1996b). Because of the country's debt levels, the World Bank and the International Monetary Fund are now in charge of its finances (McNeil 1996b), a potentially dangerous situation for both the people and the environment. On the positive side, a "Debt for Nature" swap was carried out in Madagascar, in which a portion of the foreign debt was exchanged for the establishment of nature reserves and parks.

To date, efforts to slow the population growth rate are still in their early stages. A program that addresses population growth, based not on threats or punishment, but on persuasion, was launched by Population Communications International (PCI) of New York City in 1996. As the organization has done in other countries, it trains local people to create communication programs for radio and television with a message that limiting family size is advantageous. The majority of the population on the island lives in cities and has access to these media. The programs, described as "soap operas" by PCI, create melodramas with characters the audience can identify with, who act out dramas. The characters in these dramas come to realize that different behavior, such as having fewer children, will result in positive changes in their lives (Ryerson 1994). In many cases, this involves elevating the status of women, and convincing men that women must be allowed to make decisions about their own reproduction (Ryerson 1994). PCI is cooperating with organizations that are actively trying to conserve the wildlife of Madagascar, such as Conservation International and the African Wildlife Foundation. Ranomafana National Park began a family planning center in 1994 to help the people of the region, many of whom have as many as 14 children, of which 62 percent are underweight and 17 percent malnourished, according to a study by the University of North Carolina (Tyson 2000).

Madagascar is a magnet for scientists from around the world and has been the recipient of millions of dollars in foreign aid and grants from international conservation agencies. Conservationists are initiating many highly inventive and effective programs to interest the Malagasy in conservation and employ them in biodiversity work. Environmental education is a key to the future of Madagascar, and programs are being carried out at Beza-Mahafaly Reserve. This protected portion of endangered spiny desert and shrubland was established when the local Mahafaly people agreed to donate the land, and funds were raised by Alison Richard, a Yale primatologist, for a training program for Malagasy scientists (Tyson 2000). Patricia Wright has set up a similar program in which Malagasy students complete master's theses based on wildlife research in Ranomafana National Park, and some students travel to the United States to receive advanced training in biodiversity and environmental protection (Tyson 2000). They will help guide the country in new directions in the future. It also opens new worlds to these students, who, in turn, will make young people aware of the natural treasures in their country. Schools that Patricia Wright has helped establish in the area of the park teach environmental education to young people. Others are also helping introduce this subject to children. Josephine Andrews, a Scottish scientist studying Black Lemurs in Nosy Be since 1988, teaches children about the lemurs with the help of a Malagasy named Julien, who guides people around the forest preserve (Tyson 2000). "If the kids are really into it, then the adults will switch on as well," she said (Tyson 1994). Forests are the key to the future survival of the island and its people, and an education program aimed at rural people, teaching the value of trees in preventing floods, landslides and in maintaining the flow of rivers and streams, could save countless trees.

Scientists--both Malagasy and foreign--working on the island, could share their findings by talking with local people about the uniqueness of Madagascar's natural world. Ornithologists with the Peregrine Fund, who rediscovered the Red Owl and taught local schoolchildren about the species donated money from bird-watchers to the school, provided such an example. Scientists typically conduct research and depart without having taught local people about their findings. Villagers near Ranomafana National Park were so interested in learning about research results that they asked Wright for copies of reports. She began a bimonthly newsletter, in the Malagasy language, describing the natural history of the park (Tyson 2000).

Films and books about Madagascar's wildlife and plants tend to be distributed only in foreign countries, and never translated into Malagasy. Translations of books and subtitled films could be shown to schoolchildren to introduce them to Madagascar's tremendously interesting and beautiful natural world. It is ironic that Westerners may be more familiar with lemurs and chameleons that most Malagasy. Some projects for the future might include donation of solar

collectors and windmills to supply power to rural people. This could elevate their standard of living and cut back on firewood collection for fuel. Donation of projection and video equipment to regional schools provided with electricity would help them appreciate their natural heritage through viewing nature films of Madagascan wildlife. Satellite dishes would facilitate communication with people around the world through the Internet.

The government of Madagascar developed a 20-year National Conservation Strategy and Environmental Action Plan as long ago as 1984. In 1986, a survey of protected areas began with the aim of implementing management plans for priority protected areas and recommending new protected areas, as well as training Malagasy people to work in reserve management and conservation biology. The government has been working to create a sense of pride and ownership in the nation's biodiversity through this program (Morell 1999). The President of Madagascar has stated that the environment is important, a key to whether foreign scientists and tourists will be able to come to the country and aid in its conservation in the future (Tyson 2000). The World Bank and various organizations funded this Environmental Action Plan with $168 million for its first five years (Tyson 2000). This has resulted in many biological studies, education of a growing number of Malagasy for conservation work and a Biodiversity Planning Centre (Sayer *et al.* 1992). The Geographical Information System database is a cornerstone of the government program, concentrating data from all fields to help establish conservation priorities (Tyson 2000). Conservation International has an office in the capital and is contributing to biological inventory data, as it has in other countries, as well as conducting research on particular species and data management. It coordinates its work with local organizations and trains Malagasy scientists (Sayer *et al.* 1992).

Ecotourism is another budding industry, and Madagascar is one of the few countries in the world to share park fees with local people. As a result of an initiative put forth by a Malagasy non-governmental organization, the National Association for the Management of Protected Areas, one-half of all fees are given to local people (Tyson 2000). Ninety-three villages in the Ranomafana National Park area received about $10,000 in a recent year from park fees; a committee designated by the villages decides how to spend the money. In 1995 they bought seeds and built campgrounds, a crafts training center and small dams (Tyson 2000). Many local people are employed as park workers, and the aim of the program is to turn over management of this park and its biodiversity work to the Malagasy people. There needs to be a national park system with strict rules for management and protection, according to Patricia Wright, who deplored the illegal tree cutting by the previous park director at Ranomafana (Tyson 2000). She also has proposed that a national biodiversity institute be built, which would offer centralized training in biology and technology, as well as five new long-term biodiversity research stations similar to those in La Selva National Park in Costa Rica and the Smithsonian Institution's Panama tropical research laboratory (Tyson 2000).

Jobs, which are desperately needed by the Malagasy, are increasing as a result of the rise in the number of tourists. Selling crafts to tourists, running hotels and restaurants, and serving as guides are among these. Villagers who used to demand that parks be declassified so that they could legally gather wood, now request that more national parks be established, an apparent result of the new income that comes from fees and tourism (Morell 1999). International tourists have provided a major new source of revenue in Madagascar's economy and are helping the Malagasy see their wildlife in a new way, as so fascinating and biologically important that visitors come from every continent to view it. *Madagascar. The Bradt Travel Guide*, by Hilary Bradt (1999), published in various editions since 1988, is a useful aid for tourists, providing information about accommodations, natural history, protected areas, and the Malagasy and their history. Nature reserves and parks provide jobs by attracting scientists who employ local people, another incentive for the Malagasy to urge that more protected areas be set aside.

Compensation for lost access to forests has not been paid in the past, and new arrangements reached with villagers to allow some extraction of resources from the forests may heal some of these wounds and placate those who still wish to cut trees. Medicinal plants obtained from Madagascar may be another source of revenue in the future. The Rosy Periwinkle may be only one of many native plants highly valuable in treating disease. Research on the potential of other plants may uncover other such treasures. In the past, revenues from plants used for medicine have not been returned in part to the country of origin, but recently a new trend has begun. In one case, a pharmaceutical company agreed to pay people in a South American country a portion of the revenues gained from any native plant providing a

marketable drug.

Another potential source of revenue is the placement of videocameras connected to the Internet, which present websites with general information as well as live camera views of wildlife. South African parks have a number of these videocameras placed at water holes, animal dens and other key areas that capture live views of animals transmitted to the Internet for a small viewing fee. This has proven very successful, funding many of the South African National Parks system s expenses. A similar system could be established in Madagascar with solar-powered videocameras, which have already been in use in Alaska, trained on tree canopies, rainforest flowers or lemurs, along with websites that provide basic information on Madagascar's environment, biodiversity and the Malagasy people. For millions of people who cannot visit Madagascar, such a website might be fascinating as a learning tool for teachers and the public, as well as an exciting view of these unique animals and their environments. If managed in such a way that profits were shared between poor Malagasy to alleviate their poverty, and conservation organizations to preserve biodiversity, such a system has great potential.

A satellite connection with classrooms in the United States or other countries would be another opportunity for interactive communication and learning. In December 2000, for example, students in an American classroom talked with students in a school in Guyana about endangered Giant Otters and their conservation through a visual satellite hookup. Students and others might set up an interactive link with biologists and conservationists working in Madagascar, asking questions and offering help. Students have provided many excellent ideas for conservation, and classes have raised money to save rainforests and threatened wildlife habitat and to help stop poaching of endangered species in countries half a world away from their own. Malagasy young people might be inspired and enthusiastic through talking with others of their own age about conservation and biodiversity. Video cameras and still cameras might be donated to Malagasy students and young people to record nature and compete for prizes with their results.

Madagascar s Lessons

Madagascar's story is one of ecological catastrophe and the gradual extermination of its life forms. One's first response might be that its experience is as far from the rest of the world as it is geographically remote. However, it is from the extremes that one acquires basic knowledge. The effects of immigrants, whether human, animal, plant or disease, can devastate natural ecosystems wherever they occur. Islands are especially vulnerable to the effects of invasive species, including humans, because their flora and fauna have limited habitats and tend to be endemic, with small populations.

Exotic or non-indigenous species threaten 350 species of birds, or 30 percent of all threatened birds listed by BirdLife International in *Threatened Birds of the World* (BI 2000). Likewise, 361 plant species and 69 species of mammals listed by the *2000 IUCN Red List of Threatened Species* are threatened as a result of non-indigenous species (Hilton-Taylor 2000). The effects of invasive species, including humans, have been the major cause of extinction of virtually all bird species, almost all of which have occurred on islands. In the case of Madagascar, the Malagasy and other immigrant peoples and their livestock, and their subsequent hunting and habitat destruction, presented the vulnerable native species with threats against which they had no defense. Islands throughout the world continue to suffer losses in biodiversity, as do areas with large numbers of endemic species in mainland areas. Species with restricted ranges are the most likely to go extinct or become endangered. Such species dominate the list of birds in *Threatened Birds of the World* (BI 2000). In this age of international commerce, where plant diseases and other viruses are brought into countries in shiploads of lumber or ballast water, and exotic animals and plants continue to colonize and be released in delicate ecosystems with endemic species, whether on islands or mainlands, it has become extremely difficult to defend native species from such invasions. Nevertheless, through preserving native plants and animals and legislating against such introductions, while removing non-native species, ecosystems and their diversity can be protected. Preserving natural ecosystems is vitally important, not just for wildlife preservation, but for humans

as well, so that precious water supplies, topsoils and biological diversity, which stabilize all ecosystems, are protected. These lessons have not yet been put into practice in Madagascar or in many other parts of the world, including developed countries. Ecological and faunal changes may be so gradual that they go unnoticed until ecosystems have been destroyed.

Madagascar Testing Quotes

About 500 A.D., immigrant people from Asia, most probably Indonesia or Malaysia, arrived on Madagascar's shores in hand-hewn canoes, bringing domestic animals with them. They began clearing forests and burning them for farmland, and turned lakes and wetlands into rice paddies. Cleared land produced crops for only a few years until the thin soil became sterile. Farmers then moved on to other parts of the forest, in this slash-and-burn agriculture. At some point, African herdsmen colonized the island, bringing zebu cattle, which crowded out wildlife (Tyson 2000). Gradually, abuse of the land eroded the soil in the central highlands to bare earth, pocketed and gouged by deep gullies and cavernous holes. This region had harbored a great variety of lemurs, along with a wealth of birds, reptiles and unique plants. Throughout the island, wildlife declined as habitats disappeared, isolating animals in smaller and smaller patches of forest and wetlands. The large lemurs, tortoises and elephant birds were avidly hunted.

Within 600 years of the arrival of the Malagasy, extinctions claimed many native animals. Several elephant bird species, the larger lemurs and many native plants vanished. Two kinds of pygmy hippos inhabited the island. The Madagascar Hippopotamuses (*Hippopotamus lemerlei*), an amphibious species, and *Hippopotamus madagascariensis*, a forest species, were both about 6.5 feet long and 2.5 feet tall, smaller than the Common Hippopotamus of Africa, which is about 10 feet long (Tyson 2000). From genetic and anatomical analysis, both seem to have evolved from the latter species (Tyson 2000). The hippos had been widely distributed and very common prior to the arrival of the Malagasy (Dewar 1984). Their bones have been found with marks indicating that they had been butchered (Tyson 2000). Both died out long before Europeans arrived. The native crocodile, whose large bones have been found, is believed by some scientists to represent large specimens of Nile Crocodiles, the species native today (Tyson 2000). It is thus possible that the crocodile survived. A large mongoose-like viverrid, *Cryptoprocta spelea*, and a very unusual aardvark-like animal, *Plesiorycteropus madagascariensis*, died out at an early date (Dewar 1984).

Prior to the arrival of humans, elephant birds had been abundant in most parts of the island, as attested by the prevalence of their bones. There were two genera, and from six to 12 species of these birds (Tyson 2000). It is likely that the flightless birds fell prey to the primitive weapons of the Malagasy and were crowded out of their habitats by livestock (Tyson 2000). The last to die out was the Great Elephant Bird (*Aepyornis maximus*), which may have survived until recent times by retreating to remote swamps. Dr. Alexander Wetmore of the Smithsonian Institution examined bones of a Great Elephant Bird unearthed in archeological excavations in the 1960s. He was amazed by their size: "The incredible femur, or thighbone, of this ponderous bird is by far the largest I have ever seen" (Wetmore 1967). Estimated to weigh at least 1,000 pounds, more than three times the weight of an Ostrich, it produced eggs larger than any dinosaur's, with a capacity of 2 gallons (equivalent to seven Ostrich eggs), 180 chicken eggs or 12,000 hummingbird eggs (Bradbury 1919, Fuller 1987). When one was X rayed, the bones of an embryo three fourths developed were revealed (Wetmore 1967). Something had interrupted the embryo's growth and frozen it within the eggshell for hundreds and perhaps thousands of years (Wetmore 1967).

Despite its fearsome size, the Great Elephant Bird lacked a hooked beak for tearing prey and was plainly not a predator (Wetmore 1967). Its large, clawed feet may have helped it defend itself against the small native predators but were not enough to protect it from Malagasy arrows. Its short legs prevented it from running as fast as its relative, the Ostrich, but it may have been quite agile when chased. This vegetarian bird browsed and cropped plants, able to reach with its long neck to the lower branches of trees (Wetmore 1967). By the mid-16th century, when Europeans had managed to establish a foothold in Madagascar, the new French Governor, Sieur Etienne de Flacourt, wrote in 1661

that the Great Elephant Bird was still found in the south of the island, "seeking the most deserted places" to avoid human hunters (Tyson 2000). Villagers of Antandroy told of an Ostrich-like bird that was difficult to catch, according to Flacourt (Tyson 2000).

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Lemur-like primates once lived on many continents, but nowhere had they evolved into such a great variety of species. When the Malagasy people arrived some 1,500 years ago, lemurs occupied every habitat, even marshland. A species as tall as a man must have startled the Malagasy immigrants, giving rise to legends that these animals had superhuman powers. The first French naturalists were told by the Malagasy that these primates were thought to be the ghosts of sacred ancestors of man, inspiring the genus name Lemur, the word for ghost in Latin. The Malagasy considered some lemurs sacred and punished anyone who harmed them, but most species were feared as evil demons and were killed on sight.

From their arrival on Madagascar, the Malagasy hunted the larger species of lemurs, almost all of which are now extinct. Archaeological excavations show that they formed a staple in the immigrants' diets. Such diggings have unearthed the skulls and bones of long extinct lemurs in early Malagasy jars and kitchen middens; their heads had been split by ax-heads made from an extinct flightless bird (Jolly 1980).

In the centuries following colonization by the Malagasy immigrants, some 15 species of lemurs of eight genera became extinct (Mittermeier 1997). These extinct lemurs were, for the most part, far larger than surviving species and had evolved to fill many ecological niches. Three *Megaladapis* lemurs weighed between 90 and 170 pounds and moved slowly through the trees, feeding on foliage (Tattersall 1993). Another species, *Archaeolemur*, was about the size of a female baboon and lived on the ground (Tattersall 1993). Two *Palaeopropithecus* species weighed between 90 and 130 pounds and were sloth like tree dwellers with flexible bodies (Tattersall 1993). These extinct lemurs had evolved many unusual means of movement and locomotion that have no parallels in living species of lemurs.

Largest of all, the massive 400 pound *Archaeoindris* was apparently a ground dweller, moving on all fours; many of its anatomical characteristics are unlike any living primate (Tattersall 1993). One entire lemur family, Archaeolemuridae, was obliterated. In this family were many species of lemurs weighing between 35 and 55 pounds; they were powerfully built and short legged (Tattersall 1993). The heaviest lemur surviving today, the Indri (*Indri indri*), weighs only about 15 pounds (Tattersall 1993). These lemurs had survived for millions of years, and their extinctions were indeed a major biological loss to the planet. According to primatologists, the surviving lemurs resemble the very earliest primates from the Eocene (Tattersall 1993). Like prosimians in Africa and Asia, but to a far greater degree, lemurs have a highly developed sense of smell. Some species have long, fox-like noses (Preston-Mafham 1991). Genetic analysis of their DNA has revealed that all lemurs are descended from a single ancestor that probably arrived from Africa about 60 million years ago (Garbutt 1999).

The Giant Aye-aye (*Daubentonia robusta*) lemur was somewhat larger and 2.5 to 5 times heavier than the surviving

Aye-aye (see below), but in other respects was very similar (Garbutt 1999). It is known from subfossil remains found in southwestern Madagascar (Nowak 1999). The date of its disappearance is unknown but may be fairly recent.

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In addition to the Giant Elephant Bird, the large Snail-eating Coua (*Coua delalandei*), a member of the cuckoo family, became extinct. The last specimen of this large, slate-blue bird was taken on an islet off the east coast, Ile Sainte-Marie, in 1834 (Morris and Hawkins 1998); reports by observers who claimed to have seen the bird were recorded as late as 1930 (Fuller 1987). The causes of this bird's disappearance, and even its exact range, remain obscure (Langrand 1990). Many specimens of this bird were taken before its extinction and kept in museums in Leiden; London; New York; Paris; Philadelphia; Tananarive (Madagascar); and Cambridge (Massachusetts) (Fuller 1987). The long feathers of this bird were highly valued by the Malagasy, and hunting may have reduced its numbers to a critically low level (Fuller 1987). It is also possible that the many birds killed for zoological specimens may have pushed this already rare bird to extinction, since its distribution may have been limited to the tiny Ile Sainte-Marie. No reliable record exists of its presence on the main island of Madagascar, but there is hope that it might be found in lowland forest near the Bay of Antongil (Morris and Hawkins 1998). Ten closely related species of couas survive, all smaller than the Snail-eating Coua.

Madagascar Testing Quotes 2
Testing "quotes again" to see whether they are "going" to have 'slashes' added to them or not.

Madagascar and other Islands

http://www.endangeredspecieshandbook.org/madagascar_human.php

Madagascar

Imagine an island more than 1,000 miles long in a blue tropical ocean. Forests cover vast areas, interspersed with swamps where crocodiles 8 meters long lie in wait to prey on pygmy hippopotamuses. Thousands of giant tortoises with shells 4 feet across lumber about. In the forests and in dryer parts of the island live some of the strangest primates to have ever existed on Earth. Some 45 species of these lemurs live throughout the island and range in size from the world's smallest primate, weighing about 1 ounce, to a lemur the size of a Gorilla (Tattersall 1993).

Huge white birds plod along forest trails and through savannah grasses. Many kinds of these birds inhabit the island. The largest resembles an Ostrich, but is far more massive in build, weighing 1,000 pounds (Feduccia 1996). It stands 10 feet tall and lays 20-pound eggs, 13 inches long (Feduccia 1996, Greenway 1967). More than 100 other kinds of tropical birds that exist nowhere else fly in forests and deserts and wade in still marshes.

Primitive hedgehog-like mammals, called tenrecs, scurry in forest underbrush. One type of tenrec lives in cold mountain streams, swimming with webbed feet and flattened tail, while another has spines like a porcupine and stripes down its back like a skunk. It communicates with its young by vibrating its spines.

Hundreds of kinds of amphibians and reptiles inhabit forests, aquatic environments, savannahs and drylands. Frogs of every imaginable color and pattern leap in green shadows. Chameleons, some brilliantly colored, and others shades of mottled brown, creep invisibly about. The largest, 2 feet long, can capture mice and birds, while the smallest, measuring only 1.5 inches, feeds on insects (Amos 1980). Tortoises with shells adorned in delicate yellow sunburst patterns inhabit shrub and deserts.

Plants exist in unparalleled variety, a botanical paradise. Relicts of species long-extinct on mainland areas--tall tree ferns, palms, red-flowered flame trees, massive deciduous and rainforest trees, giant tamarinds and aloes, desert oddities, and baobabs of many sizes--grow in even the driest parts of the island. Orchids in a rainbow of colors bloom among the deep green rainforests. Waterfalls abound, cascading down tall cliffs into rivers and lakes. Along the west coast, a dry deciduous forest stretches the length of the island**.** The central highlands are a mosaic of woodland and savannah, while the eastern regions are covered in dense, humid rainforest. In the extreme south, a desert environment prevails, harboring *Didierea*, strange cactus-resembling plants that form long, spiny, twisted shafts rising 30 feet into the air. An impenetrable wilderness of limestone spikes and sharp rocks dominates the far north. Rare birds and lemurs find refuge in this craggy landscape and feed in oases watered by meandering streams.

Flightlessness, fearlessness, gigantism, dwarfism, and survival of ancient species all occurred in this evolutionary laboratory. That such a large land mass went uninhabited by humans for so long is truly remarkable. Nowhere else on the planet has such a large land area remained isolated for such a prolonged period, allowing a flowering of diverse life forms to flourish and adapt to the island's many habitats and terrains in this mild, tropical climate. Such is the history of the island from Madagascar in 400 A.D., a century before the arrival of the Malagasy people of Asia. Had humans reached Madagascar earlier, it might not have evolved its diverse, yet vulnerable, fauna and flora.

How such an extraordinary diversity of animals and plants inhabits Madagascar is tied to its geological history. Some 160 million years ago, when Africa, Australia, New Zealand and South America were united in the super-continent Gondwana, Madagascar was attached to eastern Africa and what is now peninsular India. Dinosaurs, giant turtles, crocodiles, primitive mammals, reptilian birds and lizards roamed on this massive land mass. Gondwana gradually broke apart as a result of movements of tectonic plates covering the Earth's crust. For many millions of years, India and Madagascar formed a mini-continent. Then, about 88 million years ago, they split along Madagascar's east coast, and peninsular India moved northward toward Asia (Garbutt 1999, Tyson 2000). Paleontologists have only recently discovered that Madagascar was home to dinosaurs and other primitive animals quite unlike those found in other parts of the world. The oldest known species of dinosaur, dating back 227 million years, may be the ancestor of all dinosaurs (Flynn 2000). One dinosaur had teeth that were clove-shaped (Stenzelt and Thiessen 2000). Seven species of crocodiles inhabited Madagascar from the Cretaceous period onward, including a pug-nosed vegetarian species (Flynn 2000). About 65 million years ago, the last dinosaurs died out, concurrent with their extinction throughout the world. Some native plants and animals survived from the time when Madagascar was part of Gondwana. Giant tortoises, crocodiles, boas, tenrec ancestors and possibly an early form of elephant birds may have lived on the super-continent, although most ornithologists are certain that the ancestor of the elephant bird flew to the island and became flightless (Feduccia 1996). Plants of many kinds, virtually unchanged from their ancient forms, grow on the island.

Immigrant animals arrived during the millennia from many sources. Because Madagascar separated from India and Gondwana long before the evolution of the prosimians that were the ancestors of the lemurs, these primates must have come from mainland Africa, where their close relatives, bush babies and galagos, survive today. Some scientists believe they might have traveled over a land connection that existed between Africa and Madagascar at some point (Tyson 2000). Others dispute that there ever was such a land bridge and maintain that they arrived by sea, perhaps sheltering on large mats of floating vegetation or clinging to uprooted tree trunks that swept down mainland rivers to the sea and washed up on Madagascar's shores. Few modern mammals of Africa, whether baboons, monkeys, gazelles, antelope or other hoofed mammals, reached Madagascar. The hippopotamuses must have originated in Africa, but how they came to the island is another mystery.

Over many millennia, a blossoming of evolution occurred in this mild, tropical climate of Gondwandan and immigrant species, radiating into entire new families and creating a flora and fauna of great diversity unlike any in the world. Birds, bats and insects flew or were blown to the island by wind currents and storms from Africa and Asia. No large carnivores arrived, however. The largest mammal predators are relatives of mongooses, primitive viverrids. Grazing and browsing roles were filled by hippopotamuses, land tortoises, lemurs and elephant birds.

Human Settlers Invade Paradise

About 500 A.D., immigrant people from Asia, most probably Indonesia or Malaysia, arrived on Madagascar's shores in hand-hewn canoes, bringing domestic animals with them. They began clearing forests and burning them for farmland, and turned lakes and wetlands into rice paddies. Cleared land produced crops for only a few years until the thin soil became sterile. Farmers then moved on to other parts of the forest, in this slash-and-burn agriculture. At some point, African herdsmen colonized the island, bringing zebu cattle, which crowded out wildlife (Tyson 2000). Gradually, abuse of the land eroded the soil in the central highlands to bare earth, pocketed and gouged by deep gullies and cavernous holes. This region had harbored a great variety of lemurs, along with a wealth of birds, reptiles and unique plants. Throughout the island, wildlife declined as habitats disappeared, isolating animals in smaller and smaller patches of forest and wetlands. The large lemurs, tortoises and elephant birds were avidly hunted.

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The Biological Wealth of an Impoverished Country

The Madagascar of today is still a remarkable place, although about 90 percent of the forests, including almost all lowland rainforests that were richest in wildlife, were destroyed (Mittermeier *et al.* 1999). Some 33 lemur species survive, along with all but one species of tenrec, various mongooses and their relatives, more chameleons than any other country, several hundred kinds of frogs and reptiles, and thousands of endemic invertebrates and plants. Madagascar has no native fish, but many introduced species. Its fauna and flora represent many extremely unusual and unique examples of evolution (Mittermeier *et al.* 1999). This island is considered one of the five most biologically important areas in the world; its primates are the world's highest priority for conservation (Mittermeier *et al.* 1999).

Forests and Plants
Mammals
Birds
Reptiles and Amphibians
Invertebrates

The Biological Wealth of an Impoverished Country: Forests and Plants

Madagascar has one of the richest floras in the world. Eighty percent of its plants are found nowhere else (McNeely *et al.* 1990, Preston-Mafham 1991). The diversity of plants that survived almost 2,000 years of forest destruction continues to astound biologists and conservationists. Tropical trees with fruit growing on their trunks (various species of the genus *Tambourissa*) are native, as is a cactus (*Rhipsalis*), related to American species, that lives in the rainforest. A tree, *Symphonia*, which has leathery leaves and red-and-white striped flowers that look like peppermint candies (Morell 1999), also survives. The Flame Tree (*Delonix regia*), which produces cascades of red flowers, is grown around the world for its beauty, but few realize that it originated in Madagascar (Preston-Mafham 1991). Miraculously, many endemic plants have survived the fires and tree cutting that have destroyed much of the island. One mountain chain has 150 endemic vascular plants, a very high number (Preston-Mafham 1991). They are among the 7,300 to 12,000 species of plants native to Madagascar (Preston-Mafham 1991). Its flowering plants make up 20 percent of all the plants in the African region (McNeely 1990). At least 191 botanical families, a very large number for a relatively small area, evolved from ancestor species (Preston-Mafham 1991).

Some 2,000 years ago, the eastern rainforest stretched in a band 100 miles wide from north to south, covering 27 million acres (Tyson 2000). Ninety percent of the plants were endemic, with a profusion of unusual ferns, some types growing on tree trunks; wild ginger, with delicate purple flowers; bamboos; and far more orchids than in an African rainforest (Preston-Mafham 1991). An early traveler described the woods as so dense that there was a deep gloom: below the canopy at mid-day (Tyson 2000). Rainfall must have been greater and general climate more humid than at present as a result of these extensive rainforests. In the montane ridges, huge tree ferns, mosses and lichens cover the ground and hang from tree branches (Preston-Mafham 1991). Over the centuries, Malagasy burned many portions of the rainforest, especially in the south. Few tall trees remain in the rainforest today, although at one time there must have been many giants. During the 19th century, a palace was built for a woman ruler, centering on a 130-foot tree that had been carried by 5,000 laborers from the eastern rainforest (Tyson 2000). The palace was destroyed by an uprising in the 1850s. About this time, Malagasy dragged a tombstone through the forest, cutting 25,000 trees just to make a path (Tyson 2000). Early decrees banned cutting of virgin forest, with severe penalties, in the 19th century, but these were largely ignored (Tyson 2000).

About half of the island's forests had been cut by the late 19th century, and intensive cutting continued in the 20th century (Tyson 2000). The prime lowland forests throughout the island and three-fourths of the rainforest were cleared by the French for growing coffee and other crops in the first three decades of the century (Tyson 2000). The rainforest was heavily logged between 1950 and 1985, with 275,000 acres cleared and burned each year (Tyson 2000). The northeast Masoala Peninsula still retains sizeable areas of unlogged rainforest, but the southern region has been reduced to fragments of the original unbroken expanses. The remnants tend to be on sharp ridges where soil is poor and access difficult. For example, Ranomafana, a recently declared national park, straddles such an escarpment. Even so, many of its trees had been removed prior to its protection (Tyson 2000). What was once a closed-canopy, humid rainforest is now far dryer and cooler, with many openings among the trees, and some illegal logging continues (Tyson 2000). Still, botanists from the Missouri Botanical Garden, who were conducting a census of the trees in this park, counted 37 families of trees with 105 species in a 1-hectare plot (Tyson 2000). Outside the park's boundaries, rainforest is still being cleared and burned by the Malagasy, many of whom believe that their wealth lies in the amount of land they clear (Morell 1999).

The western dry, deciduous forest lies in the shadow of eastern mountains, which block moist ocean air currents (Preston-Mafham 1991). Trees do not attain heights of more than 80 feet, but many types of plants have adapted to this environment. Liana vines grow among the trees, and dead leaves carpet the forest floor. Large tamarind trees grow along rivers, and baobabs grow in plateaus (Preston-Mafham 1991). Beautiful orange bell flowers of the *Ipomoea carnea* plant burst into bloom during the short rainy season. As with the eastern rainforests, the once continuous stretches of deciduous forests have been largely destroyed, replaced by grasses able to survive in the eroded or bare soil.

Throughout the island, most deforested areas fail to regenerate into second-growth forests, even when left fallow,

because Madagascar lacks vigorous colonizing trees that can quickly protect cleared ground and prevent further erosion (Preston-Mafham 2000). Cleared hillsides become covered in non-native grasses and exotic South American trees (*Psidium cattleyanum* and *Psidium guajava*) or plantations of eucalyptus, which inhibit the establishment of native seedlings (Preston-Mafham 1991; Sayer *et al.* 1992). Only if soils are rich and remnants of original forest are nearby will native forests regenerate. Unfortunately, the original forests and their native wildlife are lost permanently, and even regeneration cannot take place without a cessation of the slash-and-burn cycle, known as tavy by the Malagasy (Preston-Mafham 1991). Moreover, foreign logging companies have obtained logging concessions on most of the unprotected remnants of native forest. Tree cutting consumes some 7.8 million cubic meters of wood per year, of which 7 million cubic meters is for fuel and charcoal (Sayer *et al.* 1992). Valuable timber trees have been logged to extinction in most of Madagascar. The two native species of ebony trees of the genus *Diospyros* have been heavily logged for centuries, and few large trees are left (Sayer *et al.* 1992). The understory plants, such as tree ferns, are also exploited, dug up to sell as potted plants (Sayer *et al.* 1992).

The net result of this logging and burning, especially in the barren central highlands, is the loss of "a priceless reservoir of plant and animal species, replaced by one of the most impoverished forms of vegetation on the planet" (Preston-Mafham 1991). Many species of trees and other plants are highly endangered. Madagascar is one of the world's 12 "hot spot" areas of tropical forests, having a high percentage of endemic species which are under great threat (McNeely *et al.* 1990). Since an estimated 94 percent of Madagascar's trees are endemic, and many occupy very restricted ranges, they are highly vulnerable to extinction. Further research will likely reveal even more threatened species. Some authorities believe that even this rich plant diversity must represent only a fraction of the "vast original flora," since 80 percent of the vegetation and forests is gone (Ayensu *et al.* 1984). The *1997 IUCN Red List of Threatened Plants* includes 19 species of plants that may have recently become extinct, and an additional 287 species that are threatened with extinction (Walter and Gillett 1998).

Resident since the days of the dinosaurs, trees of a family of primitive pines, Podocarpaceae, grow on the island. The family is represented by species in other parts of the world that were part of Gondwana, from South America west to Southeast Asia. Madagascar has a number of native Podocarps, of which four endemic species or varieties are listed by the *IUCN Red List* as either Vulnerable or Rare (Walter and Gillett 1998). At least 26 genera of plants are native to Madagascar and South America, but not to Africa, and are believed to be remnants from Gondwana (Preston-Mafham 1991). Another one of these, Madagascar's national tree, the Traveller's Tree (*Ravenala madagascariensis*), is a palm-like species of the banana family (Musaceae). Its closest relative of the same genus grows in Brazil and Guiana, but not in Africa (Preston-Mafham 1991). This tree has leathery petals covering its pollen and nectar and is a key food source for both bats and lemurs. In return, it depends on lemurs for pollination. Lemurs feed on the nectar, getting their noses covered with pollen in the process. They are so fond of the nectar that they travel miles to find another Traveller's Tree, still carrying the nectar on their noses and, unknowingly, pollinate the next tree they feed on (Attenborough 1995).

A plant of the Winteraceae family that has been growing on the island for 30 million years was recently seen again after a period of 90 years (Hsu 1997). This tree, *Takhtajania perrieri*, has many primitive features, such as a lack of vessels to move water and minerals; like many of Madagascar's relict species, it once grew on much of continental Africa, but long ago disappeared there (Hsu 1997).

Madagascar has more palms (Palmae family) than all of Africa (Preston-Mafham 1991). Many are in danger, however. The *IUCN Red List of Threatened Plants* lists 148 native species in various categories (Walter and Gillett 1998). The Big-leaf Palm (*Marojeya darianii*) was chosen by the Species Survival Committee of the IUCN to be one of 12 critically endangered species highlighted at its 1988 General Assembly in Costa Rica. This species was only discovered in 1982 and is confined to a single swamp in the northeast (Prance 1990). An agricultural program to raise rice cleared half its habitat, and then failed. This huge-leafed palm has been over-harvested as a source of heart-of-palm, a commercially valuable product (Prance 1990). Huge palms are felled for their inner pith to supply this gourmet market. The majority of palms grow in the eastern rainforests in a great diversity of size. Two threatened palms, *Dypsis hildebrandtii* and *Dypsis louvelii*, are miniature delicate-fronded palms only 3 feet high

(Preston-Mafham 1991). Others, like the threatened *Ravenea glauca*, are majestic giants with long, straight trunks rising 50 feet or more to a luxuriant crown. Palms do not often survive the fires set by the Malagasy to clear land, disappearing from one area after another (Preston-Mafham 1991).

On the entire continent of Africa, only one species of baobab tree is native, while seven species are found in Madagascar (Preston-Mafham 1991). These strange-looking trees have wide trunks that taper to a narrow crown, looking like upside-down trees. Some baobabs grow to immense size. One famous specimen measures 46 feet around the base of the trunk (Preston-Mafham 1991). Another species, *Alluaudia ascendens*, grows in the southern desert. Although it can reach a maximum height of 16 feet, it is usually far smaller (Preston-Mafham 1991). Each of the seven species has a slightly different shape and size, but all have gray bark that resembles unwrinkled elephant skin. Baobabs are extremely important to both wildlife and humans. The Malagasy cut holes in their massive trunks and hollow out the spongy pith where water accumulates. In the dry south, these trees become wells, and villagers set ladders against the trunks, climb to the hole cut from the trunk, and lower buckets into the pool of water. Natural holes in baobob trunks and branches provide important nesting holes for birds and lemurs. These trees are fire-resistant, and fortunately, they are worthless as timber because of their soft, pulpy cores. For this reason some stands of thousands of huge, very old baobabs remain in parts of the island. Because of the heavy livestock grazing, few young baobab seedlings can survive, however, and botanists believe that the spectacular vistas of these behemoths will gradually disappear (Preston-Mafham 1991).

One very strange group of Madagascan plants native to dry areas has nine species in the same genus, *Pachypodium*. These succulent plants lose their leaves at the onset of the dry season and have evolved into a variety of forms, all with gray, smooth bark. Eight of the nine species are threatened with extinction, according to the *IUCN Red List of Threatened Plants* (Walter and Gillett 1998). One of these, the endangered *Pachypodium decaryi*, is native to Antananarivo, the "tsingy" limestone crags of the northwest. Its smooth, silvery trunk resembles a large inverted turnip, fat at the base and tapering upward, topped by a messy mop of thin, straggly branches (Preston-Mafham 1991). It bears large, white flowers during the dry season. Its main population occurs in the Ankarana Special Reserve, which bans burning (Preston-Mafham 1991), but has recently been invaded by hordes of miners who are clearing vegetation to search for sapphires (Morell 1999). Other Pachypodiums have equally bizarre shapes, such as the bulbous *Pachypodium rosulatum*, which resembles a huge gourd sprouting long, thin shafts from which its bright yellow flower bloom. The rare *Pachypodium densiflorum*, with the appearance of a domestic jade plant run amok, has a mass of short, gray branches sprouting from a squat gray base. All these plants are highly susceptible to fire. Ken Preston-Mafham, in *Madagascar: A Natural History*, describes the threat of "incessant brush fires which ravage the length and breadth of central Madagascar during the dry season. Within hours, hillsides which had been decorated with colorful rock gardens of rare succulents are converted into graveyards of charred embers." These brush fires have been intentionally set by Malagasy to improve grazing land for their cattle or clear land. Another threat to Pachypodia is collectors who tear specimens, especially bizarre forms, from mountain slopes (Preston-Mafham 1991). Few species are protected in reserves. Without strong conservation programs, these fascinating plants could easily disappear.

