Global Biodiversity Conservation: The Critical Role of Hotspots

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Chapter 1
Global Biodiversity Conservation: The Critical Role of Hotspots

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Abstract Global changes, from habitat loss and invasive species to anthropogenic climate change, have initiated the sixth great mass extinction event in Earth's history. As species become threatened and vanish, so too do the broader ecosystems and myriad benefits to human well-being that depend upon biodiversity. Bringing an end to global biodiversity loss requires that limited available resources be guided to those regions that need it most. The biodiversity hotspots do this based on the conservation planning principles of irreplaceability and vulnerability. Here, we review the development of the hotspots over the past two decades and present an analysis of their biodiversity, updated to the current set of 35 regions. We then discuss past and future efforts needed to conserve them, sustaining their fundamental role both as the home of a substantial fraction of global biodiversity and as the ultimate source of many ecosystem services upon which humanity depends.

1.1 Introduction

Earth's biodiversity is in trouble. The combination of unsustainable consumption in developed countries and persistent poverty in developing nations is destroying the natural world. Wild lands continue to suffer widespread incursions from

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agricultural expansion, urbanization, and industrial development, overexploitation threatens the viability of wild populations, invasive species wreak havoc on ecosystems, chemical pollution alters biochemical processes in the soil, air, and water, and rapidly spreading diseases jeopardize entire branches of the tree of life (Millennium Ecosystem Assessment 2005; Vitousek et al. 1997; Wake and Vredenburg 2008). As these threats continue unabated, the impacts of climate change multiply. Changing precipitation and temperature, rising and acidifying oceans, and climate-driven habitat loss will disrupt ecological processes, test species' physiological tolerances, turn forests to deserts, and drive desperate human populations toward further environmental degradation (Turner et al. 2010).

Extinction is the gravest consequence of the biodiversity crisis, since it is irreversible. Human activities have elevated the rate of species extinctions to a thousand or more times the natural background rate (Pimm et al. 1995). What are the consequences of this loss? Most obvious among them may be the lost opportunity for future resource use. Scientists have discovered a mere fraction of Earth's species (perhaps fewer than 10%, or even 1%) and understood the biology of even fewer (Novotny et al. 2002). As species vanish, so too does the health security of every human. Earth's species are a vast genetic storehouse that may harbor a cure for cancer, malaria, or the next new pathogen – cures waiting to be discovered. Compounds initially derived from wild species account for more than half of all commercial medicines – even more in developing nations (Chivian and Bernstein 2008). Natural forms, processes, and ecosystems provide blueprints and inspiration for a growing array of new materials, energy sources, hi-tech devices, and other innovations (Benyus 2009). The current loss of species has been compared to burning down the world's libraries without knowing the content of 90% or more of the books. With loss of species, we lose the ultimate source of our crops and the genes we use to improve agricultural resilience, the inspiration for manufactured products, and the basis of the structure and function of the ecosystems that support humans and all life on Earth (McNeely et al. 2009). Above and beyond material welfare and livelihoods, biodiversity contributes to security, resiliency, and freedom of choices and actions (Millennium Ecosystem Assessment 2005). Less tangible, but no less important, are the cultural, spiritual, and moral costs inflicted by species extinctions. All societies value species for their own sake, and wild plants and animals are integral to the fabric of all the world's cultures (Wilson 1984).

The road to extinction is made even more perilous to people by the loss of the broader ecosystems that underpin our livelihoods, communities, and economies (McNeely et al. 2009). The loss of coastal wetlands and mangrove forests, for example, greatly exacerbates both human mortality and economic damage from tropical cyclones (Costanza et al. 2008; Das and Vincent 2009), while disease outbreaks such as the 2003 emergence of Severe Acute Respiratory Syndrome in East Asia have been directly connected to trade in wildlife for human consumption (Guan et al. 2003). Other consequences of biodiversity loss, more subtle but equally damaging, include the deterioration of Earth's natural capital. Loss of biodiversity on land in the past decade alone is estimated to be costing the global economy

$500 billion annually (TEEB 2009). Reduced diversity may also reduce resilience of ecosystems and the human communities that depend on them. For example, more diverse coral reef communities have been found to suffer less from the diseases that plague degraded reefs elsewhere (Raymundo et al. 2009). As Earth's climate changes, the roles of species and ecosystems will only increase in their importance to humanity (Turner et al. 2009).

In many respects, conservation is local. People generally care more about the biodiversity in the place in which they live. They also depend upon these ecosystems the most – and, broadly speaking, it is these areas over which they have the most control. Furthermore, we believe that all biodiversity is important and that every nation, every region, and every community should do everything possible to conserve their living resources. So, what is the importance of setting global priorities? Extinction is a global phenomenon, with impacts far beyond nearby administrative borders. More practically, biodiversity, the threats to it, and the ability of countries to pay for its conservation vary around the world. The vast majority of the global conservation budget – perhaps 90% – originates in and is spent in economically wealthy countries (James et al. 1999). It is thus critical that those globally flexible funds available – in the hundreds of millions annually – be guided by systematic priorities if we are to move deliberately toward a global goal of reducing biodiversity loss.

