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Department of Ecology

Evaluating the Biodiversity Hotspots Approach as a Tool for Global Conservation Planning

Manuel Kohout

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Manuel Kohout

Supervisor: Lena Gustafsson, SLU, Department of Ecology

Examiner: Göran Thor, SLU, Department of Ecology

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Abstract

Given the alarming loss of biodiversity and considering that the location and threats to this biodiversity are distributed unevenly across the globe, a systematic strategy of international conservation planning must complement national conservation actions by directing inadequate flexible funding to places where the greatest biological distinctiveness coincides with the greatest threat, thus safeguarding the protection of the most species for the money invested. One such approach is Conservation International's *Biodiversity Hotspots*, regions where extraordinary biological diversity coincides with exceptional threat. Drawing from discussions in the scientific literature, conservation planning theory and ecological theory, this study is an attempt to *evaluate the hotspots approach as a tool for global conservation planning*. Based on an assessment of the strategy's objectives and methods, its congruence with other approaches and the theoretical, financial and practical impact it has had so far, the biodiversity hotspots are found to be of great utility in identifying and targeting global conservation priorities until more sufficient data regarding species knowledge and threat make the use of surrogates such as endemism or habitat loss futile.

Our planet is currently facing the worst mass extinction of species since the loss of the dinosaurs 65 million years ago (Wake & Vredenburg, 2008). This ´sixth extinction event´ in the history of Earth differs significantly from the other five that were caused by gradual climate shifts or catastrophic natural disasters such as volcanic eruptions or asteroid strikes: It is caused by one species alone, man, exploiting the planet's natural resources beyond its capacity. At present, human actions cause the loss of species at 100 to 1000 times the natural rate (Pimm et al., 1995). Frighteningly, at this rate it is estimated that up to 40% of the world's species might be lost by 2050 (Thomas et al., 2004). While these numbers might be overestimations, the fact remains that a total of about 20 000 species are threatened with extinction, and nearly 20 000 more assessed to be critically endangered, endangered or vulnerable already today (IUCN, 2012).

These figures far exceed available conservation resources and funding. Furthermore, the location and threats to species are distributed unevenly, and the most biodiverse regions often coincide with being the most threatened and poorest (Fisher & Christopher, 2006). This places a premium on identifying priorities: Where can we protect the greatest number of species for the money invested? A systematic way of conservation planning, working on a global scale, and directing attention and internationally flexible funding to the areas in most urgent need, must complement the national efforts to protect biodiversity. This is absolutely crucial, if we want to halt the mass extinction we are currently causing, and which, if not stopped, will constitute the most severe threat to our own existence (Myers et al., 2000).

One such strategy of global conservation prioritization is Conservation International's Biodiversity Hotspots, areas comprising extraordinary concentrations of endemic species - that is species "occurring in a particular region and nowhere else" (Ricklefs, 2008) - and experiencing exceptional habitat loss. Overall, the 34 hotspots hold half of the world's vascular plant species and 42% of terrestrial vertebrates as endemics between them, and in total 77% of all terrestrial vertebrates and approximately 80% of all our world's species (including non-endemics) can be found within the boundaries of the hotspots. The most striking feature, however, is that these hotspots of biodiversity, due to extensive habitat loss, today only cover 2,3% of the Earth's land surface (Mittermeier et al., 2004). This means, that we could save more than half of our planet's natural heritage, if we were to succeed in protecting this insignificantly small fraction of land.

Understandably, the hotspots approach has been met with great enthusiasm and interest by conservationists, governments and the general public. But it has also received repeated criticism regarding its concepts, methods and results. It is with this in mind, this study attempts to evaluate the hotspot approach as a tool for global conservation planning, by (i) discussing the goals, methods and metrics used by the approach; (ii) comparing the strategy to other templates of global biodiversity conservation prioritization; (iii) assessing impacts and achievements the approach has produced so far.

Outline

Methods
History and Description of the Hotspots
Results and Discussion
Part I
Objectives and Methodology
Part II
Comparison to Other Approaches
Part III
Impact and Achievements
Conclusion
Future of the Hotspots

Methods

This degree project was executed over the course of six weeks. Drawing from discussions in the scientific literature, conservation planning theory and ecological theory, the project is a pure literature study. It is based on (i) literature on ecology and conservation biology; (ii) literature describing the hotspots; (iii) scientific articles discussing the approach as a tool for global conservation planning. Employing the search engines Google and Google Scholar, no standardized method was used in the search for this literature; rather discussions, concepts and issues regarding the evaluation of the hotspots were retrieved successively.

After presenting a short history and description of the approach, the results and the discussion of these results are merged into one section, "results and discussion", constituted of three parts: Part I: discussing the objectives and methods of the approach; Part II: comparing the strategy to other approaches; Part III: assessing the impacts and achievements the approach has produced so far. The evaluation is closed with a conclusion and a short prospect on the future of the strategy.

History and Description of the Hotspots

In an influential paper published in 1988 Norman Myers identified ten tropical forest "hotspots" to inform global terrestrial conservation planning on priorities of conservation (Myers, 1988). These hotspots held extraordinary concentrations of endemic vascular plant species and were experiencing unusual loss of habitat. Thus the approach applied two commonly used measures for prioritizing conservation action: irreplaceability (the endemic plant criterion), a measure of spatial conservation options, and vulnerability or 'degree of threat' (the habitat loss criterion) - a measure of temporal conservation options (Margules & Pressey, 2000). In Myers' paper the two criteria were not yet defined by any exact quantitative thresholds (Myers, 1988).

In 1989, two years after its foundation, the non-governmental organization (NGO) Conservation International (CI) *(box 1)* adopted Myers' biodiversity hotspots as its institutional blueprint. Subsequently, Myers added another eight hotspots to the original ten (Mittermeier et al., 2004).

Six years later, CI undertook a thorough reassessment of the hotspots concept (Myers et al., 2000). Since then, the two criteria are defined by strict quantitative thresholds: Firstly, to qualify as a hotspot, a region has to contain at least 0.5% or 1500 of the world's 300 000 vascular plants as endemics (comprising about 90% of all plants, and from her on simply referred to as 'plants'). The area covered by a single hotspot doesn't have any minimum or maximum threshold. When first defined, the boundaries of the hotspots were determined by ´biological communalities' featuring separate biota or communities of species (Myers et al., 2000). Later iterations of the hotspots were harmonized with WWF's 'ecoregions', irregular biogeographic units, which are defined as "relatively large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land-use change" (Olson et al., 2001).

After having met the plant criterion, the identified areas have to retain 30% or less of the primary vegetation, this being the form of habitat usually holding the most species, especially endemics (Myers et al., 2000). The third analysis took three years to complete, adding further seven hotspots to the eighteen identified so far. The 25 hotspots of this study held 44% of all plant species and 35% of terrestrial vertebrates world-wide as endemics, while being confined to only 1,4% of the Earth's land surface (Myers et al., 2000. New for this third analysis was also that endemics of the four vertebrates groups, mammals, birds, reptiles and amphibians were used to verify the plant endemism criterion. The other vertebrate group, fishes, were still excluded due to data constraints. It has to be accentuated, however, that the vertebrates don't serve as an alternative determinant for selecting hotspots, neither do their endemics have to contain 0,5% of the worldwide total. If the plant and habitat criteria are met, the area is considered a hotspot. Vertebrates serve the purpose "to determine congruence and to facilitate other comparisons among hotspots" (Myers et al., 2000).

To revisit the status of the 25 hotspots, refine their boundaries, update the information associated with them, and to consider new potential hotspots, CI followed this first reassessment with another four-year analysis, involving nearly 400 specialists. The update was published in 2004, revealing the existence of 34 hotspots, originally covering 15,7% of the Earth's land surface, but through extensive habitat loss covering only 2,3% today (Mittermeier et al., 2004). Now the vertebrate group fishes was assessed as well, thereby completing the coverage of endemic vertebrates.

Between them, the biodiversity hotspots hold 50% of all plants and 42% of terrestrial vertebrates as endemics. Based on the evidence from terrestrial vertebrates, of which a total of 77% (including non-endemics) occur in the hotspots, probably about 80% of all species (including non-endemics) might call the hotspots their home *(fig 1)*.

Box 1. Conservation International

CI is one of the foremost international organizations that sets global conservation priorities and implements them at regional, national, and local levels. The ENGO is today represented in 31 countries and employs more than 900 people (Conservation International, n.d.). CI uses a two-pronged strategy for setting terrestrial conservation priorities for global conservation planning: the biodiversity hotspots approach and the High Biodiversity Wilderness Areas (HBWAs) approach. Similar to the biodiversity hotspots, the HBWAs approach emphasizes biologically rich areas, but in contrast to the hotspots, these areas have large tracts of intact forest and are not immediately threatened by human population pressure. Originally referred to as "good news areas" (Myers, 1988), the HBWAs have the advantage to investing in the least threatened - and cheapest - highly biodiverse regions, and offer the opportunity to be proactive about conservation (Conservation International, n.d.). CI also has a research section, the Center for Applied Biodiversity Science (CABS), using state-of-the-art technology to collect data, and collaborating with universities, research centers and other NGOs.