Other strange trees of the southern spiny desert include the Octopus Tree (*Didierea madagascariensis*), a member of an endemic family of 11 cactus-like species, Didiereaceae. This tree has no trunk, but a bouquet-like grouping of stems covered in long, needle-sharp spines that branch out in odd, twisted shapes. Although resembling cacti, this family has no close relatives anywhere in the world (Preston-Mafham 1991). Another member of the family, *Alluaudia procera*, has a thick trunk with very long spines that grow in curving rows upward, and small, rounded leaves along its branches. In spite of this, several lemur species are able to leap onto these plants without hurting themselves (Preston-Mafham 1991). Three species in this family, all of the *Alluaudia* genus, are Rare, according to the IUCN (Walter and Gillett 1998). One of these, *Alluaudia montagnacii*, has tall, solitary tapering stems ending in a tuft of flowers.

The discovery of the medicinal effects of the endemic Rosy Periwinkle (*Catharanthus roseus*) has saved thousands of human lives. Two potent alkaloid compounds found in this plant have proven effective in the treatment of

Hodgkin s' Disease, producing a 99 percent remission in patients with acute lymphocytic leukemia (Myers 1983). It also contains 75 different alkaloids, which could produce commercial substances (Preston-Mafham 1991). Fortunately, the Rosy Periwinkle is easy to propagate, grown in greenhouses around the world. Ongoing research is uncovering other Madagascan plants of medicinal value. Samples of plants are being tested in laboratories, and elderly Malagasy healers are being consulted. More than 50 species of wild coffee (*Coffea* spp.) grow in the island's eastern rainforests, providing an important genetic base for hybridizing with other strains because of their insect-resistance and low level of caffeine (Preston-Mafham 1991). These plants are symbolic of the great botanical wealth at risk.

The Biological Wealth of an Impoverished Country: Mammals

Home to some of the world's most fascinating, beautiful and curious mammals, Madagascar has approximately 117 native species, 90 percent of which exist nowhere else (Garbutt 1999). Excluding bats, all 88 native terrestrial mammals are endemic to Madagascar. Three-fourths of native mammals, or 66 species, are threatened with extinction; 49 of these are in higher categories of threat listed in the *2000 IUCN Red List of Threatened Species*. This represents 42 percent of all mammals found in Madagascar, by far the greatest percentage of threatened mammals of any country in the world (Hilton-Taylor 2000). As new species of mammals continue to be discovered, the numbers that are threatened continues to rise. A few have not been seen in the wild since their discovery. The majority is made of forest-dwellers, and a few inhabit marshy areas or woodland streams. The loss of forest, predation on them by Malagasy and domestic dogs, and introduction of exotic species of mammals that out-compete native species are combining to push many of the island's mammals toward extinction.

Page 1 (Tenrecs)
Page 2 (Lemurs and Aye-ayes)
Page 3 (Bats)
Page 4 (Viverrids)
Page 5 (Rodents)

The Biological Wealth of an Impoverished Country: Mammals: Page 1

The publication of *Mammals of Madagascar*, by Nick Garbutt, in 1999 filled a void for a complete guide to all native mammals, illustrated with color photos of most species and major habitats. This supplemented *Madascar: A Natural History* in 1991, an important reference on mammals and their environment. Conservation work has focused mainly on lemurs, with many organizations involved, including Earthwatch Institute, which sponsors field research; Conservation International; Jersey Wildlife Preservation Trust (based in England); and CARE. Several of these groups sponsored biodiversity studies and helped establish national parks, benefiting thousands of species, including tenrecs and other native mammals. A growing number of Malagasy zoologists are taking part in studies and conservation work, and new programs have been initiated to help local people while conserving mammals and their environments. Certain mammals have received inadequate attention to date, notably bats, rodents and some viverrids, who will undoubtedly benefit from the swell of interest and enthusiasm for Madagascar fauna that has developed in recent years. Filmmakers have recently produced a number of excellent wildlife documentaries, photographing rare species and spreading knowledge and concern about endangered mammals (see Video section).

Among Madagascar's mammals are many primitive forms. The tenrecs' closest relatives are insectivores known as solenodons, native to Cuba, Hispaniola and other vestiges of Gondwana in the Caribbean. Tenrecs and solenodons may have had a common ancestor living on the supercontinent, progenitor of all mammals. The remains of similar

species have been found in Africa and South America, indicating that they were once very widespread but died out on all but isolated refuges such as Madagascar and West Indian islands. Tenrecs belong to a family of insectivores, Tenrecidae, related to shrews, moles and hedgehogs, but quite distinct from them. Twenty-seven species of three types of tenrecs make up this family--spiny, furred and otter-shrews (Garbutt 1999). They range in size from the Common Tenrec (*Tenrec ecaudatus*), which resembles the European Hedgehog and weighs more than 5 pounds, to the shrew-like tenrecs, *Microgale* genus, weighing less than 2 ounces (Nowak 1999). Tenrecs have some very unusual physical characteristics placing them far from any close mammalian relative. They have variable body temperatures that change with the ambient temperature and, an even more reptilian or avian trait, a cloaca that combines urinal, rectal and generative canals into one (Garbutt 1999).

A striking tenrec is the Lowland Streaked Tenrec (*Hemicentetes semispinosus*). It and a similar species, the Highland Streaked Tenrec (*Hemicentetes nigriceps*), weigh about 5 to 7 ounces and measure some 6 inches in length. White stripes run down their backs like skunks, and barbed, porcupine-like spines are detachable (Eisenberg 1975). The Highland species has a stiff, white neck ruff rising several inches at the back of its head that can be stabbed into the nose of an unwary predator (Eisenberg 1975). Family groups forage together and communicate by vibrating quills that produce low-frequency sounds like dry grass being rubbed together; tenrecs can detect these sounds from distances of more than 4 meters (Garbutt 1999). They also make a number of sounds that are audible to humans.

The Aquatic Tenrec (*Limnogale mergulus*), listed as Endangered in the *2000 IUCN Red List of Threatened Species*, inhabits streams and lakes, living at altitudes between 600 and 2,000 meters (Nowak 1999). This 8-inch tenrec has clawed, webbed feet, and a long, thin tail for propelling it through the water to feed on small crustaceans and fish. Its habitat in the central highlands has been greatly affected by human disturbance and deforestation. The Aquatic Tenrec has at least one refuge, the new Ranomafana National Park, created for the bamboo lemurs (Preston-Mafham 1991). In 1990, Dr. David Stone managed to lure an Aquatic Tenrec into a live trap, the first one of its kind seen alive in 25 years (Preston-Mafham 1991). Later, four more were taken and studied in captivity for three weeks prior to being returned to the river Namorona in Ranomafana, one of the few clear, unsilted rivers left in Madagascar (Preston-Mafham 1991). This species requires such streams, and only the preservation of forests, such as that in Ranomafana, will ensure its survival.

Another six species in this family, all shrew-tenrecs of the genus *Microgale*, are listed in the *2000 IUCN Red List of Threatened Species*. These tiny insectivores are found in all parts of Madagascar in areas of heavy vegetation, and have dark, soft fur. They range in size from 1.5 to 5 inches in length, and weigh as little as 1.8 ounces (Nowak 1999). Several of the threatened species are highly restricted in range and habitat, and one, *Microgale dryas*, listed as Critical, occurs only in Ambatovaky Special Reserve in the northeastern rainforest (Garbutt 1999).

The Biological Wealth of an Impoverished Country: Mammals: Page 2

Far better known to the world, the lemurs are the focus of many programs to conserve them, as well as research on their wild behavior and biology. New species continue to be discovered; most recently in 2000, three new species of tiny mouse lemurs. Three more have been rediscovered, an indication that other species may yet be discovered to add to the present total of 33 species (Garbutt 1999)**.** This is the only country with five families of primates, making up more than one-third of all primate families; it is home to 12 percent of all primate species and 21 percent of all primate genera (Mittermeier *et al.* 1999). Unlike Brazil, however, which is another center for endemic mammals, Madagascar is far smaller, the size of Kenya, covering 226,656 square miles, or 0.4 percent of Earth's surface (NYT 2000). The number of lemur species is not an indication of their variety since many subspecies differ so radically from one another that in the future, each may be accorded full species status. One species of sifaka, a long-legged kind of lemur, has one subspecies that is pitch black, and another that is pure white. At least 51 species and subspecies of lemurs are known to exist (Mittermeier *et al.* 1999).

The most gregarious of the lemurs are the Ring tailed Lemurs (*Lemur catta*), who travel about in boisterous, friendly troops, living mainly on the ground. These lemurs have long, fox-like muzzles, large, soft golden-brown eyes, fluffy, gray fur, and black-and-white striped tails. Their body length is 15 to 17 inches, but their rope-like tails are half-again as long, from 21 to 24 inches (Nowak 1999). These 5-pound primates use their boldly patterned tails in a complex language of mutual visual and scent signals. They wave them about to show dominance, as a signal to follow other group members, or rub them on their wrist glands to wave at their rivals in territorial battles (Sleeper 1997). Moving about in troops of up to 25 individuals, they walk rapidly on the ground with the tail held high, waving it about. They wrap their tails around themselves for warmth on chilly nights. Extremely affectionate and playful, their core group is dominated by females (Jolly 1988).

In reserves where they are strictly protected, Ring-tailed Lemurs become very tame, napping on the ground in piles of leaves near tourists. Sometimes they sprawl out on their backs with arms spread wide apart. Females usually have a single young, but when twins are born, one may be "adopted" by a non-pregnant female, who may begin to produce milk in response to her surrogate role (Preston-Mafham 1991). Aunts also help in raising the young, and the daughter born the previous year babysits (Jolly 1988). Lemur babies are a source of great interest to the entire troop, females gathering around the mother and her young, grooming one another and the babies, forming a "grooming pod" (Preston-Mafham 1991). Only half of the infants survive their first year, and only 30 percent reach adulthood (Garbutt 1999). "A Lemur's Tale," shown on PBS in 1996, is a touching film about the death of a young Ring-tailed Lemur. Some fall from high branches, are killed by small carnivores or hawks, die of undiagnosed illness or starve in years of drought in their arid habitat. Ring-tailed Lemurs communicate with one another in a variety of sounds, from soft mewing contact calls to a territorial "bark-howl." Sometimes chasing and cuffing other members of their group, they are mainly peaceful, spending many hours a day in mutual grooming and in "snoozing-huddles," in which several animals form a complicated embrace from which tails and feet stick out in all directions (Preston-Mafham 1991).

In recent years, Ring tailed Lemurs have been classified "high priority" for conservation by the IUCN and the Species Survival Commission (SSC) Primate Specialist Group because their habitat of dry woodlands in southern Madagascar is disappearing at an alarming rate due to fires, overgrazing by livestock and tree cutting; they are also hunted with dogs in some areas, and captured as pets (Mittermeier *et al.* 1992, Garbutt 1999). Their distribution has become increasingly patchy as forests are cut (Garbutt 1999). The *2000 IUCN Red List of Threatened Species* lists the Ring-tailed Lemur as Vulnerable, or declining toward endangered status.

One of the strangest mammals in the world is the Aye aye (*Daubentonia madagascariensis*), so unique that it is assigned to its own family, Daubentoniidae. When first discovered, scientists classified it as a squirrel because of its long, bushy tail and short legged body. In 1863, however, after anatomical studies, the Aye aye was revealed to be a lemur, in spite of incisor teeth that never stop growing, long, clawed fingers and other unlemur like characteristics. Aye-ayes have a perpetually startled expression: huge, round protruding eyes dominate the face, the pupils completely surrounded by deep golden irises. Dark rings surround their eyes, heightening the eerie appearance. The rest of the face and body are gray to black, with long grizzled guard hairs. Spending the day in their twig and leaf nests, Aye-ayes emerge at night to forage for insects and fruit (Garbutt 1999). The Aye-aye's enormous ears are sensitive to the movements of insects under tree bark. At Duke University Primate Center, which has the world's largest number of captive lemurs, Aye ayes have been filmed using their middle finger, which is twice the length of the other fingers, and skeletally thin, to tap on wood, listening for the movement of insects under the bark. When presented with a block of wood containing insect larvae in holes, the Aye aye taps the wood and, cocking its head, can tell, even in the case of a hidden hole, the location of the insects, which it then extracts almost surgically, with its middle finger. This primate fills the ecological role of a woodpecker. Aye ayes eat fruit as well, biting holes into the hard shells of coconuts and scraping the meat out with their middle fingers (Petter 1965). They have also been seen eating nuts of a native tree, nectar from the Traveller's Tree, fungus and lychee nuts (Garbutt 1999).

Aye-ayes have been heavily persecuted by the Malagasy, who consider them to be the embodiment of evil. In general, they are killed whenever seen. Dr. Ian Tattersall once found a dead Aye aye with a wire pulled tight around its neck

(McNulty 1975). In 1990, apparently to dispel the bad luck caused by its having entered a village, local people set an Aye aye tail on a pole next to the road (Simons 1993). At one time, Aye-ayes were considered among the most endangered animals in the world, facing imminent extinction. To prevent their extinction, a few were captured and released on Nosy Mangabe, a small islet off the northeast coast. Fortunately, Aye ayes survived on the main island, perhaps because coconut plantations provided food when their forests were cut. Feeding at night, they remained undetected until recently. The Malagasy continue to persecute them.

Since the early 1980s, field surveys have revealed that Aye-ayes have a larger distribution than was originally thought. In 1991, they were seen for the first time in western Madagascar in the northern mountains (Simons 1993). With confirmed sightings in many eastern and northern forests and a few western localities, Aye-ayes inhabit a variety of forest types (Garbutt 1999). They can survive in secondary forest, coming out of their stick nests only at night. And while once thought solitary, groups of three to four individuals have been seen traveling together and feeding at foraging sites (Garbutt 1999). In spite of the greater distribution, the Aye-aye is an endangered species and almost certainly is declining (Garbutt 1999). Aye-ayes require large tracts of forest to maintain viable populations and to protect them from the persecution that often results in their deaths (Garbutt 1999). Although very rare in captivity, several captive births have occurred in recent years at the Duke University Primate Center and Jersey Wildlife Preservation Society zoo in England.

One lemur has recently been rediscovered in the wild and, in the process, an entirely new species was found. The Greater Bamboo Lemur (*Hapalemur simus*) seemed to have disappeared in the wild some time in the mid-19th century. Not until 1964 was this 5-pound, grizzled, gray-olive lemur seen again in a village market, where it was purchased by a French scientist. Unfortunately, it escaped. A pair captured in 1972 in a southeastern rainforest lived in the zoo in Madagascar's capital city, Antananarivo, until both male and female and their two offspring died (Quammen 1996).

Patricia Wright, an American primatologist, decided to search for this species in 1986 in its supposed range. Fossil evidence indicates that 1,000 years ago, the Greater Bamboo Lemur was widely distributed throughout most of Madagascar's forests, and European naturalists saw it fairly regularly in the 19th century. When she saw a russet-colored lemur clinging to a trunk, making loud "tonking" calls, Wright assumed that she had rediscovered the Greater Bamboo Lemur. Although a different color, she concluded that these animals probably represented a color variation (Quammen 1996). A German primatologist, Bernhard Meier, made independent studies in this patch of rainforest at the same time, also discovering the reddish-gold lemur. Both scientists had great difficulty making observations because of its extreme shyness (Quammen 1996). Finally one was caught, and in 1987, after chromosomal and anatomical studies were done in France, this lemur was found to be an entirely new species (Jolly 1988). It was named the Golden Bamboo Lemur (*Hapalemur aureus*) in a joint zoological paper by Meier, Wright and three other biologists (Preston-Mafham 1991). After months of unsuccessful attempts, Wright took the first photographs of the Golden Bamboo Lemur in the wild. Its beautiful golden-red face mask and belly contrast with darker brown fur on the rest of its body. (See color photographs in Garbutt 1999, Jolly 1988 and Preston-Mafham 1991). This lemur has been found at another location further north, and it is not known whether these populations are isolated from one another. Its population is apparently very low, as only about 1,000 animals have been estimated in the original location of discovery, and its habitat continues to be cleared (Garbutt 1999). The *2000 IUCN Red List of Threatened Species* has classified the Golden Bamboo Lemur as Critical, the most endangered category. Its limited range places it in great jeopardy, and it has been hunted with slingshots; its long-term survival is not secure (Garbutt 1999).

The Greater Bamboo Lemur, the animal first sought, was later found in the same forest, resembling original descriptions and clearly a separate species from the Golden Bamboo Lemur; a third species of bamboo lemur, the Gray Bamboo Lemur (*Hapalemur griseus*), weighs only 2 pounds. It has smoky gray fur and golden eyes, and lives alongside the latter two species in this same forest. This lemur lives in other parts of Madagascar as well (Preston-Mafham 1991).

Each of these three bamboo lemurs eats different parts or species of bamboo plants. One eats the leaves, another the pith, and the third confines itself to new shoots, leaf bases and pith from narrow stems (Quammen 1996). Amazingly, chemical analyses of the plants eaten by the Golden Bamboo Lemur found them to have high concentrations of cyanide, a chemical usually toxic to mammals. Golden Bamboo Lemurs weigh only about 2.2 pounds, and Wright and her co-workers found that, based on toxicity tests of other mammals, they eat 12 times the amount of cyanide that should kill them (Quammen 1996). This is another example of the biological mysteries of Madagascan wildlife.

The Ranomafana forest, with its rare and endemic lemurs and other unusual fauna and flora, would likely have been cut by the Malagasy for more farmland, but Wright spent five years in a successful effort to protect it in the newly created Ranomafana National Park (Bohlen 1993, Mittermeier *et al.* 1992). This new park covers 108,000 acres of old-growth eastern lowland rainforest. Giant rosewood and other ancient trees tower above a lush understory. It is an extremely important--perhaps the most important--forest for lemurs. Fourteen species of lemurs and 18 other endemic species of mammals live in the park (Jolly 1988). Local people cooperated fully in setting the park s boundaries, aware of the importance of saving forests. They had experienced a major catastrophe when a cyclone caused landslides, burying entire families in their homes, all precipitated by deforestation (Jolly 1988). In spite of these remarkable achievements, some tree cutting still occurs in Ranomafana National Park (Garbutt 1999).

Wright has continued to study lemurs, now specializing in the exquisite Diademed Sifaka (*Propithecus diadema*) (Brody 1998). Sifakas are the most acrobatic lemurs, leaping from tree to tree, but they have a unique means of locomotion to cross open spaces between trees. Standing on their long hind legs in an upright posture, they hop sideways, with their arms raised high above their heads. Sifakas can move very quickly in this amazing, dance-like gait, covering distances of more than 100 yards. They are also able to leap vertically to tree branches from a standing position, even carrying babies on their backs. One of their spectacular leaps, some 30 feet up, is the equivalent of a person jumping to the top of a telephone pole. The Golden-crowned or Tattersall's Sifaka (*Propithecus tattersalli*) is a beautiful, nearly all white species with rich yellow-orange on the crown and tinges of this color on its back, legs and chest. Orange eyes contrast with a furless black face. The smallest of the sifakas, it is confined to a tiny area of only about 15 square miles of forest fragments in northeast Madagascar. The Golden-crowned Sifaka's small population of fewer than 8,000 animals, fragmented into isolated populations, is threatened by forest cutting, brush fires, loss of habitat to agriculture and hunting (Garbutt 1999). Distributed in discontinuous patches of forest, these sifakas may become inbred if corridors are not acquired to link populations. A core part of their forest had been scheduled for cutting for charcoal when scientists named these sifakas. The PBS Nature program, Madagascar. Island of Ghosts, was the first to film these delicate lemurs (see Video section, Regional - Africa and Indian Ocean Islands). They move about in small groups and feed on a variety of unripe fruits, seeds, shoots, leaves, bark and flowers (Garbutt 1999). No reserve has been set aside for this highly endangered sifaka, although a three-parcel national park covering 20,000 hectares (49,420 acres) has been proposed to protect this species from extinction (Garbutt 1999). The IUCN classifies this species as Critical (Hilton-Taylor 2000).

Although many Malagasy have become far more aware of the need to protect lemurs, some do not understand their rarity or the importance of conserving them. Many rural people still hunt them for food or kill them because of superstitious beliefs. In some areas, the Malagasy try to sell lemurs to foreign scientists. Visiting zoologists studying lemurs have been approached by Malagasy holding captive, and usually injured or dying lemurs, in hopes of a reward. On one occasion, an endangered species of sifaka was brought to primatologist Dr. Alison Jolly, dragged half choked by a vine around its neck, with one arm dangling loose below the elbow, a jagged bone protruding; blood oozed down its white fur, and it gasped for air through a muzzle smashed by a flung stone (Jolly 1980). Jolly expressed horror at its condition and refused to pay them any reward. She then amazed them by telling them it was a unique sifaka, found only in that small part of Madagascar. They were incredulous . . . not in Antananarivo? . . . Not in France? . . . Not in America? (Jolly 1980). For the majority of people, lemurs are familiar animals, easy to capture and valuable as food. Malagasy schools, established by the French colonial government, taught them only about European animals, encouraging people to assume that their lemurs were unimportant. Fortunately, many Malagasy are becoming concerned about protecting lemurs, and conservation education is taught in an increasing number of schools.

Some lemurs have bred in captivity in zoos and breeding centers, but most, like the endangered Indri (*Indri indri*), have never survived in captivity long enough to breed. In their rainforests, they perch high up, clinging to tree trunks to feed, and suddenly leaping vertically to a neighboring tree, pushing off with their extremely muscular, long legs. Panda-like fur of contrasting black and white--black faces and bodies and white arms and legs--gives them a dramatic appearance. Nearly tailless and heavy--but graceful--their eerie songs, sung at dawn and sometimes during the day, form a loud chorus of high-pitched voices that carries for long distances. Indris were once very common in the eastern rainforest, but much of their habitat has been burned away, making them extremely sensitive to the danger of fires. When a 1992 fire threatened a group in a reserve, they raised such a loud cry that the guards were alerted. They rushed to the scene and put out the fire (Rajaonson 1993).

Although originally found in the far north and central highlands, the Indri is now limited to a narrow strip encompassing only half the rainforests on the island (Garbutt 1999). Indris do not reach sexual maturity until between 7 and 9 years of age, and females are thought to give birth only every second or third year (Garbutt 1999). With such a low reproductive rate, they have been very vulnerable to habitat loss and hunting, especially by immigrants (Garbutt 1999). Moving about in small family groups, they are conspicuous to hunters. The Indri is one of the few lemurs whose killing is considered taboo by the Malagasy, but the old taboos are breaking down, resulting in capture and killing. In some cases, religious leaders encourage such killing. A lemur scientist met a Catholic priest who killed several Indris, roasted them and served them to his congregation, as recorded by Faith McNulty in 1975, and this killing has not ceased. In *Mammals of Madagascar* (Garbutt 1999), two terrified Indris were photographed clinging to poles in a hut, awaiting slaughter for food.

In contrast to the Indri, mouse lemurs (*Microcebus* spp) are so small that it is hard to think of them as primates. The tiniest is the newly discovered Pygmy Mouse Lemur (*Microcebus myoxinus*), with an average weight of only 30 grams, or 1.05 ounces, smaller than any other primate (Garbutt 1999). This tiny mammal is 2.73 inches long, with a tail just under 6 inches in length (Garbutt 1999). The other species are slightly larger, with body lengths ranging up to about 5 inches, and tails of equal or greater length (Garbutt 1999). These nocturnal lemurs have huge dark eyes and are agile and active, resembling African bushbabies. They feed on insects, spiders, and even small frogs and lizards, as well as fruit, flowers and nectar (Nowak 1999). Females form groups and sleep in a nest together with up to nine individuals, while males usually nest alone or in pairs; occasionally males are found in a group of females (Nowak 1999).

A key to protecting lemurs and their forest homes is educating the people of Madagascar about them. The Jersey Wildlife Preservation Trust has put up posters with pictures of lemurs and their protected status around the island. Habitat protection is obviously key to conserving lemurs, and another recent development is the protection of the largest remaining area of rainforest in Madagascar. The Masoala Peninsula in the northeast is the sole home of the Red Ruffed Lemur (*Varecia variegata rubra*), a 9-pound, reddish subspecies of the Ruffed Lemur, but bearing little resemblance to the latter black-and-white species. With $3 million from USAID (United States Agency for International Development) and three years of planning, the new Masoala National Park, covering 210,000 hectares (518,910 acres or 840 square miles), was announced in June 1996 (Terry 1996). This immense park was formally signed into law on October 18, 1997 (Kremen 1998). Thai and Indonesian timber companies had hoped to log these virgin rainforests, but this new law will prevent clearcutting and slash-and-burn agriculture that would have destroyed the forest within less than 50 years. A coalition of organizations helped establish this park, including the Wildlife Conservation Society, CARE and the Peregrine Fund (Garbutt 1999). It will prevent the extinction of the endangered Red Ruffed Lemur, as well as that of the newly rediscovered Madagascar Serpent Eagle (*Eutriorchis astur*) (see below).

In 1997, five Ruffed Lemurs born and raised in the Duke University Primate Center in North Carolina were released in the Betampona Reserve in the northeast to bolster a small, isolated population of this species (Welch 1997). This reintroduction represented a goal in the captive-breeding program at Duke University, which has long planned such a return of these highly endangered primates to the wild. John Cleese, actor and a member of the 1970s British comedy team, Monty Python's Flying Circus, took an interest in the reintroduction program as an enthusiastic lemur admirer.

After contributing to the Ruffed Lemur reintroduction program, he wanted to see how they were faring in the wild, and trekked to their remote release site. A delightful film based on this experience, "Lemurs with John Cleese," was shown on PBS in 1999. These Ruffed Lemurs have been released in an area of dense rainforest and rugged hillsides, a long hike from the nearest road. The biologists and assistants who take part in this reintroduction program show their dedication by living for long periods under extremely primitive conditions. Cleese managed to inject humor into this otherwise arduous situation.

At least six species of lemurs, and perhaps more, serve the ecologically important role of pollinating flowers. Many of Madagascar's plants produce unusually large flowers with strong odors and copious nectars attracting lemurs to feed on them. Should any of these lemurs become extinct, the plants that they pollinate will likely follow. Lemurs also play an important role in dispersing seeds. Research by the German Primate Centre at Hamburg University has found that Brown Lemurs are crucial to the regeneration of the western dry forests. About 10 percent of the island's tree species rely largely or entirely on this species to disperse seeds, which pass through their digestive systems.

The surviving lemurs are in extreme danger of following their relatives into extinction. Conservation organizations accord them extremely high priority among endangered primates, and they are the focus of many programs to preserve them. Twenty-nine of the 33 species are listed in the *2000 IUCN Red List of Threatened Species*, all but seven in higher categories of threat. This is an increase of nine species in the four years since the previous edition of the *IUCN Red List* was published (Baillie and Groombridge 1996). Three species and several more subspecies are in the Critical category of species on the verge of extinction, while seven are Endangered, an increase of four species since 1996. All lemurs are listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the category prohibiting commercial trade, and as Endangered on the U.S. Endangered Species Act.

Although lemurs are protected by Madagascan law, hunting is a major cause of mortality. High fines and even jail sentences may be imposed for killing a lemur, but the severity of the penalties might make officials reluctant to enforce the laws (Peterson 1989). Blowguns, snares, traps, sharpened sticks, slings, stones, guns or even clubs are used to kill them (Peterson 1989). To kill small species of nocturnal lemurs, trees are sometimes cut down, and hunters seize them from their nest holes (Peterson 1989). In the late 1980s, a "sport" hunter bragged of killing 12 highly endangered Verreaux's Sifakas in one afternoon (Peterson 1989). In spite of education programs launched in the 1990s urging the Malagasy to protect lemurs, and the rise in tourists who come to see them, which provides revenues, few have benefited from tourism. Hunting remains a major threat (Garbutt 1999). The rise in human population has resulted in an increased demand for food, particularly protein, far more than the ailing agricultural system can supply (Garbutt 1999). The larger lemur species are especially affected. Because laws against killing lemurs are not enforced, much more education is needed about their potential value in attracting tourism and research funds that provide new jobs. Already tourism has raised income levels among some Malagasy, but hunger is still widespread (Tyson 2000).

In the late 1980s, a World Bank official studying the extreme and worsening poverty on the island said that there might come a time when the people of the capital city would scale the walls of the city zoo and eat the lemurs: "On the downward spiral, animals are at the bottom" (Peterson 1989). Such a tragedy is not inconceivable considering that hunger and poverty have deepened in the decade since. Conservation programs must involve communities while providing an incentive to conserve lemurs. Otherwise, it may be impossible to persuade the Malagasy not to slaughter them.

Although the status of lemurs is deteriorating along with their forests, much is being done to prevent their extinction. The past two decades have been of critical importance to lemur conservation. These extraordinary animals are receiving worldwide attention, and habitat protection for some species has been achieved. Not too long ago, their extinctions seemed inevitable and imminent. Conservation education programs, including showing slides of lemurs and other wildlife to rural children, have been launched. Wright helped to finance the building of new schools and the renovation of existing schools near Ranomafana National Park (Tyson 2000). A number of international organizations are integrating lemur and biodiversity studies with the economic development of entire communities (Garbutt 1999).

For a growing number of Malagasy, learning how special their lemurs are has made lemurs a source of pride and an important national treasure. In the future, Malagasy children may learn from an early age about lemurs and want to protect them. A few decades ago, few films had been made of these fascinating primates, while today many films show their habitats, biology and conservation work on their behalf. One is Spirits of the Forest, a charming film about many species of lemurs. Others are listed in the Video Section Mammals. Films of lemurs and the island's environment would provide new insights about these animals if shown to the Malagasy people. Lemurs have also been prominently featured in *Madagascar: A Natural History*, by Ken Preston-Mafham, a beautiful and informative book, and the first guide book, *Mammals of Madagascar*, which provides color photos of nearly every species and subspecies, as well as information on habitats, conservation and status (Garbutt 1999).

In some areas of Madagascar, notably on Nosy Be island, lemurs are fully protected by taboo respected by the Malagasy. Here, beautiful Black Lemurs are fed by the villagers and tourists. This island is being developed intensively for tourism, and the strict nature reserve may be made into a national park (Tyson 2000). This will have mixed results, with new income flowing to the local people from park fees--one of the few countries where this occurs--yet with habitat lost and wildlife disturbed as a result of new hotels and a crush of visitors (Tyson 2000).

The gentle, curious gazes and charming behavior of lemurs have left an indelible impression on many people, and their extinction would be tragic, not just for biological reasons, but also because of their unique and delightful qualities.

The Biological Wealth of an Impoverished Country: Mammals: Page 3

Bats, which perform vital ecological roles in controlling insect populations and pollinating plants, tend to be ignored and often persecuted. Madagascar is no exception. Fifteen species of the 29 species of bats are endemic, living nowhere else (Garbutt 1999). The remaining 14 species live in mainland Africa as well. Fourteen species, or almost half the native bats, are listed by the *2000 IUCN Red List of Threatened Species*. The Yellow Bat (*Scotophilus borbonicus*), the most endangered, is listed as Critical (Hilton-Taylor 2000). This bat has been seen in both eastern and western regions but is extremely rare. A Vulnerable species, the Sucker-footed Bat (*Myzopoda aurita*), is the sole member of its family, Myzopodidae, and an extremely unusual bat. It is able to walk up tree leaves using sucker disks at the bend of its wings and on its feet to adhere to the slippery leaves (Jolly 1988). Only 2 inches long, with a forearm length of 1.9 inches, this tiny bat occurred in East Africa during the Pleistocene, but at present, it is found only in several locations in the eastern rainforest region of Madagascar (Garbutt 1999). It roosts in the Traveller s Tree. It possesses a complex echolocation system and emits very long calls used to hunt insects (Garbutt 1999).

The largest bat, the endemic Madagascar Flying Fox (*Pteropus rufus*), has a 4-foot wing-span. An extremely colorful bat, its crown and nape are yellowish, and its upper chest and shoulders are rufous to golden brown (Garbutt 1999). It feeds on fruit juices by squeezing pieces of fruit pulp in its mouth, swallowing the juice and very soft fruit pulp, especially of figs, papayas, lychees and guavas (Garbutt 1999). Colonies of these bats roost in tall trees in primary forests or plantations (Garbutt 1999). One large roost at the Berenty reserve has decreased, apparently because of daytime disturbance by tourists who come to see them hanging upside down in the tamarind trees (Preston-Mafham 1991). Elsewhere on Madagascar, the species has declined precipitously from hunting for its meat; only on inaccessible offshore islands do these bats survive without persecution (Preston-Mafham 1991). Of Asian origin, this species is related to fruit bats in the Mascarene Islands. Through captive studies, flying foxes have been found to be extremely devoted to one another (see discussion of Rodrigues Flying Fox in Chapter One).

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The Viverrid family is represented in Madagascar by mongooses, civets, and related carnivores that have evolved into eight species of three endemic subfamilies (Preston-Mafham 1991). Their ancestor is thought to have originated in Africa, and may have colonized the island at an early period. The largest carnivore on the island is the Fossa, or Fosa (*Cryptoprocta ferox*). A zoological oddity, it resembles the Jaguarundi, a neotropical cat, but most authorities place it either in the Viverrid family with civets (Preston-Mafham 1991) or the Herpestidae family with mongoose (Nowak 1999). The only member of its genus, it walks flat on its feet, rather than on its toes like cats (Nowak 1999). Sleek and slender, with golden reddish-brown fur, it has a small head with a blunt, dog-like muzzle, and an extremely long tail. Males weigh up to 22 pounds, with a body length of 2.6 feet and a tail of equal length, while the smaller females measure 2.3 feet and weigh about 15 pounds (Garbutt 1999). It has scent glands which discharge a strong odor when the animal is irritated (Nowak 1999). Widespread but rare in forests throughout the island, this nocturnal predator kills small lemurs, rodents and tenrecs, as well as birds, reptiles, amphibians, invertebrates and, reputedly, domestic chickens (Garbutt 1999). The Fossa often excavates animals from their burrows and can pursue fleeing prey by climbing up trees (Nowak 1999).

The first research study of the Fossa is being conducted by zoologist Luke Dollar, funded by the Earthwatch Institute. Helped by volunteers, he is radio-tracking several Fossa to determine their movements, habits and territory size. As the largest predator on the island, the Fossa plays an extremely important role in the evolution, behavior and population dynamics of lemurs and other prey animals. During the research project, several Fossa have shown extreme confidence by raiding the tents of the researchers when unoccupied, ransacking them and even chewing metal objects, leather boots, rucksacks, soap and bottles of malaria tablets (Garbutt 1999). For centuries, Fossas have been persecuted by the Malagasy, believing them to be ferocious and evil.

The Fossa gives birth to a litter of two to four young, which mature very slowly and may not be fully independent until they are about 4 years old (Garbutt 1999). This slow rate of reproduction has made the Fossa vulnerable to extinction. Along with losses from killing by the Malagasy, its forest home has been steadily whittled away by slash-and-burn agriculture. The Fossa is listed as Endangered in the *2000 IUCN Red List of Threatened Species*, a higher category of threat than it received in the 1996 version of this list.

Gerald Durrell, renowned author and conservationist, traveled in the western forests to capture Aye-ayes for captive breeding. He encountered a Fossa venturing out during the day--an unusual behavior: "A flash of russet red caught my eye in the bushes some six feet in front of the vehicle and, suddenly, from out of the undergrowth, silent as a cloud shadow, came a Fossa which walked languidly to the middle of the road and sat down" (Durrell 1993). Remaining there, the Fossa proceeded to groom himself, apparently unaware of Durrell's presence. Then, with a sigh and a wide yawn, the Fossa crossed the road and disappeared into the forest, "his immense sickle of a tail swinging from side to side like a bellrope behind him. To have spent ten minutes with such a rare and beautiful creature was a privilege" (Durrell 1993).

The Falanouc (*Eupleres goudotii*), sole member of its genus and a viverrid, is the size of a domestic cat. It has dense, woolly fur and an extremely pointed and narrow muzzle. Native to humid eastern lowland forests and marsh areas and portions of the northwest, Falanoucs are active at twilight and during the night. Feeding mainly on earthworms and other invertebrates, they use their long snouts and tiny, conical teeth to catch prey in leaf litter (Garbutt 1999). The species is rare or extremely rare over most of its range and is classified as Endangered by the IUCN (Hilton-Taylor 2000). Like the Fossa, it has declined as a result of deforestation, drainage of marshes, hunting by the Malagasy, attacks by feral domestic dogs, and possibly competition with the introduced Small Indian Civet (*Viverricula indica*).

The Malagasy Civet or Fanaloka has the scientific name *Fossa fossana*, which has been confused with the Fossa. Like the Fossa and Falanouc, it is the only member of its genus. Looking more like spotted civets from mainland Africa and Asia, this reddish 3-pound carnivore has rows of black spots on its back, merging into stripes toward its bushy, grayish tail. Its distribution is far more restricted than the Fossa's or the Falanouc's, being confined to eastern rainforests which have been reduced to less than 10 percent of their original size. Sheltering in tree holes or crevices, the Malagasy Civet lives in pairs and feeds on crustaceans, worms, small eels and frogs (Nowak 1999). A pair has a single young, and a captive civet lived 11 years. Hunting and trapping have also threatened the Malagasy Civet, which is listed as Vulnerable by the IUCN (Hilton-Taylor 2000).

Five other viverrids, all mongooses, are native to Madagascar, and all are threatened with extinction from a loss of forest habitat and persecution. A few have very restricted distributions. They tend to be secretive unless in a secure forest reserve, and little attention has been paid to their conservation, biology or habitat requirements. Several are uniform brown or russet, while two have bold black dorsal stripes ending in white, bushy tails. One, the Brown-tailed Mongoose (*Salanoia concolor*), is native to the northeast rainforests, but almost nothing is known of this small carnivore (Garbutt 1999). All of the eight native civets, mongooses and related animals are listed as Vulnerable or Endangered by the *2000 IUCN Red List of Threatened Species*.