The establishment of priorities for biodiversity conservation is complex, but can be framed as a single question. Given the choice, where should action toward reducing the loss of biodiversity be implemented first? The field of conservation planning addresses this question and revolves around a framework of vulnerability and irreplaceability (Margules and Pressey 2000). Vulnerability measures the risk to the species present in a region – if the species and ecosystems that are highly threatened are not protected now, we will not get another chance in the future. Irreplaceability measures the extent to which spatial substitutes exist for securing biodiversity. The number of species alone is an inadequate indication of conservation priority because several areas can share the same species. In contrast, areas with high levels of endemism are irreplaceable. We must conserve these places because the unique species they contain cannot be saved elsewhere. Put another way, biodiversity is not evenly distributed on our planet. It is heavily concentrated in certain areas, these areas have exceptionally high concentrations of endemic species found nowhere else, and many (but not all) of these areas are the areas at greatest risk of disappearing because of heavy human impact.

1.2 History of Hotspots

Myers' seminal paper (Myers 1988) was the first application of the principles of irreplaceability and vulnerability to guide conservation planning on a global scale. Myers described ten tropical forest "hotspots" on the basis of extraordinary plant endemism and high levels of habitat loss, albeit without quantitative criteria for the designation of “hotspot” status. A subsequent analysis added eight additional hotspots, including four from Mediterranean-type ecosystems (Myers 1990). After adopting hotspots as an institutional blueprint in 1989, Conservation International worked with Myers in a first systematic update of the hotspots. It introduced two strict quantitative criteria: to qualify as a hotspot, a region had to contain at least 1,500 vascular plants as endemics (>0.5% of the world’s total), and it had to have 30% or less of its original vegetation (extent of historical habitat cover) remaining. These efforts culminated in an extensive global review (Mittermeier et al. 1999) and scientific publication (Myers et al. 2000) that introduced seven new hotspots on the basis of both the better-defined criteria and new data. A second systematic update (Mittermeier et al. 2004) did not change the criteria, but revisited the set of hotspots based on new data on the distribution of species and threats, as well as genuine changes in the threat status of these regions. That update redefined several hotspots, such as the Eastern Afromontane region, and added several others that were suspected hotspots but for which sufficient data either did not exist or were not accessible to conservation scientists outside of those regions. Sadly, it uncovered another region – the East Melanesian Islands – which rapid habitat destruction had in a short period of time transformed from a biodiverse region that failed to meet the “less than 30% of original vegetation remaining” criterion to a genuine hotspot.

Analyses up to now have revealed a set of 34 biodiversity hotspots. These regions collectively hold no fewer than 50% of vascular plants and 42% of terrestrial vertebrates (amphibians, mammals, birds, and reptiles) as endemics (Mittermeier et al. 2004). Because of the extreme habitat loss in these regions, this irreplaceable wealth of biodiversity is concentrated in remaining habitat totaling just 2.3% of the world’s land area (3.4 million km^2; the original extent of habitat in these regions was 23.5 million km^2, or 15.7%).

In contrast with the terrestrial realm, data on the distribution and status of aquatic species are just beginning to be synthesized at a global scale. The publication of a first comprehensive global assessment of conservation priorities for an aquatic system – the coral reef study by Roberts et al. (2002) – has led to much-needed attention on marine hotspots. Our data on marine regions remain sparse compared with information on terrestrial systems (Sala and Knowlton 2006), and our lack of knowledge about freshwater systems is even more pronounced. However, significant strides are being made on aquatic biodiversity, for example, with efforts such as the Global Freshwater Biodiversity Assessment (Darwall et al. 2005) and the Global Marine Species Assessment, which includes comprehensive status assessments completed for reef-forming corals (Carpenter et al. 2008), and similar work under way for many thousands of other species.

The impacts of the biodiversity hotspots on conservation have been diverse and profound. Perhaps the most easily tracked metric is scientific impact. This metric indicates that the hotspots benchmark paper, Myers et al. (2000), has been cited by thousands of peer-reviewed articles, becoming the single most cited paper in the ISI Essential Science Indicators category “Environment/Ecology” for the decade ending 2005. Yet the far more substantive impact has been in resource allocation. Myers (2003) estimated that the hotspots concept focused US$750 million in globally flexible funding over the preceding 15 years. Entire funding mechanisms have been established to reflect global prioritization, among them are the US$235 million Critical Ecosystem Partnership Fund (cepf.net/) and the US$100 million Global Conservation Fund (conservation.org/gcf/; GCF additionally targets high-biodiversity wilderness areas). The ideas have also been incorporated into the Resource Allocation Framework of the Global Environment Facility (gefweb.org/), the largest conservation donor. All told, it is likely that the concept has focused well in excess of US$1 billion on these globally important regions.