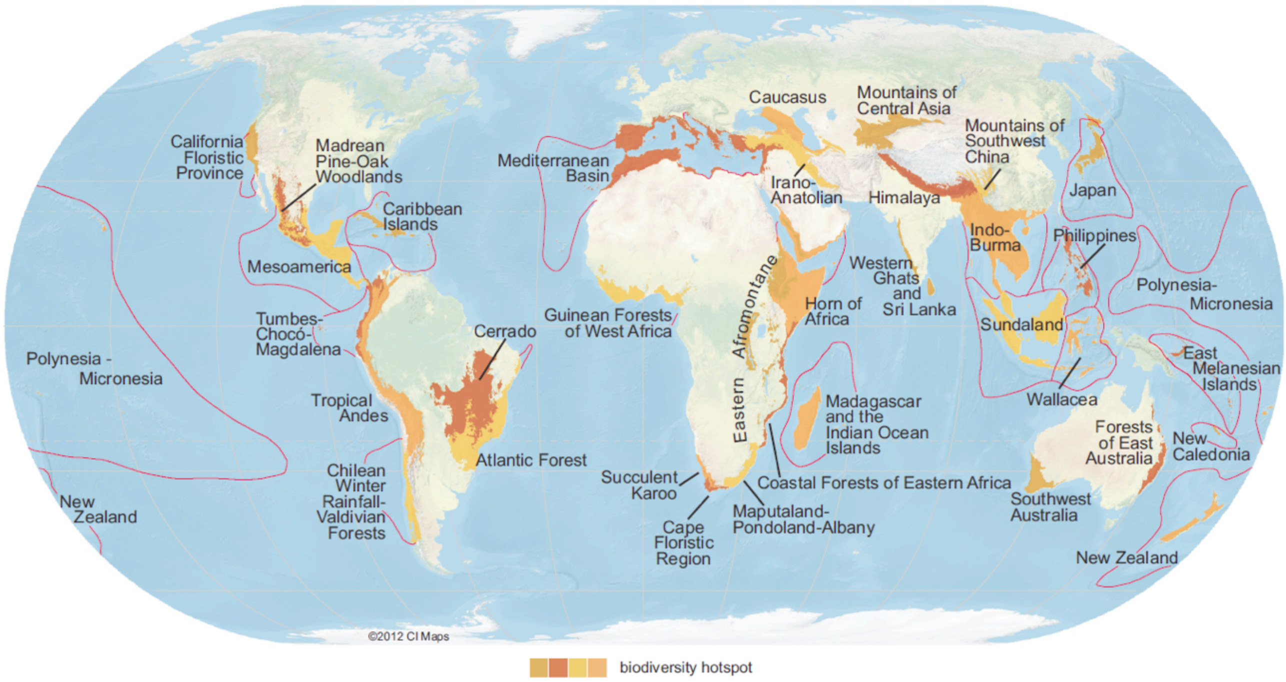

Figure 1. **The Biodiversity Hotspots.** Conservation International (n.d.).

Results and Discussion

Part I, Section I: Objectives of the Approach

CI's earlier mission was to "conserve the earth's natural living heritage, our global biodiversity, and to demonstrate that human societies are able to live harmoniously with nature" (Gordon et al., 2005). This objective was reformulated lately, to explicitly express that CI holds the aspiration not only to focus on the care for nature, but on the well-being of people. It reads as follows: "Building upon a strong foundation of science, partnership and field demonstration, CI empowers societies to responsibly and sustainably care for nature, our global biodiversity, for the well-being of humanity" (Conservation International n.d.).

CI's biodiversity hotspots approach, being one of the tools for implementing this mission has one central objective: to "protect the most species per dollar invested." (Myers et al., 2000); that is, to preserve global biodiversity in a systematic and expeditious manner. When evaluating the approach as a tool for global conservation planning beyond CI's overall mission, a necessary first step must be a discussion, to which extent the hotspots approach's objective is in concert with the goals of conservation of the scientific community, governments, stakeholders, and, most importantly, the society in general.

Biodiversity's 'sentimental value'

Firstly, it must be stressed that the discipline of conservation biology is mission or crisis-oriented, and as such at its core normative: Certain value judgements are intrinsic to the field, since the conservation of nature only has meaning in context to human intentions. Thus it is part of a social movement, assuming certain values concerning the relationship between humans and nature (Jepson & Canney, 2001). While these values certainly vary from person to person to some extent, Soulé (1985) asserts that an underlying set of 'normative postulates' guiding conservation efforts generally are shared by most conservationists and many biologists, and, I would argue, by society in general.

For example, most people do probably support the central objective of conservation biology in general and the hotspots approach in particular - to preserve biodiversity - simply because they *appreciate* biodiversity. The many millions of people visiting zoos, botanical gardens and national parks annually testify to this appeal. The deeper reasons behind this love for multiformity can only be speculated upon. Some scientists have suggested that there might be a genetic basis in humans to love biodiversity (Corral-Verdugo et al. 2009), caused by the dependency as hunter-gatherers on a wide array of recourses and habitats for virtually all our past. Be that as it may, the natural world clearly holds a great spiritual and aesthetic value to many - it has inspired artists and religious thinkers since the dawn of time, and is enjoyed and treasured by millions of people every day throughout the world.

Nevertheless, the biodiversity hotspots approach doesn't specifically aim to select areas, which engage people emotionally due to exceptional natural beauty. The criteria for selection are straightforwardly based on their virtue of safeguarding high diversity of species, not on any other aesthetical virtues. Although they may hold particular fascination for biologists, it might be argued that people in general are more selective in their appreciation of what is spectacular, beautiful or valuable (Jepson & Canney, 2001). Many people surely feel that the selection of hotspots, which are predominantly comprised of tropical forests (65%) (Mittermeier et al. 2004), due to the concentration of species richness in these biomes, neglects the protection of spectacular landscapes in other parts of the world; a desert, for instance, holding comparably little life, may anyhow inspire awe, as does a species-poor Scandinavian forest, a snow-covered mountain range in the Antarctica or other areas of great natural beauty, but little 'biologically spectacle'. Yet, it is exactly this appreciation of spectacular landscapes without regard to their biological value that was the motivational force for the establishment of the first nation parks in North America (Sellars, 1997). Likewise, society in general, arguably attaches greater sentimental importance to "charismatic" species than to more inconspicuous or even unattractive ones; a fact, by the way, exploited by many ENGO's in using charismatic flagship species such as eagles, orangutans or lions as umbrellas for the protection of other less charismatic species or ecosystems *(fig. 2)*.

Figure 2. **Yosemite National Park**. Many national parks are selected primarily for their scenic beauty and only secondarily for their biological distinctiveness, highlighting the point that the protection of biodiversity is only one motivation driving conservation efforts. From: author.

Considering these points, Jepson & Canney (2001) argue that the biodiversity hotspots approach, which treats "all species as equal units of analysis and uses non-sentient species (plants) as the primary identifier", holds only partial answers for societies' aesthetic and ethical reasons to protect nature and natural beauty.

However, I am convinced that this was never the intention and goal for the hotspots approach. The hotspots approach doesn't claim to be a cure-all for the ongoing destruction of habitats and loss of species. It seeks to complement the "traditional scattergun approach of much conservation activity" (Myers et al. 2000) by a 'silver bullet' strategy, concentrating efforts on areas in greatest need of protection, which simultaneously have the greatest payoff from safeguard measures.

Admittedly, people care about and cherish most what is close to them (Hunter & Hutchinson, 1994). No matter how little biologically unique or significant the landscape of ones childhood might be, most people certainly value it higher than some unknown place far away, having much greater biological significance according to the hotspot criteria; this affinity can actually be a great motivation for local or national conservation actions. It is, for instance, no coincidence that around 90% of annual conservation funding both originates in and is spent within economically wealthy countries (Brooks et al., 2006). However, Brooks et al. (2006) also reason, "this leaves globally flexible funding of hundreds of millions of dollars annually from multilateral agencies (such as the Global Environment Facility), bilateral aid, and private sources including environmentally focused corporations, foundations and individuals"; millions, which can be invested in areas, where conservation is most urgent. This is a significant and necessary complement to national conservation efforts; put differently: Just because we care about the state of the world in general, we shouldn't care less about what happens in our own backyard - one venture simply and strongly complements the other.

Biodiversity's 'use value'

Returning to the discussion on the hotspots approach's goal to protect biodiversity, there are a number of more rational arguments supporting the preservation of species, than the ones driven by the more emotional or aesthetical reasons mentioned above:

Firstly, species interact and are interdependent in complex ways in natural systems. The loss of a single species might imply far-reaching consequences for the rest of the community. This is especially true for keystone species, such as top predators, but even for more insignificant seeming species, such as seaweeds serving as hiding places for small fish and other delicate sea creatures (Hughes et al., 2009). The loss of one member of the complicated web of species interactions can lead to the extinction of other species, sometimes triggering a trophic cascade that eventually destabilizes the entire ecosystem, and in the worst case renders it dysfunctional (Ricklefs, 2008).

The human induced mass extinction of species, which can already be noticed today, will constitute a problem with far deeper and longer lasting impact than any other environmental problem, if not refrained quickly and vehemently. Archaeological history tells us that evolutionary processes aren't able to replace the loss of species within less than several million years (Myers & Knoll, 2001). Ultimately, this reverberates back to us humans: We are totally dependent on nature for our survival: from clean water, food and fuel, to ecosystem services such as disease control, climate regulation, pollution and flood control, carbon sequestration and fresh air. Only diverse ecosystems are stable and resilient enough to guarantee these services for a long period of time (Ricklefs, 2008). Thus, even if we only value human beings, and not other life forms, “our instincts toward self-preservation should impel us to preserve biodiversity” (Primack, 2012) - if not for our own sake, for the sake of our children and future generations.

A corollary of this fact is that biodiversity, and the ecosystem services connected to it, hold an enormous monetary value, estimated by some authors to be in the range of US$16-54 trillion for the entire biosphere per year, thus actually exceeding the annual value of the world’s economy (Costanza et al., 1997). However staggering this amount at first sight appears, it is easy to comprehend its size, considering the fact that nature not only supports us with this absolutely indispensible life support system mentioned above, but even comprises enormous monetary value for as diverse fields as education and research or recreation and tourism. As an example: tourism is today among the world’s most prosperous industries, comparable in size to automotive or petroleum industries. Ecotourism, in its turn, using pristine, undisturbed areas as targets of exploration, currently represents about 20% of this $940 billion worldwide tourist industry (Primack, 2012).

Also, while many species arguably may have little direct economic value today, some of them have enormous potential value as future commodities, such as medicines, raw materials, pest controls or, more generally, genetic banks, containing the blueprint of unique biological solutions to the struggle for survival. The loss of just one of these species before its discovery is a tremendous loss to the global economy - even if the majority of the earth’s other species are preserved. Thus, by spending money on the protection of species, one actually invests wisely in a resource we firstly can’t possibly live without, and secondly can’t possibly afford to live without *(fig.3)*.

Figure 3. **Natural medicines**. Comprising more than 50% of all species, tropical forests are giant ‘genetic banks’ holding an enormous economic value of future commodities such as raw materials or medicines. From: author.

Biodiversity and ecosystem services

It must be emphasized at this point, that CI’s biodiversity hotspot approach doesn’t particularly aim at protecting ecosystem services. With its focus on highly biodiverse, species-rich regions, other, species-poorer areas, such as wetlands, which have great significance for flood control, water purification and other ecosystem services, or the vast boreal forests of Alaska or Russia, providing substantial services such as carbon sequestration and storage, are neglected by the approach. For this fact the hotspot strategy has received repeated criticism.