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Among Madagascar's 11 species of murid rodents are several extremely bizarre forms. The largest is the Giant Jumping Rat (*Hypogeomys antimena*), the size of a rabbit and weighing 2 pounds, 10 ounces (Preston-Mafham 1991). Restricted to a small area in western dry, deciduous forests north of Morondava, in west-central Madagascar, its entire range is thought to encompass only 39 square miles (Preston-Mafham 1991). Once far more widely distributed, remains have been found in southwest and central Madagascar (Garbutt 1999). These huge rodents search for food, such as fallen fruit, on the forest floor and feed by sitting on their hindquarters and holding food in their forepaws like a rabbit (Garbutt 1999). Giant Jumping Rats build deep burrows and, unlike the vast majority of rodents, a mated pair maintains long bonds with one another and with their young (Garbutt 1999). Male young leave after one year, and females stay with both parents for two to three years (Garbutt 1999). Only one or two young are born in a litter, and predation by Fossa and the Madagascar Ground Boa (*Acrantophis madagascariensis*) is high (Garbutt 1999). With no reserve and a habitat that continues to decline, this huge-eared rodent is in danger of extinction. A reserve is planned for this species, which is listed as Endangered by the *2000 IUCN Red List of Threatened Species*. Madagascar. Island of Ghosts filmed the Giant Jumping Rat in the wild, one of the only videos of this fast-disappearing species (see Video section).

Eight of Madagascar's native rodents, or 73 percent, are listed by the IUCN in various categories of threat. Two are considered Critical: the Madagascar Mouse (*Macrotarsomys ingens*) and the Madagascar Rat (*Eliurus penicillatus*). The mouse is known only from a single area in northwestern Madagascar, in dry deciduous forests where the type specimen was found, and it is thought to be almost totally arboreal and nocturnal (Garbutt 1999). The Madagascar Rat has not been seen since the type specimen was collected in central-eastern montane rainforest.

The Biological Wealth of an Impoverished Country: Birds

Page 1 (Native birds)
Page 2 (Avain & Terrestrial)
Page 3 (Aquatic)
Page 4 (Bird-watchers)

The Biological Wealth of an Impoverished Country: Birds: Page 1

Until recently, the amazing lemurs and other mammals of Madagascar eclipsed its remarkable bird life. Apart from the extinct elephant birds, 120 species of the 204 native birds are unique to the island (Morris and Hawkins 1998). Like tropical birds of other parts of the world, most are dazzlingly beautiful in brilliant hues. Unlike most tropical birds, however, they represent fascinating examples of evolution, including families of birds that exist nowhere else, having evolved from a single ancestor into many forms, some very bizarre. Most ornithologists recognize five bird families as unique to Madagascar, each with extremely distinctive characteristics. Four of these have some or all species that are threatened. The fifth, a family consisting of a single bird, the Cuckoo-Roller (*Leptosomus discolor*), is secure for the moment (Morris and Hawkins 1998). A few thousand years ago, there may have been far more native bird species that disappeared without a trace as their habitats were destroyed.

Native birds are not thriving, as people and livestock destroy their varied habitats, to which they had adapted over thousands of years. A total of 41 species, all but three of which are endemic, have been listed in the *2000 IUCN Red List of Threatened Species*, based on the research of BirdLife International published in 2000 in *Threatened Birds of the World*. The latter book illustrates each threatened Madagascan bird and describes status, population numbers, distribution and other pertinent information. The three non-endemic birds also breed in the neighboring Comoros or Seychelles (BI 2000). Thus, 20 percent of all native birds and 34 percent of endemic birds are threatened, five species listed as Critical, six as Endangered, 16 as Vulnerable, and 14 as Near-Threatened (BI 2000). Moreover, many native birds that were once widespread have become restricted to isolated forest reserves and parks, not yet endangered but far less numerous than in previous times. While the percentage of threatened birds is less than that of endemic mammals, it is significant, especially considering that 27 species are either Critical, Endangered or Vulnerable in the *2000 IUCN Red List of Threatened Species.* Madagascar has more threatened birds that all of the continental United States (excluding Puerto Rico and Hawaii). Its threatened birds total 41 threatened species, five greater than the United States 36 (BI 2000). Only 4 percent of the 810 breeding birds native to continental US and Canada combined (Sibley 2000) are threatened. If birds in the United States faced the same degree of threat as Madagascar's birds, at least 162 species would be threatened with extinction.

Fortunately for the future of these unique birds, organizations such as BirdLife International; the Peregrine Fund; Conservation International; the Jersey Wildlife Preservation Trust; and an ad hoc group, The Working Group on Birds in the Madagascar Region, are researching and working to conserve Madagascar's native birds. Malagasy ornithologists and members of the public are participating in surveys, studies and conservation programs. An inventory of the status and taxonomy of all of Madagascar's birds is in progress (Morris and Hawkins 1998).

In spite of Madagascar s many unusual birds, interesting to specialists and amateur birdwatchers alike, no bird guide or text illustrating and describing the island's avifauna existed until 1990, when Olivier Langrand's *Guide to the Birds of Madagascar* was published, providing information on natural history, status, habitats and distribution, as well as color paintings of all native birds. This material supplemented the lengthy descriptions in *Threatened Birds of Africa and Related Islands*, a 1985 publication of the International Council for Bird Preservation, now called BirdLife International (Collar and Stuart 1985). *Madagascar: A Natural History*, by Ken Preston-Mafham (1991), included extensive information on many native birds and their habitats. *Birds of Madagascar, A Photographic Guide* (Morris and Hawkins 1998), published in 1998, updates the latter publications with vivid color photographs illustrating almost all native birds, including many species discovered or rediscovered during the 1990s, such as the two new species, the Cryptic Warbler (*Cryptosylvicola randrianasoloi*) and the Red-shouldered Vanga (*Calicalicus rufocarpalis*), and the rediscovery of several birds thought extinct: the Madagascar Serpent Eagle, Madagascar Red Owl (*Tyto soumagnei*) and Red-tailed or Fanovana Newtonia (*Newtonia fanovanae*). The 1990s also saw the making of many films about the island's wildlife, including its birds (see Video section).

The Biological Wealth of an Impoverished Country: Birds: Page 2
Birds native to aquatic habitats have declined even more dramatically than many forest birds. The largest lake on Madagascar, Lake Alaotra in the northeast, was once a paradise of waterbirds, turtles, frogs and other wildlife. Traditionally, portions of the lake were used by the Malagasy for rice cultivation, without serious damage to the environment or resident wildlife. But as their populations and food requirements grew, people began to destroy more and more of the natural marsh and reed beds that lined the lake, and cleared the surrounding forest for firewood and agriculture. This destroyed the lake's water quality. With no trees to hold back the soil and conserve water, this once-beautiful lake became heavily silted by runoff (Durrell 1993). Added to this, non-native tilapia fish were introduced into the lake as a food source for the local people. The fish eat vegetation needed by dragonflies and other fauna that form the basis of the lake's food chain (Preston-Mafham 1991). This ecological collapse has greatly reduced rice production on the lake, although reeds are still being cleared for rice growing, fragmenting wildlife habitat (Garbutt 1999).

The effects on native aquatic birds have been catastrophic. Lake Alaotra is the only known habitat of the endemic Alaotra Grebe (*Tachybaptus rufolavatus*), which is presumed extinct (BI 2000, Morris and Hawkins 1998). No sightings have been made since 1985, when only two birds were seen. It declined from loss of its habitat, hunting and hybridizing with the Little Grebe (*Podiceps ruficollis*), a recent arrival from Africa (Morris and Hawkins 1998). Many fruitless searches for the species have been carried out in the lake and surrounding area since then (BI 2000, Morris and Hawkins 1998). This small, black-capped grebe was very sedentary and may have been nearly flightless because of its extremely short wings.

Another waterbird restricted to Lake Alaotra, the Madagascar Pochard (*Aythya innotata*), is also probably extinct, having been eliminated by the same threats as the Alaotra Grebe (BI 2000). This duck declined steeply from 1930 on, and the last known bird, a male, was captured in August 1991, having been caught in fishing gear. This bird later died, and intensive searches in 1989 and 1990, and again in 1993 and 1994, failed to discover more Madagascar Pochards (BI 2000, Collar *et al.* 1994). A handsome bird, the pochard was chestnut-colored, with dark gray bill and yellow eyes (see photograph in Morris and Hawkins 1998). A shy species, its breeding and behavior were studied, but apparently nothing was done during its precipitous decline to prevent its extinction. Classified as Critical, hope remains that a few birds exist in wetland habitats around Lake Alaotra (Morris and Hawkins 1998).

The Jersey Wildlife Preservation Trust has begun education campaigns in the vicinity of Lake Alaotra to teach local people about the presence of the highly endangered Alaotra Reed Lemur or Bandru (*Hapalemur griseus alaotrensis*), a subspecies of the Grey Bamboo Lemur, and the importance of protecting the reed and papyrus beds. This lemur has been classified as Critical by the IUCN. The only lemur to live in an aquatic environment, the Alaotra Reed Lemur is larger than other subspecies of the Grey Gentle Lemur and lives in close, family groups (Garbutt 1999). To move about in the reed beds, they climb up a reed stem until it bends, and then walk along it to reach the next stem; their major food is the endemic papyrus, along with grasses and ferns (Garbutt 1999). Lake Alaotra's reed beds are its sole habitat, and although previously widespread in this and another lake to the north, only two isolated populations of lemurs, one of which numbers fewer than 60 animals and is on the verge of extinction, remain in marsh fragments (Garbutt 1999). This lemur has the most restricted range of any lemur species or subspecies (Garbutt 1999). The film, Madagascar. A World Apart, includes a moving segment on these lemurs feeding among the papyrus when a Malagasy canoe enters the marsh and sets a fire, causing the terrified lemurs to flee. (See Video section). Local village leaders have requested that the government set aside a protected zone in the marshes. There is hope that this lake will be brought back as a functioning ecosystem in the future and that a strict sanctuary will be set aside for this endangered lemur and the highly endangered waterbirds.

While sizeable areas of forest have been protected, few aquatic environments on Madagascar have been preserved, and native waterbird species are declining precipitously. The Madagascar Little Grebe (*Tachybaptus pelzelnii*) was once common and widespread in many parts of the island; with the pollution and destruction of marshes throughout the island for rice farms, this bird has declined greatly. The introduced tilapia was threatening this species by consuming its food supply. This grebe also hybridizes with the introduced Little Grebe (Collar *et al.* 1994). The Little Grebe, an African species which has colonized the island, prefers the habitat created by the tilapia, and is now abundant (Langrand 1990). The Madagascar Little Grebe has also drowned in fish nets, and has lost the vegetation it needed for nesting (BI 2000). It is expected to follow the Alaotra Grebe and Madagascar Pochard into extinction.

Another endemic waterbird, the Sakalava Rail (*Amaurornis olivieri*), native to western wetlands, is also extinct or nearly so. A small, sooty-black bird with yellow beak and pinkish-red legs and feet, it was native to streams and marshes in the western parts of the island. For more than 30 years, this species was not seen at all. In 1995, one was glimpsed at Lake Bemamba, and another in 1999 at the same lake (BI 2000). This species is classified as Critical (BI 2000), and Lake Bemamba and other lakes and wetlands on the west coast may be given protection by the Malagasy government, which has ratified the Ramsar Convention on wetlands preservation (BI 2000).

As a result of extensive habitat destruction and hunting, the Madagascar or Bernier's Teal (*Anas bernieri*) has likewise declined to endangered status in the few sites from which it is known on the west coast. Once widespread on the island, it is now restricted to a few marshes and shallow lakes. Small populations remain on Bemamba Lake and a few other sites (Morris and Hawkins 1998), and a flock of 67 was seen in another area (BI 2000). In 1970, 60 of these birds were seen on a lake, and as soon as this became known, European sportsmen went to the lake and killed more than 25 percent of the population (Curry-Lindahl 1972). In the 1970s, Bernier's Teal inhabited Lake Masama, but heavy hunting by both Europeans and natives with dogs has nearly eliminated them (Todd 1979). In 1993, four birds were captured for captive breeding (Collar *et al.* 1994). The Jersey Wildlife Preservation Trust is working to preserve this beleaguered species and the marshes of the west. The Madagascar Teal has been seen in three protected areas, and a conservation program at one lake has been initiated (BI 2000).

The critically endangered Madagascar Fish Eagle (*Haliaeetus vociferoides*) numbers about 250 pairs in the 600-kilometer stretch of western coastline to which it has become confined (BI 2000). This large eagle resembles the African Fish Eagle, from which it probably evolved, but instead of a snowy white head and upper body, it is streaked with brown and has shaggy, buff crown feathers. About 35 inches long, with a 6.5-foot-wingspan, it is by far the largest bird on Madagascar. Persecuted by local people, these eagles have been shot and their nests destroyed. On one occasion in the 1990s, ornithologists saw some immigrants cut the tree where an active nest of a Madagascar Fish Eagle was located, and proceed to kill and eat the chicks! The only remaining habitat for this species is the western coast, where mangrove swamps are rapidly being destroyed (Langrand 1990, Preston-Mafham 1991). The Peregrine Fund is sponsoring research on this species, and 10 nests have been located in an area on the west coast in the Three Lakes Complex (BI 2000). The Fund has removed and raised chicks that would have been killed by siblings and released them to augment the population. The fish it feeds on are being depleted, however, by a gill-net fishery that has recently been established. A new Malagasy law allows local communities to control their own resources, and the people in this region are being encouraged to formalize conservation regulations prohibiting gill netting and tree cutting.

The Biological Wealth of an Impoverished Country: Birds: Page 3

Birds native to aquatic habitats have declined even more dramatically than many forest birds. The largest lake on Madagascar, Lake Alaotra in the northeast, was once a paradise of waterbirds, turtles, frogs and other wildlife. Traditionally, portions of the lake were used by the Malagasy for rice cultivation, without serious damage to the environment or resident wildlife. But as their populations and food requirements grew, people began to destroy more

and more of the natural marsh and reed beds that lined the lake, and cleared the surrounding forest for firewood and agriculture. This destroyed the lake's water quality. With no trees to hold back the soil and conserve water, this once-beautiful lake became heavily silted by runoff (Durrell 1993). Added to this, non-native tilapia fish were introduced into the lake as a food source for the local people. The fish eat vegetation needed by dragonflies and other fauna that form the basis of the lake's food chain (Preston-Mafham 1991). This ecological collapse has greatly reduced rice production on the lake, although reeds are still being cleared for rice growing, fragmenting wildlife habitat (Garbutt 1999).

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The Biological Wealth of an Impoverished Country: Birds: Page 4

As more and more bird-watchers come to Madagascar, the government may place a higher priority on bird conservation. A special fund to which bird-watchers could contribute might be established to purchase and maintain refuges and to conduct conservation education and other projects for local people, especially in aquatic habitats. The preservation of threatened Madagascan birds has reached a critical point. The most endangered habitats, the last of the western forests, aquatic environments, and many parts of the eastern lowland rainforests, continue to decline. The fragmentation of forests that forces animals into islands of isolation needs to be studied and remedied by establishing habitat corridors between them. One Malagasy ornithologist, Aristide Andrianarimisa, is researching the effects of forest fragmentation on birds.

Pete Morris and Frank Hawkins, authors of *Birds of Madagascar. A Photographic Guide*, state that their purpose in writing their book was to inspire people to visit Madagascar and take an interest in its avifauna and the plight of so many threatened birds, as well as to promote greater interest in wildlife and conservation among the Malagasy people. Ecotourists bring revenue to the island and, thereby, help to preserve natural areas and wildlife (Morris and Hawkins 1998). The discovery of a new species of songbird, the Cryptic Warbler, by bird-watchers in Ranomafana National

Park, is an exciting byproduct of ecotourism and an indication that the study of Madagascar's birds has just begun. It also proves that amateurs play an important role in bird observation. *Birds of Madagascar* establishes a good precedent by identifying, on a species-by-species basis, the avian habitats and those birds lacking reserves within their ranges. The authors request that people coming to see the wildlife of the island let the government know why they have come in order to convince decision makers that biodiversity conservation represents a worthy investment (Morris and Hawkins 1998).

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians

The distribution and diversity of Madagascar's reptiles and amphibians have not been carefully researched until the present. Chris Raxworthy, a British herpetologist, is in the process of carrying out the first methodical survey of the estimated 500 non-marine species, all of which are endemic (Holmes 1997). To date, at least 300 reptile and about 200 frog species have been identified (Tyson 2000). This would make it one of the top five countries in the world for diversity of reptiles and amphibians. The British Isles, by contrast, with about half the land area of Madagascar, have only six species of reptiles (Preston Mafham 1991). Even the ranges of newly described lizards and frogs will not be delineated precisely for some time. Some areas remain unexplored by herpetologists, and Raxworthy finds new species of lizards and frogs on each expedition into the tangled swamps and forest fragments. On one day when accompanied by a journalist, he and fellow researchers, including Malagasy biologists, found a bright green day gecko, a strikingly beautiful yellow-and-black snake, tiny frogs resembling lichens, a leaf-tailed gecko and 4-inch chameleons with upper legs the colors of Rainbow Trout, and lower legs like toothpicks (Holmes 1997). In a reserve on Nosy Be island, he and some Earthwatch Institute volunteers rediscovered a 10-inch green lizard that had been lost to science since the 1890s, when last collected (Tyson 2000). Raxworthy is doing inventories in reserves as part of an island-wide biodiversity program, and hopes that in some impenetrable area, giant tortoises long considered extinct will be rediscovered (Holmes 1997).

Page 1 (Threatened)
Page 2 (Tortoises and Turtles)
Page 3 (Lizards)
Page 4 (Snakes)
Page 5 (Amphibians)

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians: Page 1

Of these native reptiles and amphibians, at least 19 are known to be threatened with extinction. A preliminary list includes 17 species of reptiles (four tortoises, a freshwater turtle, four sea turtles, a gecko, four chameleons and three boa snakes) and two amphibians, both frogs. All are in higher categories of threat: Endangered or Vulnerable by the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor 2000). All but the sea turtles are endemic to Madagascar.

The arid regions at the northern and southern ends of Madagascar are home to two intricately patterned tortoises, both in danger of extinction. In the north is a species considered by many to be the world's most endangered tortoise: the 18-inch Madagascar or Plowshare Tortoise (*Geochelone yniphora*), whose tan, domed shell is marked with narrow black lines in delicate hexagonal patterns. The Plowshare name came about because of a protuberance on the tortoise s lower shell that turns up, a kind of knob that remotely resembles a plowshare. This knob is used by males in sparring contests. From the 17th century onward, thousands of these tortoises, which were once abundant and widespread, were shipped every year to the nearby Comoro Islands to use as meat for settlers, driving the species to the edge of extinction before the trade finally ended in the 19th century (Juvic *et al.* 1981). Their populations never

recovered, due to the continued take by villagers for pets and the massive destruction of their habitat. Known to the Malagasy as the "Angonoka," this tortoise was headed for extinction until 1985 when the Jersey Wildlife Preservation Trust was requested by the IUCN to work with the Malagasy government in formulating a rescue plan, Project Angonoka (Reid 1995). Research on the tortoise s wild status and behavior began immediately, and a captive-breeding program was established at a government forestry station (Reid 1995).

By 1986, eight adult tortoises had been gathered from the wild and placed in an enclosure which had ample vegetation and conditions natural enough that two male Angonokas immediately began their fights of strength (Reid 1995). Gerald Durrell, founder of the Jersey Wildlife Preservation Trust, in his book, *The Aye-aye and I* (1993), described lone males showing no interest in breeding, even if surrounded by females. But when another male is present, they face each other prepared for combat: "The two males, rotund as Tweedledum and Tweedledee dressed for battle, approach each other at what, for a tortoise, is a smart trot. The shells clash together, and then the plowshare comes into use. Each male struggles to get this projection beneath his opponent and overturn him to win a victory in this bloodless duel" (Durrell 1993). Finally, when one is able to overturn his opponent, he lumbers over to mate with the female while the vanquished male "wanders dispiritedly away" (Durrell 1993).

Project Angonoka has shown success both in captive breeding these tortoises, which may number only between 300 and 1,000 in the wild, and in working with local people to conserve remaining wild populations (Durbin *et al.* 1996). In fact, by 1995, a total of 140 captive-bred juveniles, ranging in age from 10 months to 6 years, had been produced at the breeding center. The breeding program was described in an illustrated article entitled "Observations on Hatchling and Juvenile Captive-bred Angonoka in Madagascar," published in the Jersey Wildlife Preservation Trust's annual journal, *The Dodo,* issued early in 1996. Within months, the captive-breeding program was devastated by the theft of 76 animals--two adult females and 74 hatchlings. On May 6, 1996, someone cut through the flimsy chain-link fence and the wire of the enclosure and took half the animals that were the fruit of a decade's work. Not until a female is 20 years old does she begin breeding, so the loss of two breeding females and their hatchlings dealt the program a devastating setback (McNeil 1996a). The burglary may have been an inside job, since the dog on the premises did not bark to alert the personnel who were sleeping close by (Tyson 2000). It is unlikely that these adult females will breed in captivity, as there are almost no adult male Plowshare Tortoises in breeding programs, and without more than one, no breeding occurs.

Animal smugglers care little about the effect of their actions on the survival of endangered species. Reptile collectors will pay thousands of dollars for rare specimens, and this break-in had been planned. A Dutch rare animal dealer had advertised Plowshare hatchlings for sale the month before, at $3,000 apiece, saying they would be "available soon" (McNeil 1996a). Ten of the hatchlings were traced to Prague, where wildlife law enforcement is weak, and others were suspected to be in the Netherlands, where they would be sold to collectors in the United States, Spain, Germany and Japan (McNeil 1996a). The loss of these tortoises cost the breeding program years of work. Don Reid, the Conservation Field Officer in charge of the Plowshare Tortoise captive-breeding program, had experimented for years to achieve a proper diet for the tortoises, arranged male combats, and conducted lengthy experiments to learn proper conditions for the eggs to hatch (Reid 1995). These tortoises became so tame that they would stretch their necks out to be scratched (McNeil 1996a). Although discouraged by the theft, he continued the breeding program; 40 new tortoise hatchlings were produced in late 1996, bringing the total to 130 juveniles. In 1998, several of the smuggled tortoises were seized from a Malaysian animal dealer in Mexico City who had been the subject of a long-term U.S. Fish and Wildlife Service undercover investigation. The same year, three more Plowshare Tortoises were seized in Belgium as they were being imported (TRAFFIC 1999a). The species is listed by the *2000 IUCN Red List of Threatened Species* as Vulnerable, and is protected by the Malagasy government, which bans trade.

Officials from the Jersey Wildlife Preservation Trust and other conservationists have sponsored education programs aimed at informing local people about the tortoises and their rarity. This has resulted in their cooperation in helping to guard wild tortoises from poachers and control brush fires (Durbin *et al.* 1996). This region in northwestern Madagascar has lost most of its forest cover; Arab residents cut trees and burn them to clear the land for agriculture,

and feral pigs kill the young wild tortoises (Durbin *et al.* 1996). So much clearance of natural vegetation has taken place that the climate has become increasingly more arid, causing ponds to dry up. Tree cutters are now turning to the mangroves, causing siltation of the inlets, which affects prawn harvests (Durbin *et al.* 1996) and destroys a key aquatic environment on the island.

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians: Page 2

The Plowshare Tortoises have been reduced to a few forest sites, and in spite of the urgent need for a reserve, none has been set aside. The area is getting conservation help with the formation of a new organization by conservation biologists, the Association to Safeguard the Environment. Its purpose is to involve local people in environmental projects, such as planting cashew trees, learning fire suppression methods, and trapping bush pigs; they are also giving conservation lessons to children and conducting literacy classes (Durbin *et al.* 1996).

The Radiated Tortoise (*Geochelone radiata*) inhabits the drylands of the extreme south, where the strange Didierea plants and other desert vegetation grow in open shrubland. Many people consider this tortoise to be the most beautiful in the world. Delicate yellow sunburst patterns adorn the top of its 16-inch-long black shell, and the underside is marked with diamond patterns. These tortoises also declined after tens of thousands were killed to supply local villagers with meat, or exported to the Comoro Islands from the 17th century on for meat markets abroad. In 1922 alone, 22,000 of these tortoises were exported (Jolly 1980). The legal trade did not cease until 1930. The tortoise populations have not rebounded, and illegal capture for collectors and zoos may be the explanation. The slow reproduction of this species means that it cannot quickly make up for losses in its population. An extremely long-lived species, it has evolved with low natural mortality and has few young. As an example of its longevity, a Radiated Tortoise of unknown age presented to the Queen of Tonga by Captain Cook in the 1770s, lived until 1966, making it almost 190 years old at its death (Jackson 1993).

The lovely patterns on this tortoise's shell, which vary from individual to individual, have placed it in great demand around the world, encouraging poverty-stricken Malagasy to risk jail to earn the money that these tortoises bring. Thousands of Radiated Tortoises have been collected for the international market, sold in Europe, North America and elsewhere for $2,000 or more per animal. In spite of having a range that is far larger than that of the Plowshare Tortoise, the Radiated Tortoise is declining rapidly toward extinction. The species is listed by the *2000 IUCN Red List of Threatened Species* as Vulnerable. Export and collection of Radiated Tortoises are prohibited by the Malagasy government, with severe penalties for violations including prison sentences. The United States lists both the Radiated and Plowshare Tortoises on the Endangered Species Act, which prohibits commercial importation. International commercial trade is banned by their listing on Appendix I of CITES. Still, the smuggling continues, fed by the many wealthy collectors who have no conscience about the effect their purchase has on wild populations, and the zoos that knowingly purchase smuggled animals. Malagasy authorities have failed to put an end to the poaching, especially of the Radiated Tortoise and other southern species.

Donovan Webster, a journalist, researched the rampant smuggling of Radiated Tortoises and other wildlife from the island for *The New York Times Magazine*, which published his lengthy article on February 16, 1997. The magazine cover featured the article and read: "I was caught in Madagascar. Peddled for 30 cents. Smuggled to Orlando. Sold for $10,000. I'm a rare, coveted tortoise--coldblooded contraband." Webster found that Madagascar was a "pirate's paradise," with little or no local enforcement of conservation laws. Its long and unpatrolled coastline is used by smugglers, who load tortoises onto small boats at night, with little fear of arrest (Webster 1997). Although some enforcement of capture bans takes place in the range of the Radiated Tortoise, local people have learned to avoid arrest.

The contrast between the attitudes of local people toward the Plowshare Tortoise in the north, where education

programs have been carried out by the Jersey Wildlife Preservation Trust, and the south, where no strong program exists to protect the Radiated Tortoise and other wildlife, could not be more dramatic. In the south, poaching Radiated Tortoises and other reptiles is considered an accepted form of revenue by the extremely poor people of the region. At local bars and restaurants, Webster was approached by people who offered to produce a rare snake within 24 hours. Snakes are a favorite animal for smugglers because they can be secreted in small bags and placed in luggage or, if they are small enough, in pockets. He refused a boa, which was offered at $300 and could be sold for $2,000 in the United States (Webster 1997).

Webster exposed a large-scale and fairly open trade in Radiated Tortoises in local markets within the range of these tortoises. He visited a woman who was reputed to have many of these tortoises for sale. She showed him 24 Radiated Tortoises which she kept ready for sale to anyone who would pay the right price; they were crowded into a make-shift pen in her living room, stacked two and three deep in filthy conditions (Webster 1997). They grunted and made hissing sounds when disturbed, scratching and scrabbling against one another and the pen sides; their shells were covered with dust, and most appeared to be sickly (Webster 1997). The woman tossed the tortoises back into the pile after handling them. She claimed that she sold them to local people for $1.35, and to outsiders for $4 or more, depending on how many tortoises she had at the time (Webster 1997). She also admitted supplying a smuggler who arrived once a week in a canoe at a remote beach with any Radiated Tortoises she had in stock (Webster 1997).

These tortoises are absurdly easy to collect in the wild, living in open shrubland and moving so slowly that they can be picked up as easily as rocks. Webster witnessed the capture of one mature tortoise which Benjamin, one of the collectors, located in the shadow of a boulder. When he approached, the tortoise hissed and tried to crawl beneath bushes, but it was easily grabbed, and he flipped it on its back; soon he caught two other adult tortoises who had a baby the size of a small stone wedged beneath them in an apparent attempt to protect it (Webster 1997). Collectors wrap string around the tortoises shells to form handles for carrying them. When they met at the end of the day, they had taken 54 mature tortoises and many young ones, making it a "banner day" (Webster 1997). The occasional presence of enforcement officers and World Wildlife Fund (WWF) representatives did not seem to present any anxiety of threat of arrest to the collectors (Webster 1997).

Each Radiated Tortoise is worth at least $2,000 once smuggled out of Madagascar, and those with unusually exquisite patterns bring as much as $10,000 (Webster 1997). Benjamin later admitted that he was aware that the tortoises were becoming rarer and that their range had shrunk in recent years; he also knew that many were very old, probably older than his own 53 years. It was obvious that the tortoises would soon be gone, but he believed this was his only potential income source; he was uncertain about how he would make a living when there were no more Radiated Tortoises (Webster 1997).

Some of the smuggled Radiated Tortoises leaving Madagascar have been seized by importing countries. In May 1992, for example, a Dutch citizen arriving from Madagascar was stopped by Customs at Roissy Airport in the Netherlands in possession of 46 Radiated Tortoises as well as 14 bamboo lemurs of several species and seven endangered Madagascar Boas (*Acrantophis madagascariensis*); the animals were confiscated and returned to Madagascar (TRAFFIC 1992). In 1998, a Radiated Tortoise was among many rare tortoises seized in Belgium as they were being imported, and U.S. authorities, under Operation Chameleon, an undercover investigation of trafficking in illegal Madagascar reptiles, seized Radiated Tortoises from an American reptile dealer in Miami. In May 1999, French Customs officers seized 450 tortoises smuggled by three Malagasy citizens living in Paris (TRAFFIC 1999b). Among them were 120 Radiated Tortoises; the suspects were not arrested (TRAFFIC 1999b).

Most ecotourism on the island has been developed for viewing lemurs, chameleons and birds, but the Radiated Tortoise and its extraordinary habitat of endemic plants have the potential of attracting many tourists. Also living in this tortoise's habitat are spectacular sifakas, many unusual birds, and other reptiles. In Beza-Mahafaly Reserve, scientists are studying the ecology and longevity of these tortoises, as well as searching for a permanent form of marking that would make them unattractive to collectors. The Radiated Tortoise could be conserved while helping local people like Benjamin. Grants from international organizations could finance jobs held by local people, such as

ex-poachers, to protect the tortoises and serve as wardens. Former collectors could help educate schoolchildren and local people about protecting Radiated Tortoises and other wildlife. Organizations, such as Earthwatch Institute, might sponsor research to study the status of these tortoises. The presence of scientists would pose a deterrent to poachers.

Two other endemic tortoises, the Spider Tortoise (*Pyxis archnoides*) and the highly endangered Flat shelled Tortoise (*Pyxis planicauda*), are much smaller, about 5 or 6 inches long (Preston Mafham 1991). The latter tortoise is restricted to a forest of only 40 square miles, and a captive breeding program is attempting to prevent its extinction. Both these tortoises lay only a single, large egg (Preston Mafham 1991). These tortoises are also in demand by reptile collectors. In August 1996, six men were indicted after being arrested with four Spider Tortoises in their luggage at the Orlando International Airport in Florida. They were part of a smuggling ring supplying rare reptiles to collectors. In 1999, 330 Spider Tortoises were seized along with Radiated Tortoises in the case cited above (TRAFFIC 1999b).

The Madagascar Big-headed Turtle (*Erymnochelys madagascariensis*), is an endangered freshwater species listed in the *2000 IUCN Red List of Threatened Species* and on Appendix II of CITES. This turtle is related to South American river turtles, another link that may date back to the time before Madagascar drifted away from Gondwana. The Jersey Wildlife Preservation Trust began a breeding program for these turtles in 1999 with the objective of releasing young turtles back into the wild after educating local people.

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians: Page 3

Madagascar is home to two thirds of the world's chameleons--at least 62 species--more than any other country (Tyson 2000). Among the island's endemic chameleons are the world's smallest and largest species. The smallest, *Brookesia minima*, is only 1.3 inches long, while the largest, *Furcifer oustaleti*, measures 27 inches in length (Preston Mafham 1991). Their conical eyes, moving independently, can look forward and backward at the same time, swiveling almost 180 degrees in either direction (Preston-Mafham 1991). This adaptation, processing totally divergent information spontaneously, would confuse most vertebrates, but chameleons, even very young ones, are adept at using these dual periscopes to locate insects and other prey. They hold onto the thinnest branch with their prehensile tails, and with long, thin legs bent at the knees, they walk in an odd back-and-forth swaying motion that resembles leaves moving in the wind. Their chunky bodies and spindly legs give them an awkward appearance, but they are superbly adapted to catching their prey by unfurling a long, sticky tongue--curled upside their mouth--with lightning speed, nailing an unaware insect with astonishing accuracy.

Their camouflage coloration, which varies greatly from bright greens, mottled browns, reds and blues, helps protect them from avian and mammal predators. Contrary to general opinion, chameleons do not change colors as they move about in the trees or on the ground to match their background. When they suddenly change colors, it is as a territorial or sexual display meant for other chameleons (Preston-Mafham 1991). Some species have horns and other protuberances, giving them the appearance of miniature dinosaurs. A few species show sexual dimorphism, or a physical difference between the sexes. The contrast can be so striking that some were considered separate species when first identified (Burger and Price 1996). In one species, for example, the female is black and yellow, and the male a mottled brown and white (Burger and Price 1996).

Chameleons are heavily exploited by collectors who capture them for sale in pet stores around the world, threatening them. Collectors will pay $1,000 or more per animal for rare species. This trade, which involves thousands of individuals, has caused declines in many species. The Malagasy government has banned trade in most species, but enforcement is not strong. One chameleon, *Chamaeleo brevicornis*, of which 795 were exported in the first six months of 1990, is restricted to only a few areas of primary forest (Behra 1993). An ongoing study will evaluate whether to allow trade in the commoner species. Chameleons captured and shipped abroad for the pet trade suffer very high mortality as a result of inhumane transport conditions and inadequate care in pet stores and people's homes. They

require special conditions of temperature and humidity, and many have specialized diets. In short, they are not suited to being house pets. In the care of specialists, they can be kept alive, but most captive breeding has been unsuccessful. Some of the rarer species, such as the beautiful blue-green Parson's Chameleon (*Chamaeleo parsonii*), which can reach lengths of more than 20 inches, have not been bred to the second generation**,** and mortality is high. All chameleons are on Appendix II of CITES, which requires export permits, but none has been listed on Appendix I of CITES, which would ban commercial trade.

Although some chameleons have adapted to disturbed habitats, such as weedy fields and shrub landscape, the majority favor natural habitats. The small *Brookesia* chameleons, of which one species is listed by IUCN as Vulnerable (Hilton-Taylor 2000), require undisturbed, primary old-growth forest. Three other chameleons, all *Furcifer* genus, are listed as Vulnerable by IUCN. All are in decline, approaching endangered status.

Although many Malagasy regard chameleons as ugly porters of bad luck (Burger and Price 1996), for tourists, they are the second most popular animals, after lemurs. Some Malagasy, aware of the fascination with which chameleons are held by tourists, capture them and offer them for viewing or sale.

Another lizard being captured for the pet trade is the extraordinary 4-inch-long Leaf tailed Gecko, *Uroplatus fimbriatus*, a true master of camouflage. Resting during the day with its head tight against a tree trunk, an elaborate lacy fringe along the underside of the body allows it to melt into the tree, while its skin is patterned to resemble tree bark. Even its golden eyes are streaked with tiny dark lines that imitate bark. With broad, flattened front feet splayed out against the bark and hind legs held vertically under a spatula like tail, it becomes virtually invisible (Preston Mafham 1991). If discovered, however, it has a defense. Opening its mouth wide to reveal a crimson red tongue, it raises its tail vertically and emits an ear-splitting screech, no doubt intended to be a fearsome display (Preston Mafham 1991, Tyson 1994). Malagasy boys have discovered the haunts of the Leaf-tailed Geckos, and capture hundreds--thousands by their accounting--for sale to foreign middlemen who pay them less than $1. They are sold in the United States for $250 a pair (Tyson 1994, Tyson 2000). On Nosy Be island off the northern coast, schoolboys claim to have captured 40,000 over the past six years (Tyson 2000). A threatened gecko, Standing's Day Gecko (*Phelsuma standingi*), is native to the spiny forests of the south and is one of the most coveted by collectors (Tyson 2000). It is hunted out of many areas because Malagasy have captured hundreds, receiving $1.20 per gecko, while reporting only a few to authorities (Tyson 2000). It is on CITES Appendix II, and sells in the United States for $80 to $200 apiece (Tyson 2000). Most species of geckos bring the village collectors only about 3 U.S. cents, while the exporter receives $9 to $13 and U.S. retailers get $75 or more (Burger and Price 1996). In most cases, these pet reptiles live a very short time, and represent a mere toy to the consumer.

The export trade in live lizards involves an enormous number of animals. One gecko, *Phelsuma serraticauda*, was known only from a few museum specimens until 1,360 specimens were chronicled as exported during the first six months of 1990 for the pet trade (Behra 1993). During this same period, 22,837 lizards--geckos, *Phelsuma* genus, and chameleons, *Chamaeleo* genus--were exported from Madagascar (Behra 1993). Between 1986 and 1991, almost 145,000 lizards of 17 species were exported; of these at least 38,325 were chameleons of 21 species (Burger and Price 1996). Many of these are species that are endemic to restricted areas, or threatened in the wild. The U.S. Fish and Wildlife Service s Operation Chameleon succeeded in arresting 19 people in 1998, among whom was a major Malaysian smuggler and an American, Tommy Crutchfield, who was arrested at Miami International Airport with suitcases full of rare snakes, tortoises and lizards. In another case, a Canadian and a Dutchman were arrested at Chiang Kai-shek International Airport in Taiwan with numerous chameleons and geckos, including some threatened Standing's Day Geckos.