The last major hotspots update (Mittermeier et al. 2004) gave “honorable mention” to two other areas, the island of Taiwan and the Queensland Wet Tropics of northeast Australia, which just missed making the hotspots cutoff criteria. However, it was noted that *all* the rain forests of east Australia, and not just the very circumscribed Wet Tropics, should be included as a hotspot, but that data gathering to support this had not yet been completed. That investigation has now been concluded, showing that the region does in fact merit hotspot status, harboring at least 2,144 vascular plant species as endemics in an area with just 23% of its original vegetative cover remaining. This new addition to the hotspots list is detailed in Williams et al. (2011), bringing the total number of hotspots to 35 (Fig. 1.1). Table 1.1 tracks the regions considered biodiversity hotspots from the inception of the concept in 1988 through the various revisions to the present version, which includes the Forests of East Australia Hotspot.

1.3 Hotspots and Biodiversity

As new data enable us to periodically update the hotspots, they also grant us an increasingly complete picture of the natural wealth and human context of these important areas. Here, we examine the current state of our knowledge, building from earlier analyses with updated biodiversity data. The Global Mammal Assessment (Schipper et al. 2008), for example, provides substantially revised data on the status and distribution of Earth’s mammals, while recently compiled population (LandScan 2006) and poverty (CIESIN 2005) data sets provide important socio-economic context.

A total of 35 regions now meet the hotspot criteria, each holding at least 1,500 endemic plant species and each having lost 70% or more of its original habitat extent. Combined, the 35 hotspots once covered a land area of 23.7 million km^2, or 15.9% of Earth’s land surface, just less than the land area of Russia and Australia combined. However, as a result of the extreme habitat destruction in these regions over the past century, what remains of the natural vegetation in these areas is down to just 2.3% of the world’s land area (3.4 million km^2), just greater than the land area of India. More than 85% of the habitat originally present in the hotspots has

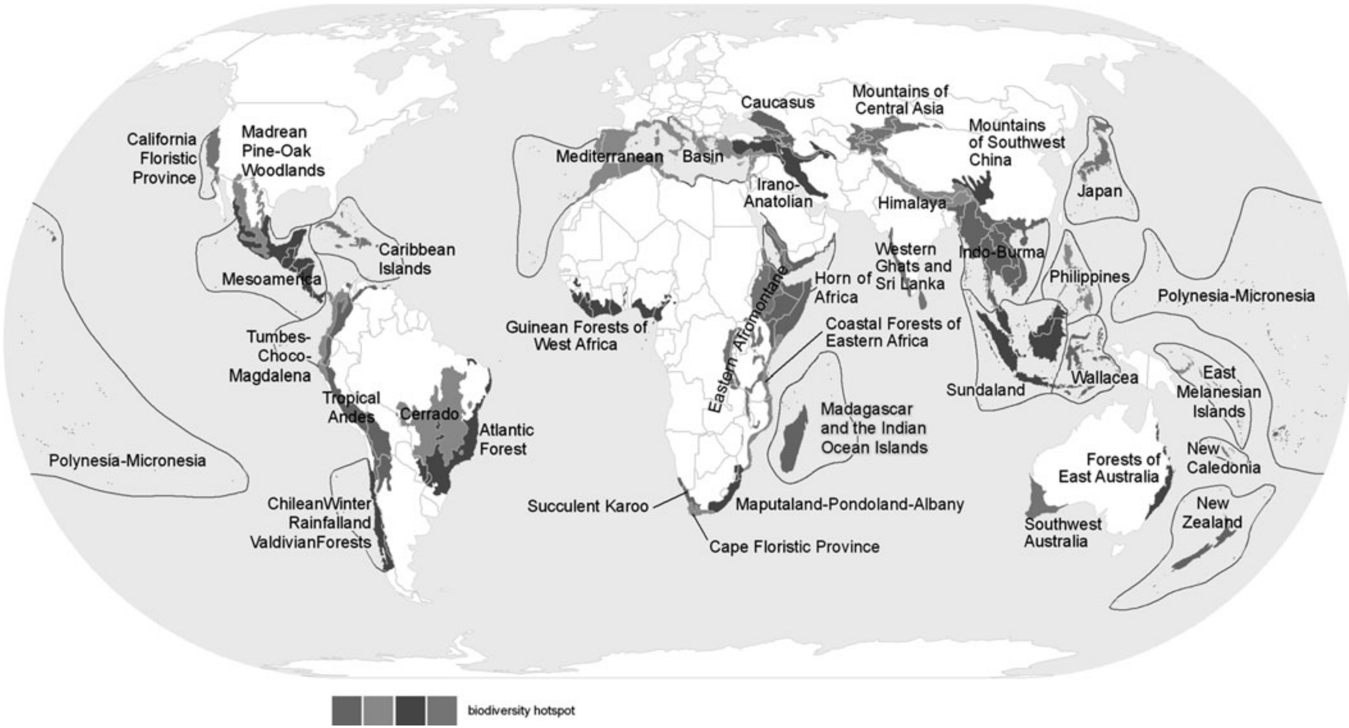

Fig. 1.1 The biodiversity hotspots, Earth's biologically richest and most threatened terrestrial ecosystems. Numbering 35 as of 2011, these include the newly added Forests of East Australia Hotspot