On the one hand, numerous studies have shown, that ecosystem services and biodiversity are positively correlated: loss of biodiversity is reciprocally linked to loss of ecosystem services (Balvanera et al., 2006). Thus, by protecting biodiversity, the hotspots approach actually safeguards the maintenance of many essential ecosystem services as well. Some scientists, however, argue that this relationship is not linear and that the benefits of higher biodiversity on ecosystem services are realized with an initial accumulation of species, but level off thereafter (Kareiva & Marvier, 2003).

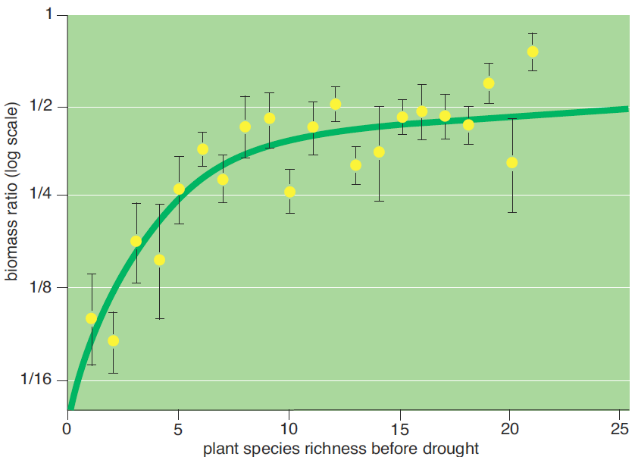

Figure 4. **Biodiversity and Ecosystem services**. Some biologists argue that the relationship of biodiversity and ecosystem functioning is not linear: the benefits of greater species diversity are realized quickly and then level out. The diagram shows that the resistance of an ecosystem to drought (measured as the ratio of biomass before to the ratio after a drought) depends on species numbers - but only to a certain point. From: Kareiva & Marvier (2003), adopted from Tilman & Downing (1994).

Consistent with this, Naidoo et al. (2008) conclude in a study comparing maps of ecosystem services with the global distribution of conventional targets for biodiversity conservation (among others the CI’s hotspot approach), that regions selected to maximize biodiversity don’t furnish more ecosystem services than randomly chosen regions. However, they also stress that levels of congruence between biodiversity and ecosystem services across the same region are as of yet poorly understood, and that “the little quantitative evidence available to date have led to mixed conclusions”. The spatial estimation of ecosystem service values remains so rude, in fact, that only four services are included in their analysis: carbon sequestration, carbon storage, grassland production of livestock and water provision. Even the four spatial proxies describing these services have, according to the authors, several limitations regarding their quantitative values. Thus the results of this study are far from being unambiguous.

Yet, even without this debate regarding the relationship of biodiversity and ecosystem services being fully resolved, it can be stated that, by focusing on biodiversity as a measure of conservation priority, the hotspots approach inevitably has certain limitations.

Biodiversity's intrinsic value

Concluding this discussion on the value of biodiversity used as a vindication for investing in certain regions, I want to mention one last concern: economic arguments, which can be used to demonstrate the value of biodiversity in dollars, might equally well be employed to argue, why a particular species or ecosystem should *not* be protected, or that the preservation of one species should be preferred to that of another.

It must therefore be recognized that, finally, and most importantly, biodiversity has an intrinsic value, regardless of its emotional, aesthetical or economical value and importance to humans. It can be argued that every species asserts its will to live though its fight for survival, ultimately cumulating in the production of offspring, and the perpetuation of life. To me this suggests that we as conscious creatures must take on the moral responsibility to go beyond reasons rooted in self-interest and act as 'stewards of nature' by preserving and protecting other species from going extinct.

Summary of objectives

Synoptically, by aiming to protect biodiversity, and not other aspects of nature, such as aesthetically appealing areas or ecosystem services, the hotspots approach meets the emotional and economical intentions behind conservation efforts, as held by the scientific community and society in general, only partly. Yet, I also argue, that this disregard of certain conservation goals is intentional, and a necessary corollary of the approach's main objective of focusing limited resources on a minute fraction of Earth's habitats of extraordinary irreplaceability and vulnerability. The strategy's main agenda is to serve as a first line of defence against the most imminent threats of mass extinctions, thus complementing and supporting national and local goals of conservation efforts in adding an international perspective.

Part I, Section II: Methodology of the Approach

Critique

In connection with the lively interest the hotspots approach has aroused in the scientific community and the great influence it has had on the field of conservation planning, there has arisen an animated debate to whether the surrogates it uses for measuring irreplaceability and vulnerability are better or worse than others. The approach has, for instance, been criticised for "relying too much on counts of plant species, [thereby loosing] sight of whole ecosystems, habitats and the needs of people" (Kareiva & Marvier, 2003).

With this in mind, I will discuss several of the metrics used by the hotspot approach in the following section. First the two surrogate criteria for irreplaceability and threat, plant species endemism and habitat loss respectively, then the irregular biogeographic unit of ecoregions and finally data sources and accuracy. This discussion constitutes the central part of this essay.

Outline: Methods

1. The endemism criterion
2. The habitat loss criterion
3. The biogeographic unit
4. Data sources and accuracy

1. The endemism criterion

When attempting to measure biodiversity, it is impossible in practice to account for all its components - it simply is too complex. Furthermore, in many regions there are severe data constraints regarding species knowledge, species numbers and habitat condition. In most cases it would be too expensive and time consuming to make an exact inventory of the biodiversity of a given region. Therefore, some kind of surrogate criterion or index has to be employed as measurement of overall biodiversity.

There are many different biological or ecological indices that can be used to identify an area as 'irreplaceable' or 'biological distinct'. Among them are the *species distribution criteria*, overall species richness, threatened species richness, and endemic species richness; and the *ecoregions-scale criteria*, unusual ecological and evolutionary phenomena and global rarity of habitat types (Gordon et al., 2005).

The hotspots approach's logic behind choosing endemism as a measure of irreplaceability is straightforward: If one of the endemic species is lost in the hotspots, it is lost to the world. Simultaneously, I would stress, endemism as an index of biological distinctiveness has the great advantage of (i) reducing the number and area of total sites needed for protection - hence supporting CI's 'efficiency goal' of channelling limited funds to areas most in need; (ii) good measurability.

One concern is that the hotspots' boundaries are determined by irregular biogeographic units, which have no fixed size. Thus the identification of a plant species as endemic to a specific hotspot is to some extent a fluid definition and not replicable, leading to questions regarding the strategy's transparency. Nevertheless, its good measurability makes endemism paramount to other ecoregions-scale indices of irreplaceability, such as global rarity of habitat types, unusual ecological phenomena (e.g. large-scale migrations of large vertebrates) or taxonomic uniqueness (above referred to as unusual evolutionary phenomena). All of these irreplaceability indices might succeed equally well at focusing efforts on a few selected sites, but as of yet they are much more difficult to quantify (Brooks et al. 2006). Also, I would argue, while being useful as complements to the index of endemism, they don't capture biological distinctiveness equally well taken for themselves: Protecting the migration-route of a large vertebrate species doesn't necessarily capture any other unusual phenomena, such as, say, exceptional seasonal concentrations of wildlife; the endemism criterion employed by the hotspots approach, on the other hand, succeeds in capturing even other aspects of irreplaceability, such as, for example, overall species diversity, demonstrated by the finding that about 80% of all species occur in the 34 hotspots.

The species distribution index 'overall species richness', in its turn, has another disadvantage compared to endemic species richness. Alike endemic species richness, overall species richness is relatively easy to measure. In other contexts than global priority setting it is probably the most traditional, predominant and direct index of biodiversity in use (Ricklefs, 2008). The big drawback of species richness, however, is that it is driven by common, widespread species, rather than by rare, restricted-range species (such as exemplified by endemics) (Lennon et al., 2004). Strategies, which focus on species richness instead of endemism, miss therefore exactly those aspects of biological diversity, which are most vulnerable and in greatest need of protection.

Accordingly, Reid (1998) argues that hotspots of species richness tend to be very insufficient in maximizing the protection of species diversity, because they seldom include rare species. To prove his point he refers to a study executed in the UK, examining species-rich areas for the occurrence of rare species. The results are conspicuous: Some of the top 5% hotspots of species richness do not comprise any rare species at all, other only low numbers (Prendergast et al., 1993). Thus, Reid (1998), along with many others, evaluates endemic species richness as more useful in conservation planning than overall species richness.

The reason why the hotspot approach doesn't use threatened species richness (the third of the species distribution indices), as a measure of irreplaceability, is, in my perception, rooted in site scale issues: Threatened species richness (that is the relative abundance of threatened species, as defined by IUCN), is most likely propelled by extensive anthropogenic activities (such as, for example, pervasive land use, hunting pressure or other forms of biological exploitation) eroding diversity in a given region (Orme et al., 2005). Global maps show that threatened species from different taxa don't inhabit the same area (Imperial College London, 2006); instead they often occur at rather small-scaled, specific sites in different corners of the world. Endemics, on the other hand, often occur clustered together on islands, such as Madagascar or New Zealand or in ´ecological islands' on continents, such as the Eastern Arc or the Caucasus, i.e. in larger-scaled regions. Threatened species are therefore difficult to capture by a regional-scale strategy such as exemplified by the hotspot approach. To account for these pinpoint threats, a site-scale strategy such as implemented by the Alliance for Zero Extinctions (AZE) is of much greater utility *(fig. 5)*.