Several gecko species have extremely limited ranges. A newly described leaf gecko, *Uroplatus malama*, is known from a single specimen taken in a remnant of lowland rainforest in southeastern Madagascar (Burger and Price 1996). Only two specimens of a closely related species, *Uroplatus malahelo*, exist, native to a small patch of forest in the south (Burger and Price 1996). When discovered, its habitat was being logged, and the species may already be extinct (Burger and Price 1996). An extremely rare lizard, *Zonosaurus boettgeri*, known from two specimens that were taken

in the 1890s and subsequently disappeared, has been rediscovered on the island of Nosy Be by herpetologist Chris Raxworthy and volunteers from Earthwatch Institute (Tyson 2000). The two individual lizards were killed as specimens upon rediscovery (Tyson 2000).

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Among Madagascar's 80 types of snakes--all non-poisonous--are three boas, whose closest relatives are found in South America (Burger and Price 1996). They are thought to be among the island's most ancient inhabitants, resident since the early breakup of Gondwana (Preston Mafham 1991). All are considered Vulnerable by the IUCN (Hilton-Taylor 2000): Dumeril's Boa (*Acrantophis dumerili*), Madagascar Boa (*Acrantophis madagascariensis)*, and the Madagascar Tree Boa (*Sanzinia madagascariensis*). The first two are Madagascar's largest snakes, reaching almost 6 feet in length; Dumeril's Boa is restricted to the south and southwest, while the Madagascar Boa is found in the north and northeast (Preston Mafham 1991). Both species require humid habitats along streams and watercourses. Placid and slow moving, they are often killed or captured by local people. The Madagascar Tree Boa is smaller and more common, shaded in delicate grayish-green with a purplish blue tinge. Little is known of any of these species' life histories and diets (Preston Mafham 1994). A very rare and possibly extinct snake, *Pararhadinea albignaci*, is known only from a single specimen picked up, dead, off the road in eastern Madagascar in 1970. This species has never been seen alive in its forest home (Preston-Mafham 1991).

One of the most extraordinary snakes in the world, *Langaha nasuta*, mimics a dry, pencil-thin twig to camouflage itself among the leaves. The female's nose is extended into a leaf shaped structure adorned with scales and small tooth like projections, while the nose of the male is elongated, tapering into a sharp point to resemble a thorn (photo in Preston Mafham 1991 and Lamar 1997).

A smuggling operation involving hundreds of Madagascar reptiles was exposed in August 1996, when six men were charged with conspiracy to smuggle rare Madagascar reptiles into the United States and Canada. According to the U.S. Justice Department, two men were arrested at Orlando International Airport in Florida with 61 Madagascan tree snakes in their suitcases that were to be sold at a large reptile breeders show in Orlando (Reuters 1996). Four Germans, one Canadian and one South African were indicted. Simon Harris, the South African, had $100,000 worth of rare reptiles in his luggage; he cooperated to implicate the other suspects, who are still being sought (Reuters 1996). These smugglers shipped snakes and tortoises, concealed in suitcases, from Europe to Canada and the United States and received payment by international wire transfers. Most of the snakes and tortoises were listed on CITES. In 1998, 26 Madagascan Tree Boas were seized in Belgium, and an American reptile dealer was caught by the U.S. Fish and Wildlife Service with the latter species and Dumeril's Ground Boas in his luggage at Miami International Airport (TRAFFIC 1999a).

The sea turtles inhabiting Madagascar's coastal waters are heavily exploited in spite of their listing on Appendix I of CITES. A survey in 1971 estimated that 13,000 were killed along the west coast alone (Burger and Price 1996). Little is known of their present populations.

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Some 176 species of amphibians, all frogs, have been named and described (Mittermeier *et al.* 1999). Raxworthy estimates that there are another 124, many of which have already been found but not yet described scientifically (Tyson 2000). Salamanders and toads are absent from Madagascar. All but two frogs are endemic, one of which was introduced from Asia by French colonialists as a gourmet food source (Burger and Price 1996). The majority are

native to rainforest environments, the most endangered type of habitat on the island. In one such area, a montane rainforest in the Andasibe region, 90 species are native--the highest diversity of frogs in the world (Burger and Price 1996). Since 1990, 13 new species of a single, colorful genus, *Boophis*, have been described, and others await naming by scientists (Burger and Price 1996). A candidate for the world's smallest frog--and perhaps the world's smallest vertebrate--is a minute frog, *Stumpffia pygmaea*, which measures less than 3 millimeters in length (0.117 inches) (Burger and Price 1996). This frog lays its eggs in foam nests hidden among leaves on the forest floor, and the tadpoles grow into froglets without ever feeding (Burger and Price 1996).

The most spectacular Malagasy frog may be the bright red Tomato Frog (*Dyscophus antongili*), which secretes poisonous white mucous when threatened. Some authorities consider the species to be endangered (Bauer 1995), while the *2000 IUCN Red List of Threatened Species* lists it as Vulnerable. To protect it from trade, it is listed on Appendix I of CITES. Fat and squat, this toad-like frog is large enough to cover the palm of a hand (Preston-Mafham 1991). Tomato Frogs have a very restricted range in the region of Tamatave on the east coast; some live in plantations, where pools of water gather, and even in garden ponds (Preston-Mafham 1991). Collectors, pet dealers and zoos have offered thousands of dollars for these frogs, and illegal shipments containing 40 or more Tomato Frogs have been confiscated.

One study entitled "The Export of Reptiles and Amphibians from Madagascar," by Olivier Behra (1993), chronicled the extent of exploitation of frogs. In 1988, 230 frogs of the genus *Mantella*, endemic to Madagascar, were exported. The demand increased, causing exports to rise astronomically to 11,058 in 1989; in the first six months of 1990 alone, almost 11,000 were exported, mainly to Denmark and other European countries, the United States and Japan (Behra 1993). These brightly colored little frogs are sold as pets and to decorate terrariums. The most popular Madagascar frog in this trade is the tiny Golden Mantella (*Mantella aurantiaca*), of which 3,237 were exported in the first six months of 1990 (Behra 1993). This frog is restricted to eastern Madagascar, and is apparently rare and declining (IUCN 1994). It lives in pandanus swamps in rainforests, which are rapidly disappearing, and no part of its habitat has been set aside in a reserve (IUCN 1994). Unlike most frogs, the Golden Mantella is slow-reproducing (IUCN 1994). In the 1990s, 3,000 to 6,000 were exported annually from Madagascar, and in 1994, two proposals sought to list this species on CITES, one on Appendix I and the other on Appendix II. The latter proposal succeeded, which is unfortunate, since it allows the trade to continue. The *2000 IUCN Red List of Threatened Species* lists the Golden Mantella as Vulnerable (see photos of gold and red phases of this species in Lamar 1997).

In 1998, two people were arrested in Taiwan trying to smuggle frogs of two *Mantella* species (*Mantella madagascariensis* and *Mantella aurantiaca*), along with some Madagascar lizards. Another seizure of 50 Mantella frogs occurred at Zaventem Airport in Belgium in 1998 as they were being smuggled from Madagascar (TRAFFIC 1999a). Such seizures involved shipments without the proper export permits. Appendix I listing under CITES would provide greater protection.

The Biological Wealth of an Impoverished Country: Invertebrates

Like the rest of its fauna, Madagascar's invertebrates are extraordinary. One insect from the age of the dinosaurs, the Giraffe-necked Weevil (*Trachelophorus giraffa*), has an elongated neck which rises vertically, then makes a right-angle turn and extends horizontally, and ends in a tiny head with furry antennae. Amazingly, this insect has counterparts in New Zealand known as giraffe weevils (Molloy 1994). This may be explained by the fact that New Zealand was also part of Gondwana prior to its breakup (Molloy 1994). Other ancient species include the 100 species of hissing cockroaches. Some are far larger than any other cockroach species in the world; their heavy bodies resemble long-extinct trilobites. The largest species measure up to four inches long, and thousands are exported for the novelty pet trade and for zoos. When touched, they hiss loudly, and males aggressively charge one another with their armored, knobbed shields (Preston-Mafham 1991).

One of the richest land-snail faunas in the world is native, with more than 380 species named so far, 361 of which are endemic and differ greatly from land snails in Africa (Preston-Mafham 1991). Many are threatened, however, by introduced African Giant Snails (*Achatina fulica*) and several other non-native snails introduced to control the African Giant Snail, but threatening native species instead. One native snail, *Tropidophora deburghiae*, is considered endangered by some authorities. Brilliantly colored slugs, or shell-less snails up to 6 inches long, striped in black-and-red or yellow-and-brown, live on the damp rainforest floor (Preston-Mafham 1991). Many have limited distributions and can be easily eliminated by habitat destruction (Preston-Mafham 1991).

An extremely ancient family of spiders, Archaeidae, first described from a specimen frozen in amber several million years old, has seven species on Madagascar, one in South Africa, three in Australia, five in New Zealand and one at the tip of South America; these species appear to be vestiges from the ancient supercontinent (Preston-Mafham 1991). The Archaeidae spiders have strange, grotesquely shaped bodies, visible only through a microscope since they are only 0.14 inches long; they live among leaf litter on the ground (Preston-Mafham 1991). Some Madagascar spiders are extremely bizarre, with shapes that resemble bat-winged leaves, bright red thorns, or mottled brown lumps on logs (Preston-Mafham 1991).

Millipedes on Madagascar reach 6 inches and exude droplets of poison when attacked; Brown Lemurs have found ways of avoiding this toxin and feed on them (Preston-Mafham 1991). Shield-bugs, or stink-bugs, of the family Pentatomidae, have 220 species on Madagascar, many of which are brightly colored in reds, oranges and blacks; 120 species of water bugs, of which 80 percent are endemic, and a variety of assassin bugs add to the rich insect fauna (Preston-Mafham 1991). About 20,000 beetle species, including 500 species of endemic jewel-beetles, are native to Madagascar. Jewel-beetles, with their colorful, metallic bodies, appear during the rainy season in southern and western forests (Preston-Mafham 1991). Many species of scarab beetles, among which are dung beetles, are also native to Madagascar; one endemic genus, *Helictopleurus*, roll the dung balls into their nests and lay their eggs in them (Preston-Mafham 1991).

Madagascar's butterflies, totaling 300 species, are not as diverse as in some parts of the world, such as the Tambopata Natural Reserve in Peru, which has 1,300 species. This may be because they colonized the island fairly recently. Another possibility is that many species have faded into extinction, leaving no trace, when the plant species upon which they depended were driven to extinction by habitat destruction. Since 80 percent of the island's forests have been cut, hundreds or thousands of species may have disappeared without a trace millennia ago. One Madagascar butterfly, a pale cream-and-black Swallowtail, *Papilio mangoura*, is hotly pursued by collectors because of its rarity (Preston-Mafham 1991). Several butterflies of the Nymphalidae family, or Fritillaries, are threatened, as are two species of the family Acraeidae.

In the 19th century, Charles Darwin learned of a spectacular, white Madagascar orchid (*Angraecum sesquipedale*) that had an extremely long, nectar-bearing tube dangling down from the flower. He reasoned that it could be pollinated only by an insect that could reach its nectar. He guessed that it might be "some huge moth, with a wonderfully long proboscis." Entomologists verified his belief with the 1903 discovery of the hawkmoth, *Xanthopan morgani praedicta*. This moth has a 9-inch tongue that it keeps wound in a spiral in its mouth, unfurling it to reach the nectar of this particular orchid. In a similar arrangement, another orchid (*Angraecum arachnites*), exudes a strange odor that attracts only one pollinator, the rainforest hawkmoth, *Panogena lingens* (Preston-Mafham 1991). The nectar at the base of this orchid's long, twisted tube can be reached only by this single species of moth--and not even every individual, but only one race of this moth which has a long, tapered proboscis (Preston-Mafham 1991). These species co-evolved, and should the moths become extinct, the orchids would have no pollinators and would follow them into extinction. Another unusual moth, the huge Comet Moth (*Argema mittrei*), is one of the largest moths in the world (Preston-Mafham 1991).

Preserving Madagascar's Natural Wonders

This fourth largest island in the world is, in many respects, a minicontinent. This evolutionary treasure-house is of great importance from a worldwide perspective. Madagascar's diversity of life forms is so great that as many as 200,000 species, most of them undescribed, may be native, of which an estimated 150,000 are endemic species (Daley 1997). The habitat loss is proceeding so rapidly, however, that the underfunded biological assessment studies will be unable to appraise this biological wealth before it disappears before their very eyes. Logging and burning have reduced the forested area from 120,000 to 20,000 square miles; this destruction still consumes vast areas each year (Daley 1997). It is estimated that all the remaining accessible forests will disappear within the next 35 years (Sayer *et al.* 1992). With the impending loss of these treasures, many conservationists and scientists consider Madagascar the world's most threatened natural area (Sayer *et al.* 1992).

Less than 5 percent of Madagascar is protected in reserves and parks. Even if these lands remain intact, they represent too small a percentage of forest to preserve the island's genetic heritage. Other than Masoala National Park, which encompasses most of an entire peninsula, some 840 square miles, most reserves are relatively small--islands of forest surrounded by denuded land. Should all surrounding forest be leveled, these isolated fragments would not be sufficient to prevent genetic impoverishment, inbreeding, and eventual extinction of the very species the reserves were meant to protect. Recent research in the Amazon has shown that forest fragmentation results in extinctions, in direct relation to the size of the reserve (Peters and Lovejoy 1990). The larger the reserve, the fewer extinctions. For this reason, Masoala National Park is receiving special attention from scientists. Stanford University's Center for Conservation Biology is analyzing a Geographic Information System (Kremen 1998). So far, this research has revealed that forests on the eastern border of the park are the most threatened, with a likelihood that they will be completely burned away within 25 years (Kremen 1998). The borders of the park were delineated according to the results of biological surveys, a method that is so new that it has not even been used in the United States. Claire Kremen of the Wildlife Conservation Society, with additional support from the National Geographic Society, worked with a Malagasy entomologist and two American ornithologists to conduct detailed biological species diversity studies in this rugged terrain (Kremen 1998). Five new species of butterflies and many other insects were discovered. Each had its own micro-habitat, endemic to that area. Habitats included in the national park are lowland rainforest; cloud forest and montane heath; coastal and seasonally flooded forest; mangrove; marsh; estuary; bay; lagoon; and coral reef. Lemurs and a vast array of wildlife and plants will benefit from this new park.

Masoala National Park will not displace villages but will conduct education programs and involve them in the conservation of local wildlife. The Missouri Botanical Garden is also involved in the management of Masoala National Park, helping to inventory its rare plants and working with local people for non-destructive agricultural and fisheries industries. Work is also proceeding to stop the cutting of forests for firewood on Masoala and to provide public education on land use (Sayer *et al.* 1992). Some 300 or so villages exist within or nearby Masoala National Park, and the cooperation of the local people is crucial to the success of this park. The final plan for the park involved a compromise in which some cutting of four relatively fast-growing trees, including rosewood, would be allowed. Local communities, which will profit from the products, will be allowed to harvest palm seeds and butterflies. This will prevent the slash-and-burn destruction that was eating rapidly away at this forest (Kremen 1998). This park's endemic plants and animals, including the Red Ruffed Lemur, which exists only in the park, rely for their survival on the protection of this last sizeable rainforest. It will represent an experiment in conservation management that will have serious consequences should it fail. It is, however, one of the first times that ecological rules are being worked out with large numbers of local people to help protect such a large area. Elsewhere in Madagascar, similar projects are in the works.

Many of Madagascar's rarest species are not protected in any reserves, however, and may soon be lost. Reserves and

parks, the last refuge for many species, are regularly pillaged for trees, and wildlife is killed or captured. A herpetologist surveying in Bemaraha Reserve, in the western part of the island, discovered a pile of illegally cut trees that had been marked with red paint as part of a botanist's study by the trail in 1996 (Holmes 1997). This is not an isolated occurrence. The native wildlife and plants are among the most endangered in the world. More than 124 vertebrate species are listed in the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor 2000), as well as 306 species of plants (Walter and Gillett 1998). While this crisis is occurring, new species of lemurs, reptiles, invertebrates and plants are being discovered, making the preservation of the environment all the more urgent. Obviously, the amazing biological diversity of Madagascar has not been fully assessed and may be far greater than previously thought.

Several species thought long-extinct are rumored to survive, adding even more mystery to the picture. Many Malagasy have told scientists of having seen an animal that might be a pygmy hippopotamus. Shown a picture of an African Common Hippopotamus, they have said that it was similar, but had floppy ears, uncloven hooves, dark skin, except for pinkish areas around the eyes and mouth, and was the size of a calf or small cow (Tyson 2000). As recently as 1976, a man told biologists of having seen and heard one grunting; many unsolicited, independent accounts from Malagasy have agreed on these details (Tyson 2000). They call the animal "kilopilopitsofy," and many are afraid of being chased by it (Tyson 2000). The Common Hippopotamus of Africa also grunts and kills more people than any other animal on the continent.

A long-lost primate, ground-dwelling and the size of a 7-year-old child, has also been reported by several Malagasy (Tyson 2000). This may be the same animal that was described to primatologist Alison Jolly (1980). A Malagasy told her that he had been given a young lemur of a type he had never seen before. This lemur had very dark fur, walked on its hind legs, one foot after the other, rather than hopping like a sifaka, and had a flat face different from the pointed muzzles of living lemurs. After only two months, this lemur died, and its skeleton was buried in an unknown place (Jolly 1980). An old man recently told a similar story of having seen such an animal in 1952. Called the "kidoky" by others who have seen it, it has a dark coat with white spots above and below a flat, round face. When alarmed, it flees by leaping forward in short hops like a baboon. Its call was described as a long, single whoop, and other villagers who had seen the animal said it was solitary (Tyson 2000). Scientists have said that if it exists, it might be an *Archaeolemur* or *Hadropithecus* (Tyson 2000). The fact that their descriptions seem so similar to species known to have existed makes them all the more intriguing.

Alarm calls about the impending demise of Madagascar's natural world have been sounded for decades (Jolly 1980, 1988; McNulty 1975; Preston Mafham 1991; Tyson 2000). Visitors to the island are united in their descriptions of a ravaged, eroded and deforested land. Jacques Yves Cousteau and his team visited the island for a television special aired in 1995. As they sailed toward Madagascar, they were stunned to see huge, wide, red stains of eroded soil in the water, emanating from the island's rivers, and wisps of smoke from burning forests. These red rivers are bleeding the island's life blood, its topsoil. They are so pronounced that they are among the few natural phenomena on Earth visible from orbiting space craft. Cousteau's helicopter flights over the central plateau revealed a landscape among the most devastated on the planet. A research team sponsored by Earthwatch Institute described the island from the air, "Two features of the landscape stood out even from 10 kilometers up: barrenness and smoke" (Tyson 1994).

Although erosion remains a major problem, some progress has been made to stop it (Morell 1999). Erosion costs Madagascar between $100 million and $290 million per year, caused mainly by the continued slash-and-burn agriculture (Tyson 2000). It has been extremely difficult to convince many Malagasy that the last of the forests will disappear within a generation if they do not seek alternative means of growing crops. To that end, Cornell University's International Institute for Food, Agriculture and Development, run by Norman Uphoff, has been helping farmers in the vicinity of Ranomafana National Park (Tyson 2000). These desperately poor farmers have no electricity or plumbing and struggle to feed large families on soil that is leaching its nutrients. Norman Uphoff discovered that the native Wild Ginger plant had high concentrations of phosphate, and he encouraged its use as fertilizer (Tyson 2000). By supplying seedlings and information, the Cornell program also has helped establish fish farms. Their agronomists have advised farmers to mix crops and to plant certain species in order to keep the soil rich and retard erosion; they

have supplied seedlings (Tyson 2000). This agricultural advice has been helpful, but because some rural people have so many children, many are unable to produce enough crops to feed their families (Tyson 2000). Other projects involve encouraging rice cultivation with more suitable seed varieties, improved irrigation systems and application of fertilizer (Garbutt 1999). Using native bees in honey-making is also being taught to the Malagasy, who often fell old-growth trees to obtain honey (Garbutt 1999). The Kew Botanical Gardens in London and Britain's Royal Palm Society are researching the marketing of seeds from some native palm trees (Terry 1996).

International aid organizations could help preserve forests by donating fertilizer so the Malagasy would not need to practice slash-and-burn when forest soil ceases to produce crops. The urgent task of supplying the Malagasy people with methods of producing food and fuel in environmentally non-destructive ways has just begun. Villagers would be more likely to preserve trees now cut for firewood if they were provided with solar cookers or given propane tanks for fuel. Bio-gas, or methane, produced by animal dung and sewage, could be used to provide fuel and fertilizer. Such projects have been launched by international agencies in some countries of Central Asia.

Madagascar's human population is growing at a rate of 3.1 percent per year and reached 12,596,000 in 1992 (55 persons per square mile) (Anon. 1994). By 1995, it had grown to 13.9 million (61 persons per square mile) (McNeil 1996b). Another increase to 14,462,509 people (64 persons per square mile) was registered in the 1999 *World Almanac*. The *2001 New York Times Almanac* noted a population of 15,506,472, based on a July 2000 estimate. Thus, 3 million people were added to the population in just eight years. Along with the original Asians, more recent immigrants from Africa, India, Pakistan, China, Europe, and Arab countries add to the diversity. They have long since passed the carrying capacity of the land, and rice must be imported to feed the people. As one of the world's 12 poorest countries, Madagascar's external debt is approximately $4.25 billion. Average annual income is only $780 (NYT 2000). The unemployment rate is about 33 percent, and 51 percent of children are malnourished, according to a study by USAID (Tyson 2000). The literacy rate is 46 percent, and only 42 percent of children attend schools; 70 percent of children ages 6 to 9 have had no formal education (Tyson 2000). Jacques Cousteau's team filmed hordes of desperately poor people as they combed dumps for scraps of metal and food. Some people even live in these dumps in holes they have dug in the soil. Such scenes are symptoms of extreme overpopulation and rampant poverty that can also be seen in parts of Brazil and Asia.

One of the reasons that illiteracy is so high in Madagascar is that millions of people must spend their days searching for food, water and firewood, requiring the help of their children, who are then unable to attend school. In general, foreign corporations have looted the island's resources, leaving no economic base that would help the people as a whole. One U.S. company, the Esso Corporation, is owed $25 million by the Madagascan government and demanded payment in spite of the country's cash reserves of less than $2 million (McNeil 1996b). Because of the country's debt levels, the World Bank and the International Monetary Fund are now in charge of its finances (McNeil 1996b), a potentially dangerous situation for both the people and the environment. On the positive side, a "Debt for Nature" swap was carried out in Madagascar, in which a portion of the foreign debt was exchanged for the establishment of nature reserves and parks.

To date, efforts to slow the population growth rate are still in their early stages. A program that addresses population growth, based not on threats or punishment, but on persuasion, was launched by Population Communications International (PCI) of New York City in 1996. As the organization has done in other countries, it trains local people to create communication programs for radio and television with a message that limiting family size is advantageous. The majority of the population on the island lives in cities and has access to these media. The programs, described as "soap operas" by PCI, create melodramas with characters the audience can identify with, who act out dramas. The characters in these dramas come to realize that different behavior, such as having fewer children, will result in positive changes in their lives (Ryerson 1994). In many cases, this involves elevating the status of women, and convincing men that women must be allowed to make decisions about their own reproduction (Ryerson 1994). PCI is cooperating with organizations that are actively trying to conserve the wildlife of Madagascar, such as Conservation International and the African Wildlife Foundation. Ranomafana National Park began a family planning center in 1994 to help the people of the region, many of whom have as many as 14 children, of which 62 percent are underweight and 17 percent

malnourished, according to a study by the University of North Carolina (Tyson 2000).

Madagascar is a magnet for scientists from around the world and has been the recipient of millions of dollars in foreign aid and grants from international conservation agencies. Conservationists are initiating many highly inventive and effective programs to interest the Malagasy in conservation and employ them in biodiversity work. Environmental education is a key to the future of Madagascar, and programs are being carried out at Beza-Mahafaly Reserve. This protected portion of endangered spiny desert and shrubland was established when the local Mahafaly people agreed to donate the land, and funds were raised by Alison Richard, a Yale primatologist, for a training program for Malagasy scientists (Tyson 2000). Patricia Wright has set up a similar program in which Malagasy students complete master's theses based on wildlife research in Ranomafana National Park, and some students travel to the United States to receive advanced training in biodiversity and environmental protection (Tyson 2000). They will help guide the country in new directions in the future. It also opens new worlds to these students, who, in turn, will make young people aware of the natural treasures in their country. Schools that Patricia Wright has helped establish in the area of the park teach environmental education to young people. Others are also helping introduce this subject to children. Josephine Andrews, a Scottish scientist studying Black Lemurs in Nosy Be since 1988, teaches children about the lemurs with the help of a Malagasy named Julien, who guides people around the forest preserve (Tyson 2000). "If the kids are really into it, then the adults will switch on as well," she said (Tyson 1994). Forests are the key to the future survival of the island and its people, and an education program aimed at rural people, teaching the value of trees in preventing floods, landslides and in maintaining the flow of rivers and streams, could save countless trees.

Scientists--both Malagasy and foreign--working on the island, could share their findings by talking with local people about the uniqueness of Madagascar's natural world. Ornithologists with the Peregrine Fund, who rediscovered the Red Owl and taught local schoolchildren about the species donated money from bird-watchers to the school, provided such an example. Scientists typically conduct research and depart without having taught local people about their findings. Villagers near Ranomafana National Park were so interested in learning about research results that they asked Wright for copies of reports. She began a bimonthly newsletter, in the Malagasy language, describing the natural history of the park (Tyson 2000).

Films and books about Madagascar's wildlife and plants tend to be distributed only in foreign countries, and never translated into Malagasy. Translations of books and subtitled films could be shown to schoolchildren to introduce them to Madagascar's tremendously interesting and beautiful natural world. It is ironic that Westerners may be more familiar with lemurs and chameleons that most Malagasy. Some projects for the future might include donation of solar collectors and windmills to supply power to rural people. This could elevate their standard of living and cut back on firewood collection for fuel. Donation of projection and video equipment to regional schools provided with electricity would help them appreciate their natural heritage through viewing nature films of Madagascan wildlife. Satellite dishes would facilitate communication with people around the world through the Internet.

The government of Madagascar developed a 20-year National Conservation Strategy and Environmental Action Plan as long ago as 1984. In 1986, a survey of protected areas began with the aim of implementing management plans for priority protected areas and recommending new protected areas, as well as training Malagasy people to work in reserve management and conservation biology. The government has been working to create a sense of pride and ownership in the nation's biodiversity through this program (Morell 1999). The President of Madagascar has stated that the environment is important, a key to whether foreign scientists and tourists will be able to come to the country and aid in its conservation in the future (Tyson 2000). The World Bank and various organizations funded this Environmental Action Plan with $168 million for its first five years (Tyson 2000). This has resulted in many biological studies, education of a growing number of Malagasy for conservation work and a Biodiversity Planning Centre (Sayer *et al.* 1992). The Geographical Information System database is a cornerstone of the government program, concentrating data from all fields to help establish conservation priorities (Tyson 2000). Conservation International has an office in the capital and is contributing to biological inventory data, as it has in other countries, as well as conducting research on particular species and data management. It coordinates its work with local organizations and trains Malagasy scientists (Sayer *et al.* 1992).

Ecotourism is another budding industry, and Madagascar is one of the few countries in the world to share park fees with local people. As a result of an initiative put forth by a Malagasy non-governmental organization, the National Association for the Management of Protected Areas, one-half of all fees are given to local people (Tyson 2000). Ninety-three villages in the Ranomafana National Park area received about $10,000 in a recent year from park fees; a committee designated by the villages decides how to spend the money. In 1995 they bought seeds and built campgrounds, a crafts training center and small dams (Tyson 2000). Many local people are employed as park workers, and the aim of the program is to turn over management of this park and its biodiversity work to the Malagasy people. There needs to be a national park system with strict rules for management and protection, according to Patricia Wright, who deplored the illegal tree cutting by the previous park director at Ranomafana (Tyson 2000). She also has proposed that a national biodiversity institute be built, which would offer centralized training in biology and technology, as well as five new long-term biodiversity research stations similar to those in La Selva National Park in Costa Rica and the Smithsonian Institution's Panama tropical research laboratory (Tyson 2000).

Jobs, which are desperately needed by the Malagasy, are increasing as a result of the rise in the number of tourists. Selling crafts to tourists, running hotels and restaurants, and serving as guides are among these. Villagers who used to demand that parks be declassified so that they could legally gather wood, now request that more national parks be established, an apparent result of the new income that comes from fees and tourism (Morell 1999). International tourists have provided a major new source of revenue in Madagascar's economy and are helping the Malagasy see their wildlife in a new way, as so fascinating and biologically important that visitors come from every continent to view it. *Madagascar. The Bradt Travel Guide*, by Hilary Bradt (1999), published in various editions since 1988, is a useful aid for tourists, providing information about accommodations, natural history, protected areas, and the Malagasy and their history. Nature reserves and parks provide jobs by attracting scientists who employ local people, another incentive for the Malagasy to urge that more protected areas be set aside.

Compensation for lost access to forests has not been paid in the past, and new arrangements reached with villagers to allow some extraction of resources from the forests may heal some of these wounds and placate those who still wish to cut trees. Medicinal plants obtained from Madagascar may be another source of revenue in the future. The Rosy Periwinkle may be only one of many native plants highly valuable in treating disease. Research on the potential of other plants may uncover other such treasures. In the past, revenues from plants used for medicine have not been returned in part to the country of origin, but recently a new trend has begun. In one case, a pharmaceutical company agreed to pay people in a South American country a portion of the revenues gained from any native plant providing a marketable drug.

Another potential source of revenue is the placement of videocameras connected to the Internet, which present websites with general information as well as live camera views of wildlife. South African parks have a number of these videocameras placed at water holes, animal dens and other key areas that capture live views of animals transmitted to the Internet for a small viewing fee. This has proven very successful, funding many of the South African National Parks system s expenses. A similar system could be established in Madagascar with solar-powered videocameras, which have already been in use in Alaska, trained on tree canopies, rainforest flowers or lemurs, along with websites that provide basic information on Madagascar's environment, biodiversity and the Malagasy people. For millions of people who cannot visit Madagascar, such a website might be fascinating as a learning tool for teachers and the public, as well as an exciting view of these unique animals and their environments. If managed in such a way that profits were shared between poor Malagasy to alleviate their poverty, and conservation organizations to preserve biodiversity, such a system has great potential.

A satellite connection with classrooms in the United States or other countries would be another opportunity for interactive communication and learning. In December 2000, for example, students in an American classroom talked with students in a school in Guyana about endangered Giant Otters and their conservation through a visual satellite hookup. Students and others might set up an interactive link with biologists and conservationists working in Madagascar, asking questions and offering help. Students have provided many excellent ideas for conservation, and

classes have raised money to save rainforests and threatened wildlife habitat and to help stop poaching of endangered species in countries half a world away from their own. Malagasy young people might be inspired and enthusiastic through talking with others of their own age about conservation and biodiversity. Video cameras and still cameras might be donated to Malagasy students and young people to record nature and compete for prizes with their results.

Madagascar s Lessons

Madagascar's story is one of ecological catastrophe and the gradual extermination of its life forms. One's first response might be that its experience is as far from the rest of the world as it is geographically remote. However, it is from the extremes that one acquires basic knowledge. The effects of immigrants, whether human, animal, plant or disease, can devastate natural ecosystems wherever they occur. Islands are especially vulnerable to the effects of invasive species, including humans, because their flora and fauna have limited habitats and tend to be endemic, with small populations.

Exotic or non-indigenous species threaten 350 species of birds, or 30 percent of all threatened birds listed by BirdLife International in *Threatened Birds of the World* (BI 2000). Likewise, 361 plant species and 69 species of mammals listed by the *2000 IUCN Red List of Threatened Species* are threatened as a result of non-indigenous species (Hilton-Taylor 2000). The effects of invasive species, including humans, have been the major cause of extinction of virtually all bird species, almost all of which have occurred on islands. In the case of Madagascar, the Malagasy and other immigrant peoples and their livestock, and their subsequent hunting and habitat destruction, presented the vulnerable native species with threats against which they had no defense. Islands throughout the world continue to suffer losses in biodiversity, as do areas with large numbers of endemic species in mainland areas. Species with restricted ranges are the most likely to go extinct or become endangered. Such species dominate the list of birds in *Threatened Birds of the World* (BI 2000). In this age of international commerce, where plant diseases and other viruses are brought into countries in shiploads of lumber or ballast water, and exotic animals and plants continue to colonize and be released in delicate ecosystems with endemic species, whether on islands or mainlands, it has become extremely difficult to defend native species from such invasions. Nevertheless, through preserving native plants and animals and legislating against such introductions, while removing non-native species, ecosystems and their diversity can be protected. Preserving natural ecosystems is vitally important, not just for wildlife preservation, but for humans as well, so that precious water supplies, topsoils and biological diversity, which stabilize all ecosystems, are protected. These lessons have not yet been put into practice in Madagascar or in many other parts of the world, including developed countries. Ecological and faunal changes may be so gradual that they go unnoticed until ecosystems have been destroyed.

Madagascar Testing Quotes

About 500 A.D., immigrant people from Asia, most probably Indonesia or Malaysia, arrived on Madagascar's shores in hand-hewn canoes, bringing domestic animals with them. They began clearing forests and burning them for farmland, and turned lakes and wetlands into rice paddies. Cleared land produced crops for only a few years until the thin soil became sterile. Farmers then moved on to other parts of the forest, in this slash-and-burn agriculture. At some point, African herdsmen colonized the island, bringing zebu cattle, which crowded out wildlife (Tyson 2000). Gradually, abuse of the land eroded the soil in the central highlands to bare earth, pocketed and gouged by deep gullies and cavernous holes. This region had harbored a great variety of lemurs, along with a wealth of birds, reptiles and unique plants. Throughout the island, wildlife declined as habitats disappeared, isolating animals in smaller and smaller patches of forest and wetlands. The large lemurs, tortoises and elephant birds were avidly hunted.

Within 600 years of the arrival of the Malagasy, extinctions claimed many native animals. Several elephant bird species, the larger lemurs and many native plants vanished. Two kinds of pygmy hippos inhabited the island. The Madagascar Hippopotamuses (*Hippopotamus lemerlei*), an amphibious species, and *Hippopotamus madagascariensis*, a forest species, were both about 6.5 feet long and 2.5 feet tall, smaller than the Common Hippopotamus of Africa, which is about 10 feet long (Tyson 2000). From genetic and anatomical analysis, both seem to have evolved from the latter species (Tyson 2000). The hippos had been widely distributed and very common prior to the arrival of the Malagasy (Dewar 1984). Their bones have been found with marks indicating that they had been butchered (Tyson 2000). Both died out long before Europeans arrived. The native crocodile, whose large bones have been found, is believed by some scientists to represent large specimens of Nile Crocodiles, the species native today (Tyson 2000). It is thus possible that the crocodile survived. A large mongoose-like viverrid, *Cryptoprocta spelea*, and a very unusual aardvark-like animal, *Plesiorycteropus madagascariensis*, died out at an early date (Dewar 1984).

Prior to the arrival of humans, elephant birds had been abundant in most parts of the island, as attested by the prevalence of their bones. There were two genera, and from six to 12 species of these birds (Tyson 2000). It is likely that the flightless birds fell prey to the primitive weapons of the Malagasy and were crowded out of their habitats by livestock (Tyson 2000). The last to die out was the Great Elephant Bird (*Aepyornis maximus*), which may have survived until recent times by retreating to remote swamps. Dr. Alexander Wetmore of the Smithsonian Institution examined bones of a Great Elephant Bird unearthed in archeological excavations in the 1960s. He was amazed by their size: "The incredible femur, or thighbone, of this ponderous bird is by far the largest I have ever seen" (Wetmore 1967). Estimated to weigh at least 1,000 pounds, more than three times the weight of an Ostrich, it produced eggs larger than any dinosaur's, with a capacity of 2 gallons (equivalent to seven Ostrich eggs), 180 chicken eggs or 12,000 hummingbird eggs (Bradbury 1919, Fuller 1987). When one was X rayed, the bones of an embryo three fourths developed were revealed (Wetmore 1967). Something had interrupted the embryo's growth and frozen it within the eggshell for hundreds and perhaps thousands of years (Wetmore 1967).

Despite its fearsome size, the Great Elephant Bird lacked a hooked beak for tearing prey and was plainly not a predator (Wetmore 1967). Its large, clawed feet may have helped it defend itself against the small native predators but were not enough to protect it from Malagasy arrows. Its short legs prevented it from running as fast as its relative, the Ostrich, but it may have been quite agile when chased. This vegetarian bird browsed and cropped plants, able to reach with its long neck to the lower branches of trees (Wetmore 1967). By the mid-16th century, when Europeans had managed to establish a foothold in Madagascar, the new French Governor, Sieur Etienne de Flacourt, wrote in 1661 that the Great Elephant Bird was still found in the south of the island, "seeking the most deserted places" to avoid human hunters (Tyson 2000). Villagers of Antandroy told of an Ostrich-like bird that was difficult to catch, according to Flacourt (Tyson 2000).

The exact date this giant bird became extinct is not known with certainty. Alan Feduccia (1996), an eminent paleo-ornithologist, asserts that elephant birds of many species were still widespread in the 10th century but gradually disappeared as a result of human activity. He cites an account by a French merchant sailor in 1848, who visited Madagascar and saw the shell of the Great Elephant Bird; he was told that it belonged to the chief and that the bird that produced such eggs "is still more rarely seen" (Feduccia 1996). Some authorities estimate that it died out in the mid-17th century, although there is no proof that any European ever saw one of these birds (Tyson 2000). It has been suggested that Europeans were responsible for the bird s extinction by hunting and destroying its habitat (Quammen 1996). But Thomas Brooks (2000) of the Center for Applied Biodiversity Science, Conservation International, asserted in a list of extinct birds in *Threatened Birds of the World* (BI 2000) that all the elephant birds had disappeared by 1500. In a bizarre footnote to this species' epitaph, an *Aepyornis* egg washed up on Australia's western coast in 1995. No conclusive explanation for this strange event has been put forth, although it is likely that it became unearthed from long interment by rains, and washed out to sea. Much less is known of the other species of elephant birds, which existed in a variety of sizes down to a chicken-sized species.