Table 1.1 The biodiversity hotspots from 1988 to present

Myers (1988)	Myers (1990)	Mittermeier et al. (1999)/Myers et al. (2000)	Mittermeier et al. (2004)	2011 Revision
Uplands of Western Amazonia	Uplands of Western Amazonia	Tropical Andes[a]	Tropical Andes	Tropical Andes
Western Ecuador	Western Ecuador			
Colombian Choco	Colombian Choco	Choco/Darien/western Ecuador[b]	Tumbes-Choco-Magdalena	Tumbes-Choco-Magdalena
Atlantic Coast Brazil	Atlantic Coast Brazil	Atlantic Coast Brazil[a]	Atlantic Forest	Atlantic Forest
		Brazilian Cerrado	Cerrado	Cerrado
	Central Chile	Central Chile[a]	Chilean Winter Rainfall and Valdivian Forests	Chilean Winter Rainfall and Valdivian Forests
		Mesoamerica	Mesoamerica	Mesoamerica
			Madrean Pine–Oak Woodlands	Madrean Pine–Oak Woodlands
		Caribbean	Caribbean Islands	Caribbean Islands
	California Floristic Province	California Floristic Province	California Floristic Province	California Floristic Province
	Ivory Coast	Guinean Forests of West Africa[a]	Guinean Forests of West Africa	Guinean Forests of West Africa
	Cape Floristic Region	Cape Floristic Province	Cape Floristic Region	Cape Floristic Region
		Succulent Karoo	Succulent Karoo	Succulent Karoo
			Maputaland-Pondoland-Albany	Maputaland-Pondoland-Albany
			Eastern Afromontane[d]	Eastern Afromontane
	Tanzania	Eastern Arc and Coastal Forests of Tanzania/Kenya[c]	Coastal Forests of Eastern Africa[d]	Coastal Forests of Eastern Africa
			Horn of Africa	Horn of Africa
Eastern Madagascar	Eastern Madagascar	Madagascar and Indian Ocean Islands	Madagascar and Indian Ocean Islands	Madagascar and Indian Ocean Islands
		Mediterranean Basin	Mediterranean Basin	Mediterranean Basin
		Caucasus	Caucasus	Caucasus

(continued)

Table 1.1 (continued)

Myers (1988)	Myers (1990)	Mittermeier et al. (1999)/Myers et al. (2000)	Mittermeier et al. (2004)	2011 Revision
			Irano-Anatolian	Irano-Anatolian
			Mountains of Central Asia	Mountains of Central Asia
	Western Ghats in India			
	Southwestern Sri Lanka	Western Ghats and Sri Lanka[b]	Western Ghats and Sri Lanka	Western Ghats and Sri Lanka
		Mountains of South-Central China	Mountains of Southwest China	Mountains of Southwest China
			Indo-Burma	Indo-Burma
Eastern Himalayas	Eastern Himalayas	Indo-Burma[e]	Himalaya[f]	Himalaya
Peninsular Malaysia	Peninsular Malaysia			
Nothern Borneo	Nothern Borneo	Sundaland[b]	Sundaland	Sundaland
		Wallacea	Wallacea	Wallacea
Philippines	Philippines	Philippines	Philippines	Philippines
			Japan	Japan
	Southwest Australia	Southwest Australia[a]	Southwest Australia	Southwest Australia
				Forests of East Australia
			East Melanesian Islands	East Melanesian Islands
		New Zealand	New Zealand	New Zealand
New Caledonia	New Caledonia	New Caledonia	New Caledonia	New Caledonia
		Polynesia–Micronesia	Polynesia–Micronesia	Polynesia–Micronesia

[a]Expanded
[b]Merged and/or expanded
[c]Expanded to include Coastal Forests of Tanzania and parts of Kenya
[d]The Eastern Arc and Coastal Forests of Tanzania/Kenya hotspot was split into the Eastern Afromontane hotspot (the Eastern Arc Mountains and Southern Rift, the Albertine Rift, and the Ethiopian Highlands) and Coastal Forests of Eastern Africa (southern Somalia south through Kenya, Tanzania and Mozambique)
[e]Eastern Himalayas was divided into Mountains of South-Central China and Indo-Burma, the latter of which was expanded
[f]The Indo-Burma hotspot was redefined and the Himalayan chain was separated as a new Himalayan hotspot, which was expanded

been destroyed. This means that an irreplaceable wealth of biodiversity is concentrated in what is in fact a very small portion of our planet.

Updated data and the addition of the Forests of East Australia Hotspot reconfirm the extraordinary concentration of biodiversity within the hotspots (Table 1.2). The hotspots hold more than 152,000 plant species, or over 50% of the world's total, as single-hotspot endemics, and many additional species are surely endemic to combinations of hotspots. While plant numbers are based on specialist estimates, major advances in the reliability of species distribution data allow much more accurate statistics to be compiled for terrestrial vertebrates (birds, amphibians, mammals, and reptiles). Overall, 22,939 terrestrial vertebrates, or 77% of the world's total, are found in the hotspots. A total of 12,717 vertebrate species (43%) are found only within the biodiversity hotspots, including 10,600 that are endemic to single hotspots and the remainder confined to multiple hotspots. Among individual vertebrate classes, the hotspots harbor as endemics 1,845 mammals (35% of all mammal species), 3,551 birds (35%), 3,608 amphibians (59%), and 3,723 reptiles (46%). If one considers only threatened species – those that are assessed as Critically Endangered, Endangered, or Vulnerable on the IUCN Red List of Threatened Species (IUCN 2008) – we find that 60% of threatened mammals, 63% of threatened birds, and 79% of threatened amphibians are found exclusively within the hotspots. Although reptiles and amphibians show a greater tendency toward hotspot endemism than the generally more wide-ranging birds and mammals, the overall similarity among plant and various vertebrate taxa confirms a general congruence of higher-priority regions across multiple taxa.

