The Tortoises and Freshwater Turtles of Madagascar in the Context of Biodiversity Conservation in the Madagascar Hotspot

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ABSTRACT. – Madagascar is a Megadiversity country as well as the core of the Madagascar and Indian Ocean Islands Biodiversity Hotspot, with exceptionally high numbers and percentages of endemic species and higher taxa of plants and animals. Much of Madagascar’s biodiversity is severely threatened, with less than 60,000 sq. km, or 10% of the total land surface, retaining natural vegetation. Developing a comprehensive system of protected areas accelerated from 2003, but went into reverse since political turmoil erupted in 2009. The tortoise and freshwater turtle fauna of Madagascar comprises 9 species (one with 3 subspecies) in 6 genera; of these, 3 genera, 5 species, and 8 terminal taxa are endemic to the country. All 5 endemic species are rated as Critically Endangered in the IUCN Red List, primarily as a result of targeted exploitation for human consumption and international pet trade, as well as habitat loss. Two species of Aldabrachelys tortoises have gone extinct since humans settled Madagascar. Preventing further extinctions of Madagascar’s unique tortoises and turtles will require urgent and coordinated conservation action focused on species, ecosystems, and socio-economic development.

KEY WORDS. – Reptilia, Testudines, Madagascar, conservation, endemism, biodiversity hotspots

Biodiversity is the wealth of genes, species, ecosystems, and ecological processes that make our living planet what it is. It can also be described as the sum total of all life on Earth, our living legacy to future generations, and the basic underpinning of sustainable development. To many of us, biodiversity warrants conservation for its intrinsic values, or for a moral imperative, or for its aesthetic, cultural, or scientific value. In addition, there is the clear economic value, as demonstrated by biotechnology, biomimetics, agriculture, and recreation and ecotourism. And finally, the values of ecosystem services are beginning to be understood, including forests and watersheds as supply systems for healthy drinking water and other resources, as disaster prevention or impact reduction services (e.g., fires, landslides, floods, tsunamis), and the key role forests and other natural systems play in climate change buffering, making the case for avoiding deforestation. Notably, there is a high spatial correspondence between areas of highest priority for biodiversity conservation, and areas with high ecosystem service values for humanity.

Biodiversity is under a multitude of threats worldwide, including deforestation for agriculture, timber, fuelwood extraction, human-initiated forest fires, dams, reservoirs and water diversion projects, mining and effluent runoff, urban sprawl, roads and other major infrastructure development, pollution from sewage, agro-chemical runoff, and oil spill, the spread of invasive species, and targeted exploitation of wildlife species for food, medicine, pets, and other purposes, and the side effects of such exploitation on other species through by-catch. Hovering over all of these threats is the specter of human-induced climate changes, the impacts of which are still difficult to measure, but which are already affecting the distributions and survival prospects of many species from tropical mountains to the polar ice-caps, with effects ranging from average temperature change to habitat aridification and desertification and the prevalence of extreme weather events.

Species loss is irreversible. Once a species goes extinct, it is gone forever and will never be seen again, unless at some future date we are successful in cloning at least those species that have disappeared in the recent past, and even then their ecological roles will be exceptionally difficult to restore. We face an impending extinction crisis, potentially one of the largest extinction episodes in our planet’s history, and many of us consider this to be the most critical phenomenon of our time.

Conservation Strategies

How do we best preserve the wealth of biodiversity for future generations? Conservation actions need to be continued and scaled up: understand the basic taxonomy of species, assess their conservation status (recorded in the IUCN Red List), determine priorities, develop strategies and action plans, get the word out (through both professional and popular channels), and raise the funds needed to get the job done. A basic premise of conservation is that all biodiversity is important, and that all nations should do everything possible
to conserve their living resources. However, biodiversity is by no means evenly distributed over the face of the planet; rather, it is heavily concentrated in a relatively small total area, a large proportion of which has already been heavily impacted by human activities.