Lemur-like primates once lived on many continents, but nowhere had they evolved into such a great variety of species. When the Malagasy people arrived some 1,500 years ago, lemurs occupied every habitat, even marshland. A

species as tall as a man must have startled the Malagasy immigrants, giving rise to legends that these animals had superhuman powers. The first French naturalists were told by the Malagasy that these primates were thought to be the ghosts of sacred ancestors of man, inspiring the genus name Lemur, the word for ghost in Latin. The Malagasy considered some lemurs sacred and punished anyone who harmed them, but most species were feared as evil demons and were killed on sight.

From their arrival on Madagascar, the Malagasy hunted the larger species of lemurs, almost all of which are now extinct. Archaeological excavations show that they formed a staple in the immigrants' diets. Such diggings have unearthed the skulls and bones of long extinct lemurs in early Malagasy jars and kitchen middens; their heads had been split by ax-heads made from an extinct flightless bird (Jolly 1980).

In the centuries following colonization by the Malagasy immigrants, some 15 species of lemurs of eight genera became extinct (Mittermeier 1997). These extinct lemurs were, for the most part, far larger than surviving species and had evolved to fill many ecological niches. Three *Megaladapis* lemurs weighed between 90 and 170 pounds and moved slowly through the trees, feeding on foliage (Tattersall 1993). Another species, *Archaeolemur*, was about the size of a female baboon and lived on the ground (Tattersall 1993). Two *Palaeopropithecus* species weighed between 90 and 130 pounds and were sloth like tree dwellers with flexible bodies (Tattersall 1993). These extinct lemurs had evolved many unusual means of movement and locomotion that have no parallels in living species of lemurs.

Largest of all, the massive 400 pound *Archaeoindris* was apparently a ground dweller, moving on all fours; many of its anatomical characteristics are unlike any living primate (Tattersall 1993). One entire lemur family, Archaeolemuridae, was obliterated. In this family were many species of lemurs weighing between 35 and 55 pounds; they were powerfully built and short legged (Tattersall 1993). The heaviest lemur surviving today, the Indri (*Indri indri*), weighs only about 15 pounds (Tattersall 1993). These lemurs had survived for millions of years, and their extinctions were indeed a major biological loss to the planet. According to primatologists, the surviving lemurs resemble the very earliest primates from the Eocene (Tattersall 1993). Like prosimians in Africa and Asia, but to a far greater degree, lemurs have a highly developed sense of smell. Some species have long, fox-like noses (Preston-Mafham 1991). Genetic analysis of their DNA has revealed that all lemurs are descended from a single ancestor that probably arrived from Africa about 60 million years ago (Garbutt 1999).

The Giant Aye-aye (*Daubentonia robusta*) lemur was somewhat larger and 2.5 to 5 times heavier than the surviving Aye-aye (see below), but in other respects was very similar (Garbutt 1999). It is known from subfossil remains found in southwestern Madagascar (Nowak 1999). The date of its disappearance is unknown but may be fairly recent.

Archaeologists have uncovered remains of a massive bird of prey, the Malagasy Crowned Eagle (*Stephanoaetus mahery*), which undoubtedly preyed on lemurs (Feduccia 1996). In fact, at one locality the diet of this eagle, based on the bones of eagles and lemurs found together, contained at least 80 percent primates, including specimens weighing up to 26.5 pounds (Feduccia 1996). Remains of another large eagle of the genus *Aquila* have been discovered, and it, too, preyed on large lemurs and became extinct after the arrival of the Malagasy. These extinct birds preyed on smaller lemurs as well, including some species still surviving (Feduccia 1996). A bird of prey flying overhead still elicits fear in lemurs, causing them to seek cover. Neither of the two remaining species of eagles on Madagascar preys on lemurs, but two hawk species have been seen preying on young lemurs (Garbutt 1999).

In addition to the Giant Elephant Bird, the large Snail-eating Coua (*Coua delalandei*), a member of the cuckoo family, became extinct. The last specimen of this large, slate-blue bird was taken on an islet off the east coast, Ile Sainte-Marie, in 1834 (Morris and Hawkins 1998); reports by observers who claimed to have seen the bird were recorded as late as 1930 (Fuller 1987). The causes of this bird's disappearance, and even its exact range, remain obscure (Langrand 1990). Many specimens of this bird were taken before its extinction and kept in museums in Leiden; London; New York; Paris; Philadelphia; Tananarive (Madagascar); and Cambridge (Massachusetts) (Fuller 1987). The long feathers of this bird were highly valued by the Malagasy, and hunting may have reduced its numbers to a critically low level (Fuller 1987). It is also possible that the many birds killed for zoological specimens may have

pushed this already rare bird to extinction, since its distribution may have been limited to the tiny Ile Sainte-Marie. No reliable record exists of its presence on the main island of Madagascar, but there is hope that it might be found in lowland forest near the Bay of Antongil (Morris and Hawkins 1998). Ten closely related species of couas survive, all smaller than the Snail-eating Coua.

Madagascar Testing Quotes 2
Testing "quotes again" to see whether they are "going" to have 'slashes' added to them or not.

Madagascar and other Islands

Madagascar

Imagine an island more than 1,000 miles long in a blue tropical ocean. Forests cover vast areas, interspersed with swamps where crocodiles 8 meters long lie in wait to prey on pygmy hippopotamuses. Thousands of giant tortoises with shells 4 feet across lumber about. In the forests and in dryer parts of the island live some of the strangest primates to have ever existed on Earth. Some 45 species of these lemurs live throughout the island and range in size from the world's smallest primate, weighing about 1 ounce, to a lemur the size of a Gorilla (Tattersall 1993).

Huge white birds plod along forest trails and through savannah grasses. Many kinds of these birds inhabit the island. The largest resembles an Ostrich, but is far more massive in build, weighing 1,000 pounds (Feduccia 1996). It stands 10 feet tall and lays 20-pound eggs, 13 inches long (Feduccia 1996, Greenway 1967). More than 100 other kinds of tropical birds that exist nowhere else fly in forests and deserts and wade in still marshes.

Primitive hedgehog-like mammals, called tenrecs, scurry in forest underbrush. One type of tenrec lives in cold mountain streams, swimming with webbed feet and flattened tail, while another has spines like a porcupine and stripes down its back like a skunk. It communicates with its young by vibrating its spines.

Hundreds of kinds of amphibians and reptiles inhabit forests, aquatic environments, savannahs and drylands. Frogs of every imaginable color and pattern leap in green shadows. Chameleons, some brilliantly colored, and others shades of mottled brown, creep invisibly about. The largest, 2 feet long, can capture mice and birds, while the smallest, measuring only 1.5 inches, feeds on insects (Amos 1980). Tortoises with shells adorned in delicate yellow sunburst patterns inhabit shrub and deserts.

Plants exist in unparalleled variety, a botanical paradise. Relicts of species long-extinct on mainland areas--tall tree ferns, palms, red-flowered flame trees, massive deciduous and rainforest trees, giant tamarinds and aloes, desert oddities, and baobabs of many sizes--grow in even the driest parts of the island. Orchids in a rainbow of colors bloom among the deep green rainforests. Waterfalls abound, cascading down tall cliffs into rivers and lakes. Along the west coast, a dry deciduous forest stretches the length of the island**.** The central highlands are a mosaic of woodland and savannah, while the eastern regions are covered in dense, humid rainforest. In the extreme south, a desert environment prevails, harboring *Didierea*, strange cactus-resembling plants that form long, spiny, twisted shafts rising 30 feet into the air. An impenetrable wilderness of limestone spikes and sharp rocks dominates the far north. Rare birds and lemurs find refuge in this craggy landscape and feed in oases watered by meandering streams.

Flightlessness, fearlessness, gigantism, dwarfism, and survival of ancient species all occurred in this evolutionary laboratory. That such a large land mass went uninhabited by humans for so long is truly remarkable. Nowhere else on the planet has such a large land area remained isolated for such a prolonged period, allowing a flowering of diverse

life forms to flourish and adapt to the island's many habitats and terrains in this mild, tropical climate. Such is the history of the island from Madagascar in 400 A.D., a century before the arrival of the Malagasy people of Asia. Had humans reached Madagascar earlier, it might not have evolved its diverse, yet vulnerable, fauna and flora.

How such an extraordinary diversity of animals and plants inhabits Madagascar is tied to its geological history. Some 160 million years ago, when Africa, Australia, New Zealand and South America were united in the super-continent Gondwana, Madagascar was attached to eastern Africa and what is now peninsular India. Dinosaurs, giant turtles, crocodiles, primitive mammals, reptilian birds and lizards roamed on this massive land mass. Gondwana gradually broke apart as a result of movements of tectonic plates covering the Earth's crust. For many millions of years, India and Madagascar formed a mini-continent. Then, about 88 million years ago, they split along Madagascar's east coast, and peninsular India moved northward toward Asia (Garbutt 1999, Tyson 2000). Paleontologists have only recently discovered that Madagascar was home to dinosaurs and other primitive animals quite unlike those found in other parts of the world. The oldest known species of dinosaur, dating back 227 million years, may be the ancestor of all dinosaurs (Flynn 2000). One dinosaur had teeth that were clove-shaped (Stenzelt and Thiessen 2000). Seven species of crocodiles inhabited Madagascar from the Cretaceous period onward, including a pug-nosed vegetarian species (Flynn 2000). About 65 million years ago, the last dinosaurs died out, concurrent with their extinction throughout the world. Some native plants and animals survived from the time when Madagascar was part of Gondwana. Giant tortoises, crocodiles, boas, tenrec ancestors and possibly an early form of elephant birds may have lived on the super-continent, although most ornithologists are certain that the ancestor of the elephant bird flew to the island and became flightless (Feduccia 1996). Plants of many kinds, virtually unchanged from their ancient forms, grow on the island.

Immigrant animals arrived during the millennia from many sources. Because Madagascar separated from India and Gondwana long before the evolution of the prosimians that were the ancestors of the lemurs, these primates must have come from mainland Africa, where their close relatives, bush babies and galagos, survive today. Some scientists believe they might have traveled over a land connection that existed between Africa and Madagascar at some point (Tyson 2000). Others dispute that there ever was such a land bridge and maintain that they arrived by sea, perhaps sheltering on large mats of floating vegetation or clinging to uprooted tree trunks that swept down mainland rivers to the sea and washed up on Madagascar's shores. Few modern mammals of Africa, whether baboons, monkeys, gazelles, antelope or other hoofed mammals, reached Madagascar. The hippopotamuses must have originated in Africa, but how they came to the island is another mystery.

Over many millennia, a blossoming of evolution occurred in this mild, tropical climate of Gondwandan and immigrant species, radiating into entire new families and creating a flora and fauna of great diversity unlike any in the world. Birds, bats and insects flew or were blown to the island by wind currents and storms from Africa and Asia. No large carnivores arrived, however. The largest mammal predators are relatives of mongooses, primitive viverrids. Grazing and browsing roles were filled by hippopotamuses, land tortoises, lemurs and elephant birds.

Human Settlers Invade Paradise

About 500 A.D., immigrant people from Asia, most probably Indonesia or Malaysia, arrived on Madagascar's shores in hand-hewn canoes, bringing domestic animals with them. They began clearing forests and burning them for farmland, and turned lakes and wetlands into rice paddies. Cleared land produced crops for only a few years until the thin soil became sterile. Farmers then moved on to other parts of the forest, in this slash-and-burn agriculture. At some point, African herdsmen colonized the island, bringing zebu cattle, which crowded out wildlife (Tyson 2000). Gradually, abuse of the land eroded the soil in the central highlands to bare earth, pocketed and gouged by deep gullies and cavernous holes. This region had harbored a great variety of lemurs, along with a wealth of birds, reptiles

and unique plants. Throughout the island, wildlife declined as habitats disappeared, isolating animals in smaller and smaller patches of forest and wetlands. The large lemurs, tortoises and elephant birds were avidly hunted.

Within 600 years of the arrival of the Malagasy, extinctions claimed many native animals. Several elephant bird species, the larger lemurs and many native plants vanished. Two kinds of pygmy hippos inhabited the island. The Madagascar Hippopotamuses (*Hippopotamus lemerlei*), an amphibious species, and *Hippopotamus madagascariensis*, a forest species, were both about 6.5 feet long and 2.5 feet tall, smaller than the Common Hippopotamus of Africa, which is about 10 feet long (Tyson 2000). From genetic and anatomical analysis, both seem to have evolved from the latter species (Tyson 2000). The hippos had been widely distributed and very common prior to the arrival of the Malagasy (Dewar 1984). Their bones have been found with marks indicating that they had been butchered (Tyson 2000). Both died out long before Europeans arrived. The native crocodile, whose large bones have been found, is believed by some scientists to represent large specimens of Nile Crocodiles, the species native today (Tyson 2000). It is thus possible that the crocodile survived. A large mongoose-like viverrid, *Cryptoprocta spelea*, and a very unusual aardvark-like animal, *Plesiorycteropus madagascariensis*, died out at an early date (Dewar 1984).

Prior to the arrival of humans, elephant birds had been abundant in most parts of the island, as attested by the prevalence of their bones. There were two genera, and from six to 12 species of these birds (Tyson 2000). It is likely that the flightless birds fell prey to the primitive weapons of the Malagasy and were crowded out of their habitats by livestock (Tyson 2000). The last to die out was the Great Elephant Bird (*Aepyornis maximus*), which may have survived until recent times by retreating to remote swamps. Dr. Alexander Wetmore of the Smithsonian Institution examined bones of a Great Elephant Bird unearthed in archeological excavations in the 1960s. He was amazed by their size: "The incredible femur, or thighbone, of this ponderous bird is by far the largest I have ever seen" (Wetmore 1967). Estimated to weigh at least 1,000 pounds, more than three times the weight of an Ostrich, it produced eggs larger than any dinosaur's, with a capacity of 2 gallons (equivalent to seven Ostrich eggs), 180 chicken eggs or 12,000 hummingbird eggs (Bradbury 1919, Fuller 1987). When one was X rayed, the bones of an embryo three fourths developed were revealed (Wetmore 1967). Something had interrupted the embryo's growth and frozen it within the eggshell for hundreds and perhaps thousands of years (Wetmore 1967).

Despite its fearsome size, the Great Elephant Bird lacked a hooked beak for tearing prey and was plainly not a predator (Wetmore 1967). Its large, clawed feet may have helped it defend itself against the small native predators but were not enough to protect it from Malagasy arrows. Its short legs prevented it from running as fast as its relative, the Ostrich, but it may have been quite agile when chased. This vegetarian bird browsed and cropped plants, able to reach with its long neck to the lower branches of trees (Wetmore 1967). By the mid-16th century, when Europeans had managed to establish a foothold in Madagascar, the new French Governor, Sieur Etienne de Flacourt, wrote in 1661 that the Great Elephant Bird was still found in the south of the island, "seeking the most deserted places" to avoid human hunters (Tyson 2000). Villagers of Antandroy told of an Ostrich-like bird that was difficult to catch, according to Flacourt (Tyson 2000).

The exact date this giant bird became extinct is not known with certainty. Alan Feduccia (1996), an eminent paleo-ornithologist, asserts that elephant birds of many species were still widespread in the 10th century but gradually disappeared as a result of human activity. He cites an account by a French merchant sailor in 1848, who visited Madagascar and saw the shell of the Great Elephant Bird; he was told that it belonged to the chief and that the bird that produced such eggs "is still more rarely seen" (Feduccia 1996). Some authorities estimate that it died out in the mid-17th century, although there is no proof that any European ever saw one of these birds (Tyson 2000). It has been suggested that Europeans were responsible for the bird s extinction by hunting and destroying its habitat (Quammen 1996). But Thomas Brooks (2000) of the Center for Applied Biodiversity Science, Conservation International, asserted in a list of extinct birds in *Threatened Birds of the World* (BI 2000) that all the elephant birds had disappeared by 1500. In a bizarre footnote to this species' epitaph, an *Aepyornis* egg washed up on Australia's western coast in 1995. No conclusive explanation for this strange event has been put forth, although it is likely that it became unearthed from long interment by rains, and washed out to sea. Much less is known of the other species of elephant birds, which existed in a variety of sizes down to a chicken-sized species.

Lemur-like primates once lived on many continents, but nowhere had they evolved into such a great variety of species. When the Malagasy people arrived some 1,500 years ago, lemurs occupied every habitat, even marshland. A species as tall as a man must have startled the Malagasy immigrants, giving rise to legends that these animals had superhuman powers. The first French naturalists were told by the Malagasy that these primates were thought to be the ghosts of sacred ancestors of man, inspiring the genus name Lemur, the word for ghost in Latin. The Malagasy considered some lemurs sacred and punished anyone who harmed them, but most species were feared as evil demons and were killed on sight.

From their arrival on Madagascar, the Malagasy hunted the larger species of lemurs, almost all of which are now extinct. Archaeological excavations show that they formed a staple in the immigrants' diets. Such diggings have unearthed the skulls and bones of long extinct lemurs in early Malagasy jars and kitchen middens; their heads had been split by ax-heads made from an extinct flightless bird (Jolly 1980).

In the centuries following colonization by the Malagasy immigrants, some 15 species of lemurs of eight genera became extinct (Mittermeier 1997). These extinct lemurs were, for the most part, far larger than surviving species and had evolved to fill many ecological niches. Three *Megaladapis* lemurs weighed between 90 and 170 pounds and moved slowly through the trees, feeding on foliage (Tattersall 1993). Another species, *Archaeolemur*, was about the size of a female baboon and lived on the ground (Tattersall 1993). Two *Palaeopropithecus* species weighed between 90 and 130 pounds and were sloth like tree dwellers with flexible bodies (Tattersall 1993). These extinct lemurs had evolved many unusual means of movement and locomotion that have no parallels in living species of lemurs.

Largest of all, the massive 400 pound *Archaeoindris* was apparently a ground dweller, moving on all fours; many of its anatomical characteristics are unlike any living primate (Tattersall 1993). One entire lemur family, Archaeolemuridae, was obliterated. In this family were many species of lemurs weighing between 35 and 55 pounds; they were powerfully built and short legged (Tattersall 1993). The heaviest lemur surviving today, the Indri (*Indri indri*), weighs only about 15 pounds (Tattersall 1993). These lemurs had survived for millions of years, and their extinctions were indeed a major biological loss to the planet. According to primatologists, the surviving lemurs resemble the very earliest primates from the Eocene (Tattersall 1993). Like prosimians in Africa and Asia, but to a far greater degree, lemurs have a highly developed sense of smell. Some species have long, fox-like noses (Preston-Mafham 1991). Genetic analysis of their DNA has revealed that all lemurs are descended from a single ancestor that probably arrived from Africa about 60 million years ago (Garbutt 1999).

The Giant Aye-aye (*Daubentonia robusta*) lemur was somewhat larger and 2.5 to 5 times heavier than the surviving Aye-aye (see below), but in other respects was very similar (Garbutt 1999). It is known from subfossil remains found in southwestern Madagascar (Nowak 1999). The date of its disappearance is unknown but may be fairly recent.

Archaeologists have uncovered remains of a massive bird of prey, the Malagasy Crowned Eagle (*Stephanoaetus mahery*), which undoubtedly preyed on lemurs (Feduccia 1996). In fact, at one locality the diet of this eagle, based on the bones of eagles and lemurs found together, contained at least 80 percent primates, including specimens weighing up to 26.5 pounds (Feduccia 1996). Remains of another large eagle of the genus *Aquila* have been discovered, and it, too, preyed on large lemurs and became extinct after the arrival of the Malagasy. These extinct birds preyed on smaller lemurs as well, including some species still surviving (Feduccia 1996). A bird of prey flying overhead still elicits fear in lemurs, causing them to seek cover. Neither of the two remaining species of eagles on Madagascar preys on lemurs, but two hawk species have been seen preying on young lemurs (Garbutt 1999).

In addition to the Giant Elephant Bird, the large Snail-eating Coua (*Coua delalandei*), a member of the cuckoo family, became extinct. The last specimen of this large, slate-blue bird was taken on an islet off the east coast, Ile Sainte-Marie, in 1834 (Morris and Hawkins 1998); reports by observers who claimed to have seen the bird were recorded as late as 1930 (Fuller 1987). The causes of this bird's disappearance, and even its exact range, remain obscure (Langrand 1990). Many specimens of this bird were taken before its extinction and kept in museums in

Leiden; London; New York; Paris; Philadelphia; Tananarive (Madagascar); and Cambridge (Massachusetts) (Fuller 1987). The long feathers of this bird were highly valued by the Malagasy, and hunting may have reduced its numbers to a critically low level (Fuller 1987). It is also possible that the many birds killed for zoological specimens may have pushed this already rare bird to extinction, since its distribution may have been limited to the tiny Ile Sainte-Marie. No reliable record exists of its presence on the main island of Madagascar, but there is hope that it might be found in lowland forest near the Bay of Antongil (Morris and Hawkins 1998). Ten closely related species of couas survive, all smaller than the Snail-eating Coua.

The Biological Wealth of an Impoverished Country

The Madagascar of today is still a remarkable place, although about 90 percent of the forests, including almost all lowland rainforests that were richest in wildlife, were destroyed (Mittermeier *et al.* 1999). Some 33 lemur species survive, along with all but one species of tenrec, various mongooses and their relatives, more chameleons than any other country, several hundred kinds of frogs and reptiles, and thousands of endemic invertebrates and plants. Madagascar has no native fish, but many introduced species. Its fauna and flora represent many extremely unusual and unique examples of evolution (Mittermeier *et al.* 1999). This island is considered one of the five most biologically important areas in the world; its primates are the world's highest priority for conservation (Mittermeier *et al.* 1999).

Forests and Plants
Mammals
Birds
Reptiles and Amphibians
Invertebrates

The Biological Wealth of an Impoverished Country: Forests and Plants

Madagascar has one of the richest floras in the world. Eighty percent of its plants are found nowhere else (McNeely *et al.* 1990, Preston-Mafham 1991). The diversity of plants that survived almost 2,000 years of forest destruction continues to astound biologists and conservationists. Tropical trees with fruit growing on their trunks (various species of the genus *Tambourissa*) are native, as is a cactus (*Rhipsalis*), related to American species, that lives in the rainforest. A tree, *Symphonia*, which has leathery leaves and red-and-white striped flowers that look like peppermint candies (Morell 1999), also survives. The Flame Tree (*Delonix regia*), which produces cascades of red flowers, is grown around the world for its beauty, but few realize that it originated in Madagascar (Preston-Mafham 1991). Miraculously, many endemic plants have survived the fires and tree cutting that have destroyed much of the island. One mountain chain has 150 endemic vascular plants, a very high number (Preston-Mafham 1991). They are among the 7,300 to 12,000 species of plants native to Madagascar (Preston-Mafham 1991). Its flowering plants make up 20 percent of all the plants in the African region (McNeely 1990). At least 191 botanical families, a very large number for a relatively small area, evolved from ancestor species (Preston-Mafham 1991).

Some 2,000 years ago, the eastern rainforest stretched in a band 100 miles wide from north to south, covering 27 million acres (Tyson 2000). Ninety percent of the plants were endemic, with a profusion of unusual ferns, some types growing on tree trunks; wild ginger, with delicate purple flowers; bamboos; and far more orchids than in an African rainforest (Preston-Mafham 1991). An early traveler described the woods as so dense that there was a deep gloom: below the canopy at mid-day (Tyson 2000). Rainfall must have been greater and general climate more humid than at present as a result of these extensive rainforests. In the montane ridges, huge tree ferns, mosses and lichens cover the ground and hang from tree branches (Preston-Mafham 1991). Over the centuries, Malagasy burned many portions of

the rainforest, especially in the south. Few tall trees remain in the rainforest today, although at one time there must have been many giants. During the 19th century, a palace was built for a woman ruler, centering on a 130-foot tree that had been carried by 5,000 laborers from the eastern rainforest (Tyson 2000). The palace was destroyed by an uprising in the 1850s. About this time, Malagasy dragged a tombstone through the forest, cutting 25,000 trees just to make a path (Tyson 2000). Early decrees banned cutting of virgin forest, with severe penalties, in the 19th century, but these were largely ignored (Tyson 2000).

About half of the island's forests had been cut by the late 19th century, and intensive cutting continued in the 20th century (Tyson 2000). The prime lowland forests throughout the island and three-fourths of the rainforest were cleared by the French for growing coffee and other crops in the first three decades of the century (Tyson 2000). The rainforest was heavily logged between 1950 and 1985, with 275,000 acres cleared and burned each year (Tyson 2000). The northeast Masoala Peninsula still retains sizeable areas of unlogged rainforest, but the southern region has been reduced to fragments of the original unbroken expanses. The remnants tend to be on sharp ridges where soil is poor and access difficult. For example, Ranomafana, a recently declared national park, straddles such an escarpment. Even so, many of its trees had been removed prior to its protection (Tyson 2000). What was once a closed-canopy, humid rainforest is now far dryer and cooler, with many openings among the trees, and some illegal logging continues (Tyson 2000). Still, botanists from the Missouri Botanical Garden, who were conducting a census of the trees in this park, counted 37 families of trees with 105 species in a 1-hectare plot (Tyson 2000). Outside the park's boundaries, rainforest is still being cleared and burned by the Malagasy, many of whom believe that their wealth lies in the amount of land they clear (Morell 1999).

The western dry, deciduous forest lies in the shadow of eastern mountains, which block moist ocean air currents (Preston-Mafham 1991). Trees do not attain heights of more than 80 feet, but many types of plants have adapted to this environment. Liana vines grow among the trees, and dead leaves carpet the forest floor. Large tamarind trees grow along rivers, and baobabs grow in plateaus (Preston-Mafham 1991). Beautiful orange bell flowers of the *Ipomoea carnea* plant burst into bloom during the short rainy season. As with the eastern rainforests, the once continuous stretches of deciduous forests have been largely destroyed, replaced by grasses able to survive in the eroded or bare soil.

Throughout the island, most deforested areas fail to regenerate into second-growth forests, even when left fallow, because Madagascar lacks vigorous colonizing trees that can quickly protect cleared ground and prevent further erosion (Preston-Mafham 2000). Cleared hillsides become covered in non-native grasses and exotic South American trees (*Psidium cattleyanum* and *Psidium guajava*) or plantations of eucalyptus, which inhibit the establishment of native seedlings (Preston-Mafham 1991; Sayer *et al.* 1992). Only if soils are rich and remnants of original forest are nearby will native forests regenerate. Unfortunately, the original forests and their native wildlife are lost permanently, and even regeneration cannot take place without a cessation of the slash-and-burn cycle, known as tavy by the Malagasy (Preston-Mafham 1991). Moreover, foreign logging companies have obtained logging concessions on most of the unprotected remnants of native forest. Tree cutting consumes some 7.8 million cubic meters of wood per year, of which 7 million cubic meters is for fuel and charcoal (Sayer *et al.* 1992). Valuable timber trees have been logged to extinction in most of Madagascar. The two native species of ebony trees of the genus *Diospyros* have been heavily logged for centuries, and few large trees are left (Sayer *et al.* 1992). The understory plants, such as tree ferns, are also exploited, dug up to sell as potted plants (Sayer *et al.* 1992).

The net result of this logging and burning, especially in the barren central highlands, is the loss of "a priceless reservoir of plant and animal species, replaced by one of the most impoverished forms of vegetation on the planet" (Preston-Mafham 1991). Many species of trees and other plants are highly endangered. Madagascar is one of the world's 12 "hot spot" areas of tropical forests, having a high percentage of endemic species which are under great threat (McNeely *et al.* 1990). Since an estimated 94 percent of Madagascar's trees are endemic, and many occupy very restricted ranges, they are highly vulnerable to extinction. Further research will likely reveal even more threatened species. Some authorities believe that even this rich plant diversity must represent only a fraction of the "vast original flora," since 80 percent of the vegetation and forests is gone (Ayensu *et al.* 1984). The *1997 IUCN Red*

List of Threatened Plants includes 19 species of plants that may have recently become extinct, and an additional 287 species that are threatened with extinction (Walter and Gillett 1998).

Resident since the days of the dinosaurs, trees of a family of primitive pines, Podocarpaceae, grow on the island. The family is represented by species in other parts of the world that were part of Gondwana, from South America west to Southeast Asia. Madagascar has a number of native Podocarps, of which four endemic species or varieties are listed by the *IUCN Red List* as either Vulnerable or Rare (Walter and Gillett 1998). At least 26 genera of plants are native to Madagascar and South America, but not to Africa, and are believed to be remnants from Gondwana (Preston-Mafham 1991). Another one of these, Madagascar's national tree, the Traveller's Tree (*Ravenala madagascariensis*), is a palm-like species of the banana family (Musaceae). Its closest relative of the same genus grows in Brazil and Guiana, but not in Africa (Preston-Mafham 1991). This tree has leathery petals covering its pollen and nectar and is a key food source for both bats and lemurs. In return, it depends on lemurs for pollination. Lemurs feed on the nectar, getting their noses covered with pollen in the process. They are so fond of the nectar that they travel miles to find another Traveller's Tree, still carrying the nectar on their noses and, unknowingly, pollinate the next tree they feed on (Attenborough 1995).

A plant of the Winteraceae family that has been growing on the island for 30 million years was recently seen again after a period of 90 years (Hsu 1997). This tree, *Takhtajania perrieri*, has many primitive features, such as a lack of vessels to move water and minerals; like many of Madagascar's relict species, it once grew on much of continental Africa, but long ago disappeared there (Hsu 1997).

Madagascar has more palms (Palmae family) than all of Africa (Preston-Mafham 1991). Many are in danger, however. The *IUCN Red List of Threatened Plants* lists 148 native species in various categories (Walter and Gillett 1998). The Big-leaf Palm (*Marojeya darianii*) was chosen by the Species Survival Committee of the IUCN to be one of 12 critically endangered species highlighted at its 1988 General Assembly in Costa Rica. This species was only discovered in 1982 and is confined to a single swamp in the northeast (Prance 1990). An agricultural program to raise rice cleared half its habitat, and then failed. This huge-leafed palm has been over-harvested as a source of heart-of-palm, a commercially valuable product (Prance 1990). Huge palms are felled for their inner pith to supply this gourmet market. The majority of palms grow in the eastern rainforests in a great diversity of size. Two threatened palms, *Dypsis hildebrandtii* and *Dypsis louvelii*, are miniature delicate-fronded palms only 3 feet high (Preston-Mafham 1991). Others, like the threatened *Ravenea glauca*, are majestic giants with long, straight trunks rising 50 feet or more to a luxuriant crown. Palms do not often survive the fires set by the Malagasy to clear land, disappearing from one area after another (Preston-Mafham 1991).

On the entire continent of Africa, only one species of baobab tree is native, while seven species are found in Madagascar (Preston-Mafham 1991). These strange-looking trees have wide trunks that taper to a narrow crown, looking like upside-down trees. Some baobabs grow to immense size. One famous specimen measures 46 feet around the base of the trunk (Preston-Mafham 1991). Another species, *Alluaudia ascendens*, grows in the southern desert. Although it can reach a maximum height of 16 feet, it is usually far smaller (Preston-Mafham 1991). Each of the seven species has a slightly different shape and size, but all have gray bark that resembles unwrinkled elephant skin. Baobabs are extremely important to both wildlife and humans. The Malagasy cut holes in their massive trunks and hollow out the spongy pith where water accumulates. In the dry south, these trees become wells, and villagers set ladders against the trunks, climb to the hole cut from the trunk, and lower buckets into the pool of water. Natural holes in baobob trunks and branches provide important nesting holes for birds and lemurs. These trees are fire-resistant, and fortunately, they are worthless as timber because of their soft, pulpy cores. For this reason some stands of thousands of huge, very old baobabs remain in parts of the island. Because of the heavy livestock grazing, few young baobab seedlings can survive, however, and botanists believe that the spectacular vistas of these behemoths will gradually disappear (Preston-Mafham 1991).

One very strange group of Madagascan plants native to dry areas has nine species in the same genus, *Pachypodium*. These succulent plants lose their leaves at the onset of the dry season and have evolved into a variety

of forms, all with gray, smooth bark. Eight of the nine species are threatened with extinction, according to the *IUCN Red List of Threatened Plants* (Walter and Gillett 1998). One of these, the endangered *Pachypodium decaryi*, is native to Antananarivo, the "tsingy" limestone crags of the northwest. Its smooth, silvery trunk resembles a large inverted turnip, fat at the base and tapering upward, topped by a messy mop of thin, straggly branches (Preston-Mafham 1991). It bears large, white flowers during the dry season. Its main population occurs in the Ankarana Special Reserve, which bans burning (Preston-Mafham 1991), but has recently been invaded by hordes of miners who are clearing vegetation to search for sapphires (Morell 1999). Other Pachypodiums have equally bizarre shapes, such as the bulbous *Pachypodium rosulatum*, which resembles a huge gourd sprouting long, thin shafts from which its bright yellow flower bloom. The rare *Pachypodium densiflorum*, with the appearance of a domestic jade plant run amok, has a mass of short, gray branches sprouting from a squat gray base. All these plants are highly susceptible to fire. Ken Preston-Mafham, in *Madagascar: A Natural History*, describes the threat of "incessant brush fires which ravage the length and breadth of central Madagascar during the dry season. Within hours, hillsides which had been decorated with colorful rock gardens of rare succulents are converted into graveyards of charred embers." These brush fires have been intentionally set by Malagasy to improve grazing land for their cattle or clear land. Another threat to Pachypodia is collectors who tear specimens, especially bizarre forms, from mountain slopes (Preston-Mafham 1991). Few species are protected in reserves. Without strong conservation programs, these fascinating plants could easily disappear.

Other strange trees of the southern spiny desert include the Octopus Tree (*Didierea madagascariensis*), a member of an endemic family of 11 cactus-like species, Didiereaceae. This tree has no trunk, but a bouquet-like grouping of stems covered in long, needle-sharp spines that branch out in odd, twisted shapes. Although resembling cacti, this family has no close relatives anywhere in the world (Preston-Mafham 1991). Another member of the family, *Alluaudia procera*, has a thick trunk with very long spines that grow in curving rows upward, and small, rounded leaves along its branches. In spite of this, several lemur species are able to leap onto these plants without hurting themselves (Preston-Mafham 1991). Three species in this family, all of the *Alluaudia* genus, are Rare, according to the IUCN (Walter and Gillett 1998). One of these, *Alluaudia montagnacii*, has tall, solitary tapering stems ending in a tuft of flowers.

The discovery of the medicinal effects of the endemic Rosy Periwinkle (*Catharanthus roseus*) has saved thousands of human lives. Two potent alkaloid compounds found in this plant have proven effective in the treatment of Hodgkin s' Disease, producing a 99 percent remission in patients with acute lymphocytic leukemia (Myers 1983). It also contains 75 different alkaloids, which could produce commercial substances (Preston-Mafham 1991). Fortunately, the Rosy Periwinkle is easy to propagate, grown in greenhouses around the world. Ongoing research is uncovering other Madagascan plants of medicinal value. Samples of plants are being tested in laboratories, and elderly Malagasy healers are being consulted. More than 50 species of wild coffee (*Coffea* spp.) grow in the island's eastern rainforests, providing an important genetic base for hybridizing with other strains because of their insect-resistance and low level of caffeine (Preston-Mafham 1991). These plants are symbolic of the great botanical wealth at risk.

The Biological Wealth of an Impoverished Country: Mammals

Home to some of the world's most fascinating, beautiful and curious mammals, Madagascar has approximately 117 native species, 90 percent of which exist nowhere else (Garbutt 1999). Excluding bats, all 88 native terrestrial mammals are endemic to Madagascar. Three-fourths of native mammals, or 66 species, are threatened with extinction; 49 of these are in higher categories of threat listed in the *2000 IUCN Red List of Threatened Species*. This represents 42 percent of all mammals found in Madagascar, by far the greatest percentage of threatened mammals of any country in the world (Hilton-Taylor 2000). As new species of mammals continue to be discovered, the numbers that are threatened continues to rise. A few have not been seen in the wild since their discovery. The majority is made of

forest-dwellers, and a few inhabit marshy areas or woodland streams. The loss of forest, predation on them by Malagasy and domestic dogs, and introduction of exotic species of mammals that out-compete native species are combining to push many of the island's mammals toward extinction.

Page 1 (Tenrecs)
Page 2 (Lemurs and Aye-ayes)
Page 3 (Bats)
Page 4 (Viverrids)
Page 5 (Rodents)

The Biological Wealth of an Impoverished Country: Mammals: Page 1

The publication of *Mammals of Madagascar*, by Nick Garbutt, in 1999 filled a void for a complete guide to all native mammals, illustrated with color photos of most species and major habitats. This supplemented *Madascar: A Natural History* in 1991, an important reference on mammals and their environment. Conservation work has focused mainly on lemurs, with many organizations involved, including Earthwatch Institute, which sponsors field research; Conservation International; Jersey Wildlife Preservation Trust (based in England); and CARE. Several of these groups sponsored biodiversity studies and helped establish national parks, benefiting thousands of species, including tenrecs and other native mammals. A growing number of Malagasy zoologists are taking part in studies and conservation work, and new programs have been initiated to help local people while conserving mammals and their environments. Certain mammals have received inadequate attention to date, notably bats, rodents and some viverrids, who will undoubtedly benefit from the swell of interest and enthusiasm for Madagascar fauna that has developed in recent years. Filmmakers have recently produced a number of excellent wildlife documentaries, photographing rare species and spreading knowledge and concern about endangered mammals (see Video section).