Although the concentration of species-level richness and endemism in the hotspots is striking, it is not sufficient to assess the overall biological diversity of the hotspots. It may be that other measures that assess phylogenetic diversity or evolutionary history better represent some aspects of biodiversity – for example, ecological diversity, evolutionary potential, and the range of options for future human use – than does endemism at the species level alone. However, our knowledge of phylogenetic information for entire clades is not yet sufficient for detailed analysis of the evolutionary history found within hotspots or other regions (but see Sechrest et al. 2002). Although the delineation of higher taxa (i.e., Linnean categories) is somewhat subjective, taxonomic distinctiveness should be a useful proxy for evolutionary, physiological, and ecological distinctiveness. Overall, the biodiversity hotspots harbor a disproportionate share of higher taxonomic diversity, holding as endemics 1,523 vertebrate genera (23% of all mammal, bird, fish, reptile, and amphibian genera) and 61 families (9%). This is nowhere more striking than in Madagascar and the Indian Ocean Islands Hotspot, which by itself harbors 175 endemic vertebrate genera and 22 endemic vertebrate families, the importance of which cannot be overstated. Other island systems such as the Caribbean, New Zealand, and New Caledonia harbor tremendous endemic diversity at higher taxonomic levels, as do mainland systems such as the Tropical Andes and the Eastern Afromontane region (Table 1.3).

Although by definition we know little about what future options biodiversity may provide, time and again humanity finds solutions in biodiversity – medicines,

Table 1.2 Plant and vertebrate species occurring in (O) and endemic to (E) each of the biodiversity hotspots

	Plants[a]		Birds[a]		Reptiles[a]		Freshwater fishes[a]		Amphibians[b]		Mammals[c]	
Hotspot	O	E	O	E	O	E	O	E	O	E	O	E
Tropical Andes	30,000	15,000	1,728	584	610	275	380	131	1,095	763	595	117
Tumbes-Choco-Magdalena	11,000	2,750	892	112	325	98	251	115	209	33	277	16
Atlantic Forest	20,000	8,000	936	148	306	94	350	133	516	323	312	48
Cerrado	10,000	4,400	605	16	225	33	800	200	205	34	300	10
Chilean Winter Rainfall and Valdiv	3,892	1,957	226	12	41	27	43	24	44	32	69	19
Mesoamerica	17,000	2,941	1,124	213	686	240	509	340	585	385	418	97
Madrean pine-Oak Woodlands	5,300	3,975	525	23	384	37	84	18	213	59	304	14
Caribbean Islands	13,000	6,550	607	167	499	468	161	65	176	169	65	48
California Floristic Province	3,488	2,124	341	8	69	4	73	15	54	27	141	15
Guinean Forests of West Africa	9,000	1,800	793	75	206	52	512	143	229	88	315	47
Cape Floristic Region	9,000	6,210	324	6	100	22	34	14	47	16	109	0
Succulent Karoo	6,356	2,439	227	1	94	15	28	0	21	1	101	1
Maputal and-Pondoland–Albany	8,100	1,900	541	0	205	36	73	20	73	11	197	3
Costal Forest of Eastern Africa	4,000	1,750	636	12	250	54	219	32	95	10	236	7
Eastern Afromontane	7,598	2,356	1,325	110	347	93	893	617	244	75	510	52
Horn of Africa	5,000	2,750	704	25	284	93	100	10	30	6	189	18
Madagascar and the Indian Ocean I	13,000	11,600	313	183	381	367	164	97	250	249	200	192
Mediterranean Basin	22,500	11,700	497	32	228	77	216	63	91	41	216	27
Caucasus	6,400	1,600	381	2	87	20	127	12	18	3	146	12
Irano-Anatolian	6,000	2,500	364	0	116	13	90	30	20	3	150	9
Mountains of Central Asia	5,500	1,500	493	0	59	1	27	5	8	4	116	7
Western Ghats and Sri Lanka	5,916	3,049	457	35	265	176	191	139	204	156	143	27
Himalaya	10,000	3,160	979	15	177	49	269	33	111	46	269	18
Mountains of Southwest China	12,000	3,500	611	1	94	15	92	23	92	8	237	8
Indo-Burma	13,500	7,000	1,277	73	518	204	1,262	553	328	193	401	100
Sundaland	25,000	15,000	771	146	449	244	950	350	258	210	397	219
Wallacea	10,000	1,500	650	265	222	99	250	50	49	33	244	144