Clear strategic priorities, based on the best available science, facilitate fundraising and attract donors. At Conservation International, we have prioritized Megadiversity Countries, Biodiversity Hotspots, and High Biodiversity Wilderness Areas for targeted conservation strategies. The Megadiversity Country concept was first developed by Mittermeier (1988) and elaborated in Mittermeier et al. (1997). It recognizes that of the nearly 200 countries on our planet, 18 of these, the biologically wealthiest nations, collectively contain over two-thirds of all known terrestrial, freshwater, and marine species.

The second category, and the most influential over the past 20 years, is that of Biodiversity Hotspots, which prioritizes areas with high irreplaceability (as measured by endemic species, especially plants) and high threat (as measured by remaining natural vegetation). First formulated by Myers (1988, 1990), and then expanded and refined several times by Conservation International (Mittermeier et al. 1999, 2004; Myers et al. 2000; Williams et al. 2011), the latest analysis now documents 35 Hotspots globally (Fig. 1). The original extent of the 35 hotspots comprises 23,747,300 km², or 15.9% of earth’s land surface; of this, over 85% has lost its natural vegetation cover and associated biodiversity. The result is that what remains in the 35 Hotspots is now no more than 3,438,146 km², or 2.3% of Earth’s land surface. Over half the world’s total species of plants (over 150,000 of about 300,000 species) are endemic to the Hotspots, and occur nowhere else. In addition, more than 12,220 (or > 42%) of all known tetrapod vertebrates are endemic to Hotspots. What is more, a major portion of all Threatened species (i.e., IUCN Red List Critically Endangered, Endangered, or Vulnerable) occur in the hotspots, including 82% of all Threatened mammal species, 83% of Threatened birds, and 90% of Threatened amphibians.

However, the Hotspots are more than tropical rain forests and concentrations of species richness; they also host concentrations of higher levels of diversity, such as families and genera, many of these endemic and representing deep lineages and evolutionary histories found nowhere else. Moreover, Hotspots largely coincide with the Vavilov centers of origin and diversity of cultivated plants, and Hotspots and High Biodiversity Wilderness Areas combined host 73.7% of all human languages spoken worldwide, again including some of the most threatened languages spoken by rapidly disappearing human cultures (Gorenflo et al. 2012) (Fig. 2).

The third concept, High Biodiversity Wilderness Areas, another first developed by Mittermeier (1988) and originally referred to as Major Tropical Wilderness Areas, are those places that host high biodiversity, yet still remain largely intact (Mittermeier et al. 2002). Collectively, Hotspots and High Biodiversity Wilderness Areas contain the vast majority of terrestrial and freshwater species and ecosystems, and represent the top priorities in terrestrial biodiversity conservation. If conservation fails in these areas, especially the Hotspots, we will lose a major portion of the world’s terrestrial biodiversity, regardless of how successful we are in other areas.
Given their high-priority biodiversity status and great importance for human well-being and cultural values, hotspots remain one of the most effective tools for conservation fund-raising, including dedicated mechanisms like the Critical Ecosystem Partnership Fund (CEPF), which continues to provide significant support to civil society organizations in Hotspots (www.cepf.net), and the Global Conservation Fund (GCF) which focuses on creating new parks and reserves in Hotspots and Wilderness Areas.

On the ground, the process of identifying a Key Biodiversity Area (KBA; Langhammer et al. 2007) focuses on specific areas for conservation within Hotspots and Wilderness Areas, with the most critical areas represented by the Alliance for Zero Extinction (AZE) sites, single sites representing the only remaining areas of occurrence of Critically Endangered and Endangered species whose loss will result in the extinction of those species (www.zeroextinction.org).

Madagascar – Possibly the World’s Highest Priority Biodiversity Hotspot

Madagascar is both a Megadiversity Country and a Biodiversity Hotspot. This island-continent, located off the east coast of Africa in the Indian Ocean, covers about 587,041 km² and has just over 20 million inhabitants (2009 estimate). Its remarkable and distinct vegetation zones contain about 14,000–15,000 plant species, with over 80% of these endemic. Of 363 reptile species, 92% are endemic; 260 bird species occur, of which about 140 species and an amazing 5 families are endemic. A special place is taken by the lemurs, a major primate branch that includes 5 families, 15 genera, and at least 101 species, every one of them endemic to Madagascar (Mittermeier et al. 2010).