Among Madagascar's mammals are many primitive forms. The tenrecs' closest relatives are insectivores known as solenodons, native to Cuba, Hispaniola and other vestiges of Gondwana in the Caribbean. Tenrecs and solenodons may have had a common ancestor living on the supercontinent, progenitor of all mammals. The remains of similar species have been found in Africa and South America, indicating that they were once very widespread but died out on all but isolated refuges such as Madagascar and West Indian islands. Tenrecs belong to a family of insectivores, Tenrecidae, related to shrews, moles and hedgehogs, but quite distinct from them. Twenty-seven species of three types of tenrecs make up this family--spiny, furred and otter-shrews (Garbutt 1999). They range in size from the Common Tenrec (*Tenrec ecaudatus*), which resembles the European Hedgehog and weighs more than 5 pounds, to the shrew-like tenrecs, *Microgale* genus, weighing less than 2 ounces (Nowak 1999). Tenrecs have some very unusual physical characteristics placing them far from any close mammalian relative. They have variable body temperatures that change with the ambient temperature and, an even more reptilian or avian trait, a cloaca that combines urinal, rectal and generative canals into one (Garbutt 1999).

A striking tenrec is the Lowland Streaked Tenrec (*Hemicentetes semispinosus*). It and a similar species, the Highland Streaked Tenrec (*Hemicentetes nigriceps*), weigh about 5 to 7 ounces and measure some 6 inches in length. White stripes run down their backs like skunks, and barbed, porcupine-like spines are detachable (Eisenberg 1975). The Highland species has a stiff, white neck ruff rising several inches at the back of its head that can be stabbed into the nose of an unwary predator (Eisenberg 1975). Family groups forage together and communicate by vibrating quills that produce low-frequency sounds like dry grass being rubbed together; tenrecs can detect these sounds from distances of more than 4 meters (Garbutt 1999). They also make a number of sounds that are audible to humans.

The Aquatic Tenrec (*Limnogale mergulus*), listed as Endangered in the *2000 IUCN Red List of Threatened Species*, inhabits streams and lakes, living at altitudes between 600 and 2,000 meters (Nowak 1999). This 8-inch tenrec has

clawed, webbed feet, and a long, thin tail for propelling it through the water to feed on small crustaceans and fish. Its habitat in the central highlands has been greatly affected by human disturbance and deforestation. The Aquatic Tenrec has at least one refuge, the new Ranomafana National Park, created for the bamboo lemurs (Preston-Mafham 1991). In 1990, Dr. David Stone managed to lure an Aquatic Tenrec into a live trap, the first one of its kind seen alive in 25 years (Preston-Mafham 1991). Later, four more were taken and studied in captivity for three weeks prior to being returned to the river Namorona in Ranomafana, one of the few clear, unsilted rivers left in Madagascar (Preston-Mafham 1991). This species requires such streams, and only the preservation of forests, such as that in Ranomafana, will ensure its survival.

Another six species in this family, all shrew-tenrecs of the genus *Microgale*, are listed in the *2000 IUCN Red List of Threatened Species*. These tiny insectivores are found in all parts of Madagascar in areas of heavy vegetation, and have dark, soft fur. They range in size from 1.5 to 5 inches in length, and weigh as little as 1.8 ounces (Nowak 1999). Several of the threatened species are highly restricted in range and habitat, and one, *Microgale dryas*, listed as Critical, occurs only in Ambatovaky Special Reserve in the northeastern rainforest (Garbutt 1999).

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Far better known to the world, the lemurs are the focus of many programs to conserve them, as well as research on their wild behavior and biology. New species continue to be discovered; most recently in 2000, three new species of tiny mouse lemurs. Three more have been rediscovered, an indication that other species may yet be discovered to add to the present total of 33 species (Garbutt 1999)**.** This is the only country with five families of primates, making up more than one-third of all primate families; it is home to 12 percent of all primate species and 21 percent of all primate genera (Mittermeier *et al.* 1999). Unlike Brazil, however, which is another center for endemic mammals, Madagascar is far smaller, the size of Kenya, covering 226,656 square miles, or 0.4 percent of Earth's surface (NYT 2000). The number of lemur species is not an indication of their variety since many subspecies differ so radically from one another that in the future, each may be accorded full species status. One species of sifaka, a long-legged kind of lemur, has one subspecies that is pitch black, and another that is pure white. At least 51 species and subspecies of lemurs are known to exist (Mittermeier *et al.* 1999).

The most gregarious of the lemurs are the Ring tailed Lemurs (*Lemur catta*), who travel about in boisterous, friendly troops, living mainly on the ground. These lemurs have long, fox-like muzzles, large, soft golden-brown eyes, fluffy, gray fur, and black-and-white striped tails. Their body length is 15 to 17 inches, but their rope-like tails are half-again as long, from 21 to 24 inches (Nowak 1999). These 5-pound primates use their boldly patterned tails in a complex language of mutual visual and scent signals. They wave them about to show dominance, as a signal to follow other group members, or rub them on their wrist glands to wave at their rivals in territorial battles (Sleeper 1997). Moving about in troops of up to 25 individuals, they walk rapidly on the ground with the tail held high, waving it about. They wrap their tails around themselves for warmth on chilly nights. Extremely affectionate and playful, their core group is dominated by females (Jolly 1988).

In reserves where they are strictly protected, Ring-tailed Lemurs become very tame, napping on the ground in piles of leaves near tourists. Sometimes they sprawl out on their backs with arms spread wide apart. Females usually have a single young, but when twins are born, one may be "adopted" by a non-pregnant female, who may begin to produce milk in response to her surrogate role (Preston-Mafham 1991). Aunts also help in raising the young, and the daughter born the previous year babysits (Jolly 1988). Lemur babies are a source of great interest to the entire troop, females gathering around the mother and her young, grooming one another and the babies, forming a "grooming pod" (Preston-Mafham 1991). Only half of the infants survive their first year, and only 30 percent reach adulthood (Garbutt 1999). "A Lemur's Tale," shown on PBS in 1996, is a touching film about the death of a young Ring-tailed Lemur. Some fall from high branches, are killed by small carnivores or hawks, die of undiagnosed illness or starve in years of

drought in their arid habitat. Ring-tailed Lemurs communicate with one another in a variety of sounds, from soft mewing contact calls to a territorial "bark-howl." Sometimes chasing and cuffing other members of their group, they are mainly peaceful, spending many hours a day in mutual grooming and in "snoozing-huddles," in which several animals form a complicated embrace from which tails and feet stick out in all directions (Preston-Mafham 1991).

In recent years, Ring tailed Lemurs have been classified "high priority" for conservation by the IUCN and the Species Survival Commission (SSC) Primate Specialist Group because their habitat of dry woodlands in southern Madagascar is disappearing at an alarming rate due to fires, overgrazing by livestock and tree cutting; they are also hunted with dogs in some areas, and captured as pets (Mittermeier *et al.* 1992, Garbutt 1999). Their distribution has become increasingly patchy as forests are cut (Garbutt 1999). The *2000 IUCN Red List of Threatened Species* lists the Ring-tailed Lemur as Vulnerable, or declining toward endangered status.

One of the strangest mammals in the world is the Aye aye (*Daubentonia madagascariensis*), so unique that it is assigned to its own family, Daubentoniidae. When first discovered, scientists classified it as a squirrel because of its long, bushy tail and short legged body. In 1863, however, after anatomical studies, the Aye aye was revealed to be a lemur, in spite of incisor teeth that never stop growing, long, clawed fingers and other unlemur like characteristics. Aye-ayes have a perpetually startled expression: huge, round protruding eyes dominate the face, the pupils completely surrounded by deep golden irises. Dark rings surround their eyes, heightening the eerie appearance. The rest of the face and body are gray to black, with long grizzled guard hairs. Spending the day in their twig and leaf nests, Aye-ayes emerge at night to forage for insects and fruit (Garbutt 1999). The Aye-aye's enormous ears are sensitive to the movements of insects under tree bark. At Duke University Primate Center, which has the world's largest number of captive lemurs, Aye ayes have been filmed using their middle finger, which is twice the length of the other fingers, and skeletally thin, to tap on wood, listening for the movement of insects under the bark. When presented with a block of wood containing insect larvae in holes, the Aye aye taps the wood and, cocking its head, can tell, even in the case of a hidden hole, the location of the insects, which it then extracts almost surgically, with its middle finger. This primate fills the ecological role of a woodpecker. Aye ayes eat fruit as well, biting holes into the hard shells of coconuts and scraping the meat out with their middle fingers (Petter 1965). They have also been seen eating nuts of a native tree, nectar from the Traveller's Tree, fungus and lychee nuts (Garbutt 1999).

Aye-ayes have been heavily persecuted by the Malagasy, who consider them to be the embodiment of evil. In general, they are killed whenever seen. Dr. Ian Tattersall once found a dead Aye aye with a wire pulled tight around its neck (McNulty 1975). In 1990, apparently to dispel the bad luck caused by its having entered a village, local people set an Aye aye tail on a pole next to the road (Simons 1993). At one time, Aye-ayes were considered among the most endangered animals in the world, facing imminent extinction. To prevent their extinction, a few were captured and released on Nosy Mangabe, a small islet off the northeast coast. Fortunately, Aye ayes survived on the main island, perhaps because coconut plantations provided food when their forests were cut. Feeding at night, they remained undetected until recently. The Malagasy continue to persecute them.

Since the early 1980s, field surveys have revealed that Aye-ayes have a larger distribution than was originally thought. In 1991, they were seen for the first time in western Madagascar in the northern mountains (Simons 1993). With confirmed sightings in many eastern and northern forests and a few western localities, Aye-ayes inhabit a variety of forest types (Garbutt 1999). They can survive in secondary forest, coming out of their stick nests only at night. And while once thought solitary, groups of three to four individuals have been seen traveling together and feeding at foraging sites (Garbutt 1999). In spite of the greater distribution, the Aye-aye is an endangered species and almost certainly is declining (Garbutt 1999). Aye-ayes require large tracts of forest to maintain viable populations and to protect them from the persecution that often results in their deaths (Garbutt 1999). Although very rare in captivity, several captive births have occurred in recent years at the Duke University Primate Center and Jersey Wildlife Preservation Society zoo in England.

One lemur has recently been rediscovered in the wild and, in the process, an entirely new species was found. The Greater Bamboo Lemur (*Hapalemur simus*) seemed to have disappeared in the wild some time in the mid-19th

century. Not until 1964 was this 5-pound, grizzled, gray-olive lemur seen again in a village market, where it was purchased by a French scientist. Unfortunately, it escaped. A pair captured in 1972 in a southeastern rainforest lived in the zoo in Madagascar's capital city, Antananarivo, until both male and female and their two offspring died (Quammen 1996).

Patricia Wright, an American primatologist, decided to search for this species in 1986 in its supposed range. Fossil evidence indicates that 1,000 years ago, the Greater Bamboo Lemur was widely distributed throughout most of Madagascar's forests, and European naturalists saw it fairly regularly in the 19th century. When she saw a russet-colored lemur clinging to a trunk, making loud "tonking" calls, Wright assumed that she had rediscovered the Greater Bamboo Lemur. Although a different color, she concluded that these animals probably represented a color variation (Quammen 1996). A German primatologist, Bernhard Meier, made independent studies in this patch of rainforest at the same time, also discovering the reddish-gold lemur. Both scientists had great difficulty making observations because of its extreme shyness (Quammen 1996). Finally one was caught, and in 1987, after chromosomal and anatomical studies were done in France, this lemur was found to be an entirely new species (Jolly 1988). It was named the Golden Bamboo Lemur (*Hapalemur aureus*) in a joint zoological paper by Meier, Wright and three other biologists (Preston-Mafham 1991). After months of unsuccessful attempts, Wright took the first photographs of the Golden Bamboo Lemur in the wild. Its beautiful golden-red face mask and belly contrast with darker brown fur on the rest of its body. (See color photographs in Garbutt 1999, Jolly 1988 and Preston-Mafham 1991). This lemur has been found at another location further north, and it is not known whether these populations are isolated from one another. Its population is apparently very low, as only about 1,000 animals have been estimated in the original location of discovery, and its habitat continues to be cleared (Garbutt 1999). The *2000 IUCN Red List of Threatened Species* has classified the Golden Bamboo Lemur as Critical, the most endangered category. Its limited range places it in great jeopardy, and it has been hunted with slingshots; its long-term survival is not secure (Garbutt 1999).

The Greater Bamboo Lemur, the animal first sought, was later found in the same forest, resembling original descriptions and clearly a separate species from the Golden Bamboo Lemur; a third species of bamboo lemur, the Gray Bamboo Lemur (*Hapalemur griseus*), weighs only 2 pounds. It has smoky gray fur and golden eyes, and lives alongside the latter two species in this same forest. This lemur lives in other parts of Madagascar as well (Preston-Mafham 1991).

Each of these three bamboo lemurs eats different parts or species of bamboo plants. One eats the leaves, another the pith, and the third confines itself to new shoots, leaf bases and pith from narrow stems (Quammen 1996). Amazingly, chemical analyses of the plants eaten by the Golden Bamboo Lemur found them to have high concentrations of cyanide, a chemical usually toxic to mammals. Golden Bamboo Lemurs weigh only about 2.2 pounds, and Wright and her co-workers found that, based on toxicity tests of other mammals, they eat 12 times the amount of cyanide that should kill them (Quammen 1996). This is another example of the biological mysteries of Madagascan wildlife.

The Ranomafana forest, with its rare and endemic lemurs and other unusual fauna and flora, would likely have been cut by the Malagasy for more farmland, but Wright spent five years in a successful effort to protect it in the newly created Ranomafana National Park (Bohlen 1993, Mittermeier *et al.* 1992). This new park covers 108,000 acres of old-growth eastern lowland rainforest. Giant rosewood and other ancient trees tower above a lush understory. It is an extremely important--perhaps the most important--forest for lemurs. Fourteen species of lemurs and 18 other endemic species of mammals live in the park (Jolly 1988). Local people cooperated fully in setting the park s boundaries, aware of the importance of saving forests. They had experienced a major catastrophe when a cyclone caused landslides, burying entire families in their homes, all precipitated by deforestation (Jolly 1988). In spite of these remarkable achievements, some tree cutting still occurs in Ranomafana National Park (Garbutt 1999).

Wright has continued to study lemurs, now specializing in the exquisite Diademed Sifaka (*Propithecus diadema*) (Brody 1998). Sifakas are the most acrobatic lemurs, leaping from tree to tree, but they have a unique means of locomotion to cross open spaces between trees. Standing on their long hind legs in an upright posture, they hop

sideways, with their arms raised high above their heads. Sifakas can move very quickly in this amazing, dance-like gait, covering distances of more than 100 yards. They are also able to leap vertically to tree branches from a standing position, even carrying babies on their backs. One of their spectacular leaps, some 30 feet up, is the equivalent of a person jumping to the top of a telephone pole. The Golden-crowned or Tattersall's Sifaka (*Propithecus tattersalli*) is a beautiful, nearly all white species with rich yellow-orange on the crown and tinges of this color on its back, legs and chest. Orange eyes contrast with a furless black face. The smallest of the sifakas, it is confined to a tiny area of only about 15 square miles of forest fragments in northeast Madagascar. The Golden-crowned Sifaka's small population of fewer than 8,000 animals, fragmented into isolated populations, is threatened by forest cutting, brush fires, loss of habitat to agriculture and hunting (Garbutt 1999). Distributed in discontinuous patches of forest, these sifakas may become inbred if corridors are not acquired to link populations. A core part of their forest had been scheduled for cutting for charcoal when scientists named these sifakas. The PBS Nature program, Madagascar. Island of Ghosts, was the first to film these delicate lemurs (see Video section, Regional - Africa and Indian Ocean Islands). They move about in small groups and feed on a variety of unripe fruits, seeds, shoots, leaves, bark and flowers (Garbutt 1999). No reserve has been set aside for this highly endangered sifaka, although a three-parcel national park covering 20,000 hectares (49,420 acres) has been proposed to protect this species from extinction (Garbutt 1999). The IUCN classifies this species as Critical (Hilton-Taylor 2000).

Although many Malagasy have become far more aware of the need to protect lemurs, some do not understand their rarity or the importance of conserving them. Many rural people still hunt them for food or kill them because of superstitious beliefs. In some areas, the Malagasy try to sell lemurs to foreign scientists. Visiting zoologists studying lemurs have been approached by Malagasy holding captive, and usually injured or dying lemurs, in hopes of a reward. On one occasion, an endangered species of sifaka was brought to primatologist Dr. Alison Jolly, dragged half choked by a vine around its neck, with one arm dangling loose below the elbow, a jagged bone protruding; blood oozed down its white fur, and it gasped for air through a muzzle smashed by a flung stone (Jolly 1980). Jolly expressed horror at its condition and refused to pay them any reward. She then amazed them by telling them it was a unique sifaka, found only in that small part of Madagascar. They were incredulous . . . not in Antananarivo? . . . Not in France? . . . Not in America? (Jolly 1980). For the majority of people, lemurs are familiar animals, easy to capture and valuable as food. Malagasy schools, established by the French colonial government, taught them only about European animals, encouraging people to assume that their lemurs were unimportant. Fortunately, many Malagasy are becoming concerned about protecting lemurs, and conservation education is taught in an increasing number of schools.

Some lemurs have bred in captivity in zoos and breeding centers, but most, like the endangered Indri (*Indri indri*), have never survived in captivity long enough to breed. In their rainforests, they perch high up, clinging to tree trunks to feed, and suddenly leaping vertically to a neighboring tree, pushing off with their extremely muscular, long legs. Panda-like fur of contrasting black and white--black faces and bodies and white arms and legs--gives them a dramatic appearance. Nearly tailless and heavy--but graceful--their eerie songs, sung at dawn and sometimes during the day, form a loud chorus of high-pitched voices that carries for long distances. Indris were once very common in the eastern rainforest, but much of their habitat has been burned away, making them extremely sensitive to the danger of fires. When a 1992 fire threatened a group in a reserve, they raised such a loud cry that the guards were alerted. They rushed to the scene and put out the fire (Rajaonson 1993).

Although originally found in the far north and central highlands, the Indri is now limited to a narrow strip encompassing only half the rainforests on the island (Garbutt 1999). Indris do not reach sexual maturity until between 7 and 9 years of age, and females are thought to give birth only every second or third year (Garbutt 1999). With such a low reproductive rate, they have been very vulnerable to habitat loss and hunting, especially by immigrants (Garbutt 1999). Moving about in small family groups, they are conspicuous to hunters. The Indri is one of the few lemurs whose killing is considered taboo by the Malagasy, but the old taboos are breaking down, resulting in capture and killing. In some cases, religious leaders encourage such killing. A lemur scientist met a Catholic priest who killed several Indris, roasted them and served them to his congregation, as recorded by Faith McNulty in 1975, and this killing has not ceased. In *Mammals of Madagascar* (Garbutt 1999), two terrified Indris were photographed clinging to poles in a hut, awaiting slaughter for food.

In contrast to the Indri, mouse lemurs (*Microcebus* spp) are so small that it is hard to think of them as primates. The tiniest is the newly discovered Pygmy Mouse Lemur (*Microcebus myoxinus*), with an average weight of only 30 grams, or 1.05 ounces, smaller than any other primate (Garbutt 1999). This tiny mammal is 2.73 inches long, with a tail just under 6 inches in length (Garbutt 1999). The other species are slightly larger, with body lengths ranging up to about 5 inches, and tails of equal or greater length (Garbutt 1999). These nocturnal lemurs have huge dark eyes and are agile and active, resembling African bushbabies. They feed on insects, spiders, and even small frogs and lizards, as well as fruit, flowers and nectar (Nowak 1999). Females form groups and sleep in a nest together with up to nine individuals, while males usually nest alone or in pairs; occasionally males are found in a group of females (Nowak 1999).

A key to protecting lemurs and their forest homes is educating the people of Madagascar about them. The Jersey Wildlife Preservation Trust has put up posters with pictures of lemurs and their protected status around the island. Habitat protection is obviously key to conserving lemurs, and another recent development is the protection of the largest remaining area of rainforest in Madagascar. The Masoala Peninsula in the northeast is the sole home of the Red Ruffed Lemur (*Varecia variegata rubra*), a 9-pound, reddish subspecies of the Ruffed Lemur, but bearing little resemblance to the latter black-and-white species. With $3 million from USAID (United States Agency for International Development) and three years of planning, the new Masoala National Park, covering 210,000 hectares (518,910 acres or 840 square miles), was announced in June 1996 (Terry 1996). This immense park was formally signed into law on October 18, 1997 (Kremen 1998). Thai and Indonesian timber companies had hoped to log these virgin rainforests, but this new law will prevent clearcutting and slash-and-burn agriculture that would have destroyed the forest within less than 50 years. A coalition of organizations helped establish this park, including the Wildlife Conservation Society, CARE and the Peregrine Fund (Garbutt 1999). It will prevent the extinction of the endangered Red Ruffed Lemur, as well as that of the newly rediscovered Madagascar Serpent Eagle (*Eutriorchis astur*) (see below).

In 1997, five Ruffed Lemurs born and raised in the Duke University Primate Center in North Carolina were released in the Betampona Reserve in the northeast to bolster a small, isolated population of this species (Welch 1997). This reintroduction represented a goal in the captive-breeding program at Duke University, which has long planned such a return of these highly endangered primates to the wild. John Cleese, actor and a member of the 1970s British comedy team, Monty Python's Flying Circus, took an interest in the reintroduction program as an enthusiastic lemur admirer. After contributing to the Ruffed Lemur reintroduction program, he wanted to see how they were faring in the wild, and trekked to their remote release site. A delightful film based on this experience, "Lemurs with John Cleese," was shown on PBS in 1999. These Ruffed Lemurs have been released in an area of dense rainforest and rugged hillsides, a long hike from the nearest road. The biologists and assistants who take part in this reintroduction program show their dedication by living for long periods under extremely primitive conditions. Cleese managed to inject humor into this otherwise arduous situation.

At least six species of lemurs, and perhaps more, serve the ecologically important role of pollinating flowers. Many of Madagascar's plants produce unusually large flowers with strong odors and copious nectars attracting lemurs to feed on them. Should any of these lemurs become extinct, the plants that they pollinate will likely follow. Lemurs also play an important role in dispersing seeds. Research by the German Primate Centre at Hamburg University has found that Brown Lemurs are crucial to the regeneration of the western dry forests. About 10 percent of the island's tree species rely largely or entirely on this species to disperse seeds, which pass through their digestive systems.

The surviving lemurs are in extreme danger of following their relatives into extinction. Conservation organizations accord them extremely high priority among endangered primates, and they are the focus of many programs to preserve them. Twenty-nine of the 33 species are listed in the *2000 IUCN Red List of Threatened Species*, all but seven in higher categories of threat. This is an increase of nine species in the four years since the previous edition of the *IUCN Red List* was published (Baillie and Groombridge 1996). Three species and several more subspecies are in the Critical category of species on the verge of extinction, while seven are Endangered, an increase of four species since 1996. All

lemurs are listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the category prohibiting commercial trade, and as Endangered on the U.S. Endangered Species Act.

Although lemurs are protected by Madagascan law, hunting is a major cause of mortality. High fines and even jail sentences may be imposed for killing a lemur, but the severity of the penalties might make officials reluctant to enforce the laws (Peterson 1989). Blowguns, snares, traps, sharpened sticks, slings, stones, guns or even clubs are used to kill them (Peterson 1989). To kill small species of nocturnal lemurs, trees are sometimes cut down, and hunters seize them from their nest holes (Peterson 1989). In the late 1980s, a "sport" hunter bragged of killing 12 highly endangered Verreaux's Sifakas in one afternoon (Peterson 1989). In spite of education programs launched in the 1990s urging the Malagasy to protect lemurs, and the rise in tourists who come to see them, which provides revenues, few have benefited from tourism. Hunting remains a major threat (Garbutt 1999). The rise in human population has resulted in an increased demand for food, particularly protein, far more than the ailing agricultural system can supply (Garbutt 1999). The larger lemur species are especially affected. Because laws against killing lemurs are not enforced, much more education is needed about their potential value in attracting tourism and research funds that provide new jobs. Already tourism has raised income levels among some Malagasy, but hunger is still widespread (Tyson 2000).

In the late 1980s, a World Bank official studying the extreme and worsening poverty on the island said that there might come a time when the people of the capital city would scale the walls of the city zoo and eat the lemurs: "On the downward spiral, animals are at the bottom" (Peterson 1989). Such a tragedy is not inconceivable considering that hunger and poverty have deepened in the decade since. Conservation programs must involve communities while providing an incentive to conserve lemurs. Otherwise, it may be impossible to persuade the Malagasy not to slaughter them.

Although the status of lemurs is deteriorating along with their forests, much is being done to prevent their extinction. The past two decades have been of critical importance to lemur conservation. These extraordinary animals are receiving worldwide attention, and habitat protection for some species has been achieved. Not too long ago, their extinctions seemed inevitable and imminent. Conservation education programs, including showing slides of lemurs and other wildlife to rural children, have been launched. Wright helped to finance the building of new schools and the renovation of existing schools near Ranomafana National Park (Tyson 2000). A number of international organizations are integrating lemur and biodiversity studies with the economic development of entire communities (Garbutt 1999).

For a growing number of Malagasy, learning how special their lemurs are has made lemurs a source of pride and an important national treasure. In the future, Malagasy children may learn from an early age about lemurs and want to protect them. A few decades ago, few films had been made of these fascinating primates, while today many films show their habitats, biology and conservation work on their behalf. One is Spirits of the Forest, a charming film about many species of lemurs. Others are listed in the Video Section Mammals. Films of lemurs and the island's environment would provide new insights about these animals if shown to the Malagasy people. Lemurs have also been prominently featured in *Madagascar: A Natural History*, by Ken Preston-Mafham, a beautiful and informative book, and the first guide book, *Mammals of Madagascar*, which provides color photos of nearly every species and subspecies, as well as information on habitats, conservation and status (Garbutt 1999).

In some areas of Madagascar, notably on Nosy Be island, lemurs are fully protected by taboo respected by the Malagasy. Here, beautiful Black Lemurs are fed by the villagers and tourists. This island is being developed intensively for tourism, and the strict nature reserve may be made into a national park (Tyson 2000). This will have mixed results, with new income flowing to the local people from park fees--one of the few countries where this occurs--yet with habitat lost and wildlife disturbed as a result of new hotels and a crush of visitors (Tyson 2000).

The gentle, curious gazes and charming behavior of lemurs have left an indelible impression on many people, and their extinction would be tragic, not just for biological reasons, but also because of their unique and delightful qualities.

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Bats, which perform vital ecological roles in controlling insect populations and pollinating plants, tend to be ignored and often persecuted. Madagascar is no exception. Fifteen species of the 29 species of bats are endemic, living nowhere else (Garbutt 1999). The remaining 14 species live in mainland Africa as well. Fourteen species, or almost half the native bats, are listed by the *2000 IUCN Red List of Threatened Species*. The Yellow Bat (*Scotophilus borbonicus*), the most endangered, is listed as Critical (Hilton-Taylor 2000). This bat has been seen in both eastern and western regions but is extremely rare. A Vulnerable species, the Sucker-footed Bat (*Myzopoda aurita*), is the sole member of its family, Myzopodidae, and an extremely unusual bat. It is able to walk up tree leaves using sucker disks at the bend of its wings and on its feet to adhere to the slippery leaves (Jolly 1988). Only 2 inches long, with a forearm length of 1.9 inches, this tiny bat occurred in East Africa during the Pleistocene, but at present, it is found only in several locations in the eastern rainforest region of Madagascar (Garbutt 1999). It roosts in the Traveller s Tree. It possesses a complex echolocation system and emits very long calls used to hunt insects (Garbutt 1999).

The largest bat, the endemic Madagascar Flying Fox (*Pteropus rufus*), has a 4-foot wing-span. An extremely colorful bat, its crown and nape are yellowish, and its upper chest and shoulders are rufous to golden brown (Garbutt 1999). It feeds on fruit juices by squeezing pieces of fruit pulp in its mouth, swallowing the juice and very soft fruit pulp, especially of figs, papayas, lychees and guavas (Garbutt 1999). Colonies of these bats roost in tall trees in primary forests or plantations (Garbutt 1999). One large roost at the Berenty reserve has decreased, apparently because of daytime disturbance by tourists who come to see them hanging upside down in the tamarind trees (Preston-Mafham 1991). Elsewhere on Madagascar, the species has declined precipitously from hunting for its meat; only on inaccessible offshore islands do these bats survive without persecution (Preston-Mafham 1991). Of Asian origin, this species is related to fruit bats in the Mascarene Islands. Through captive studies, flying foxes have been found to be extremely devoted to one another (see discussion of Rodrigues Flying Fox in Chapter One).

The Biological Wealth of an Impoverished Country: Mammals: Page 4
The Viverrid family is represented in Madagascar by mongooses, civets, and related carnivores that have evolved into eight species of three endemic subfamilies (Preston-Mafham 1991). Their ancestor is thought to have originated in Africa, and may have colonized the island at an early period. The largest carnivore on the island is the Fossa, or Fosa (*Cryptoprocta ferox*). A zoological oddity, it resembles the Jaguarundi, a neotropical cat, but most authorities place it either in the Viverrid family with civets (Preston-Mafham 1991) or the Herpestidae family with mongoose (Nowak 1999). The only member of its genus, it walks flat on its feet, rather than on its toes like cats (Nowak 1999). Sleek and slender, with golden reddish-brown fur, it has a small head with a blunt, dog-like muzzle, and an extremely long tail. Males weigh up to 22 pounds, with a body length of 2.6 feet and a tail of equal length, while the smaller females measure 2.3 feet and weigh about 15 pounds (Garbutt 1999). It has scent glands which discharge a strong odor when the animal is irritated (Nowak 1999). Widespread but rare in forests throughout the island, this nocturnal predator kills small lemurs, rodents and tenrecs, as well as birds, reptiles, amphibians, invertebrates and, reputedly, domestic chickens (Garbutt 1999). The Fossa often excavates animals from their burrows and can pursue fleeing prey by climbing up trees (Nowak 1999).

The first research study of the Fossa is being conducted by zoologist Luke Dollar, funded by the Earthwatch Institute. Helped by volunteers, he is radio-tracking several Fossa to determine their movements, habits and territory size. As the largest predator on the island, the Fossa plays an extremely important role in the evolution, behavior and population dynamics of lemurs and other prey animals. During the research project, several Fossa have shown

extreme confidence by raiding the tents of the researchers when unoccupied, ransacking them and even chewing metal objects, leather boots, rucksacks, soap and bottles of malaria tablets (Garbutt 1999). For centuries, Fossas have been persecuted by the Malagasy, believing them to be ferocious and evil.

The Fossa gives birth to a litter of two to four young, which mature very slowly and may not be fully independent until they are about 4 years old (Garbutt 1999). This slow rate of reproduction has made the Fossa vulnerable to extinction. Along with losses from killing by the Malagasy, its forest home has been steadily whittled away by slash-and-burn agriculture. The Fossa is listed as Endangered in the *2000 IUCN Red List of Threatened Species*, a higher category of threat than it received in the 1996 version of this list.

Gerald Durrell, renowned author and conservationist, traveled in the western forests to capture Aye-ayes for captive breeding. He encountered a Fossa venturing out during the day--an unusual behavior: "A flash of russet red caught my eye in the bushes some six feet in front of the vehicle and, suddenly, from out of the undergrowth, silent as a cloud shadow, came a Fossa which walked languidly to the middle of the road and sat down" (Durrell 1993). Remaining there, the Fossa proceeded to groom himself, apparently unaware of Durrell's presence. Then, with a sigh and a wide yawn, the Fossa crossed the road and disappeared into the forest, "his immense sickle of a tail swinging from side to side like a bellrope behind him. To have spent ten minutes with such a rare and beautiful creature was a privilege" (Durrell 1993).

The Falanouc (*Eupleres goudotii*), sole member of its genus and a viverrid, is the size of a domestic cat. It has dense, woolly fur and an extremely pointed and narrow muzzle. Native to humid eastern lowland forests and marsh areas and portions of the northwest, Falanoucs are active at twilight and during the night. Feeding mainly on earthworms and other invertebrates, they use their long snouts and tiny, conical teeth to catch prey in leaf litter (Garbutt 1999). The species is rare or extremely rare over most of its range and is classified as Endangered by the IUCN (Hilton-Taylor 2000). Like the Fossa, it has declined as a result of deforestation, drainage of marshes, hunting by the Malagasy, attacks by feral domestic dogs, and possibly competition with the introduced Small Indian Civet (*Viverricula indica*).

The Malagasy Civet or Fanaloka has the scientific name *Fossa fossana*, which has been confused with the Fossa. Like the Fossa and Falanouc, it is the only member of its genus. Looking more like spotted civets from mainland Africa and Asia, this reddish 3-pound carnivore has rows of black spots on its back, merging into stripes toward its bushy, grayish tail. Its distribution is far more restricted than the Fossa's or the Falanouc's, being confined to eastern rainforests which have been reduced to less than 10 percent of their original size. Sheltering in tree holes or crevices, the Malagasy Civet lives in pairs and feeds on crustaceans, worms, small eels and frogs (Nowak 1999). A pair has a single young, and a captive civet lived 11 years. Hunting and trapping have also threatened the Malagasy Civet, which is listed as Vulnerable by the IUCN (Hilton-Taylor 2000).

Five other viverrids, all mongooses, are native to Madagascar, and all are threatened with extinction from a loss of forest habitat and persecution. A few have very restricted distributions. They tend to be secretive unless in a secure forest reserve, and little attention has been paid to their conservation, biology or habitat requirements. Several are uniform brown or russet, while two have bold black dorsal stripes ending in white, bushy tails. One, the Brown-tailed Mongoose (*Salanoia concolor*), is native to the northeast rainforests, but almost nothing is known of this small carnivore (Garbutt 1999). All of the eight native civets, mongooses and related animals are listed as Vulnerable or Endangered by the *2000 IUCN Red List of Threatened Species*.

The Biological Wealth of an Impoverished Country: Mammals: Page 5

Among Madagascar's 11 species of murid rodents are several extremely bizarre forms. The largest is the Giant Jumping Rat (*Hypogeomys antimena*), the size of a rabbit and weighing 2 pounds, 10 ounces (Preston-Mafham 1991).

Restricted to a small area in western dry, deciduous forests north of Morondava, in west-central Madagascar, its entire range is thought to encompass only 39 square miles (Preston-Mafham 1991). Once far more widely distributed, remains have been found in southwest and central Madagascar (Garbutt 1999). These huge rodents search for food, such as fallen fruit, on the forest floor and feed by sitting on their hindquarters and holding food in their forepaws like a rabbit (Garbutt 1999). Giant Jumping Rats build deep burrows and, unlike the vast majority of rodents, a mated pair maintains long bonds with one another and with their young (Garbutt 1999). Male young leave after one year, and females stay with both parents for two to three years (Garbutt 1999). Only one or two young are born in a litter, and predation by Fossa and the Madagascar Ground Boa (*Acrantophis madagascariensis*) is high (Garbutt 1999). With no reserve and a habitat that continues to decline, this huge-eared rodent is in danger of extinction. A reserve is planned for this species, which is listed as Endangered by the *2000 IUCN Red List of Threatened Species*. Madagascar. Island of Ghosts filmed the Giant Jumping Rat in the wild, one of the only videos of this fast-disappearing species (see Video section).

Eight of Madagascar's native rodents, or 73 percent, are listed by the IUCN in various categories of threat. Two are considered Critical: the Madagascar Mouse (*Macrotarsomys ingens*) and the Madagascar Rat (*Eliurus penicillatus*). The mouse is known only from a single area in northwestern Madagascar, in dry deciduous forests where the type specimen was found, and it is thought to be almost totally arboreal and nocturnal (Garbutt 1999). The Madagascar Rat has not been seen since the type specimen was collected in central-eastern montane rainforest.

The Biological Wealth of an Impoverished Country: Birds

Page 1 (Native birds)
Page 2 (Avain & Terrestrial)
Page 3 (Aquatic)
Page 4 (Bird-watchers)

The Biological Wealth of an Impoverished Country: Birds: Page 1

Until recently, the amazing lemurs and other mammals of Madagascar eclipsed its remarkable bird life. Apart from the extinct elephant birds, 120 species of the 204 native birds are unique to the island (Morris and Hawkins 1998). Like tropical birds of other parts of the world, most are dazzlingly beautiful in brilliant hues. Unlike most tropical birds, however, they represent fascinating examples of evolution, including families of birds that exist nowhere else, having evolved from a single ancestor into many forms, some very bizarre. Most ornithologists recognize five bird families as unique to Madagascar, each with extremely distinctive characteristics. Four of these have some or all species that are threatened. The fifth, a family consisting of a single bird, the Cuckoo-Roller (*Leptosomus discolor*), is secure for the moment (Morris and Hawkins 1998). A few thousand years ago, there may have been far more native bird species that disappeared without a trace as their habitats were destroyed.

Native birds are not thriving, as people and livestock destroy their varied habitats, to which they had adapted over thousands of years. A total of 41 species, all but three of which are endemic, have been listed in the *2000 IUCN Red List of Threatened Species*, based on the research of BirdLife International published in 2000 in *Threatened Birds of the World*. The latter book illustrates each threatened Madagascan bird and describes status, population numbers, distribution and other pertinent information. The three non-endemic birds also breed in the neighboring Comoros or Seychelles (BI 2000). Thus, 20 percent of all native birds and 34 percent of endemic birds are threatened, five species listed as Critical, six as Endangered, 16 as Vulnerable, and 14 as Near-Threatened (BI 2000). Moreover, many native birds that were once widespread have become restricted to isolated forest reserves and parks, not yet endangered but

far less numerous than in previous times. While the percentage of threatened birds is less than that of endemic mammals, it is significant, especially considering that 27 species are either Critical, Endangered or Vulnerable in the *2000 IUCN Red List of Threatened Species.* Madagascar has more threatened birds that all of the continental United States (excluding Puerto Rico and Hawaii). Its threatened birds total 41 threatened species, five greater than the United States 36 (BI 2000). Only 4 percent of the 810 breeding birds native to continental US and Canada combined (Sibley 2000) are threatened. If birds in the United States faced the same degree of threat as Madagascar's birds, at least 162 species would be threatened with extinction.