Philippines	9,253	6,091	535	185	235	160	281	67	94	78	178	113
Japan	5,600	1,950	368	15	64	28	214	52	53	46	104	52
Southwest Australia	5,571	2,948	285	10	177	27	20	10	32	22	55	13
East Melanesian Islands	8,000	3,000	365	154	114	54	52	3	50	45	100	44
New Zealand	2,300	1,865	198	89	37	37	39	25	7	4	12	4
New Caledonia	3,270	2,432	105	23	70	62	85	9	0	0	14	6
Polynesia–Micronesia	5,330	3,074	300	170	61	31	96	20	8	3	22	12
Forests of East Australia	8,257	2144.0	632	28	321	70	80	10	120	38	133	6

[a]Hotspot totals for Forests of East Australia from Williams et al. (2011); for all other hotspots from Mittermeier et al. (2004)
[b]Calculated based on species range maps from Stuart et al. (2008)
[c]Calculated based on species range maps from Schipper et al. (2008)

Table 1.3 Hotspots with the greatest total number of endemic higher vertebrate taxa (all mammals, amphibians, birds, freshwater fishes, and reptiles)

	Hotspot (# endemics)	
Rank	Genera	Families
1	Madagascar and the Indian Ocean Islands (175)	Madagascar and the Indian Ocean Islands (22)
2	Eastern Afromontane (119)	Philippines (16)
3	Tropical Andes (103)	Japan (8)
4	Sundaland (97)	Sundaland (7)
5	Mesoamerica (78)	Caribbean Islands (6)
6	Indo-Burma (68)	Chilean Winter Rainfall and Valdivian Forests, Wallacea, New Zealand, New Caledonia (4)
7	Caribbean Islands (65)	
8	Atlantic Forest (63)	
9	Wallacea (62)	
10	Philippines (45)	Mesoamerica, Indo-Burma, and Polynesia–Micronesia (3)

foods, engineering prototypes, and other products – that enhance human lives and address our most pressing problems. It is thus difficult to overestimate the importance of maintaining the option value afforded by the vast storehouse of evolutionary diversity that the biodiversity hotspots represent. This is perhaps nowhere illustrated more clearly than in the case of the gastric-brooding frogs of the genus *Rheobatrachus*. Discovered in the early 1970s amid the streams and forests of Australia, the two *Rheobatrachus* species were the only amphibians known to incubate their young internally, in the mother's stomach. Researchers noted that the compounds secreted to avoid harm to the young might aid the development of treatments for digestive conditions such as ulcers that affect millions of humans worldwide. However, before these possibilities could be explored, the habitats of these unique creatures had become so badly decimated that both species were extinct by the mid-1980s (Hines et al. 1999). As they were endemic to what is now known as the Forests of East Australia Hotspot, failure to conserve them there resulted in their extinction. Redoubled effort is needed in the biodiversity hotspots to ensure that we do not permanently foreclose the opportunity to learn from the evolutionary innovations of other endemic taxa.

Concurrent to the development of the hotspots concept was the recognition of the importance of conserving the least-threatened highly diverse regions of the globe. These high-biodiversity wilderness areas (Mittermeier et al. 2003) are defined on the basis of retaining at least 70% of their original habitat cover, harboring at least 1,500 plant species as endemics, and having a human population density of <5 people per km^2. Based on the updated data used in this analysis, the five High-Biodiversity Wilderness Areas (Amazonia, Congo Forests, Miombo-Mopane Woodlands and Savannas, New Guinea, and North American Deserts) hold 28% of the world's mammals and 20% of the world's amphibians, including 7% of mammals and 11% of amphibians as endemics, in about 7.9% of the world's land surface (6.1% including only intact habitats). While the highly threatened hotspots must be conserved to prevent substantial biodiversity loss in the immediate future, there is also strategic advantage in investing in conserving biodiverse wilderness areas, which by virtue of their intactness and comparatively lower costs make good targets for proactive conservation action (Brooks et al. 2006). For this reason, Conservation International has for the past two decades focused on both the biodiversity hotspots and high-biodiversity wilderness areas as part of its two-pronged strategy for global conservation prioritization.

1.4 Social and Economic Context

The biodiversity extinction crisis is one of several grave challenges facing humanity today. Climate change and the persistence of poverty pose the prospect of a grim future for Earth and billions of its human inhabitants. These challenges, though, are intimately intertwined. The same environmental degradation that threatens the persistence of species contributes substantially to anthropogenic greenhouse gas emissions and undermines the ecosystem services that support human communities. Climate change will have particularly severe impacts on the poor (Ahmed et al. 2009) and jeopardizes a large portion of Earth's species (IPCC 2007; Parmesan and Yohe 2003; Thomas et al. 2004). Yet if these problems are inextricably linked, so too are many solutions. Perhaps nowhere is this more evident than in the hotspots.

The hotspots, home to a major portion of the world's terrestrial biodiversity, are also home to a disproportionate share of its people (Cincotta et al. 2000). Recent population data (LandScan 2006) show that the 35 hotspots contain about 2.08 billion people – 31.8% of all humans – in just 15.9% of Earth's land area (Table 1.4). Populations in hotspots are generally growing faster than the rest of the world. Between the 2002 and 2006 releases of the LandScan population data set, population within hotspots grew an estimated 6.0%, while Earth's overall population increased only 4.8%. Hotspots also contain a substantial fraction of the world's poor. Although spatially explicit estimates of poverty have not been compiled globally, the incidence of child malnutrition provides one measure of the poverty in an area and has been estimated at subnational scales worldwide (CIESIN 2005). These data show that 21% of the world's malnourished children live in hotspots.