With 25 endemic families across plants and vertebrates, Madagascar exceeds the next three Hotspots with endemic families combined (New Zealand, New Caledonia, and Chilean Winter Rainfall / Valdivian Forests Hotspots, each with 7 endemic families). Madagascar’s total number of endemic genera, 478, nearly matches that of the next two Hotspots combined (the Caribbean, 269 and the Atlantic Forest, 210). In addition, new species continue to be discovered in Madagascar, ranging from more than doubling the number of lemur species between 1994 to 2010, to new palm species being discovered and censused using Google Earth, to several new lizards being described annually, to an estimated 119–221 new species of frogs still to be described (Vieites et al. 2009).

Madagascar’s environment has arguably suffered greater degradation than any other comparable area. Slash-and-burn agriculture is widespread, and its undulating landscape and delicate soils have suffered some of the most devastating erosion on Earth, with the resulting runoff in turn choking riverine and coastal ecosystems. Well over 90% of Madagascar’s natural vegetation is already lost, and the total area of remaining natural habitat is estimated at between 50,000 and 60,000 km². Hunting since first human settlement, some 2500–2300 years ago, has extirpated the entire radiation of giant elephant birds (at least eight species in two genera), at least two hippopotamus species, and at least three families, eight genera, and 17 species of giant lemurs, all of them larger than the surviving species (Mittermeier et al. 2010). What is more, many of the currently surviving species are under significant threat from continuing subsistence consumption hunting and trade, as well as massive habitat destruction. When one considers all these factors, Madagascar can be considered the world’s highest priority biodiversity hotspot.

Needed conservation actions applicable to the Madagascar situation include developing and supporting Protected Areas, supporting and facilitating the establishment of green economies including PES (Payment for Ecosystem Services) and REDD+ (Reducing Emissions from Deforestation and Forest Degradation Plus Forest Management and Biodiversity Conservation; www.unredd.org), and initiatives linking ecotourism and local communities.

In sensitive environments like Madagascar’s, the critical importance of Protected Areas cannot be overstated. This received a tremendous boost with the Durban Vision, launched at the World Parks Congress in September 2003, when Madagascar’s then new President Marc Ravalomanana committed to tripling protected area coverage over the next five years. Further to this, at the United Nations General Assembly in New York in September 2005, he committed 8% of debt relief granted by the developed countries to the developing world to Protected Areas, the only head-of-state to do so. An additional boost came when the CEO of DreamWorks, Jeffrey Katzenberg, creator of the film “Madagascar”, committed $500,000 to ecotourism development after a visit to the country in December

Figure 2. Map of the Madagascar and Indian Ocean Islands Hotspot.
2004. At the time of the Durban announcement, President Ravalomanana requested a $50 million trust fund to help implement and maintain this ambitious new program, which was achieved by March 2008, including the first million deposited from CI’s Global Conservation Fund (Fig. 3).

By August 2010, major progress had been made towards achieving the Durban Vision: the existing 47 Protected Areas managed by Madagascar National Parks / ANGAP (IUCN categories I, II, and IV) cover 1.7 million ha, extensions to these parks cover 505,488 ha, creation of 40 new Protected Areas covering 1,168,419 ha is in progress, and 29 new Protected Areas (mostly in IUCN categories V and VI) covering 2,997,145 ha have provisional status. Together these would protect over 6.3 million ha, roughly equal to the area of remaining natural habitat.

The prospects for Green Economies in Madagascar are also positive. Protected Areas serve as the anchors in larger corridors, where PES and REDD+ can generate income from local and international sources. Of particular interest is ‘greening’ of the mining sector, where initial steps have been made by Rio Tinto and others to reforest mined areas. Ecotourism was the second highest foreign exchange earner in 2008, at $430 million, and is nowhere near its full potential. Ecotourism has clear benefits to communities and linkages to biodiversity, and generates opportunities for educational initiatives and private enterprise, through Guide Associations, Community Protected Areas, and village entrepreneurs; hundreds of new sites could be developed at very low cost.