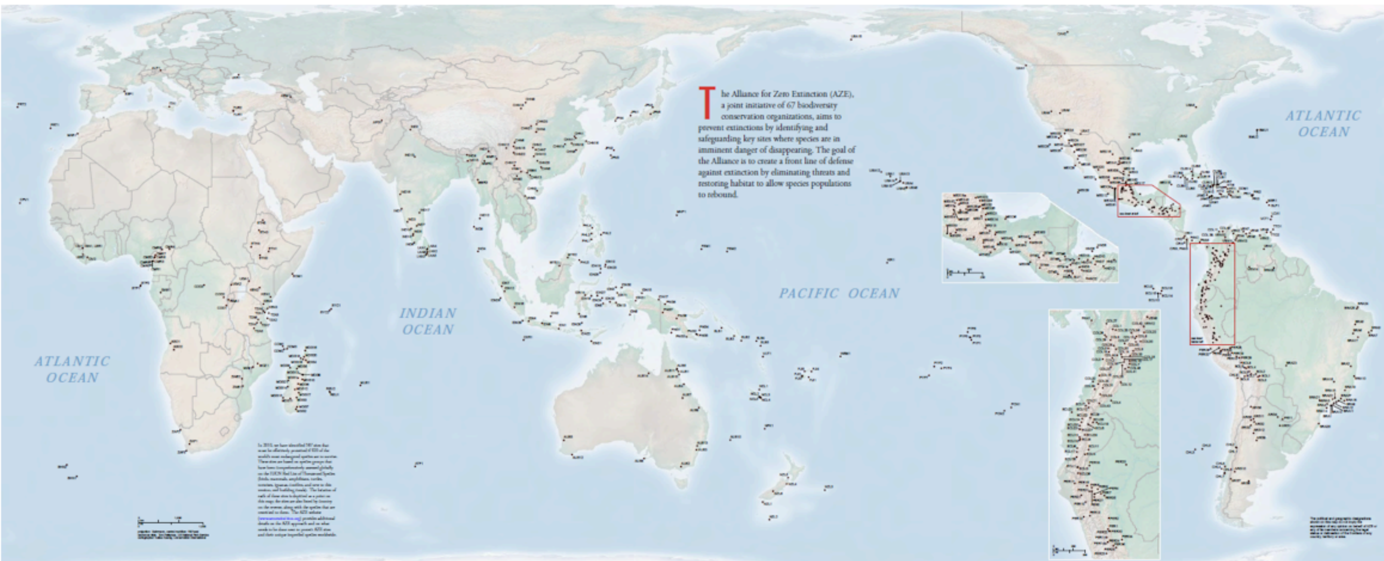

Figure 5. **Alliance for Zero Extinction sites**. The *Alliance for Zero Extinction* identifies areas that hold one or more endangered or critically endangered species. From: Alliance for Zero Extinction, 2010.

Overlap among indices of irreplaceability

How well is the overlap between different indices of irreplaceability? Comparing global hotspots of total species richness with hotspots of endemic species richness and threatened species richness, using birds as a surrogate, Orme et al. (2005) found that only 2,5% of hotspots areas were common to all three indices of diversity. Over 80% of the hotspots were idiosyncratic. This can be explained by the fact that different mechanisms drive these different indices: overall species richness is determined by common, widely distributed species, endemism by restricted-range species, and threatened species richness by extensive anthropogenic activities eroding diversity, as indicated above *(fig. 6)*.

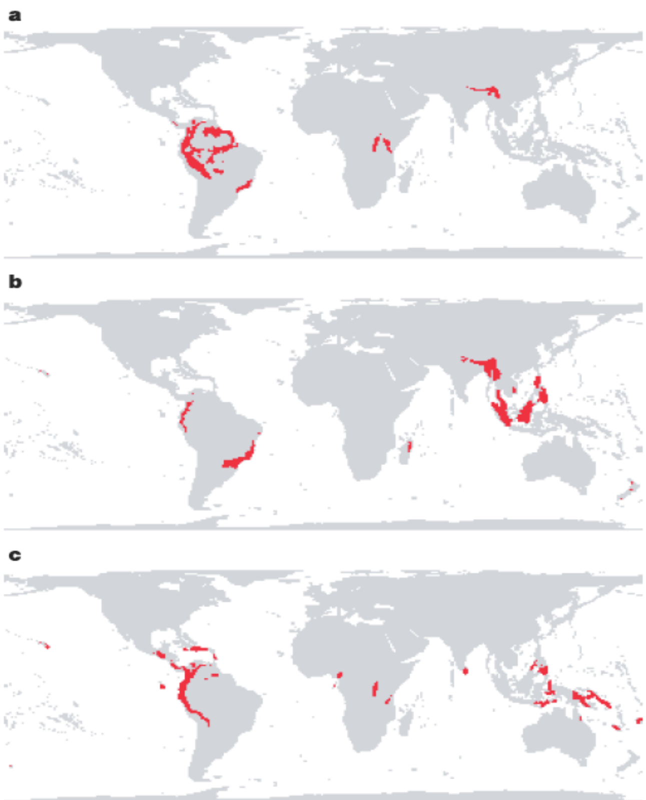

Figure 6. **Biodiversity hotspots for three aspects of diversity**. **a.** Hotspots of species richness. **b**. Hotspots of threatened species. **c**. Hotspots of endemic species. For each measure of diversity, hotspots are defined as the richest 2.5% of grid cells. From: Orme et al. (2005).

Surprisingly however, the analysis also revealed that the endemism hotspots successfully captured high proportions of both total species richness (58%), and threatened species richness (41%), whereas species richness hotspots failed to capture high proportions of endemics and threatened species, and the threatened species hotspots captured overall species richness quite well, but failed with endemics. Further, the endemism hotspots actually comprised a greater proportion of total species richness than the species richness hotspots and a higher proportion of threatened species than the threat hotspots. This is a remarkable finding, that can't be overemphasized: It strongly supports the utility and efficiency of endemism as a criterion for identifying hotspots of biodiversity.

This is not to insinuate, however, that overall species richness or threatened species richness are less important measures of irreplaceability. I believe strongly, that species threatened with extinction must be prioritized when targeting conservation efforts. As already stated, other approaches, such as the AZE, use therefore exactly the surrogate measure of 'threatened species richness' for setting conservation priorities (Ricketts et al., 2005). The different measures of irreplaceability simply account for different mechanisms threatening biodiversity, working at different spatial scales. Therefore, the different indices coordinate essentially different strategies to protect biodiversity. Yet, instead of needing to contradict each other, the apparent discrepancies between different strategies contain the great opportunity to complement each other. Accordingly, CI is part of the joint initiative aiming to protect the Alliance for Zero Extinctions Sites comprising high levels of threatened species, simultaneously to advocating their biodiversity hotspots, which house exceptional levels of endemic species.

Site-selection algorithms

Lastly, it must be mentioned that there are other reserve selection strategies, based on mathematical site-selection algorithms, which can be used to identify priority sites. Reid (1998) argues, that such mathematical models succeed even better than the use of a surrogate measure, such as endemics. Examples of such strategies are (i) *methods of complementary*, in which an inventory of the species of already existing reserves is made and then further sites are chosen, one after the other, to add additional areas contributing the greatest number of new species; (ii) *maximal-covering-location models* that use integer linear programming methods to pick simultaneously the optimal set of sites.

It has been shown, however, that the use of rare species, such as endemics, for selecting sites is paramount to methods of complementary in identifying the *minimum* number of sites necessary to represent all species at least once (Kershaw et al., 1994). Also, site-selection algorithms perform badly in maintaining the long-term persistence of biodiversity (Cabeza & Moilanen, 2003).

Yet, I would like to accentuate, that many authors assess such mathematical models as superior to the use of surrogates (Reid, 1998). A further debate on this topic would, however, go beyond the scope of this essay and my insight of the topic. Still, none of the more prominent templates of global biodiversity conservation discussed in the second part of this study *(box 2 + 3)* uses, to my knowledge, site-selection algorithms instead of surrogates for biodiversity. Whether this is an intentional choice or a disregard of better methods, I can't assess.

Plants as surrogate

The hotspots approach uses endemic *plants* as a measure for overall endemism. The logic behind this is, as I perceive it, that (i) structurally and energetically plants build a foundation, on which virtually all other life-forms dependent; (ii) along with vertebrate animals, plant species are the most well known.

In the paper first describing hotspots, Myers still omits vertebrates, due to insufficient data. His choice to rely on plant species alone is supported by the results of inventories in diverse sectors of tropical forests, which suggest, that there are at least 20 animal species per plant species, thus giving some clue to the overall animal species richness of the hotspots (Myers, 1988). As mentioned above, the reassessments of the approach carried out twelve and sixteen years later also uses vertebrates in the description (but not in the identification) of the hotspots. Thus, the 2004 analysis finds that 29% of freshwater fishes, 32% of mammals, 35% of birds, 46% of reptiles, 59% of amphibians, and in total 42% of all terrestrial vertebrates are endemic to the 34 hotspots combined (Mittermeier et al., 2004). Comparing these figures with the 50% of plants that are endemics to the hotspots, there is clearly a significant congruence between the spatial concentrations of plant and vertebrate endemics. These results strongly support the choice of plants as a surrogate for overall endemism.

A big concern is the fact, that the analysis still omits invertebrates, which probably make up 95% of all species. Again, this is due to severe data constraints. Sufficient global data are available only for two invertebrate groups: tiger beetles, and Nasutitermes termites. Reassuringly, both of these groups show equally high concordance with the plant endemic data as the five vertebrate groups. In total, 58% of all tiger beetles species, and 30% of all Nasutitermes termites are endemics to individual hotspots (Mittermeier et al., 2004).

It is impossible to take these figures and make assumptions for other less well-known invertebrate species. Still, most insects and other invertebrates are directly or indirectly dependent on plants. Therefore, I would argue, it can be assumed that a tremendous proportion of insect species would be lost, if half of the worlds endemic plants were lost - however high the congruence between plants and other less well-known invertebrate groups might be *(fig. 7)*.

Figure 7. **Butterfly**. Invertebrates, including insects probably stand for 95% of all species, but, as of yet, only a fraction are known and described, making total species estimations in the hotspots difficult. From: www.dreamstime.com

Phylogenetic diversity

While clearly targeting extraordinary levels of species endemism, the hotspots approach has been criticised for neglecting higher taxonomic groups and thus phylogenetic diversity (Kareiva & Marvier, 2003). Phylogenetic diversity describes the length of time of independent evolution of a certain species, by measuring "the sum of the lengths of all those branches [of a phylogenetic tree] that are members of the corresponding minimum spanning path" (Faith, 1992). Thus, higher phylogenetic diversity represents a higher number of different adaptations to different environments, greater evolutionary potential, and greater option value - the prospect for possible future benefits for human use (Primack, 2012). All these values should, arguably, be incorporated in a comprehensive estimation of the biological distinctiveness of a certain habitat. The hotspots strategy doesn't specifically aim to capture these values, but it might still succeed in doing so by focusing on endemic species richness. Accordingly, Sechrest et al. (2002) examined the complete phylogenies of the two mammalian orders, carnivores and primates, to see how well hotspots capture phylogenetic diversity. By investigating branch length in a phylogenetic tree of these orders, they found that hotspots comprise even greater amounts of evolutionary history (spanning 343 my) than expected, given their extraordinary endemic species richness: Nearly 70% of the total amount of evolutionary history could be found in the 25 hotspots of the 2000 assessment.