The interactions between biodiversity, extreme habitat loss, other threats, and socioeconomic context are complex. Past habitat loss may have indeed been connected to poverty. For example, the lack of alternative sources for food, fuel, shelter, and income can lead to exploitation of natural habitats to meet these urgent needs. Yet rampant consumption of energy, food, and raw materials by both developed and developing countries has played just as great a role in the degradation of these areas, albeit from regions often geographically distant from hotspots. But even this more complete picture misses a critical point. Regardless of past causes, the more pressing issue is that all of humanity depends on the habitats that remain in biodiversity hotspots. Poor communities are often those most dependent on sustaining the clean water, protection from storms, and other ecosystem services they derive from nature. Based on Turner et al. (2007), the estimated value of all services

Table 1.4 Population and poverty in the biodiversity hotspots

	Population 2006	Population density (1 km^{-2})	Malnourished children	Child malnutrition rate (%)
Tropical Andes	57,775,500	38	712,240	8
Tumbes-Choco-Magdalena	14,137,600	52	191,216	11
Atlantic Forest	111,817,000	91	464,519	5
Cerrado	28,011,300	14	160,894	5
Chilean Winter Rainfall and Valdivian Forests	15,285,100	38	11,044	1
Mesoamerica	84,590,400	75	1,493,320	13
Madrean Pine–Oak Woodlands	15,206,500	33	326,133	7
Caribbean Islands	37,516,000	164	214,842	6
California Floristic Province	36,663,100	125	10,744	0
Guinean Forests of West Africa	89,016,200	144	3,466,330	21
Cape Floristic Region	4,269,870	54	27,044	7
Succulent Karoo	372,404	4	3,327	10
Maputaland-Pondoland–Albany	19,598,000	72	179,398	7
Coastal Forests of Eastern Africa	17,024,900	59	822,586	29
Eastern Afromontane	115,799,000	114	8,463,810	38
Horn of Africa	40,017,300	24	2,410,290	31
Madagascar and the Indian Ocean Islands	21,731,700	36	1,345,790	39
Mediterranean Basin	239,517,000	115	899,708	5
Caucasus	37,073,900	69	226,073	9
Irano-Anatolian	51,799,500	58	708,419	11
Mountains of Central Asia	38,005,700	44	444,026	10
Western Ghats and Sri Lanka	51,856,400	275	2,827,980	36
Himalaya	102,492,000	138	5,839,790	40
Mountains of Southwest China	8,739,140	33	40,518	4
Indo-Burma	349,827,000	148	8,855,140	24
Sundaland	229,383,000	153	5,916,330	25
Wallacea	27,861,900	83	638,814	26
Philippines	87,757,400	296	2,846,180	28
Japan	125,347,000	335	0	0
Southwest Australia	1,816,030	5	0	0
East Melanesian Islands	1,284,660	13	0	0
New Zealand	3,935,730	15	0	0
New Caledonia	197,518	10	0	0
Polynesia–Micronesia	2,898,760	62	7,018	5
Forests of East Australia	9,147,190	36	0	0
All 35 hotspots	2,077,771,702	88	49,553,523	21

provided by the hotspots' remaining habitats is $1.59 trillion annually – on a per-area basis more than seven times that provided by the average square kilometer of land worldwide. This calculation is almost certainly an underestimate, as it does not account for the increase in value that may result from the increasing scarcity of these services in hotspots in the face of increasing need for them. Meanwhile, it is not just the poor communities in hotspots that benefit from these services. For example, based on recent data (Reusch and Gibbs 2008), the hotspots store more than 99 Gt of carbon in living plant tissues, and still more in peat and other soils. The greenhouse gas emission reductions that result from slowing high rates of habitat loss in these regions are a critical contribution to slowing global warming.

Hotspots are very important for the survival of human cultural diversity. A study of the distribution of human languages (Gorenflo et al. 2008) used human linguistic diversity as a surrogate for human cultural diversity and found that about 46% of the 6,900 languages still spoken are found within the borders of the hotspots and at least 32% of languages are spoken nowhere else. This concentration very much parallels what we see in terms of endemic species. What is more, it also includes a very high proportion of the languages, and the unique cultures speaking them, most at risk of disappearing over the next few decades.

Hotspots are also notable as centers of violent conflict. Another recent study (Hanson et al. 2009) found that 80% of the world's violent conflicts since 1950 (i.e., those involving more than 1,000 deaths) took place within the biodiversity hotspots and most hotspots experienced repeated episodes of violence over the 60-year span. This result suggests that, if conservation in hotspots is to succeed, conservation efforts must maintain focus during periods of war and that biodiversity conservation considerations should be factored into military, humanitarian, and reconstruction programs in the world's war zones.