Fortunately for the future of these unique birds, organizations such as BirdLife International; the Peregrine Fund; Conservation International; the Jersey Wildlife Preservation Trust; and an ad hoc group, The Working Group on Birds in the Madagascar Region, are researching and working to conserve Madagascar's native birds. Malagasy ornithologists and members of the public are participating in surveys, studies and conservation programs. An inventory of the status and taxonomy of all of Madagascar's birds is in progress (Morris and Hawkins 1998).

In spite of Madagascar s many unusual birds, interesting to specialists and amateur birdwatchers alike, no bird guide or text illustrating and describing the island's avifauna existed until 1990, when Olivier Langrand's *Guide to the Birds of Madagascar* was published, providing information on natural history, status, habitats and distribution, as well as color paintings of all native birds. This material supplemented the lengthy descriptions in *Threatened Birds of Africa and Related Islands*, a 1985 publication of the International Council for Bird Preservation, now called BirdLife International (Collar and Stuart 1985). *Madagascar: A Natural History*, by Ken Preston-Mafham (1991), included extensive information on many native birds and their habitats. *Birds of Madagascar, A Photographic Guide* (Morris and Hawkins 1998), published in 1998, updates the latter publications with vivid color photographs illustrating almost all native birds, including many species discovered or rediscovered during the 1990s, such as the two new species, the Cryptic Warbler (*Cryptosylvicola randrianasoloi*) and the Red-shouldered Vanga (*Calicalicus rufocarpalis*), and the rediscovery of several birds thought extinct: the Madagascar Serpent Eagle, Madagascar Red Owl (*Tyto soumagnei*) and Red-tailed or Fanovana Newtonia (*Newtonia fanovanae*). The 1990s also saw the making of many films about the island's wildlife, including its birds (see Video section).

The Biological Wealth of an Impoverished Country: Birds: Page 2

Birds native to aquatic habitats have declined even more dramatically than many forest birds. The largest lake on Madagascar, Lake Alaotra in the northeast, was once a paradise of waterbirds, turtles, frogs and other wildlife. Traditionally, portions of the lake were used by the Malagasy for rice cultivation, without serious damage to the environment or resident wildlife. But as their populations and food requirements grew, people began to destroy more and more of the natural marsh and reed beds that lined the lake, and cleared the surrounding forest for firewood and agriculture. This destroyed the lake's water quality. With no trees to hold back the soil and conserve water, this once-beautiful lake became heavily silted by runoff (Durrell 1993). Added to this, non-native tilapia fish were introduced into the lake as a food source for the local people. The fish eat vegetation needed by dragonflies and other fauna that form the basis of the lake's food chain (Preston-Mafham 1991). This ecological collapse has greatly reduced rice production on the lake, although reeds are still being cleared for rice growing, fragmenting wildlife habitat (Garbutt 1999).

The effects on native aquatic birds have been catastrophic. Lake Alaotra is the only known habitat of the endemic Alaotra Grebe (*Tachybaptus rufolavatus*), which is presumed extinct (BI 2000, Morris and Hawkins 1998). No sightings have been made since 1985, when only two birds were seen. It declined from loss of its habitat, hunting and hybridizing with the Little Grebe (*Podiceps ruficollis*), a recent arrival from Africa (Morris and Hawkins 1998). Many fruitless searches for the species have been carried out in the lake and surrounding area since then (BI 2000, Morris and Hawkins 1998). This small, black-capped grebe was very sedentary and may have been nearly flightless because

of its extremely short wings.

Another waterbird restricted to Lake Alaotra, the Madagascar Pochard (*Aythya innotata*), is also probably extinct, having been eliminated by the same threats as the Alaotra Grebe (BI 2000). This duck declined steeply from 1930 on, and the last known bird, a male, was captured in August 1991, having been caught in fishing gear. This bird later died, and intensive searches in 1989 and 1990, and again in 1993 and 1994, failed to discover more Madagascar Pochards (BI 2000, Collar *et al.* 1994). A handsome bird, the pochard was chestnut-colored, with dark gray bill and yellow eyes (see photograph in Morris and Hawkins 1998). A shy species, its breeding and behavior were studied, but apparently nothing was done during its precipitous decline to prevent its extinction. Classified as Critical, hope remains that a few birds exist in wetland habitats around Lake Alaotra (Morris and Hawkins 1998).

The Jersey Wildlife Preservation Trust has begun education campaigns in the vicinity of Lake Alaotra to teach local people about the presence of the highly endangered Alaotra Reed Lemur or Bandru (*Hapalemur griseus alaotrensis*), a subspecies of the Grey Bamboo Lemur, and the importance of protecting the reed and papyrus beds. This lemur has been classified as Critical by the IUCN. The only lemur to live in an aquatic environment, the Alaotra Reed Lemur is larger than other subspecies of the Grey Gentle Lemur and lives in close, family groups (Garbutt 1999). To move about in the reed beds, they climb up a reed stem until it bends, and then walk along it to reach the next stem; their major food is the endemic papyrus, along with grasses and ferns (Garbutt 1999). Lake Alaotra's reed beds are its sole habitat, and although previously widespread in this and another lake to the north, only two isolated populations of lemurs, one of which numbers fewer than 60 animals and is on the verge of extinction, remain in marsh fragments (Garbutt 1999). This lemur has the most restricted range of any lemur species or subspecies (Garbutt 1999). The film, Madagascar. A World Apart, includes a moving segment on these lemurs feeding among the papyrus when a Malagasy canoe enters the marsh and sets a fire, causing the terrified lemurs to flee. (See Video section). Local village leaders have requested that the government set aside a protected zone in the marshes. There is hope that this lake will be brought back as a functioning ecosystem in the future and that a strict sanctuary will be set aside for this endangered lemur and the highly endangered waterbirds.

While sizeable areas of forest have been protected, few aquatic environments on Madagascar have been preserved, and native waterbird species are declining precipitously. The Madagascar Little Grebe (*Tachybaptus pelzelnii*) was once common and widespread in many parts of the island; with the pollution and destruction of marshes throughout the island for rice farms, this bird has declined greatly. The introduced tilapia was threatening this species by consuming its food supply. This grebe also hybridizes with the introduced Little Grebe (Collar *et al.* 1994). The Little Grebe, an African species which has colonized the island, prefers the habitat created by the tilapia, and is now abundant (Langrand 1990). The Madagascar Little Grebe has also drowned in fish nets, and has lost the vegetation it needed for nesting (BI 2000). It is expected to follow the Alaotra Grebe and Madagascar Pochard into extinction.

Another endemic waterbird, the Sakalava Rail (*Amaurornis olivieri*), native to western wetlands, is also extinct or nearly so. A small, sooty-black bird with yellow beak and pinkish-red legs and feet, it was native to streams and marshes in the western parts of the island. For more than 30 years, this species was not seen at all. In 1995, one was glimpsed at Lake Bemamba, and another in 1999 at the same lake (BI 2000). This species is classified as Critical (BI 2000), and Lake Bemamba and other lakes and wetlands on the west coast may be given protection by the Malagasy government, which has ratified the Ramsar Convention on wetlands preservation (BI 2000).

As a result of extensive habitat destruction and hunting, the Madagascar or Bernier's Teal (*Anas bernieri*) has likewise declined to endangered status in the few sites from which it is known on the west coast. Once widespread on the island, it is now restricted to a few marshes and shallow lakes. Small populations remain on Bemamba Lake and a few other sites (Morris and Hawkins 1998), and a flock of 67 was seen in another area (BI 2000). In 1970, 60 of these birds were seen on a lake, and as soon as this became known, European sportsmen went to the lake and killed more than 25 percent of the population (Curry-Lindahl 1972). In the 1970s, Bernier's Teal inhabited Lake Masama, but heavy hunting by both Europeans and natives with dogs has nearly eliminated them (Todd 1979). In 1993, four birds were captured for captive breeding (Collar *et al.* 1994). The Jersey Wildlife Preservation Trust is working to preserve

this beleaguered species and the marshes of the west. The Madagascar Teal has been seen in three protected areas, and a conservation program at one lake has been initiated (BI 2000).

The critically endangered Madagascar Fish Eagle (*Haliaeetus vociferoides*) numbers about 250 pairs in the 600-kilometer stretch of western coastline to which it has become confined (BI 2000). This large eagle resembles the African Fish Eagle, from which it probably evolved, but instead of a snowy white head and upper body, it is streaked with brown and has shaggy, buff crown feathers. About 35 inches long, with a 6.5-foot-wingspan, it is by far the largest bird on Madagascar. Persecuted by local people, these eagles have been shot and their nests destroyed. On one occasion in the 1990s, ornithologists saw some immigrants cut the tree where an active nest of a Madagascar Fish Eagle was located, and proceed to kill and eat the chicks! The only remaining habitat for this species is the western coast, where mangrove swamps are rapidly being destroyed (Langrand 1990, Preston-Mafham 1991). The Peregrine Fund is sponsoring research on this species, and 10 nests have been located in an area on the west coast in the Three Lakes Complex (BI 2000). The Fund has removed and raised chicks that would have been killed by siblings and released them to augment the population. The fish it feeds on are being depleted, however, by a gill-net fishery that has recently been established. A new Malagasy law allows local communities to control their own resources, and the people in this region are being encouraged to formalize conservation regulations prohibiting gill netting and tree cutting.

The Biological Wealth of an Impoverished Country: Birds: Page 3

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The Biological Wealth of an Impoverished Country: Birds: Page 4

As more and more bird-watchers come to Madagascar, the government may place a higher priority on bird conservation. A special fund to which bird-watchers could contribute might be established to purchase and maintain refuges and to conduct conservation education and other projects for local people, especially in aquatic habitats. The preservation of threatened Madagascan birds has reached a critical point. The most endangered habitats, the last of the western forests, aquatic environments, and many parts of the eastern lowland rainforests, continue to decline. The fragmentation of forests that forces animals into islands of isolation needs to be studied and remedied by establishing habitat corridors between them. One Malagasy ornithologist, Aristide Andrianarimisa, is researching the effects of forest fragmentation on birds.

Pete Morris and Frank Hawkins, authors of *Birds of Madagascar. A Photographic Guide*, state that their purpose in writing their book was to inspire people to visit Madagascar and take an interest in its avifauna and the plight of so many threatened birds, as well as to promote greater interest in wildlife and conservation among the Malagasy people. Ecotourists bring revenue to the island and, thereby, help to preserve natural areas and wildlife (Morris and Hawkins 1998). The discovery of a new species of songbird, the Cryptic Warbler, by bird-watchers in Ranomafana National Park, is an exciting byproduct of ecotourism and an indication that the study of Madagascar's birds has just begun. It also proves that amateurs play an important role in bird observation. *Birds of Madagascar* establishes a good precedent by identifying, on a species-by-species basis, the avian habitats and those birds lacking reserves within their ranges. The authors request that people coming to see the wildlife of the island let the government know why they have come in order to convince decision makers that biodiversity conservation represents a worthy investment (Morris and Hawkins 1998).

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians

The distribution and diversity of Madagascar's reptiles and amphibians have not been carefully researched until the present. Chris Raxworthy, a British herpetologist, is in the process of carrying out the first methodical survey of the estimated 500 non-marine species, all of which are endemic (Holmes 1997). To date, at least 300 reptile and about 200 frog species have been identified (Tyson 2000). This would make it one of the top five countries in the world for diversity of reptiles and amphibians. The British Isles, by contrast, with about half the land area of Madagascar, have only six species of reptiles (Preston Mafham 1991). Even the ranges of newly described lizards and frogs will not be delineated precisely for some time. Some areas remain unexplored by herpetologists, and Raxworthy finds new species of lizards and frogs on each expedition into the tangled swamps and forest fragments. On one day when accompanied by a journalist, he and fellow researchers, including Malagasy biologists, found a bright green day gecko, a strikingly beautiful yellow-and-black snake, tiny frogs resembling lichens, a leaf-tailed gecko and 4-inch chameleons with upper legs the colors of Rainbow Trout, and lower legs like toothpicks (Holmes 1997). In a reserve on Nosy Be island, he and some Earthwatch Institute volunteers rediscovered a 10-inch green lizard that had been lost to science since the 1890s, when last collected (Tyson 2000). Raxworthy is doing inventories in reserves as part of an

island-wide biodiversity program, and hopes that in some impenetrable area, giant tortoises long considered extinct will be rediscovered (Holmes 1997).

Page 1 (Threatened)
Page 2 (Tortoises and Turtles)
Page 3 (Lizards)
Page 4 (Snakes)
Page 5 (Amphibians)

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Of these native reptiles and amphibians, at least 19 are known to be threatened with extinction. A preliminary list includes 17 species of reptiles (four tortoises, a freshwater turtle, four sea turtles, a gecko, four chameleons and three boa snakes) and two amphibians, both frogs. All are in higher categories of threat: Endangered or Vulnerable by the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor 2000). All but the sea turtles are endemic to Madagascar.

The arid regions at the northern and southern ends of Madagascar are home to two intricately patterned tortoises, both in danger of extinction. In the north is a species considered by many to be the world's most endangered tortoise: the 18-inch Madagascar or Plowshare Tortoise (*Geochelone yniphora*), whose tan, domed shell is marked with narrow black lines in delicate hexagonal patterns. The Plowshare name came about because of a protuberance on the tortoise s lower shell that turns up, a kind of knob that remotely resembles a plowshare. This knob is used by males in sparring contests. From the 17th century onward, thousands of these tortoises, which were once abundant and widespread, were shipped every year to the nearby Comoro Islands to use as meat for settlers, driving the species to the edge of extinction before the trade finally ended in the 19th century (Juvic *et al.* 1981). Their populations never recovered, due to the continued take by villagers for pets and the massive destruction of their habitat. Known to the Malagasy as the "Angonoka," this tortoise was headed for extinction until 1985 when the Jersey Wildlife Preservation Trust was requested by the IUCN to work with the Malagasy government in formulating a rescue plan, Project Angonoka (Reid 1995). Research on the tortoise s wild status and behavior began immediately, and a captive-breeding program was established at a government forestry station (Reid 1995).

By 1986, eight adult tortoises had been gathered from the wild and placed in an enclosure which had ample vegetation and conditions natural enough that two male Angonokas immediately began their fights of strength (Reid 1995). Gerald Durrell, founder of the Jersey Wildlife Preservation Trust, in his book, *The Aye-aye and I* (1993), described lone males showing no interest in breeding, even if surrounded by females. But when another male is present, they face each other prepared for combat: "The two males, rotund as Tweedledum and Tweedledee dressed for battle, approach each other at what, for a tortoise, is a smart trot. The shells clash together, and then the plowshare comes into use. Each male struggles to get this projection beneath his opponent and overturn him to win a victory in this bloodless duel" (Durrell 1993). Finally, when one is able to overturn his opponent, he lumbers over to mate with the female while the vanquished male "wanders dispiritedly away" (Durrell 1993).

Project Angonoka has shown success both in captive breeding these tortoises, which may number only between 300 and 1,000 in the wild, and in working with local people to conserve remaining wild populations (Durbin *et al.* 1996). In fact, by 1995, a total of 140 captive-bred juveniles, ranging in age from 10 months to 6 years, had been produced at the breeding center. The breeding program was described in an illustrated article entitled "Observations on Hatchling and Juvenile Captive-bred Angonoka in Madagascar," published in the Jersey Wildlife Preservation Trust's annual journal, *The Dodo,* issued early in 1996. Within months, the captive-breeding program was devastated by the theft of 76 animals--two adult females and 74 hatchlings. On May 6, 1996, someone cut through the flimsy chain-link fence and the wire of the enclosure and took half the animals that were the fruit of a decade's work. Not until a female is 20

years old does she begin breeding, so the loss of two breeding females and their hatchlings dealt the program a devastating setback (McNeil 1996a). The burglary may have been an inside job, since the dog on the premises did not bark to alert the personnel who were sleeping close by (Tyson 2000). It is unlikely that these adult females will breed in captivity, as there are almost no adult male Plowshare Tortoises in breeding programs, and without more than one, no breeding occurs.

Animal smugglers care little about the effect of their actions on the survival of endangered species. Reptile collectors will pay thousands of dollars for rare specimens, and this break-in had been planned. A Dutch rare animal dealer had advertised Plowshare hatchlings for sale the month before, at $3,000 apiece, saying they would be "available soon" (McNeil 1996a). Ten of the hatchlings were traced to Prague, where wildlife law enforcement is weak, and others were suspected to be in the Netherlands, where they would be sold to collectors in the United States, Spain, Germany and Japan (McNeil 1996a). The loss of these tortoises cost the breeding program years of work. Don Reid, the Conservation Field Officer in charge of the Plowshare Tortoise captive-breeding program, had experimented for years to achieve a proper diet for the tortoises, arranged male combats, and conducted lengthy experiments to learn proper conditions for the eggs to hatch (Reid 1995). These tortoises became so tame that they would stretch their necks out to be scratched (McNeil 1996a). Although discouraged by the theft, he continued the breeding program; 40 new tortoise hatchlings were produced in late 1996, bringing the total to 130 juveniles. In 1998, several of the smuggled tortoises were seized from a Malaysian animal dealer in Mexico City who had been the subject of a long-term U.S. Fish and Wildlife Service undercover investigation. The same year, three more Plowshare Tortoises were seized in Belgium as they were being imported (TRAFFIC 1999a). The species is listed by the *2000 IUCN Red List of Threatened Species* as Vulnerable, and is protected by the Malagasy government, which bans trade.

Officials from the Jersey Wildlife Preservation Trust and other conservationists have sponsored education programs aimed at informing local people about the tortoises and their rarity. This has resulted in their cooperation in helping to guard wild tortoises from poachers and control brush fires (Durbin *et al.* 1996). This region in northwestern Madagascar has lost most of its forest cover; Arab residents cut trees and burn them to clear the land for agriculture, and feral pigs kill the young wild tortoises (Durbin *et al.* 1996). So much clearance of natural vegetation has taken place that the climate has become increasingly more arid, causing ponds to dry up. Tree cutters are now turning to the mangroves, causing siltation of the inlets, which affects prawn harvests (Durbin *et al.* 1996) and destroys a key aquatic environment on the island.

The Biological Wealth of an Impoverished Country: Reptiles and Amphibians: Page 2

The Plowshare Tortoises have been reduced to a few forest sites, and in spite of the urgent need for a reserve, none has been set aside. The area is getting conservation help with the formation of a new organization by conservation biologists, the Association to Safeguard the Environment. Its purpose is to involve local people in environmental projects, such as planting cashew trees, learning fire suppression methods, and trapping bush pigs; they are also giving conservation lessons to children and conducting literacy classes (Durbin *et al.* 1996).

The Radiated Tortoise (*Geochelone radiata*) inhabits the drylands of the extreme south, where the strange Didierea plants and other desert vegetation grow in open shrubland. Many people consider this tortoise to be the most beautiful in the world. Delicate yellow sunburst patterns adorn the top of its 16-inch-long black shell, and the underside is marked with diamond patterns. These tortoises also declined after tens of thousands were killed to supply local villagers with meat, or exported to the Comoro Islands from the 17th century on for meat markets abroad. In 1922 alone, 22,000 of these tortoises were exported (Jolly 1980). The legal trade did not cease until 1930. The tortoise populations have not rebounded, and illegal capture for collectors and zoos may be the explanation. The slow reproduction of this species means that it cannot quickly make up for losses in its population. An extremely long-lived

species, it has evolved with low natural mortality and has few young. As an example of its longevity, a Radiated Tortoise of unknown age presented to the Queen of Tonga by Captain Cook in the 1770s, lived until 1966, making it almost 190 years old at its death (Jackson 1993).

The lovely patterns on this tortoise's shell, which vary from individual to individual, have placed it in great demand around the world, encouraging poverty-stricken Malagasy to risk jail to earn the money that these tortoises bring. Thousands of Radiated Tortoises have been collected for the international market, sold in Europe, North America and elsewhere for $2,000 or more per animal. In spite of having a range that is far larger than that of the Plowshare Tortoise, the Radiated Tortoise is declining rapidly toward extinction. The species is listed by the *2000 IUCN Red List of Threatened Species* as Vulnerable. Export and collection of Radiated Tortoises are prohibited by the Malagasy government, with severe penalties for violations including prison sentences. The United States lists both the Radiated and Plowshare Tortoises on the Endangered Species Act, which prohibits commercial importation. International commercial trade is banned by their listing on Appendix I of CITES. Still, the smuggling continues, fed by the many wealthy collectors who have no conscience about the effect their purchase has on wild populations, and the zoos that knowingly purchase smuggled animals. Malagasy authorities have failed to put an end to the poaching, especially of the Radiated Tortoise and other southern species.

Donovan Webster, a journalist, researched the rampant smuggling of Radiated Tortoises and other wildlife from the island for *The New York Times Magazine*, which published his lengthy article on February 16, 1997. The magazine cover featured the article and read: "I was caught in Madagascar. Peddled for 30 cents. Smuggled to Orlando. Sold for $10,000. I'm a rare, coveted tortoise--coldblooded contraband." Webster found that Madagascar was a "pirate's paradise," with little or no local enforcement of conservation laws. Its long and unpatrolled coastline is used by smugglers, who load tortoises onto small boats at night, with little fear of arrest (Webster 1997). Although some enforcement of capture bans takes place in the range of the Radiated Tortoise, local people have learned to avoid arrest.

The contrast between the attitudes of local people toward the Plowshare Tortoise in the north, where education programs have been carried out by the Jersey Wildlife Preservation Trust, and the south, where no strong program exists to protect the Radiated Tortoise and other wildlife, could not be more dramatic. In the south, poaching Radiated Tortoises and other reptiles is considered an accepted form of revenue by the extremely poor people of the region. At local bars and restaurants, Webster was approached by people who offered to produce a rare snake within 24 hours. Snakes are a favorite animal for smugglers because they can be secreted in small bags and placed in luggage or, if they are small enough, in pockets. He refused a boa, which was offered at $300 and could be sold for $2,000 in the United States (Webster 1997).

Webster exposed a large-scale and fairly open trade in Radiated Tortoises in local markets within the range of these tortoises. He visited a woman who was reputed to have many of these tortoises for sale. She showed him 24 Radiated Tortoises which she kept ready for sale to anyone who would pay the right price; they were crowded into a make-shift pen in her living room, stacked two and three deep in filthy conditions (Webster 1997). They grunted and made hissing sounds when disturbed, scratching and scrabbling against one another and the pen sides; their shells were covered with dust, and most appeared to be sickly (Webster 1997). The woman tossed the tortoises back into the pile after handling them. She claimed that she sold them to local people for $1.35, and to outsiders for $4 or more, depending on how many tortoises she had at the time (Webster 1997). She also admitted supplying a smuggler who arrived once a week in a canoe at a remote beach with any Radiated Tortoises she had in stock (Webster 1997).

These tortoises are absurdly easy to collect in the wild, living in open shrubland and moving so slowly that they can be picked up as easily as rocks. Webster witnessed the capture of one mature tortoise which Benjamin, one of the collectors, located in the shadow of a boulder. When he approached, the tortoise hissed and tried to crawl beneath bushes, but it was easily grabbed, and he flipped it on its back; soon he caught two other adult tortoises who had a baby the size of a small stone wedged beneath them in an apparent attempt to protect it (Webster 1997). Collectors wrap string around the tortoises shells to form handles for carrying them. When they met at the end of the day, they

had taken 54 mature tortoises and many young ones, making it a "banner day" (Webster 1997). The occasional presence of enforcement officers and World Wildlife Fund (WWF) representatives did not seem to present any anxiety of threat of arrest to the collectors (Webster 1997).

Each Radiated Tortoise is worth at least $2,000 once smuggled out of Madagascar, and those with unusually exquisite patterns bring as much as $10,000 (Webster 1997). Benjamin later admitted that he was aware that the tortoises were becoming rarer and that their range had shrunk in recent years; he also knew that many were very old, probably older than his own 53 years. It was obvious that the tortoises would soon be gone, but he believed this was his only potential income source; he was uncertain about how he would make a living when there were no more Radiated Tortoises (Webster 1997).

Some of the smuggled Radiated Tortoises leaving Madagascar have been seized by importing countries. In May 1992, for example, a Dutch citizen arriving from Madagascar was stopped by Customs at Roissy Airport in the Netherlands in possession of 46 Radiated Tortoises as well as 14 bamboo lemurs of several species and seven endangered Madagascar Boas (*Acrantophis madagascariensis*); the animals were confiscated and returned to Madagascar (TRAFFIC 1992). In 1998, a Radiated Tortoise was among many rare tortoises seized in Belgium as they were being imported, and U.S. authorities, under Operation Chameleon, an undercover investigation of trafficking in illegal Madagascar reptiles, seized Radiated Tortoises from an American reptile dealer in Miami. In May 1999, French Customs officers seized 450 tortoises smuggled by three Malagasy citizens living in Paris (TRAFFIC 1999b). Among them were 120 Radiated Tortoises; the suspects were not arrested (TRAFFIC 1999b).

Most ecotourism on the island has been developed for viewing lemurs, chameleons and birds, but the Radiated Tortoise and its extraordinary habitat of endemic plants have the potential of attracting many tourists. Also living in this tortoise's habitat are spectacular sifakas, many unusual birds, and other reptiles. In Beza-Mahafaly Reserve, scientists are studying the ecology and longevity of these tortoises, as well as searching for a permanent form of marking that would make them unattractive to collectors. The Radiated Tortoise could be conserved while helping local people like Benjamin. Grants from international organizations could finance jobs held by local people, such as ex-poachers, to protect the tortoises and serve as wardens. Former collectors could help educate schoolchildren and local people about protecting Radiated Tortoises and other wildlife. Organizations, such as Earthwatch Institute, might sponsor research to study the status of these tortoises. The presence of scientists would pose a deterrent to poachers.

Two other endemic tortoises, the Spider Tortoise (*Pyxis archnoides*) and the highly endangered Flat shelled Tortoise (*Pyxis planicauda*), are much smaller, about 5 or 6 inches long (Preston Mafham 1991). The latter tortoise is restricted to a forest of only 40 square miles, and a captive breeding program is attempting to prevent its extinction. Both these tortoises lay only a single, large egg (Preston Mafham 1991). These tortoises are also in demand by reptile collectors. In August 1996, six men were indicted after being arrested with four Spider Tortoises in their luggage at the Orlando International Airport in Florida. They were part of a smuggling ring supplying rare reptiles to collectors. In 1999, 330 Spider Tortoises were seized along with Radiated Tortoises in the case cited above (TRAFFIC 1999b).

The Madagascar Big-headed Turtle (*Erymnochelys madagascariensis*), is an endangered freshwater species listed in the *2000 IUCN Red List of Threatened Species* and on Appendix II of CITES. This turtle is related to South American river turtles, another link that may date back to the time before Madagascar drifted away from Gondwana. The Jersey Wildlife Preservation Trust began a breeding program for these turtles in 1999 with the objective of releasing young turtles back into the wild after educating local people.

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Madagascar is home to two thirds of the world's chameleons--at least 62 species--more than any other country (Tyson

2000). Among the island's endemic chameleons are the world's smallest and largest species. The smallest, *Brookesia minima*, is only 1.3 inches long, while the largest, *Furcifer oustaleti*, measures 27 inches in length (Preston Mafham 1991). Their conical eyes, moving independently, can look forward and backward at the same time, swiveling almost 180 degrees in either direction (Preston-Mafham 1991). This adaptation, processing totally divergent information spontaneously, would confuse most vertebrates, but chameleons, even very young ones, are adept at using these dual periscopes to locate insects and other prey. They hold onto the thinnest branch with their prehensile tails, and with long, thin legs bent at the knees, they walk in an odd back-and-forth swaying motion that resembles leaves moving in the wind. Their chunky bodies and spindly legs give them an awkward appearance, but they are superbly adapted to catching their prey by unfurling a long, sticky tongue--curled upside their mouth--with lightning speed, nailing an unaware insect with astonishing accuracy.

Their camouflage coloration, which varies greatly from bright greens, mottled browns, reds and blues, helps protect them from avian and mammal predators. Contrary to general opinion, chameleons do not change colors as they move about in the trees or on the ground to match their background. When they suddenly change colors, it is as a territorial or sexual display meant for other chameleons (Preston-Mafham 1991). Some species have horns and other protuberances, giving them the appearance of miniature dinosaurs. A few species show sexual dimorphism, or a physical difference between the sexes. The contrast can be so striking that some were considered separate species when first identified (Burger and Price 1996). In one species, for example, the female is black and yellow, and the male a mottled brown and white (Burger and Price 1996).

Chameleons are heavily exploited by collectors who capture them for sale in pet stores around the world, threatening them. Collectors will pay $1,000 or more per animal for rare species. This trade, which involves thousands of individuals, has caused declines in many species. The Malagasy government has banned trade in most species, but enforcement is not strong. One chameleon, *Chamaeleo brevicornis*, of which 795 were exported in the first six months of 1990, is restricted to only a few areas of primary forest (Behra 1993). An ongoing study will evaluate whether to allow trade in the commoner species. Chameleons captured and shipped abroad for the pet trade suffer very high mortality as a result of inhumane transport conditions and inadequate care in pet stores and people's homes. They require special conditions of temperature and humidity, and many have specialized diets. In short, they are not suited to being house pets. In the care of specialists, they can be kept alive, but most captive breeding has been unsuccessful. Some of the rarer species, such as the beautiful blue-green Parson's Chameleon (*Chamaeleo parsonii*), which can reach lengths of more than 20 inches, have not been bred to the second generation**,** and mortality is high. All chameleons are on Appendix II of CITES, which requires export permits, but none has been listed on Appendix I of CITES, which would ban commercial trade.

Although some chameleons have adapted to disturbed habitats, such as weedy fields and shrub landscape, the majority favor natural habitats. The small *Brookesia* chameleons, of which one species is listed by IUCN as Vulnerable (Hilton-Taylor 2000), require undisturbed, primary old-growth forest. Three other chameleons, all *Furcifer* genus, are listed as Vulnerable by IUCN. All are in decline, approaching endangered status.

Although many Malagasy regard chameleons as ugly porters of bad luck (Burger and Price 1996), for tourists, they are the second most popular animals, after lemurs. Some Malagasy, aware of the fascination with which chameleons are held by tourists, capture them and offer them for viewing or sale.

Another lizard being captured for the pet trade is the extraordinary 4-inch-long Leaf tailed Gecko, *Uroplatus fimbriatus*, a true master of camouflage. Resting during the day with its head tight against a tree trunk, an elaborate lacy fringe along the underside of the body allows it to melt into the tree, while its skin is patterned to resemble tree bark. Even its golden eyes are streaked with tiny dark lines that imitate bark. With broad, flattened front feet splayed out against the bark and hind legs held vertically under a spatula like tail, it becomes virtually invisible (Preston Mafham 1991). If discovered, however, it has a defense. Opening its mouth wide to reveal a crimson red tongue, it raises its tail vertically and emits an ear-splitting screech, no doubt intended to be a fearsome display (Preston Mafham 1991, Tyson 1994). Malagasy boys have discovered the haunts of the Leaf-tailed Geckos, and

capture hundreds--thousands by their accounting--for sale to foreign middlemen who pay them less than $1. They are sold in the United States for $250 a pair (Tyson 1994, Tyson 2000). On Nosy Be island off the northern coast, schoolboys claim to have captured 40,000 over the past six years (Tyson 2000). A threatened gecko, Standing's Day Gecko (*Phelsuma standingi*), is native to the spiny forests of the south and is one of the most coveted by collectors (Tyson 2000). It is hunted out of many areas because Malagasy have captured hundreds, receiving $1.20 per gecko, while reporting only a few to authorities (Tyson 2000). It is on CITES Appendix II, and sells in the United States for $80 to $200 apiece (Tyson 2000). Most species of geckos bring the village collectors only about 3 U.S. cents, while the exporter receives $9 to $13 and U.S. retailers get $75 or more (Burger and Price 1996). In most cases, these pet reptiles live a very short time, and represent a mere toy to the consumer.

The export trade in live lizards involves an enormous number of animals. One gecko, *Phelsuma serraticauda*, was known only from a few museum specimens until 1,360 specimens were chronicled as exported during the first six months of 1990 for the pet trade (Behra 1993). During this same period, 22,837 lizards--geckos, *Phelsuma* genus, and chameleons, *Chamaeleo* genus--were exported from Madagascar (Behra 1993). Between 1986 and 1991, almost 145,000 lizards of 17 species were exported; of these at least 38,325 were chameleons of 21 species (Burger and Price 1996). Many of these are species that are endemic to restricted areas, or threatened in the wild. The U.S. Fish and Wildlife Service s Operation Chameleon succeeded in arresting 19 people in 1998, among whom was a major Malaysian smuggler and an American, Tommy Crutchfield, who was arrested at Miami International Airport with suitcases full of rare snakes, tortoises and lizards. In another case, a Canadian and a Dutchman were arrested at Chiang Kai-shek International Airport in Taiwan with numerous chameleons and geckos, including some threatened Standing's Day Geckos.

Several gecko species have extremely limited ranges. A newly described leaf gecko, *Uroplatus malama*, is known from a single specimen taken in a remnant of lowland rainforest in southeastern Madagascar (Burger and Price 1996). Only two specimens of a closely related species, *Uroplatus malahelo*, exist, native to a small patch of forest in the south (Burger and Price 1996). When discovered, its habitat was being logged, and the species may already be extinct (Burger and Price 1996). An extremely rare lizard, *Zonosaurus boettgeri*, known from two specimens that were taken in the 1890s and subsequently disappeared, has been rediscovered on the island of Nosy Be by herpetologist Chris Raxworthy and volunteers from Earthwatch Institute (Tyson 2000). The two individual lizards were killed as specimens upon rediscovery (Tyson 2000).

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Among Madagascar's 80 types of snakes--all non-poisonous--are three boas, whose closest relatives are found in South America (Burger and Price 1996). They are thought to be among the island's most ancient inhabitants, resident since the early breakup of Gondwana (Preston Mafham 1991). All are considered Vulnerable by the IUCN (Hilton-Taylor 2000): Dumeril's Boa (*Acrantophis dumerili*), Madagascar Boa (*Acrantophis madagascariensis)*, and the Madagascar Tree Boa (*Sanzinia madagascariensis*). The first two are Madagascar's largest snakes, reaching almost 6 feet in length; Dumeril's Boa is restricted to the south and southwest, while the Madagascar Boa is found in the north and northeast (Preston Mafham 1991). Both species require humid habitats along streams and watercourses. Placid and slow moving, they are often killed or captured by local people. The Madagascar Tree Boa is smaller and more common, shaded in delicate grayish-green with a purplish blue tinge. Little is known of any of these species' life histories and diets (Preston Mafham 1994). A very rare and possibly extinct snake, *Pararhadinea albignaci*, is known only from a single specimen picked up, dead, off the road in eastern Madagascar in 1970. This species has never been seen alive in its forest home (Preston-Mafham 1991).

One of the most extraordinary snakes in the world, *Langaha nasuta*, mimics a dry, pencil-thin twig to camouflage itself among the leaves. The female's nose is extended into a leaf shaped structure adorned with scales and small

tooth like projections, while the nose of the male is elongated, tapering into a sharp point to resemble a thorn (photo in Preston Mafham 1991 and Lamar 1997).

A smuggling operation involving hundreds of Madagascar reptiles was exposed in August 1996, when six men were charged with conspiracy to smuggle rare Madagascar reptiles into the United States and Canada. According to the U.S. Justice Department, two men were arrested at Orlando International Airport in Florida with 61 Madagascan tree snakes in their suitcases that were to be sold at a large reptile breeders show in Orlando (Reuters 1996). Four Germans, one Canadian and one South African were indicted. Simon Harris, the South African, had $100,000 worth of rare reptiles in his luggage; he cooperated to implicate the other suspects, who are still being sought (Reuters 1996). These smugglers shipped snakes and tortoises, concealed in suitcases, from Europe to Canada and the United States and received payment by international wire transfers. Most of the snakes and tortoises were listed on CITES. In 1998, 26 Madagascan Tree Boas were seized in Belgium, and an American reptile dealer was caught by the U.S. Fish and Wildlife Service with the latter species and Dumeril's Ground Boas in his luggage at Miami International Airport (TRAFFIC 1999a).

The sea turtles inhabiting Madagascar's coastal waters are heavily exploited in spite of their listing on Appendix I of CITES. A survey in 1971 estimated that 13,000 were killed along the west coast alone (Burger and Price 1996). Little is known of their present populations.

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Some 176 species of amphibians, all frogs, have been named and described (Mittermeier *et al.* 1999). Raxworthy estimates that there are another 124, many of which have already been found but not yet described scientifically (Tyson 2000). Salamanders and toads are absent from Madagascar. All but two frogs are endemic, one of which was introduced from Asia by French colonialists as a gourmet food source (Burger and Price 1996). The majority are native to rainforest environments, the most endangered type of habitat on the island. In one such area, a montane rainforest in the Andasibe region, 90 species are native--the highest diversity of frogs in the world (Burger and Price 1996). Since 1990, 13 new species of a single, colorful genus, *Boophis*, have been described, and others await naming by scientists (Burger and Price 1996). A candidate for the world's smallest frog--and perhaps the world's smallest vertebrate--is a minute frog, *Stumpffia pygmaea*, which measures less than 3 millimeters in length (0.117 inches) (Burger and Price 1996). This frog lays its eggs in foam nests hidden among leaves on the forest floor, and the tadpoles grow into froglets without ever feeding (Burger and Price 1996).

The most spectacular Malagasy frog may be the bright red Tomato Frog (*Dyscophus antongili*), which secretes poisonous white mucous when threatened. Some authorities consider the species to be endangered (Bauer 1995), while the *2000 IUCN Red List of Threatened Species* lists it as Vulnerable. To protect it from trade, it is listed on Appendix I of CITES. Fat and squat, this toad-like frog is large enough to cover the palm of a hand (Preston-Mafham 1991). Tomato Frogs have a very restricted range in the region of Tamatave on the east coast; some live in plantations, where pools of water gather, and even in garden ponds (Preston-Mafham 1991). Collectors, pet dealers and zoos have offered thousands of dollars for these frogs, and illegal shipments containing 40 or more Tomato Frogs have been confiscated.