Four years later Mittermeier et al. (2004) accounted for genera and families in different hotspots as a surrogate for phylogeny. The results are remarkable: 25% of all vertebrate genera and 10% of all vertebrate families are endemic to the 34 hotspots combined, while 85% of all vertebrate genera and 91% of all vertebrate families existing on Earth occur in any hotspots.

2. The habitat loss criterion

The second criterion of the hotspot approach, habitat loss, is a measure of vulnerability, that is, an index of temporal conservation actions (temporal in this context simply means that conservation actions must be taken quickly or habitat and species will be lost). It is the surrogate for vulnerability most frequently used in global conservation prioritization (Brooks et al., 2006). The reasoning behind the utility of habitat loss as a measure of threat is justified by the rule of species-area relationships, which states that more species are found within large areas than within small areas (Ricklefs, 2008). Thus, loss of habitat translates directly into loss of biodiversity.

The hotspots approach's requirement of a 70% habitat loss is not random. It is justified by the fact that it represents the cutoff that comprises the most large-scale concentrations of endemic plants. A 60% cutoff, for example, "would admit hardly any other hotspots, whereas a 90% cutoff would exclude 11 of the hotspots" (Myers et al., 2000).

Again, there are other surrogates that could be used to measure vulnerability. Among them are land use, human population growth and density, threatened species, and expert opinion. These indices are, however, less frequently used in global conservation planning than spatial variables, such as habitat loss (Brooks et al., 2006).

Past, present and future threats

The main criticism towards the utility of this criterion is that habitat loss accounts for land use in the past, rather than predicting future threat (Kareiva & Marvier, 2003). This is certainly true: Past habitat loss might mirror present and future loss to a certain degree, and it may also lead to higher vulnerability of the surviving species due to the extinction debt resulting from decreasing populations; yet, I think that a more accurate measure of vulnerability could be computed by additionally incorporating metrics of present and future threat.

Among such indices reflecting presents threats are (i) current human population density and growth in the given area, (ii) current human land use and exploitation, (iii) hunting pressure, (iv) threatened species, and (v) threat due to invasive species. Even future threats, such as (i) political openness to protect biodiversity or (ii) threats associated with climate change would certainly make the estimation more accurate. It is difficult for me to assess, however, if the data available for any of these indices are sufficient or not. The great advantage of past habitat loss is namely its good measurability, thus justifying its current use despite certain drawbacks.

The dilemma of representation

The degree to which reserves fulfil their goal of protecting biodiversity depends on two objectives: *persistence*, or the long-term survival of species and other elements of biodiversity, and *representation*, or the degree to which they succeed to represent the full variety of biodiversity (Margules & Pressey, 2000). It is in the second point that CI's hotspots approach repeatedly has been criticised for: The distribution of the 34 hotspots is heavily skewed towards tropical biomes: 65% are predominately tropical forests, 18% temperate forest, 15% represent Mediterranenantype ecosystems, and 3% is desert (Mittermeier et al., 2004). Smith et al. (2001) liken that to "building an investment portfolio made up of a single stock." What they mean is that it is risky to preserve populations in only one habitat type (i.e. tropical forest biomes). Populations are being lost at far higher rates than species. The loss of a population in one habitat type could result in losing novel adaptations necessary for the species to ride out future environmental changes and disturbances. Thus, neglecting objectives of representation actually goes hand in hand with neglecting persistence. Smith et al. (2001) suggest an alternative strategy, hinging on conserving a maximum amount of adaptive variation by preserving populations that occur in different habitat types and along varying environmental gradients or in ecotones (the transition zones between two different habitat types).

The critic in itself is reasonable: The greater the environmental variation between two populations of the same species, the greater their rate of diversification; the greater the span of diversification, in turn, the greater the adaptive ability to future environmental challenges. However, Smith et al. (2001) disregard some important facts: Most importantly, the 34 hotspots *are* in most cases actually located in areas of ecological transition (Araújo & Williams, 2001). Thus they capture different environmental gradients and ecotones quite well, thereby guaranteeing adaptive variation of different populations.

A second point is that there are equally good arguments, why populations at the core of a species' range may have higher viability than at the periphery (i.e. in zones of transition). Firstly, marginal populations are often more subjected to less favourable conditions than core populations. Secondly, according to the 'abundant centre model', a species is most abundant where survival and breeding performance are greatest, i.e. at the centre of its range (Lawton, 1993). Peripheral populations (in the transition zones) are generally smaller, more fragmented and more isolated. Thus, the effective population size (N_e) and gene flow is greatest in core populations, making them more viable, and as such a saver choice for conservation actions (Lawton, 1993) *(fig. 8)*.

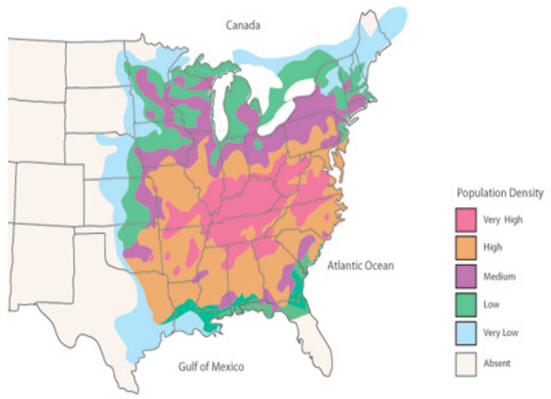

Figure 8. **The abundant centre model**. This map shows the population density throughout the range of the indigo bunting (*Passerina cyanea*), with the greatest density occurring at the core and the lowest at the periphery of the species' distribution. From: Mott, C.L. (2010).

It has to be emphasised, however, that this view is far from being unitary in the scientific community, and it is still debated, whether core or marginal populations exhibit the greatest genetic variability. Until this discussion is solved, I would argue that it might anyhow prove a better choice to target limited resources at the core of a species range - simply because it is less difficult and expensive than attempting to sample a species' complete range of environmental variation.

3. The biogeographic unit

Using WWF's ecoregions as spatial units for determining boundaries, the hotspot approach goes conform with the great majority of templates for global conservation prioritization, in using irregular biogeographic units instead of equal-area grids *(fig. 9)*.

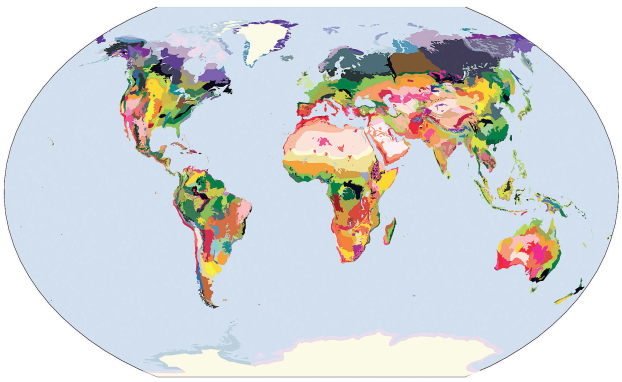

Figure 9. **Terrestrial ecoregions**. Olson et al. (2001) identified 867 terrestrial ecoregions, biogeographical units later applied by the hotspots approach. From: Olson et al. (2001)

The great advantage of biogeographic units is that their boundaries match ecological boundaries. This is most apparent in the case of islands or island groups, such as Madagascar or the Caribbean, but even for 'ecological islands' on continents, such as the Cape Floristic Province or the Caucasus. In other areas, the boundaries are based on best-judgment opinions from experts: Were the large hotspot of Sundaland, for instance, be divided into smaller units, it would still meet the criterion of biological communalities, but the result would be a much greater number of mini-hotspots, unnecessarily complicating assessments (Myers et al., 2000).

One disadvantage of biogeographic units is their disregard of political boundaries, which might lead to complications for the in situ execution of the hotspot approach. It could, for example, come to political conflicts between two countries sharing one hotspot, regarding the means and implementation of protecting biodiversity.

The use of irregular units also has the drawback of lower transparency, than would the use of regular, replicable grids: Several competing bioregional classifications are in use, and the choice of any particular classification has consequences for the resulting priority setting. Unfortunately, the reliance on expert judgment means that results are hard to replicate. Brooks et al. (2006) argue, however, that the predominant use of biogeographical units, instead of equal-area grids, is due to data limitations, and therefore essential for conservation planning until data of sufficient resolution become available.

4. Data sources and accuracy

The identification of the hotspots is based on extensive scientific data and theory. Internal sources of information, collected by CI's Center for Applied Biodiversity Science's (CABS) Regional Analysis Program, include satellite, aerial, and field observations, monitoring human impacts on biodiversity in the hotspots. External sources include the IUCN Red List, and numerous other sources, such as WWF's and TNC's Centres of Plant Diversity, satellite information provided by World Conservation Monitoring Centre or aerial maps from Global Forest Watch (Gordon et al., 2005).

Plant numbers per hotspot are derived from specialist estimates rather than from species lists, involving more then 100 scientists and around 800 references in the professional literature in the year 2000 assessment (Myers et al., 2000) and nearly 400 specialists in the reassessment four years later (Mittermeier et al., 2004). The endemism data are with great certainty underestimates, because (i) many areas lack full documentation of all plant species (ii) endemism data relate most often to individual countries, whereas several hotspots extent across multiple countries.

The precision and accuracy of data varies between areas, given the varying degree of documentation available. For instance, for several regions, such as, for instance, the Tropical Andes, rounded figures of plant endemics had to be used, since thousands of species remain to be discovered there. For others more accurate data exist. The Cape Floristic Province, for example, is considered to house exactly 5,682 known plant endemics. Similar variation in data precision applies to vertebrate data and estimates of remaining primary vegetation. However, the statistical information is considered to be accurate within 5%, in most instances (Myers et al., 2000). Some areas are still insufficiently documented to meet the hotspot criteria, even though they harbour exceptional plant endemism and experience exceptional threat, e.g. the Angola Escarpment, or southeastern China (Mittermeier et al., 2004).

Myers et al. (2000) stress: “This overall approach, uneven as it is, is justified for an analysis that seeks to convert a profound problem into a fine opportunity. After all, to decide that a potential hotspot should not be evaluated because it lacks a conventional degree of accurate data is effectively to decide that its conservation needs cannot be evaluated either, in which case its cause tends to go by default. Uncertainty can cut both ways.”