1.5 Securing Hotspots for the Future

Threats to hotspots are similar to, although generally more intense than, threats to biodiversity worldwide. Habitat destruction, projected to remain the dominant threat to terrestrial biodiversity even in an era of climate change (Sala et al. 2000), is pervasive in hotspots and driving extinctions in many (Brooks et al. 2002). The growing impacts of climate change will be felt worldwide, as altered precipitation and temperature, rising oceans, and climate-driven habitat loss threaten a large fraction of species with extinction (Thomas et al. 2004) and drive desperate human populations to further environmental degradation (Turner et al. 2010). Other threats are less widespread, but felt severely in particular regions. Introduced predators have devastated island hotspots, where species evolved in the absence of domestic cats and rats and other invasive predators (Steadman 1995). Introduced plants are having massive impacts on hydrology and biodiversity in some hotspots, particularly those having Mediterranean-type vegetation (Groves and di Castri 1991). Exploitation for protein (e.g., bushmeat), for medicine, and for the pet trade threatens species in all hotspots, particularly the Guinean forests of West Africa (Bakarr et al. 2001), Madagascar, and hotspots in Southeast Asia (van Dijk et al. 2000). Chitridiomycosis, a fungal disease, is recognized as a proximate driver of amphibian declines and extinctions worldwide (Stuart et al. 2004; Wake and Vredenburg 2008). It may prove to be the most destructive infectious disease in recorded history, with a substantial effect on the hotspots, which harbor an astonishing 59% of all amphibians as endemics.

The establishment and effective management of protected areas (Bruner et al. 2001) must continue to be the cornerstone of efforts to halt the loss of biodiversity, both in the hotspots and elsewhere. These areas may be in the form of national parks or strict biological reserves or may come in a variety of other forms, depending on local context, including indigenous reserves, private protected areas, and community conservation agreements of various kinds. An overlay of the hotspots with protected areas with defined boundaries from the World Database on Protected Areas (IUCN and WCMC 2009) reveals that 12% of the original area of the 35 hotspots is under some form of protection, while 6% is classified as IUCN category I–IV protected area (which provides a higher degree of protection in terms of constraints on human occupation or resource use). These numbers are underestimates since boundaries for many protected areas have not been systematically compiled, and they certainly overestimate the land area that is managed effectively. Yet the fraction of hotspots covered is less meaningful than the locations themselves. Efforts to conserve the hotspots must focus on ensuring long-term persistence of the areas already protected and strategically add new protected areas in the highest priority unprotected habitats that remain intact as indicated by systematic efforts to identify gaps in protected areas networks (e.g., Rodrigues et al. 2004).

Maintaining the resilience of hotspots in the face of climate change is another major challenge. Changing temperature and precipitation patterns forces species to move according to movement in their preferred habitat conditions, yet these movements will often be both difficult for species to undertake and complex for researchers to predict. Due to the nature of climatic gradients, the distances species must move are likely to be shorter in mountainous terrain and longer in flatter regions (Loarie et al. 2009). On the other hand, mountains are more likely to have habitat discontinuities that make species dispersal more difficult. Meanwhile, species' tolerance to climate variability can be low (Tewksbury et al. 2008) and changing climates are likely to produce a complex global mosaic of climates shifted in space, climates which disappear in the future, and entirely novel climates (Williams et al. 2007). To be successful, then, conservation planning must begin to systematically plan actions in both space and time. Protecting the sites where species currently exist is essential, particularly the Key Biodiversity Areas where species are at greatest current risk (Eken et al. 2004). The hotspots, in fact, harbor 81% of the global total 595 Alliance for Zero Extinction sites – locations harboring the sole remaining populations of the most threatened species (Ricketts et al. 2005). If we lose these sites now, we will not be granted another chance to save their species later. However, this is only the beginning. We must also protect habitats where species will be in the future, as well as provide "stepping stones" to facilitate movement to these new ranges. Biologists are increasing their ability to anticipate and plan for these needs (Hannah et al. 2007). To be successful, conservation in a changing climate will require a very strong focus on ending further habitat destruction as quickly as possible.

1.6 Conclusion

Based initially on plant endemism, the hotspots have in the past two decades been confirmed as priority regions for the efficient conservation of biodiversity more broadly. Collectively, they harbor more than half of all plant species and 43% of all terrestrial vertebrates as endemics, an even greater proportion of threatened species, and a substantial fraction of higher-taxonomic diversity. More recent information has revealed that this phenomenal concentration of biodiversity into habitats covering a combined 2.3% of the world's land area coincides with disproportionate concentrations of ecosystem services in many of the regions where local communities directly depend on the natural environment on a daily basis. While conservation in these areas is made difficult by ongoing threats, scarce information, and limited local financial capacity, conservation here is not optional. Indeed, if we fail in the hotspots, we will lose nearly half of all terrestrial species *regardless* of how successful we are everywhere else, not to mention an almost unthinkably large contribution to greenhouse gas emissions and extensive human suffering resulting from loss of ecosystem services upon which the human populations of the hotspots ultimately depend. Ongoing research reviewed here and in the rest of this volume serves as a rallying cry for greatly augmented funding, research, and political action on behalf of hotspot conservation. The future of life on Earth depends on it.

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