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M.Sc. Thesis in International Studies in Aquatic Tropical Ecology

Assessment of Global Marine Biodiversity Indicators for the Global Environment Facility Resource Allocation Framework (GEF RAF)

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single-handed and without using other resources than mentioned therein.

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Acronyms

ABD	Asian Development Bank
AIMS	Australian Institute of Marine Science
BFI	Broad Framework Indicator
CBD	Convention on Biological Diversity
CCD	Convention to Combat Desertification
CEC	Country Ecoregion Component
CEPIA	Country Environmental Policy and Institutional Assessment
COP	Conference of the Parties of the Convention on Biological Diversity
CPIA	Country Policy and Institutional Assessment
EEZ	Exclusive Economic Zone
EVI	Environmental Vulnerability Index
FAO	Food and Agriculture Organization
FCCC	Framework Convention on Climate Change
FSPI	Foundation of the Peoples of the South Pacific – International
GBI	GEF Benefits Index
GEBCO	General Bathymetric Chart of the Oceans
GEF	Global Environment Facility
GIS	Geographic Information System
GMSA	Global Marine Species Assessment
GPI	GEF Performance Index
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IFAD	International Fund for Agricultural Development
IOC	Intergovernmental Oceanographic Commission
IUCN	World Conservation Union
KGS	Kansas Geological Survey
LME	Large Marine Ecoregions
MEOW	Marine Ecoregions of the World
MPA	Marine Protected Area
MTI	Marine Trophic Index
NCEAS	National Center for Ecological Analysis and Synthesis
NGO	Non Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
OBIS	Ocean Biogeographic Information System

PBA	Performance-based allocation system
PIC	Pacific Island Country
PIFS	Pacific Islands Forum Secretariat
PPI	Project Portfolio Performance Indicator
RAF	Resource Allocation Framework
SAUP	Sea Around Us Project
SBSTTA	Subsidiary Body on Scientific, Technical, and Technological Advice
SD	Standard Deviation
SGP	Small Grants Program
SIDS	Small Islands Developing States
SOPAC	South Pacific Islands Applied Geoscience Commission
SPREP	South Pacific Environmental Programme
SST	Sea Surface Temperature
TNC	The Nature Conservancy
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VLIZ	Vlaams Institute Voor de Zee
WCMC	World Conservation Monitoring Center
WWF	World Wildlife Fund

Abstract

The Global Environment Facility (GEF) allocates financial resources to developing states enabling them to meet their obligations under the Convention on Biological Diversity (CBD). In order to determine indicative allocations the GEF has developed the Resource Allocation Framework (RAF). The RAF is mainly based on the GBI_{bio}-index which ranks countries according to their biodiversity. Therefore, the GBI_{bio} utilizes a terrestrial and marine sub-index of biodiversity. However, these sub-indices contribute to 80 and 20 percent respectively to the calculation of the GBI_{bio}. This is explained by the lack of marine biodiversity data available to the GEF. The different weighting has been criticised at various GEF fora, especially by Small Islands Developing States (SIDS), to discriminate marine biodiversity. Hence, the goals of this study are a) to explore and test additional datasets of marine biodiversity on a new RAF with evenly weighted biodiversity sub-indices; b) to analyse the current and new RAF for their benefits and constraints and; c) to recommend possible lines of political lobbying. Altogether, three out of seven datasets were most suitable for inclusion into the RAF. Eventually, only two of these were incorporated and their impact on allocations for a sample set of countries analysed. Clear overall upward trends were visible for all states that already have a higher marine than terrestrial biodiversity sub-index score. Most SIDS fall under this category. Equally clear were decreasing allocations for all countries with no marine score. No conspicuous trend was identified for those countries with a marine score lower than the terrestrial score, having either increasing or decreasing allocations. The current RAF exhibits an easy, sound and transparent structure, yet, the methodology of the marine indicator is equivocal. Furthermore, it does not recognize that marine and terrestrial biodiversity are equally important, contradicts the precautionary principle, and discriminates various RAF eligible states with significant marine biodiversity. The proposed RAF recognizes these issues and complements the GBI_{bio} in the most meaningful way. Nevertheless, the marine sub-index still consists of fewer and in part less detailed indicators than the terrestrial sub-index. It is concluded that there exist marine datasets that can be readily incorporated as indicators for global marine biodiversity within the RAF. The incorporation process needs peer-reviewing though to determine the best methodology suitable for the RAF. Since global biodiversity data constantly improves, further scientific studies must be implemented to identify additional datasets. Results of such studies should be provided as soon as possible to the GEF Evaluation Office for the mid-term review in late 2008. Additionally, the CBD COP, GEF member states, and the NGO sector likewise must politically support the need for improvement of the RAF.

Chapter 1

Introduction

The Problem

The Global Environment Facility (GEF) is the single financial mechanism of the Convention on Biological Diversity (CBD) to fund global projects that serve the objectives of the CBD[1]. The GEF Secretariat has developed the Resource Allocation Framework (RAF) which is a nested set of formulas that determine the maximum potential allocation for each country to implement global biodiversity projects. One of the key pillars of the RAF is the GEF's Benefits Index for Biodiversity (GBI_{bio}) which measures and ranks countries according to their amount of and threat to biodiversity. The GBI_{bio} consists of two separated and differently weighted biodiversity sub-indices which, in turn, are comprised of indicators: The terrestrial sub-index contributes 4 indicators and 80 percent while the marine sub-index contributes 1 indicator and 20 percent to the calculation of the GBI_{bio}. This is explained by a lack of adequate marine biodiversity indicators and underlying data. Nevertheless, this uneven weighting of the GBI_{bio} is the central problem of this study since it discriminates marine biodiversity and disadvantages all RAF eligible countries with significant marine biodiversity.