However, events took a turn for the worse in early 2009, when president Ravalomanana was driven from office by Andry Rajoelina, the Mayor of Antananarivo, who established a caretaker government that until now is not internationally recognized. With the breakdown of the democratically-elected government, protected areas were invaded by loggers and poachers almost immediately, and natural treasures ranging from rosewood and palissandre (*Dalbergia* spp.) to tortoises and frogs started hemorrhaging out of the country onto the world’s black markets.

Despite its international pariah status, or exactly because of it, there has never been a more critical time for a truly global commitment to conserving Madagascar’s biodiversity as a Global Good. There are no final victories in biodiversity conservation, but at any given time we must collectively prevent the extinction of species and degra-

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**Figure 3.** Map of existing and proposed protected areas of Madagascar.

**Table 1.** Numbers of tortoises and freshwater turtles in selected Megadiversity Countries, Biodiversity Hotspots (HS), and High Biodiversity Wilderness Areas (HBWA); excludes recently extinct taxa. Data current as of TTWG (2012).

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<th>Region</th>
<th>Total Species</th>
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<th>Number of Endemic Species</th>
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Turtles and Tortoises in Madagascar

Turtles trace their ancestry back to the late Triassic, over 200 million years ago. At 14 living families, about 94 genera, 322 surviving species, and 441 terminal taxa (TTWG 2012), turtles are a modestly speciose group. To conserve total biodiversity, the basic Unit of Conservation should at least be the lowest named taxonomic unit (i.e., subspecies), and conservation of identified Evolutionarily Significant Units (ESU’s) and Management Units (MU’s) is arguably as important. Different species concepts and differing interpretations by individual turtle taxonomists mean that turtle taxonomy remains dynamic, but the general outlines are well understood and effectively summarized by the an-

Figure 4. Numbers of species and terminal taxa (in brackets) of tortoises and freshwater turtles in the Megadiversity Countries (labeled in black letters) and countries with high turtle diversity (labeled in blue). National counts include species and taxa listed as unconfirmed or extinct in TTTWG 2010.

Figure 5. Numbers of endemic species and terminal taxa of tortoises and freshwater turtles in Megadiversity Countries (black labels) and other countries (blue labels) with at least three endemic turtle taxa. Species and taxa were designated as endemic to a country in the absence of confirmed occurrence in another country. Extinct taxa are excluded from counts.

The IUCN Red List of Threatened Species™ (www.iucnredlist.org) is the global standard to assess the threat status of any species. Not all turtle species have been fully assessed for the Red List yet, but an analysis of completed assessments and those in progress indicate that between 47% and 53% of all turtles are Threatened with extinction (TTWG 2012). This is a higher percentage than almost any other major animal group, more than birds (ca. 13%), mammals (ca. 21–25%), cartilaginous fishes (ca. 17–31%), or amphibians (ca. 30–41%), and paralleled among the larger vertebrate groups only by the primates (ca. 48%) (Hoffmann et al. 2010).

Madagascar has a relatively modest turtle fauna, with a total of 9 species and 11 taxa of tortoises and freshwater turtles, and 5 marine turtle species. On a global scale, for an area this large, this is not particularly rich or diverse, and Madagascar does not rank among the top turtle-rich countries by any criterion (except for a joint 25th place in the list of all terminal taxa of marine, freshwater and terrestrial turtles) (TTWG 2012) (Table 1; Fig. 4).

But the simple number of 9 tortoise and freshwater turtle species (one with 3 subspecies) belies a remarkable evolutionary history: three genera, Astrochelys (with two species, A. radiata and A. yniphora), Pyxis (with one species, P. arachnoides, and three subspecies, P. a. arachnoides, P. a. oblonga, and P. a. brygoi), and Erymnochelys (with one species, E. madagascariensis), are endemic (Fig. 7), with Erymnochelys being considered by some taxonomists as the sole surviving species of an illustrious subfamily, the Erymnochelyinae. Only a single country exceeds three endemic turtle genera (Australia, with four endemic genera), and no country matches it, making Madagascar runner-up in this category. With five species and eight terminal taxa endemic, Madagascar takes a respectable joint 9th place in the global league for endemic turtle species, and joint 6th place when comparing endemic terminal taxa (Table 1; Figs. 5, 6).