One study entitled "The Export of Reptiles and Amphibians from Madagascar," by Olivier Behra (1993), chronicled the extent of exploitation of frogs. In 1988, 230 frogs of the genus *Mantella*, endemic to Madagascar, were exported. The demand increased, causing exports to rise astronomically to 11,058 in 1989; in the first six months of 1990 alone, almost 11,000 were exported, mainly to Denmark and other European countries, the United States and Japan (Behra 1993). These brightly colored little frogs are sold as pets and to decorate terrariums. The most popular Madagascar frog in this trade is the tiny Golden Mantella (*Mantella aurantiaca*), of which 3,237 were exported in the first six

months of 1990 (Behra 1993). This frog is restricted to eastern Madagascar, and is apparently rare and declining (IUCN 1994). It lives in pandanus swamps in rainforests, which are rapidly disappearing, and no part of its habitat has been set aside in a reserve (IUCN 1994). Unlike most frogs, the Golden Mantella is slow-reproducing (IUCN 1994). In the 1990s, 3,000 to 6,000 were exported annually from Madagascar, and in 1994, two proposals sought to list this species on CITES, one on Appendix I and the other on Appendix II. The latter proposal succeeded, which is unfortunate, since it allows the trade to continue. The *2000 IUCN Red List of Threatened Species* lists the Golden Mantella as Vulnerable (see photos of gold and red phases of this species in Lamar 1997).

In 1998, two people were arrested in Taiwan trying to smuggle frogs of two *Mantella* species (*Mantella madagascariensis* and *Mantella aurantiaca*), along with some Madagascar lizards. Another seizure of 50 Mantella frogs occurred at Zaventem Airport in Belgium in 1998 as they were being smuggled from Madagascar (TRAFFIC 1999a). Such seizures involved shipments without the proper export permits. Appendix I listing under CITES would provide greater protection.

The Biological Wealth of an Impoverished Country: Invertebrates

Like the rest of its fauna, Madagascar's invertebrates are extraordinary. One insect from the age of the dinosaurs, the Giraffe-necked Weevil (*Trachelophorus giraffa*), has an elongated neck which rises vertically, then makes a right-angle turn and extends horizontally, and ends in a tiny head with furry antennae. Amazingly, this insect has counterparts in New Zealand known as giraffe weevils (Molloy 1994). This may be explained by the fact that New Zealand was also part of Gondwana prior to its breakup (Molloy 1994). Other ancient species include the 100 species of hissing cockroaches. Some are far larger than any other cockroach species in the world; their heavy bodies resemble long-extinct trilobites. The largest species measure up to four inches long, and thousands are exported for the novelty pet trade and for zoos. When touched, they hiss loudly, and males aggressively charge one another with their armored, knobbed shields (Preston-Mafham 1991).

One of the richest land-snail faunas in the world is native, with more than 380 species named so far, 361 of which are endemic and differ greatly from land snails in Africa (Preston-Mafham 1991). Many are threatened, however, by introduced African Giant Snails (*Achatina fulica*) and several other non-native snails introduced to control the African Giant Snail, but threatening native species instead. One native snail, *Tropidophora deburghiae*, is considered endangered by some authorities. Brilliantly colored slugs, or shell-less snails up to 6 inches long, striped in black-and-red or yellow-and-brown, live on the damp rainforest floor (Preston-Mafham 1991). Many have limited distributions and can be easily eliminated by habitat destruction (Preston-Mafham 1991).

An extremely ancient family of spiders, Archaeidae, first described from a specimen frozen in amber several million years old, has seven species on Madagascar, one in South Africa, three in Australia, five in New Zealand and one at the tip of South America; these species appear to be vestiges from the ancient supercontinent (Preston-Mafham 1991). The Archaeidae spiders have strange, grotesquely shaped bodies, visible only through a microscope since they are only 0.14 inches long; they live among leaf litter on the ground (Preston-Mafham 1991). Some Madagascar spiders are extremely bizarre, with shapes that resemble bat-winged leaves, bright red thorns, or mottled brown lumps on logs (Preston-Mafham 1991).

Millipedes on Madagascar reach 6 inches and exude droplets of poison when attacked; Brown Lemurs have found ways of avoiding this toxin and feed on them (Preston-Mafham 1991). Shield-bugs, or stink-bugs, of the family Pentatomidae, have 220 species on Madagascar, many of which are brightly colored in reds, oranges and blacks; 120 species of water bugs, of which 80 percent are endemic, and a variety of assassin bugs add to the rich insect fauna (Preston-Mafham 1991). About 20,000 beetle species, including 500 species of endemic jewel-beetles, are native to Madagascar. Jewel-beetles, with their colorful, metallic bodies, appear during the rainy season in southern and

western forests (Preston-Mafham 1991). Many species of scarab beetles, among which are dung beetles, are also native to Madagascar; one endemic genus, *Helictopleurus*, roll the dung balls into their nests and lay their eggs in them (Preston-Mafham 1991).

Madagascar's butterflies, totaling 300 species, are not as diverse as in some parts of the world, such as the Tambopata Natural Reserve in Peru, which has 1,300 species. This may be because they colonized the island fairly recently. Another possibility is that many species have faded into extinction, leaving no trace, when the plant species upon which they depended were driven to extinction by habitat destruction. Since 80 percent of the island's forests have been cut, hundreds or thousands of species may have disappeared without a trace millennia ago. One Madagascar butterfly, a pale cream-and-black Swallowtail, *Papilio mangoura*, is hotly pursued by collectors because of its rarity (Preston-Mafham 1991). Several butterflies of the Nymphalidae family, or Fritillaries, are threatened, as are two species of the family Acraeidae.

In the 19th century, Charles Darwin learned of a spectacular, white Madagascar orchid (*Angraecum sesquipedale*) that had an extremely long, nectar-bearing tube dangling down from the flower. He reasoned that it could be pollinated only by an insect that could reach its nectar. He guessed that it might be "some huge moth, with a wonderfully long proboscis." Entomologists verified his belief with the 1903 discovery of the hawkmoth, *Xanthopan morgani praedicta*. This moth has a 9-inch tongue that it keeps wound in a spiral in its mouth, unfurling it to reach the nectar of this particular orchid. In a similar arrangement, another orchid (*Angraecum arachnites*), exudes a strange odor that attracts only one pollinator, the rainforest hawkmoth, *Panogena lingens* (Preston-Mafham 1991). The nectar at the base of this orchid's long, twisted tube can be reached only by this single species of moth--and not even every individual, but only one race of this moth which has a long, tapered proboscis (Preston-Mafham 1991). These species co-evolved, and should the moths become extinct, the orchids would have no pollinators and would follow them into extinction. Another unusual moth, the huge Comet Moth (*Argema mittrei*), is one of the largest moths in the world (Preston-Mafham 1991).

Preserving Madagascar's Natural Wonders

This fourth largest island in the world is, in many respects, a minicontinent. This evolutionary treasure-house is of great importance from a worldwide perspective. Madagascar's diversity of life forms is so great that as many as 200,000 species, most of them undescribed, may be native, of which an estimated 150,000 are endemic species (Daley 1997). The habitat loss is proceeding so rapidly, however, that the underfunded biological assessment studies will be unable to appraise this biological wealth before it disappears before their very eyes. Logging and burning have reduced the forested area from 120,000 to 20,000 square miles; this destruction still consumes vast areas each year (Daley 1997). It is estimated that all the remaining accessible forests will disappear within the next 35 years (Sayer *et al.* 1992). With the impending loss of these treasures, many conservationists and scientists consider Madagascar the world's most threatened natural area (Sayer *et al.* 1992).

Less than 5 percent of Madagascar is protected in reserves and parks. Even if these lands remain intact, they represent too small a percentage of forest to preserve the island's genetic heritage. Other than Masoala National Park, which encompasses most of an entire peninsula, some 840 square miles, most reserves are relatively small--islands of forest surrounded by denuded land. Should all surrounding forest be leveled, these isolated fragments would not be sufficient to prevent genetic impoverishment, inbreeding, and eventual extinction of the very species the reserves were meant to protect. Recent research in the Amazon has shown that forest fragmentation results in extinctions, in direct relation to the size of the reserve (Peters and Lovejoy 1990). The larger the reserve, the fewer extinctions. For this reason, Masoala National Park is receiving special attention from scientists. Stanford University's Center for Conservation Biology is analyzing a Geographic Information System (Kremen 1998). So far, this research has revealed that forests on the eastern border of the park are the most threatened, with a likelihood that they will be

completely burned away within 25 years (Kremen 1998). The borders of the park were delineated according to the results of biological surveys, a method that is so new that it has not even been used in the United States. Claire Kremen of the Wildlife Conservation Society, with additional support from the National Geographic Society, worked with a Malagasy entomologist and two American ornithologists to conduct detailed biological species diversity studies in this rugged terrain (Kremen 1998). Five new species of butterflies and many other insects were discovered. Each had its own micro-habitat, endemic to that area. Habitats included in the national park are lowland rainforest; cloud forest and montane heath; coastal and seasonally flooded forest; mangrove; marsh; estuary; bay; lagoon; and coral reef. Lemurs and a vast array of wildlife and plants will benefit from this new park.

Masoala National Park will not displace villages but will conduct education programs and involve them in the conservation of local wildlife. The Missouri Botanical Garden is also involved in the management of Masoala National Park, helping to inventory its rare plants and working with local people for non-destructive agricultural and fisheries industries. Work is also proceeding to stop the cutting of forests for firewood on Masoala and to provide public education on land use (Sayer *et al.* 1992). Some 300 or so villages exist within or nearby Masoala National Park, and the cooperation of the local people is crucial to the success of this park. The final plan for the park involved a compromise in which some cutting of four relatively fast-growing trees, including rosewood, would be allowed. Local communities, which will profit from the products, will be allowed to harvest palm seeds and butterflies. This will prevent the slash-and-burn destruction that was eating rapidly away at this forest (Kremen 1998). This park's endemic plants and animals, including the Red Ruffed Lemur, which exists only in the park, rely for their survival on the protection of this last sizeable rainforest. It will represent an experiment in conservation management that will have serious consequences should it fail. It is, however, one of the first times that ecological rules are being worked out with large numbers of local people to help protect such a large area. Elsewhere in Madagascar, similar projects are in the works.

Many of Madagascar's rarest species are not protected in any reserves, however, and may soon be lost. Reserves and parks, the last refuge for many species, are regularly pillaged for trees, and wildlife is killed or captured. A herpetologist surveying in Bemaraha Reserve, in the western part of the island, discovered a pile of illegally cut trees that had been marked with red paint as part of a botanist's study by the trail in 1996 (Holmes 1997). This is not an isolated occurrence. The native wildlife and plants are among the most endangered in the world. More than 124 vertebrate species are listed in the *2000 IUCN Red List of Threatened Species* (Hilton-Taylor 2000), as well as 306 species of plants (Walter and Gillett 1998). While this crisis is occurring, new species of lemurs, reptiles, invertebrates and plants are being discovered, making the preservation of the environment all the more urgent. Obviously, the amazing biological diversity of Madagascar has not been fully assessed and may be far greater than previously thought.

Several species thought long-extinct are rumored to survive, adding even more mystery to the picture. Many Malagasy have told scientists of having seen an animal that might be a pygmy hippopotamus. Shown a picture of an African Common Hippopotamus, they have said that it was similar, but had floppy ears, uncloven hooves, dark skin, except for pinkish areas around the eyes and mouth, and was the size of a calf or small cow (Tyson 2000). As recently as 1976, a man told biologists of having seen and heard one grunting; many unsolicited, independent accounts from Malagasy have agreed on these details (Tyson 2000). They call the animal "kilopilopitsofy," and many are afraid of being chased by it (Tyson 2000). The Common Hippopotamus of Africa also grunts and kills more people than any other animal on the continent.

A long-lost primate, ground-dwelling and the size of a 7-year-old child, has also been reported by several Malagasy (Tyson 2000). This may be the same animal that was described to primatologist Alison Jolly (1980). A Malagasy told her that he had been given a young lemur of a type he had never seen before. This lemur had very dark fur, walked on its hind legs, one foot after the other, rather than hopping like a sifaka, and had a flat face different from the pointed muzzles of living lemurs. After only two months, this lemur died, and its skeleton was buried in an unknown place (Jolly 1980). An old man recently told a similar story of having seen such an animal in 1952. Called the "kidoky" by others who have seen it, it has a dark coat with white spots above and below a flat, round face. When alarmed, it flees

by leaping forward in short hops like a baboon. Its call was described as a long, single whoop, and other villagers who had seen the animal said it was solitary (Tyson 2000). Scientists have said that if it exists, it might be an *Archaeolemur* or *Hadropithecus* (Tyson 2000). The fact that their descriptions seem so similar to species known to have existed makes them all the more intriguing.

Alarm calls about the impending demise of Madagascar's natural world have been sounded for decades (Jolly 1980, 1988; McNulty 1975; Preston Mafham 1991; Tyson 2000). Visitors to the island are united in their descriptions of a ravaged, eroded and deforested land. Jacques Yves Cousteau and his team visited the island for a television special aired in 1995. As they sailed toward Madagascar, they were stunned to see huge, wide, red stains of eroded soil in the water, emanating from the island's rivers, and wisps of smoke from burning forests. These red rivers are bleeding the island's life blood, its topsoil. They are so pronounced that they are among the few natural phenomena on Earth visible from orbiting space craft. Cousteau's helicopter flights over the central plateau revealed a landscape among the most devastated on the planet. A research team sponsored by Earthwatch Institute described the island from the air, "Two features of the landscape stood out even from 10 kilometers up: barrenness and smoke" (Tyson 1994).

Although erosion remains a major problem, some progress has been made to stop it (Morell 1999). Erosion costs Madagascar between $100 million and $290 million per year, caused mainly by the continued slash-and-burn agriculture (Tyson 2000). It has been extremely difficult to convince many Malagasy that the last of the forests will disappear within a generation if they do not seek alternative means of growing crops. To that end, Cornell University's International Institute for Food, Agriculture and Development, run by Norman Uphoff, has been helping farmers in the vicinity of Ranomafana National Park (Tyson 2000). These desperately poor farmers have no electricity or plumbing and struggle to feed large families on soil that is leaching its nutrients. Norman Uphoff discovered that the native Wild Ginger plant had high concentrations of phosphate, and he encouraged its use as fertilizer (Tyson 2000). By supplying seedlings and information, the Cornell program also has helped establish fish farms. Their agronomists have advised farmers to mix crops and to plant certain species in order to keep the soil rich and retard erosion; they have supplied seedlings (Tyson 2000). This agricultural advice has been helpful, but because some rural people have so many children, many are unable to produce enough crops to feed their families (Tyson 2000). Other projects involve encouraging rice cultivation with more suitable seed varieties, improved irrigation systems and application of fertilizer (Garbutt 1999). Using native bees in honey-making is also being taught to the Malagasy, who often fell old-growth trees to obtain honey (Garbutt 1999). The Kew Botanical Gardens in London and Britain's Royal Palm Society are researching the marketing of seeds from some native palm trees (Terry 1996).

International aid organizations could help preserve forests by donating fertilizer so the Malagasy would not need to practice slash-and-burn when forest soil ceases to produce crops. The urgent task of supplying the Malagasy people with methods of producing food and fuel in environmentally non-destructive ways has just begun. Villagers would be more likely to preserve trees now cut for firewood if they were provided with solar cookers or given propane tanks for fuel. Bio-gas, or methane, produced by animal dung and sewage, could be used to provide fuel and fertilizer. Such projects have been launched by international agencies in some countries of Central Asia.

Madagascar's human population is growing at a rate of 3.1 percent per year and reached 12,596,000 in 1992 (55 persons per square mile) (Anon. 1994). By 1995, it had grown to 13.9 million (61 persons per square mile) (McNeil 1996b). Another increase to 14,462,509 people (64 persons per square mile) was registered in the 1999 *World Almanac*. The *2001 New York Times Almanac* noted a population of 15,506,472, based on a July 2000 estimate. Thus, 3 million people were added to the population in just eight years. Along with the original Asians, more recent immigrants from Africa, India, Pakistan, China, Europe, and Arab countries add to the diversity. They have long since passed the carrying capacity of the land, and rice must be imported to feed the people. As one of the world's 12 poorest countries, Madagascar's external debt is approximately $4.25 billion. Average annual income is only $780 (NYT 2000). The unemployment rate is about 33 percent, and 51 percent of children are malnourished, according to a study by USAID (Tyson 2000). The literacy rate is 46 percent, and only 42 percent of children attend schools; 70 percent of children ages 6 to 9 have had no formal education (Tyson 2000). Jacques Cousteau's team filmed hordes of desperately poor people as they combed dumps for scraps of metal and food. Some people even live in these dumps in

holes they have dug in the soil. Such scenes are symptoms of extreme overpopulation and rampant poverty that can also be seen in parts of Brazil and Asia.

One of the reasons that illiteracy is so high in Madagascar is that millions of people must spend their days searching for food, water and firewood, requiring the help of their children, who are then unable to attend school. In general, foreign corporations have looted the island's resources, leaving no economic base that would help the people as a whole. One U.S. company, the Esso Corporation, is owed $25 million by the Madagascan government and demanded payment in spite of the country's cash reserves of less than $2 million (McNeil 1996b). Because of the country's debt levels, the World Bank and the International Monetary Fund are now in charge of its finances (McNeil 1996b), a potentially dangerous situation for both the people and the environment. On the positive side, a "Debt for Nature" swap was carried out in Madagascar, in which a portion of the foreign debt was exchanged for the establishment of nature reserves and parks.

To date, efforts to slow the population growth rate are still in their early stages. A program that addresses population growth, based not on threats or punishment, but on persuasion, was launched by Population Communications International (PCI) of New York City in 1996. As the organization has done in other countries, it trains local people to create communication programs for radio and television with a message that limiting family size is advantageous. The majority of the population on the island lives in cities and has access to these media. The programs, described as "soap operas" by PCI, create melodramas with characters the audience can identify with, who act out dramas. The characters in these dramas come to realize that different behavior, such as having fewer children, will result in positive changes in their lives (Ryerson 1994). In many cases, this involves elevating the status of women, and convincing men that women must be allowed to make decisions about their own reproduction (Ryerson 1994). PCI is cooperating with organizations that are actively trying to conserve the wildlife of Madagascar, such as Conservation International and the African Wildlife Foundation. Ranomafana National Park began a family planning center in 1994 to help the people of the region, many of whom have as many as 14 children, of which 62 percent are underweight and 17 percent malnourished, according to a study by the University of North Carolina (Tyson 2000).

Madagascar is a magnet for scientists from around the world and has been the recipient of millions of dollars in foreign aid and grants from international conservation agencies. Conservationists are initiating many highly inventive and effective programs to interest the Malagasy in conservation and employ them in biodiversity work. Environmental education is a key to the future of Madagascar, and programs are being carried out at Beza-Mahafaly Reserve. This protected portion of endangered spiny desert and shrubland was established when the local Mahafaly people agreed to donate the land, and funds were raised by Alison Richard, a Yale primatologist, for a training program for Malagasy scientists (Tyson 2000). Patricia Wright has set up a similar program in which Malagasy students complete master's theses based on wildlife research in Ranomafana National Park, and some students travel to the United States to receive advanced training in biodiversity and environmental protection (Tyson 2000). They will help guide the country in new directions in the future. It also opens new worlds to these students, who, in turn, will make young people aware of the natural treasures in their country. Schools that Patricia Wright has helped establish in the area of the park teach environmental education to young people. Others are also helping introduce this subject to children. Josephine Andrews, a Scottish scientist studying Black Lemurs in Nosy Be since 1988, teaches children about the lemurs with the help of a Malagasy named Julien, who guides people around the forest preserve (Tyson 2000). "If the kids are really into it, then the adults will switch on as well," she said (Tyson 1994). Forests are the key to the future survival of the island and its people, and an education program aimed at rural people, teaching the value of trees in preventing floods, landslides and in maintaining the flow of rivers and streams, could save countless trees.

Scientists--both Malagasy and foreign--working on the island, could share their findings by talking with local people about the uniqueness of Madagascar's natural world. Ornithologists with the Peregrine Fund, who rediscovered the Red Owl and taught local schoolchildren about the species donated money from bird-watchers to the school, provided such an example. Scientists typically conduct research and depart without having taught local people about their findings. Villagers near Ranomafana National Park were so interested in learning about research results that they asked Wright for copies of reports. She began a bimonthly newsletter, in the Malagasy language, describing the

natural history of the park (Tyson 2000).

Films and books about Madagascar's wildlife and plants tend to be distributed only in foreign countries, and never translated into Malagasy. Translations of books and subtitled films could be shown to schoolchildren to introduce them to Madagascar's tremendously interesting and beautiful natural world. It is ironic that Westerners may be more familiar with lemurs and chameleons that most Malagasy. Some projects for the future might include donation of solar collectors and windmills to supply power to rural people. This could elevate their standard of living and cut back on firewood collection for fuel. Donation of projection and video equipment to regional schools provided with electricity would help them appreciate their natural heritage through viewing nature films of Madagascan wildlife. Satellite dishes would facilitate communication with people around the world through the Internet.

The government of Madagascar developed a 20-year National Conservation Strategy and Environmental Action Plan as long ago as 1984. In 1986, a survey of protected areas began with the aim of implementing management plans for priority protected areas and recommending new protected areas, as well as training Malagasy people to work in reserve management and conservation biology. The government has been working to create a sense of pride and ownership in the nation's biodiversity through this program (Morell 1999). The President of Madagascar has stated that the environment is important, a key to whether foreign scientists and tourists will be able to come to the country and aid in its conservation in the future (Tyson 2000). The World Bank and various organizations funded this Environmental Action Plan with $168 million for its first five years (Tyson 2000). This has resulted in many biological studies, education of a growing number of Malagasy for conservation work and a Biodiversity Planning Centre (Sayer *et al.* 1992). The Geographical Information System database is a cornerstone of the government program, concentrating data from all fields to help establish conservation priorities (Tyson 2000). Conservation International has an office in the capital and is contributing to biological inventory data, as it has in other countries, as well as conducting research on particular species and data management. It coordinates its work with local organizations and trains Malagasy scientists (Sayer *et al.* 1992).

Ecotourism is another budding industry, and Madagascar is one of the few countries in the world to share park fees with local people. As a result of an initiative put forth by a Malagasy non-governmental organization, the National Association for the Management of Protected Areas, one-half of all fees are given to local people (Tyson 2000). Ninety-three villages in the Ranomafana National Park area received about $10,000 in a recent year from park fees; a committee designated by the villages decides how to spend the money. In 1995 they bought seeds and built campgrounds, a crafts training center and small dams (Tyson 2000). Many local people are employed as park workers, and the aim of the program is to turn over management of this park and its biodiversity work to the Malagasy people. There needs to be a national park system with strict rules for management and protection, according to Patricia Wright, who deplored the illegal tree cutting by the previous park director at Ranomafana (Tyson 2000). She also has proposed that a national biodiversity institute be built, which would offer centralized training in biology and technology, as well as five new long-term biodiversity research stations similar to those in La Selva National Park in Costa Rica and the Smithsonian Institution's Panama tropical research laboratory (Tyson 2000).

Jobs, which are desperately needed by the Malagasy, are increasing as a result of the rise in the number of tourists. Selling crafts to tourists, running hotels and restaurants, and serving as guides are among these. Villagers who used to demand that parks be declassified so that they could legally gather wood, now request that more national parks be established, an apparent result of the new income that comes from fees and tourism (Morell 1999). International tourists have provided a major new source of revenue in Madagascar's economy and are helping the Malagasy see their wildlife in a new way, as so fascinating and biologically important that visitors come from every continent to view it. *Madagascar. The Bradt Travel Guide*, by Hilary Bradt (1999), published in various editions since 1988, is a useful aid for tourists, providing information about accommodations, natural history, protected areas, and the Malagasy and their history. Nature reserves and parks provide jobs by attracting scientists who employ local people, another incentive for the Malagasy to urge that more protected areas be set aside.

Compensation for lost access to forests has not been paid in the past, and new arrangements reached with villagers to

allow some extraction of resources from the forests may heal some of these wounds and placate those who still wish to cut trees. Medicinal plants obtained from Madagascar may be another source of revenue in the future. The Rosy Periwinkle may be only one of many native plants highly valuable in treating disease. Research on the potential of other plants may uncover other such treasures. In the past, revenues from plants used for medicine have not been returned in part to the country of origin, but recently a new trend has begun. In one case, a pharmaceutical company agreed to pay people in a South American country a portion of the revenues gained from any native plant providing a marketable drug.

Another potential source of revenue is the placement of videocameras connected to the Internet, which present websites with general information as well as live camera views of wildlife. South African parks have a number of these videocameras placed at water holes, animal dens and other key areas that capture live views of animals transmitted to the Internet for a small viewing fee. This has proven very successful, funding many of the South African National Parks system s expenses. A similar system could be established in Madagascar with solar-powered videocameras, which have already been in use in Alaska, trained on tree canopies, rainforest flowers or lemurs, along with websites that provide basic information on Madagascar's environment, biodiversity and the Malagasy people. For millions of people who cannot visit Madagascar, such a website might be fascinating as a learning tool for teachers and the public, as well as an exciting view of these unique animals and their environments. If managed in such a way that profits were shared between poor Malagasy to alleviate their poverty, and conservation organizations to preserve biodiversity, such a system has great potential.

A satellite connection with classrooms in the United States or other countries would be another opportunity for interactive communication and learning. In December 2000, for example, students in an American classroom talked with students in a school in Guyana about endangered Giant Otters and their conservation through a visual satellite hookup. Students and others might set up an interactive link with biologists and conservationists working in Madagascar, asking questions and offering help. Students have provided many excellent ideas for conservation, and classes have raised money to save rainforests and threatened wildlife habitat and to help stop poaching of endangered species in countries half a world away from their own. Malagasy young people might be inspired and enthusiastic through talking with others of their own age about conservation and biodiversity. Video cameras and still cameras might be donated to Malagasy students and young people to record nature and compete for prizes with their results.

Madagascar s Lessons

Madagascar's story is one of ecological catastrophe and the gradual extermination of its life forms. One's first response might be that its experience is as far from the rest of the world as it is geographically remote. However, it is from the extremes that one acquires basic knowledge. The effects of immigrants, whether human, animal, plant or disease, can devastate natural ecosystems wherever they occur. Islands are especially vulnerable to the effects of invasive species, including humans, because their flora and fauna have limited habitats and tend to be endemic, with small populations.

Exotic or non-indigenous species threaten 350 species of birds, or 30 percent of all threatened birds listed by BirdLife International in *Threatened Birds of the World* (BI 2000). Likewise, 361 plant species and 69 species of mammals listed by the *2000 IUCN Red List of Threatened Species* are threatened as a result of non-indigenous species (Hilton-Taylor 2000). The effects of invasive species, including humans, have been the major cause of extinction of virtually all bird species, almost all of which have occurred on islands. In the case of Madagascar, the Malagasy and other immigrant peoples and their livestock, and their subsequent hunting and habitat destruction, presented the vulnerable native species with threats against which they had no defense. Islands throughout the world continue to suffer losses in biodiversity, as do areas with large numbers of endemic species in mainland areas. Species with restricted ranges are the most likely to go extinct or become endangered. Such species dominate the list of birds in

Threatened Birds of the World (BI 2000). In this age of international commerce, where plant diseases and other viruses are brought into countries in shiploads of lumber or ballast water, and exotic animals and plants continue to colonize and be released in delicate ecosystems with endemic species, whether on islands or mainlands, it has become extremely difficult to defend native species from such invasions. Nevertheless, through preserving native plants and animals and legislating against such introductions, while removing non-native species, ecosystems and their diversity can be protected. Preserving natural ecosystems is vitally important, not just for wildlife preservation, but for humans as well, so that precious water supplies, topsoils and biological diversity, which stabilize all ecosystems, are protected. These lessons have not yet been put into practice in Madagascar or in many other parts of the world, including developed countries. Ecological and faunal changes may be so gradual that they go unnoticed until ecosystems have been destroyed.

Madagascar Testing Quotes

About 500 A.D., immigrant people from Asia, most probably Indonesia or Malaysia, arrived on Madagascar's shores in hand-hewn canoes, bringing domestic animals with them. They began clearing forests and burning them for farmland, and turned lakes and wetlands into rice paddies. Cleared land produced crops for only a few years until the thin soil became sterile. Farmers then moved on to other parts of the forest, in this slash-and-burn agriculture. At some point, African herdsmen colonized the island, bringing zebu cattle, which crowded out wildlife (Tyson 2000). Gradually, abuse of the land eroded the soil in the central highlands to bare earth, pocketed and gouged by deep gullies and cavernous holes. This region had harbored a great variety of lemurs, along with a wealth of birds, reptiles and unique plants. Throughout the island, wildlife declined as habitats disappeared, isolating animals in smaller and smaller patches of forest and wetlands. The large lemurs, tortoises and elephant birds were avidly hunted.

Within 600 years of the arrival of the Malagasy, extinctions claimed many native animals. Several elephant bird species, the larger lemurs and many native plants vanished. Two kinds of pygmy hippos inhabited the island. The Madagascar Hippopotamuses (*Hippopotamus lemerlei*), an amphibious species, and *Hippopotamus madagascariensis*, a forest species, were both about 6.5 feet long and 2.5 feet tall, smaller than the Common Hippopotamus of Africa, which is about 10 feet long (Tyson 2000). From genetic and anatomical analysis, both seem to have evolved from the latter species (Tyson 2000). The hippos had been widely distributed and very common prior to the arrival of the Malagasy (Dewar 1984). Their bones have been found with marks indicating that they had been butchered (Tyson 2000). Both died out long before Europeans arrived. The native crocodile, whose large bones have been found, is believed by some scientists to represent large specimens of Nile Crocodiles, the species native today (Tyson 2000). It is thus possible that the crocodile survived. A large mongoose-like viverrid, *Cryptoprocta spelea*, and a very unusual aardvark-like animal, *Plesiorycteropus madagascariensis*, died out at an early date (Dewar 1984).

Prior to the arrival of humans, elephant birds had been abundant in most parts of the island, as attested by the prevalence of their bones. There were two genera, and from six to 12 species of these birds (Tyson 2000). It is likely that the flightless birds fell prey to the primitive weapons of the Malagasy and were crowded out of their habitats by livestock (Tyson 2000). The last to die out was the Great Elephant Bird (*Aepyornis maximus*), which may have survived until recent times by retreating to remote swamps. Dr. Alexander Wetmore of the Smithsonian Institution examined bones of a Great Elephant Bird unearthed in archeological excavations in the 1960s. He was amazed by their size: "The incredible femur, or thighbone, of this ponderous bird is by far the largest I have ever seen" (Wetmore 1967). Estimated to weigh at least 1,000 pounds, more than three times the weight of an Ostrich, it produced eggs larger than any dinosaur's, with a capacity of 2 gallons (equivalent to seven Ostrich eggs), 180 chicken eggs or 12,000 hummingbird eggs (Bradbury 1919, Fuller 1987). When one was X rayed, the bones of an embryo three fourths developed were revealed (Wetmore 1967). Something had interrupted the embryo's growth and frozen it within the eggshell for hundreds and perhaps thousands of years (Wetmore 1967).

Despite its fearsome size, the Great Elephant Bird lacked a hooked beak for tearing prey and was plainly not a predator (Wetmore 1967). Its large, clawed feet may have helped it defend itself against the small native predators but were not enough to protect it from Malagasy arrows. Its short legs prevented it from running as fast as its relative, the Ostrich, but it may have been quite agile when chased. This vegetarian bird browsed and cropped plants, able to reach with its long neck to the lower branches of trees (Wetmore 1967). By the mid-16th century, when Europeans had managed to establish a foothold in Madagascar, the new French Governor, Sieur Etienne de Flacourt, wrote in 1661 that the Great Elephant Bird was still found in the south of the island, "seeking the most deserted places" to avoid human hunters (Tyson 2000). Villagers of Antandroy told of an Ostrich-like bird that was difficult to catch, according to Flacourt (Tyson 2000).

The exact date this giant bird became extinct is not known with certainty. Alan Feduccia (1996), an eminent paleo-ornithologist, asserts that elephant birds of many species were still widespread in the 10th century but gradually disappeared as a result of human activity. He cites an account by a French merchant sailor in 1848, who visited Madagascar and saw the shell of the Great Elephant Bird; he was told that it belonged to the chief and that the bird that produced such eggs "is still more rarely seen" (Feduccia 1996). Some authorities estimate that it died out in the mid-17th century, although there is no proof that any European ever saw one of these birds (Tyson 2000). It has been suggested that Europeans were responsible for the bird s extinction by hunting and destroying its habitat (Quammen 1996). But Thomas Brooks (2000) of the Center for Applied Biodiversity Science, Conservation International, asserted in a list of extinct birds in *Threatened Birds of the World* (BI 2000) that all the elephant birds had disappeared by 1500. In a bizarre footnote to this species' epitaph, an *Aepyornis* egg washed up on Australia's western coast in 1995. No conclusive explanation for this strange event has been put forth, although it is likely that it became unearthed from long interment by rains, and washed out to sea. Much less is known of the other species of elephant birds, which existed in a variety of sizes down to a chicken-sized species.

Lemur-like primates once lived on many continents, but nowhere had they evolved into such a great variety of species. When the Malagasy people arrived some 1,500 years ago, lemurs occupied every habitat, even marshland. A species as tall as a man must have startled the Malagasy immigrants, giving rise to legends that these animals had superhuman powers. The first French naturalists were told by the Malagasy that these primates were thought to be the ghosts of sacred ancestors of man, inspiring the genus name Lemur, the word for ghost in Latin. The Malagasy considered some lemurs sacred and punished anyone who harmed them, but most species were feared as evil demons and were killed on sight.

From their arrival on Madagascar, the Malagasy hunted the larger species of lemurs, almost all of which are now extinct. Archaeological excavations show that they formed a staple in the immigrants' diets. Such diggings have unearthed the skulls and bones of long extinct lemurs in early Malagasy jars and kitchen middens; their heads had been split by ax-heads made from an extinct flightless bird (Jolly 1980).

In the centuries following colonization by the Malagasy immigrants, some 15 species of lemurs of eight genera became extinct (Mittermeier 1997). These extinct lemurs were, for the most part, far larger than surviving species and had evolved to fill many ecological niches. Three *Megaladapis* lemurs weighed between 90 and 170 pounds and moved slowly through the trees, feeding on foliage (Tattersall 1993). Another species, *Archaeolemur*, was about the size of a female baboon and lived on the ground (Tattersall 1993). Two *Palaeopropithecus* species weighed between 90 and 130 pounds and were sloth like tree dwellers with flexible bodies (Tattersall 1993). These extinct lemurs had evolved many unusual means of movement and locomotion that have no parallels in living species of lemurs.

Largest of all, the massive 400 pound *Archaeoindris* was apparently a ground dweller, moving on all fours; many of its anatomical characteristics are unlike any living primate (Tattersall 1993). One entire lemur family, Archaeolemuridae, was obliterated. In this family were many species of lemurs weighing between 35 and 55 pounds; they were powerfully built and short legged (Tattersall 1993). The heaviest lemur surviving today, the Indri (*Indri indri*), weighs only about 15 pounds (Tattersall 1993). These lemurs had survived for millions of years, and their extinctions were indeed a major biological loss to the planet. According to primatologists, the surviving lemurs

resemble the very earliest primates from the Eocene (Tattersall 1993). Like prosimians in Africa and Asia, but to a far greater degree, lemurs have a highly developed sense of smell. Some species have long, fox-like noses (Preston-Mafham 1991). Genetic analysis of their DNA has revealed that all lemurs are descended from a single ancestor that probably arrived from Africa about 60 million years ago (Garbutt 1999).

The Giant Aye-aye (*Daubentonia robusta*) lemur was somewhat larger and 2.5 to 5 times heavier than the surviving Aye-aye (see below), but in other respects was very similar (Garbutt 1999). It is known from subfossil remains found in southwestern Madagascar (Nowak 1999). The date of its disappearance is unknown but may be fairly recent.

Archaeologists have uncovered remains of a massive bird of prey, the Malagasy Crowned Eagle (*Stephanoaetus mahery*), which undoubtedly preyed on lemurs (Feduccia 1996). In fact, at one locality the diet of this eagle, based on the bones of eagles and lemurs found together, contained at least 80 percent primates, including specimens weighing up to 26.5 pounds (Feduccia 1996). Remains of another large eagle of the genus *Aquila* have been discovered, and it, too, preyed on large lemurs and became extinct after the arrival of the Malagasy. These extinct birds preyed on smaller lemurs as well, including some species still surviving (Feduccia 1996). A bird of prey flying overhead still elicits fear in lemurs, causing them to seek cover. Neither of the two remaining species of eagles on Madagascar preys on lemurs, but two hawk species have been seen preying on young lemurs (Garbutt 1999).

In addition to the Giant Elephant Bird, the large Snail-eating Coua (*Coua delalandei*), a member of the cuckoo family, became extinct. The last specimen of this large, slate-blue bird was taken on an islet off the east coast, Ile Sainte-Marie, in 1834 (Morris and Hawkins 1998); reports by observers who claimed to have seen the bird were recorded as late as 1930 (Fuller 1987). The causes of this bird's disappearance, and even its exact range, remain obscure (Langrand 1990). Many specimens of this bird were taken before its extinction and kept in museums in Leiden; London; New York; Paris; Philadelphia; Tananarive (Madagascar); and Cambridge (Massachusetts) (Fuller 1987). The long feathers of this bird were highly valued by the Malagasy, and hunting may have reduced its numbers to a critically low level (Fuller 1987). It is also possible that the many birds killed for zoological specimens may have pushed this already rare bird to extinction, since its distribution may have been limited to the tiny Ile Sainte-Marie. No reliable record exists of its presence on the main island of Madagascar, but there is hope that it might be found in lowland forest near the Bay of Antongil (Morris and Hawkins 1998). Ten closely related species of couas survive, all smaller than the Snail-eating Coua.

Madagascar Testing Quotes 2
Testing "quotes again" to see whether they are "going" to have 'slashes' added to them or not.