Incorporating costs

I would like to accentuate, at this point, that, although the costs of land-acquisition and management may differ enormously between different regions, the approach doesn’t incorporate costs directly. In the same way it disregards the fact that expense of conservation generally increases simultaneously to increasing threat (consider, for example, the more severe conflict between different interests for a region, when high irreplaceability of biodiversity coincides with human exploitation or warfare). Consequently, limited resources may be invested in expensive regions, when they may have protected a greater amount of threatened biodiversity if directed to less expensive regions. Theoretically, techniques to incorporate costs are available. For instance, Wilson et al. (2006) formulate how to allocate conservation funds between regions, using a stochastic dynamic programming algorithm with the two heuristics of ‘maximizing short-term gain’ and ‘minimizing short-term loss’.

As repeatedly mentioned, the approach strives to protect the most species per dollar invested. Therefore, at first sight, it would only be logical, to take costs into account. The danger, when integrating costs, however, is that intrinsic values of nature are treated as equal to and weighted against possible expanses.

Is it really right to disregard an area of high biological value because it would be more costly to protect it, than another region of equal biological value but lower expenses? I would argue not: As stated above, costs often go hand in hand with threat. The chances of loosing species in areas of higher costs might consequently also be higher.

I would therefore argue that CI chooses to neglect costs intentionally: The approach is a crisis strategy aiming to invest in highly irreplaceable *and* threatened areas. From this point of view, it would actually be *against* the objectives of the approach to consider costs and as a result neglect threatened, more costly areas. As mentioned above *(box 1)*, CI uses a two-pronged strategy: The crisis oriented biodiversity hotspot approach, which at its core is reactive, and the High-biodiversity Wilderness Areas (HBWAs) approach *(fig. 10)*, which, on the other hand, is proactive, investing in the least threatened and cheapest areas, comprising exceptional rates of biodiversity. Thus, while intentionally disregarding costs in the crisis oriented hotspots approach, CI uses cost factors as a central criterion in the ‘good news’ areas targeted by the HBWA approach.

Figure 10. **High-biodiversity Wilderness Areas**. From: Brooks et al. (2006)

CI explains: “We utterly reject a triage approach of abandoning the hotspots to focus on less biodiverse, less threatened areas, where conservation is comparatively easier” (Conservation International, n.d.). Thus, it is no coincident that many of the hotspots are notable centres of violent conflict (e.g. Mesoamerica, the Caribbean Islands, the Tropical Andes and Tumbes-Chocó-Magdalena, the Guinean Forests of West Africa, the Caucasus, the Irano-Anatolian region…) Another good example of the commitment to protect areas of high threat is Madagascar, one of the most important hotspots, which was almost abandoned by conservationists in the 1980s and between 2001 and 2002, when undergoing political difficulties, or Liberia, experiencing periods of great instability and violence. CI, along with several other organizations, persevered in these areas, despite the dangers, paving the road for giving conservation a higher priority in more recent years (Mittermeier et al., 2004).

Summary of the Methodology of the Approach

I find the metrics used by the hotspot approach generally (i) based on firm ground regarding ecological theory; (ii) of sufficient data accuracy; (iii) of excellent utility to meet CI’s goal of protecting highly irreplaceable and threatened biodiversity.

One concern regarding the methodology of the strategy is its weak transparency: I was unable to retrieve clear information on the stepwise process of identifying hotspots. For example: How many ecoregions are merged into one hotspot? When are they merged? Which tools are used to measure habitat loss?

I assume that this information is missing, because the identification process relies heavily on specialist opinion and therefore differs from region to region in its exact methodology. This means that results are difficult to replicate and difficult to control. Yet, it must be stressed once more that conservation biology is a crisis discipline. Decisions or recommendations about priorities of conservation have to be made quickly, even when sufficient information is still missing. Any priority setting, while aiming to be based on sound reasoning, is therefore to some extent a best-judgement call.

The hotspots approach emphasizes the principle of efficiency: with limited resources available, conservation efforts must be focused on areas in most urgent need of protection, as measured by the irreplaceability/vulnerability framework. Obviously, any emphasis on one aspect, necessarily goes hand in hand with giving less attention to others. Hence, when focusing on the principle of efficiency, the objective of, say, representing the full variety of biodiversity on earth, necessarily has to be neglected to some extent. Likewise, when aiming to protect biodiversity, the maintenance of ecosystem services - while hopefully met simultaneously - receives secondary importance; and equally so, when relying on one surrogate such as endemic plants to measure irreplaceability, some aspects of irreplaceability will be emphasised, others neglected. Margules & Pressey (2000) argue therefore that "there is no best surrogate. The decision on which to use will depend on many factors including what data are available and what resources there are for data analysis … ".

This is a central point: CI's choice of which metrics to use is, to a certain degree, directed by the availability of data. For example: There are sufficient data available for endemic plants and endemic vertebrates, but severely lacking data for invertebrates. Basing the endemism criterion on plants is therefore a logical choice. Likewise, the choice of habitat loss as a proxy for threat might be, to some degree, directed by the fact, that there are sufficient data for this metric, while there are constraints regarding, for instance, future threats accompanying global climate change.

Other data accounting for the vulnerability of a region, such as current human population density and growth, land use and exploitation or hunting pressure could in my opinion beneficially be incorporated[1]. Yet, it must also be accentuated, that it is the endemism criterion that directs the attention on certain regions. Only when this criterion is met, habitat loss narrows the selection down to sites of imminent threat. The question is therefore, whether the metrics I suggest as support for the criterion of habitat loss, would have any effect on this secondary selection process.

Part II: Comparison to other approaches

When attempting to evaluate the hotspot approach as a tool for global conservation planning, a necessary component must be a comparison with other approaches serving the same goal. This comparison tries to answer questions such as (i) what are the strategic similarities and differences between approaches, and (ii) how well do the suggested priorities of conservation overlap?

Approaches of global biodiversity conservation can be sorted into those developed by NGOs and those based on intergovernmental agreements (Schmitt, 2007). Here I will only examine those strategies developed by NGOs, since only these are comparable to the hotspot approach. These approaches, in turn, can be sorted into two categories (UNEP-WCMC, 2010):

The first category is made up of *regional-scale strategies*, including the hotspots approach, that identify large regions of high biological significance, with the objective to direct conservation resources and efforts to the places in most urgent need of protection. The second category contains *site-scale strategies*, which aim to identify specific areas at the level of individual protected areas and management units, in an effort to complement the financial attention that regional-scale strategies draw to certain areas, with more fine-scaled, manageable units where conservation action can be implemented practically (Eken et al., 2004).

Among the more prominent of these approaches are (i) the *regional-scale approaches* Biodiversity Hotspots, High Biodiversity Wilderness Areas (HBWA), Megadiversity Countries, Global 200 Ecoregions, Centres of Plant Diversity (CPD), Crisis Ecoregions, Endemic Bird Areas (EBA), Frontier Forests (FF), Range-Wide Priority Setting, and Last of the Wild[2] *(box 2)*; and (ii) the *site-scale approaches* Alliance for Zero Extinction (AZE) Sites, Key Biodiversity Areas (KBA), Important Bird Areas (IBA), Important Plant Areas (IPA), Indigenous and Community Conserved Areas (ICCA), and High Conservation Value Areas (HCVA) *(box 3)*.

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[1] This is admittedly not more than an uneducated guess, considering my limited insight, regarding available data per se, but also to what degree experts identifying hotspots take these metrics into consideration. For example: Human population density, predatory invasive species, the introduction of exotic plant species or the exploitation of species for food, medicine, and the pet trade in hotspots are acknowledged in the 2004 reassessment. But whether these data are considered in retrospect or as indices of threat, I can't tell.

[2] This list is not intended to be complete, but includes the approaches I assess to be the more prominent based on Gordon et al., 2005, Brooks et al., 2006, Schmitt, 2007, and UNEP-WCMC, 2010.

While these two categories complement each other excellently, it is more difficult to make a comparison between them regarding their concepts, methods and results, due to the vastly dissimilar scales they target. Therefore I concentrate here mainly on a comparison between regional-scale approaches.

Box 2.

REGIONAL SCALE

APPROACH	ORGANIZATION/ PARTNERSHIP
Biodiversity Hotspots	Conservation International (CI)
High-biodiversity Wilderness Areas (HBWA)	
Megadiversity Countries	
Global 200 Ecoregions	World Wildlife Fund (WWF)
Centres of Plant Diversity (CPD)	WWF, IUCN
Crisis Ecoregions	
Endemic Bird Areas (EBA)	BirdLife International
Frontier Forests (FF)	World Resources Institute (WRI)
Range-Wide Priority Setting	Wildlife Conservation Society (WCS)
Last of the Wild	

Box 3.

SITE SCALE

APPROACH	ORGANIZATION/ PARTNERSHIP
Alliance for Zero Extinction (AZE) Sites	CI among many others
Key Biodiversity Areas (KBA)	
Important Bird Areas (IBA)	BirdLife International
Important Plant Areas (IPA)	Plantlife International
Indigenous and Community Conserved Areas (ICCA)	Convention on Biological Diversity (CBD)
High Conservation Value Areas (HCVA)	HCV Resource Network

Comparison

Some of the regional-scale approaches have more similar objectives and methods compared to the hotspots approach than others. The Endemic bird areas, for instance, also use endemism as their main criterion. Thus, an endemic bird area is defined as “an area which encompasses the overlapping breeding ranges of restricted-range species, such that the complete ranges of two or more restricted-range species are entirely included within the boundary of the EBA” (Stattersfield et al., 1998).

Others, such as Frontier Forests and the Last of the Wild, attempt to capture, not species richness, but other aspects of biological significance, such as vast, unbroken expanses of natural ecosystems, which display no significant human alterations, and comprising viable populations of wide-range species. They are therefore more comparable to CI’s HBWA approach.

Crisis Ecoregions and the Global 200 (200 is here referring to 200 ecoregions of special importance, while strictly speaking 238 ecoregions have been identified so far (UNEP-WCMC, 2010)), in turn, aim to expand the scope of global conservation priorities beyond the hotspots of biodiversity, by emphasizing the protection of entire ecosystems (Hoekstra et al., 2005, Olson & Dinerstein, 1998).

Thus, these approaches add the objective of *representation* to the hotspots strategy’s ‘efficiency goal’, thereby broadening the singular focus on preserving species diversity, to also encompass “habitat diversity, ecological processes, evolutionary phenomena, and adaptations of species to different environmental conditions around the world” (Olson & Dinerstein, 1998).