Moreover, until rather recently in prehistoric times, Madagascar was home to at least two species of endemic giant tortoises, Aldabrachelys grandidieri and A. abrupta, which both went extinct some 750–1050 years ago (Gerrlach 2004). Regarding the other non-marine turtle species, Kinixys zombensis domerguei, traditionally considered a subspecies of K. belliana, may be a human introduction of the widespread Eastern African hingeback tortoise species, and may thus be of debatable taxonomic validity, while the three pelomedusid taxa (Pelomedusa subrufa, Pelusios subniger, and Pelusios castanoides) are not considered taxonomically distinct from the African populations of their species, and in the case of Pelomedusa and P. subniger they have been hypothesized to be recent arrivals in Madagascar, either by human transport or natural dispersal (Vargas-Ramirez et al. 2010; Wong et al. 2010).

Madagascar has another stunning statistic: all five (100%) of its endemic turtle and tortoise species in its three endemic genera have recently (2008) been assessed as Critically Endangered on the IUCN Red List (van Dijk et al. 2013, this volume). This represents 56% of its total tortoise and freshwater turtle species, and 73% of its terminal taxa of tortoises and freshwater turtles. Only China has a comparable number of Critically Endangered endemic species, but has no endemic genera nor a 100% Critically Endangered rate for its endemic species. A similar picture emerges when comparing the turtles of Madagascar against those of other Megadiversity Countries or Biodiversity Hotspots: the actual numbers and proportions of threatened turtles of
the IndoBurma, Sundaland, and the Himalayan Foothills Hotspots are comparable to those of Madagascar.

Madagascar’s endemic tortoises and freshwater turtles are on some of the steepest decline trajectories, and populations of at least the Angonoka (A. yniphora) are among the smallest of any chelonian worldwide; consequently, this species, as well as E. madagascariensis, is currently included on the list of Top 25 turtles and tortoises worldwide most severely threatened with extinction (Turtle Conservation Coalition 2011). The need for immediate action to address crisis issues is immense, as is the need to implement the Vision Sokatra Gasy, a strategic, coordinated and sustainable long-term approach to conserving Madagascar’s unique turtles (Mittermeier et al. 2008, reprinted in this volume). We need to remain optimistic and keep working. There is only a small window of time in which to act, but it can be done.

RESUMÉ

Madagascar est autant un pays de Mégadiversité que le cœur du Hotspot de Biodiversité Madagascar et Îles de l’Océan Indien, avec des nombres et pourcentages exceptionnels d’espèces et taxons supérieurs endémiques de plantes et d’animaux. La majorité de la biodiversité de Madagascar est sévèrement menacée, avec la végétation naturelle présente sur moins de 60,000 km², soit 10% de la surface totale des terres. Le développement d’un vaste système d’aires protégées a été accéléré depuis 2003, mais a régressé suite aux agitations politiques apparues en 2009. La faune de tortues terrestres et eau douce de Madagascar compte 9 espèces (une avec 3 sous-espèces) comprises dans 6 genres, parmi lesquelles 3 genres, 5 espèces et 8 taxons terminaux sont endémiques au pays, Toutes les 5 espèces endémiques sont classées Gravement Menacées dans la Liste Rouge de l’UICN, à la suite surtout d’une exploitation ciblée pour la consommation humaine et pour le commerce d’animaux exotiques, ainsi que de la perte de leur habitat. Deux espèces de tortues Aldabrachelys se sont éteintes depuis l’arrivée des hommes à Madagascar. Afin d’empêcher d’autres extinctions de tortues uniques de Madagascar, des actions de conservation urgentes et coordonnées, concentrées sur les espèces, les écosystèmes et le développement socio-économique s’imposent.

LITERATURE CITED