WWF’s Global 200 is probably the most meticulous and ambitious of all approaches mentioned above, most notably regarding its effort to also include marine systems. To account for habitat diversity, ecoregions are at first stratified by realm (terrestrial, freshwater and marine). These realms are then divided into Major Habitat Types (MHTs), such as, for instance, savannas, tundra, or tropical and subtropical conifer forest. Each MHT is then further subdivided into biogeographic realms, and finally into ecoregions, representing the most distinctive examples of biodiversity for a given MHT *(fig. 11)*.

The prioritization of ecoregions is based on two discriminators: (i) *biological distinctiveness*, as based on the four criteria of (1) overall species richness, and (2) endemic species richness, as well as (3) unusual ecological and evolutionary phenomena, and (4) global rarity of MHTs; (ii) *conservation status*, as an estimation of the current and future ability of an ecoregion to maintain viable populations and communities, sustaining ecological processes, and responding effectively to short- and long-term environmental change. These goals are measured by the four criteria (1) habitat loss, (2) remaining habitat blocks, (3) degree of habitat fragmentation, and (4) degree of existing protection (Gordon et al., 2005).

The regions identified as priorities cover about twice as much land as the hotspots (Brooks et al., 2006). Thus the architects of the strategy actually express

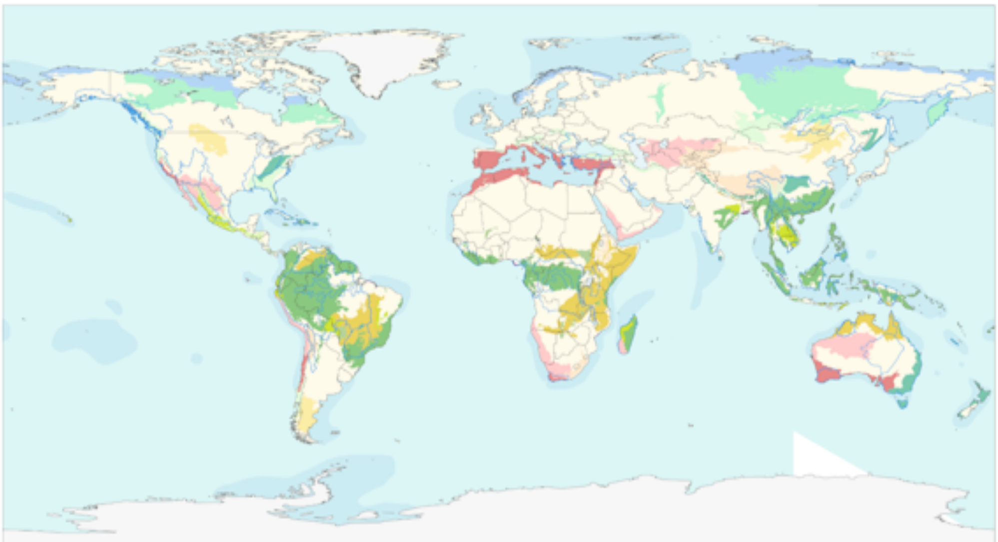

Figure 11. The Global 200. From: WWF, (2010)

the concern that the Global 200 might be *too* ambitious: “By focusing on 233 ecoregions rather than on a handful of conservation units we run the risk of placing less emphasis on the most diverse and distinct ecoregions” (Olson & Dinerstein, 1998). On the other hand, this breadth has the advantage of making almost every nation on Earth a stakeholder in global conservation strategy, creating a global perspective for lobbying efforts by local conservation groups, and ultimately safeguarding the protection, not only of species diversity, but habitat diversity, with all the consequential advantages.

Congruence among approaches

Weighing the principle of representation, employed by the Global 200, against the one of efficiency, as implemented by the hotspots, goes beyond the scope of this essay. Most interestingly, in context with the hotspots approach, however, is the fact, that the two approaches show extraordinary congruence: All hotspots contain at least one Global 200 ecoregion (Mittermeier et al., 2004), and hotspots are largely nested within the Global 200, displaying a congruence of more than 78% for the terrestrial realm (Brooks et al., 2006).

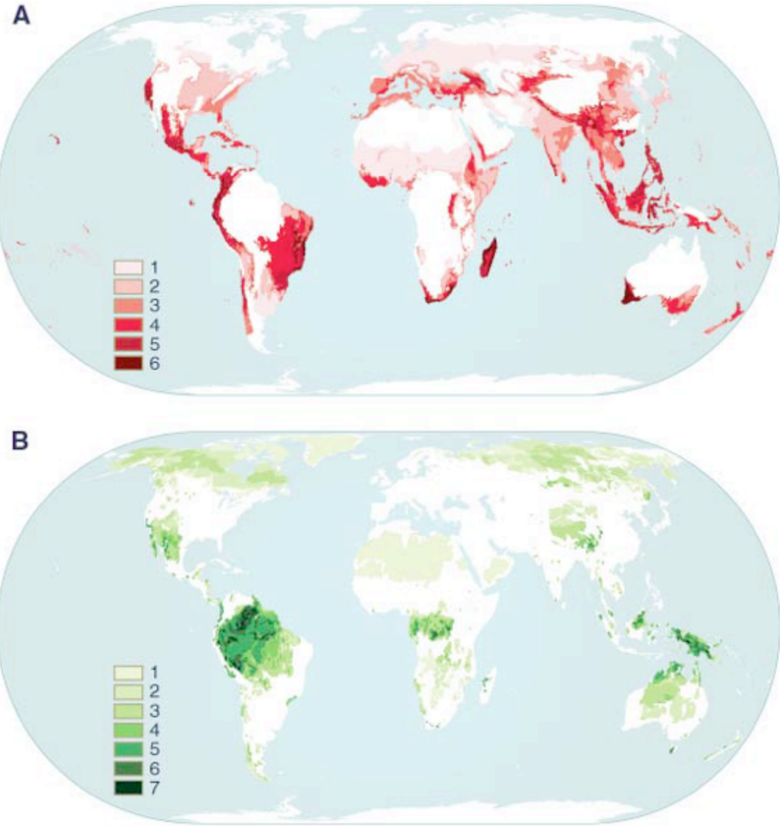

Figure 12. **Congruence among approaches.** The maps show the overlap among approaches prioritizing **(A) reactive** and **(B) proactive** conservation. Shading denotes the number of global biodiversity conservation prioritization templates that prioritize the shaded region, in both (A) and (B). From: Brooks et al. (2006).

More generally, this overlap can be seen among different approaches that use comparable criteria for setting priorities, as a striking analysis by Brooks et al. from 2006 reveals: All of the nine regional-scale approaches compared fit within the irreplaceability/vulnerability framework, as described above. However, they map onto different portions of this framework: Most of them prioritize high irreplaceability (the hotspots, HBWA, Megadiversity countries, Global 200, EBA, CPD), but some are purely proactive (prioritizing low vulnerability), including HBWA, FF, Last of the Wild, others, on the other hand are purely reactive (prioritizing high vulnerability), including the hotspots approach and Crisis Ecoregions. Most land (76%) is highlighted by at least one of the approaches, but within this area, there is significant overlap among approaches prioritizing high irreplaceability, among the reactive and the ones being proactive *(fig. 12)*.

The growing number of approaches has led to criticism, that there is a duplication of efforts in setting conservation priorities, but I cannot agree with that: The demonstrated overlap between different approaches provides (i) useful cross-verification for the methods used by the approaches, but more importantly, (ii) cross-verification of the *regions identified for prioritization*: The reactive strategies, including the hotspots, often identify tropical islands and mountains (e.g. Madagascar, the Philippines, montane Mesoamerica, the Andes), Mediterranean-type regions (e.g. California, coastal South Africa or the Mediterranean itself), and a few temperate forests (e.g. the Caucasus, southwest China). The proactive strategies, including HBWA, on the other hand, often identify the tropical rainforests of Amazonia, New Guinea, and the Congo.

The hotspots approach as complement

This brings me to a central point: I believe that the similarities *and* differences between approaches are of great value for a discussion on the utility of different concepts, methods and results and a commencing improvement of the same. More importantly, the different strategies can most beneficially be used as complements to each other, because, ultimately, they share the mutual goal of conserving our planets biodiversity. The organization explains on its website: “The challenge of conserving biodiversity in the hotspots, and indeed worldwide, is so great that no one organization can do it alone” (Conservation International, n.d.).

Consistent with this, CI employs multiple other approaches and is collaborating intensively with other NGOs, governmental agencies and private stakeholders to achieve the joint objective of preserving biological diversity. Her are some examples:

In 1998, CI identified 17 ‘megadiverse countries’ holding within their borders more than two thirds of the world's biodiversity. This concept complements the globally oriented hotspots and the HBWA approaches, which both aim to direct international, flexible funding to regions of biological significance beyond political borders, by (i) achieving significant coverage of the world's biological resources, and by (ii) raising *national* awareness for biodiversity conservation (UNEP-WCMC, 2010).

In the same spirit, CI also clearly stresses the importance of moving from the global to the local scale of conservation planning by establishing "targets for conservation outcomes", which are attempted to be met within the hotspots regions (Mittermeier et al., 2004). These outcomes are defined at three levels of ecological organization: species (where CI strives for "Extinction Avoided" outcomes); sites (where targets are "Area Protected" outcomes); and landscapes (where targets are "Corridors Consolidated" outcomes). To meet the species and site target, CI is, for instance, involved in a partnership of over 1000 national, regional and international conservation agencies aiming to identify and protect Key Biodiversity Areas (KBAs), an umbrella template including globally significant sites for conservation, as defined by the Important Bird Areas (IBAs), Important Plant Areas (IPAs), Important Sites for Freshwater Biodiversity, Ecological and Biological Significant Areas (EBSAs) in the High Seas, and the AZE sites, earlier mentioned, which aim to conserve all sites holding the entire global population of one or more Critically Endangered or Endangered Species (UNEP-WCMC, 2010). By doing so, CI, complements its "top-down" process of identifying hotspots, with a "bottom-up" process of getting involved in locally led conservation actions on the ground.

To meet the landscape targets, and guarantee the maintenance of important ecological and evolutionary processes, CI aims, among other things, to protect 'conservation corridors', areas embedded in a matrix of other natural and anthropogenic land uses with the goal to ensure sufficient dispersal between key habitats, and allowing for the long-term persistence of ecosystem services (Johnson, 1995).

Finally, while the hotspots so far only capture the terrestrial realm, CI is directing immense efforts towards protecting marine biodiversity *(box 4)*.

Box 4. Marine 'Hotspots'

A huge concern for conservationists is the severe lack of synthesized global data for aquatic species. When publishing the latest reassessment of the hotspots in 2004, CI had therefore not yet performed any comprehensive global conservation priorities regarding marine systems (Mittermeier et al., 2004). CI is, nevertheless, directing great efforts towards protecting marine biodiversity. Part of this effort is accomplished by **(i) promoting sustainable fisheries**; **(ii)** establishing an **'ocean health index'** attempting to measure ocean health, and aiming to be used globally, regionally and locally; **(iii)** identifying so called **'seascapes'**, "large, multiple-use marine areas, defined scientifically and strategically, in which government authorities, private organizations and other stakeholders cooperate to conserve the diversity and abundance of marine life, with the ultimate goal of promoting human well-being" (Conservation International, n.d.). As of yet, there are four seascapes: *the Eastern Tropical Pacific Seascape* (Costa Rica, Panama, Colombia and Ecuador); *the Bird's Head Seascape* (Indonesia); *the Sulu-Sulawesi Seascape* (Philippines, Indonesia and Malaysia) and *the Abrolhos Seascape* (Brazil). Beyond that, CI also prioritizes **(iv)** so called **'oceanscapes'**, to improve ocean governance and health across political borders.

Considering this broad involvement of CI in the protection of biodiversity, it becomes evident, that CI's hotspot approach has to be measured and evaluated in the context of all of these other strategies and actions it complements. This is not to insinuate that the biodiversity hotspots cannot or should not be evaluated for themselves. However, they have to be recognized for what they are and what they want to accomplish: Along with AZE and KBA, the hotspots form the first line of defence in the effort to protect the complete biological diversity of our planet, by drawing attention to areas and sites where the greatest biological distinctiveness coincides with the greatest threat. First when the protection of these areas of most imminent threat is guaranteed, the objective of representing, not just species diversity, but also ecosystem diversity can be tended to.

Part III: Impact and achievements

A third measure of the value of the hotspot approach as a tool for global conservation planning (beside the evaluation of its objectives and methods and a comparison to other approaches) is the actual results it has produced so far.

Theoretical impact

Undeniably, the concept itself has, as earlier mentioned, had an exceptional impact on the field of conservation planning, clearly affecting other templates aiming to target the most biological distinct and endangered habitats on Earth. Searching the web yields an enormous amount of scientific papers debating and quoting the hotspots strategy.

Financial impact

Much more importantly than this interest and awareness for efficient conservation planning the approach created, however, is the impact it had in terms of investments in the hotspots themselves: In the year of its adoption as CI's organizational blueprint, the MacArthur Foundation employed the biodiversity hotspots as its primary global investment strategy. In 2000, the Global Environmental Facility and the World Bank formed the Critical Ecosystem Partnership Fund supporting CI. The MacArthur Foundation became a partner in 2001 and the Japanese Government joined in 2002. Together with the Global Conservation Fund, also supporting the approach, the Critical Ecosystem Partnership Fund invested more than $750 million in total, in protecting biodiversity in the hotspots. This is "perhaps the largest financial investment in any single conservation strategy" (Conservation International, n.d.).

Practical impact

Obviously, identifying regions in most urgent need of protection and raising funds is only the first step, guiding and culminating in real conservation actions implemented on the ground. When updating the hotspots in 2004, the average protected area was 10.1% of their original extent, and only 5%, if considering those in IUCN protected area categories I-IV (Mittermeier et al., 2004). CI stresses therefore that the most important part of these actions is the long-term persistence of the areas already protected, while at the same time adding new reserves in the regions of intact habitat (Mittermeier et al., 2004). Thus, projects by CI in the Tropical Andes Hotspot, for instance, have helped to create 3 million hectares of new protected areas, and in the Chilean Winter Rainfall-Valdivian Forests hotspot, CI's Global Conservation Fund, together with the Nature Conservancy, WWF, and local conservation organizations acquired 60 000 hectares of biologically rich temperate rainforest in an open auction. To link old and new protected areas within the hotspots, and to thereby guarantee the possibility of species migrations within stretches of unbroken habitat, CI is furthermore involved in establishing extensive forest corridors. For example, actions are taken to create 8 million hectares of continuous habitat within the Atlantic Forest and Brazilian Amazonia, a Mesoamerican Biological Corridor in the Mesoamerican hotspot, or a corridor in the Sundaland hotspot, linking four existing and one new reserve.

Beside this involvement in the creation and acquisition of land for protection, CI is involved in all possible ways to implement the protection of the biodiversity within the hotspots, often collaborating extensively with local conservation organizations, governments and indigenous people. This can include all from implementing debt-for-nature-swaps to helping in the crafting of environmentally friendly policies (Conservation International, n.d.).

Conclusion

Synoptically, I evaluate CI's hotspot approach of great utility as a tool of global conservation planning, as based on an assessment of its objectives and methods, its congruence with other approaches and the theoretical, financial and practical impact it has had so far.

The methods it employs are in my opinion (i) based on firm ground regarding ecological theory and (ii) proven to succeed excellently in capturing overall irreplaceability and vulnerability as measures of the biological significance and precedence of a given region. The choice of surrogates for these measures is to some degree driven by the availability of data, justifying the use of proxies such as endemic plants, habitat loss or biogeographic units. It can even be argued that this reliance on proxies is to some extent unavoidable, considering that the approach is a crisis oriented strategy forced to inform conservation priorities even when data in some cases are insufficient or lacking.

A comparison with other templates of global conservation prioritization shows that there is significant overlap in the areas identified as priorities. Most land (76%) is highlighted by at least one of the approaches, but within this area, there is significant overlap among the reactive approaches such as the hotspots, Global 200 or EBA, and the ones being proactive including HBWA, FF and the Last of the Wild. This provides (i) useful cross-verification for the methods used by the approaches, but more importantly, (ii) cross-verification of the regions identified as priorities: The reactive strategies, including the hotspots, often identify tropical islands and mountains, Mediterranean-type regions and a few temperate forests. The proactive strategies, including HBWA, on the other hand, often identify the tropical rainforests of Amazonia, New Guinea, and the Congo.

The hotspots approach emphasizes the principle of efficiency: with limited resources available, it identifies areas in which investments can protect the greatest number of species. By focusing on species diversity, which predominately is found in tropical, Mediterranean-type and temperate biomes, the strategy has been criticised for neglecting places of great natural beauty, diversity of biomes, diversity of habitats, genetic diversity, certain ecosystem services and other aspects of biodiversity not captured by species richness per se. Synoptically, this is a critique towards the strategy's focus on cost-efficiency as opposed to aiming at representing all the varying aspects of biodiversity.

However, my findings strongly support that this critique is misaligned, considering that the approach never intended to be a cure-all of the planets environmental crisis. This is supported by the fact that CI uses multiple other approaches to guarantee protecting all the diverse aspects of biodiversity, working at global, regional, national and local scales and being involved in multifarious collaborations with other organizations, governments and stakeholders. The hotspot approach taken for itself seeks to complement the conservation landscape with a 'silver bullet' strategy, focusing limited resources on a minute fraction of the planet's habitats, in which the greatest biological distinctiveness coincides with the greatest threat.

Thus it attempts to act as a first line of defence against the most imminent threats of mass extinctions, complementing national and local goals of conservation in adding a systematic international perspective. First when the protection of these areas of most imminent threat is guaranteed, the objective of representing, not just species diversity, but also ecosystem diversity can be tended to. Moreover, considering the great utility of the approach to identify areas of high irreplaceability and threat, it might beneficially be applied not only on the global level, but also on regional and national levels.

The extinction crisis we are currently causing cannot be halted by one organization or one conservation strategy alone. Yet, if we don't succeed in protecting this insignificant 2,3% of our planet's land lying within the boundaries of the 34 hotspots from being destroyed, we are bound to lose at least half of our natural heritage, and probably more. This is not just a good sales argument for a plan of action … it is the best I've ever heard.

The future of the hotspots

Most of the threatened species identified today are in the most well explored groups of organisms, highlighting the point that only when a species becomes known, can the threats and dangers it faces be discerned. Unfortunately, only a fraction of the 5 to 10 or even 100 million species estimated to exist have been described today (Primack, 2012), and the accuracy of documentation regarding species numbers and taxonomy differs greatly between different regions.

It is this lack of data and the great variability in the accuracy of documentation for different regions that makes the identification of hotspots of biodiversity so challenging. As mentioned earlier, it results in the complete neglect of the entire marine realm up to now. In addition, it causes the reliance on surrogates such as endemism or habitat loss to capture irreplaceability and threat, respectively, instead of using exact species data. Thus, it is in this point that the hotspots approach can and must be improved the most in the future.

Consistently, Mittermeier et al. stress in the 2004 reassessment: "The massive acceleration of the compilation of species data will soon reach the point where bioregional classification becomes an increasingly unnecessary surrogate for species data. Within just a few years, the identification of hotspots will no longer rely on the current criteria of plant endemism and remaining habitat as surrogates for irreplaceability and threat, respectively, but will be founded on accurate species distribution data and better understanding of threats and costs". Hopefully, this increasing knowledge also empowers the strategy to comprise, not only the terrestrial realm, but also the marine realm with all its indispensible natural treasures.

Beside refined instruments for identification of hotspots of biodiversity, the success of the approach hinges heavily on an increase of funding. Recent estimations assess that an investment of about $5.4 billion annually may be necessary to safeguard the biodiversity across the 34 hotspots[3] (Mittermeier et al., 2004). Although this is far more than the annual average spent so far, this enormous figure is dwarfed by the whopping $738 billion spent on US military defence in 2010 alone, or perverse governmental subsidies (such as tax breaks, cheap fossil fuel, price support etc.) into industries that degrade not just the environment but also the economies, amounting to several *trillion* dollars each year globally (Primack, 2012).

Ever stronger and ever more sophisticated painkillers may succeed in easing the pain, but they will never cure the patient suffering from an infected tooth. Equally little can ever larger funds and ever more sophisticated strategies of investing this funding cure the health of our planet. If we want to halt the current extinction crisis, we must pull out the tooth by its root. Only when we realize ourselves as part of the fantastic web of life that is gracing our planet, and only when we learn again to live sustainably from the plentiful abundance it provides, can it be healed for good.

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[3] This is averagely $160 million per hotspot annually, however, variation regarding the funding needs among hotspots is considerable, with expenditures within more prosperous countries being 100 times greater than in lower income countries.

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