Background

Before exploring solutions to this problem it is important to fully understand the wider context of the GBI_{bio}. Therefore, a scientific overview is given in section 2.1 of what biodiversity is in the first place and what the main threats are. Section 2.2 analyses the similarities and distinctiveness between the marine and terrestrial environment, describes the essential interlinkages between the two realms, and explains the reason for the lack of marine biodiversity data. Section 2.3 describes the role of the CBD, while section 2.4 introduces the

1 Conservation and sustainable use of biodiversity and equitable sharing of benefits from genetic resources.

GEF, it's relation to the CBD, and outlines the historical background, purpose, and rough structure of the RAF.

Chapter 3 provides the full structure of the RAF with special focus on the GBI_{bio} and it's composition of sub-indices and indicators.

Null hypothesis and objectives

Since the unequal weighting of the GBI_{bio} sub-indices is explained by a lack of marine biodiversity indicators, there exists the need to explore undiscovered datasets that may serve as such indicators. Therefore, this study states the null hypothesis that there exist no indicators for global marine biodiversity that can be incorporated into the RAF.

The objectives in particular are to

A) explore and incorporate new data on marine biodiversity, in order to propose a new RAF with a more equitable recognition of marine and terrestrial biodiversity;
B) compare advantages and disadvantages of the current RAF and the proposed RAF and;
C) analyse the policy implications of the current and proposed improved formula for the recipient and contributing countries and the big conservation Non Governmental Organisations (NGO). This provides the basis for some recommended courses of policy development and political lobbying.

Methodological approach

To develop new indicators for the marine sub-index, possible datasets are filtered according to a set of criteria and categorised into marine counterparts analogous to terrestrial indicators. From all datasets only three, the Ocean Biogeographic Information System (OBIS), the Marine Ecoregions Of the World (MEOW), and the threat and impact dataset by the National Center of Ecological Analysis and Synthesis (NCEAS) are proposed as being most suitable. The latter two are incorporated into a new proposed equally weighted GBI_{bio} and their impact on allocations is assessed. Therefore, old and new allocations are calculated and directly compared. However, the proposed RAF is only tested on a sample of countries, since not all data could be provided completely. Thus all values are tentative, yet the trend of allocations due to a new GBI_{bio} is expected to correctly reflect the true impact of new datasets. Additionally, theoretical arguments are explored that justify an equal weighting and the scope of a totally different GBI_{bio} is roughly addressed.

Chapter 2

Background

2.1 Introducing biodiversity

Biodiversity is the shortform for biological diversity or biotic diversity. Generally, diversity (lat.: *diversitas*; difference, variety) is regarded as a state, an attribute and a property and not as a resource or an entity (Grassle et al., 1990; DeLong, 1996). Solbrig (2000) explains that diversity refers to a system of objects as not being identical but different in one or more characteristics. Thus, the higher the number of different characteristics among objects within a system, the higher the diversity is. Taken as such diversity is an abstract concept (Gaston, 1996b). *Biological* or the prefix *bio*- (gr.: *bios*; life) denotes all living organisms, their assemblages, and their interactions amongst each other (Wilson, 1997). In fact, this all-embracing meaning of the term led to the point that biodiversity is sometimes referred to as the 'variety of all life' (Wilson, 1988). This chapter describes the development of biodiversity, strives to assess the concept of biodiversity from a purely scientific point of view, and illustrates hazards threatening biodiversity. The terms and concepts explained, provide the necessary scientific background knowledge for following sections.

2.1.1 Creation and origin of biodiversity

The first occurrences of *biological diversity* can be traced back to the works of Lovejoy (1980) as well as Norse and McManus (1980). The abbreviated term of *biodiversity* was coined by Walter G. Rosen at the 'National Forum on BioDiversity' which convened in Washington, D.C. in September 1986 (Takacs, 1996). The proceedings of the conference were spread subsequently by Wilson and Peters (1988). The number of scientific publications on biodiversity has increased exponentially from 1988 onwards to over 1000 items in 1993 and exceeded 3000 in 2005 (Harper and Hawksworth, 1994; Koricheva and Siipi, 2005). However, the concept of biodiversity is not new and has it's origins in taxonomy[2] and especially in ecological diversity (Heywood and Baste, 1995). Ecological diversity is a central theme in ecology and aims to explain the complex and inextricable interactions between populations, communities and their environment (Magurran, 1988; Odum, 1963; Pielou, 1975).

There exists debate if biodiversity includes ecological diversity or vice versa (DeLong, 1996; Margalef, 1997; see section 2.1.2 for a more comprehensive explanation). Currently, the predominant notion within the scientific literature is that biodiversity has absorbed ecological diversity (Angermeier and Karr, 1994; Gaston and Spicer, 2004; May, 1994).

2.1.2 Definition and characterisation of biodiversity

Definition

Although the roots of *biodiversity* are scientific, it received a broad interdisciplinary and transdisciplinary acknowledgement since it's inception in the 1980's (Gaston and Spicer, 2004). This variety causes great confusion and even in science the term is not used consistently (Krishnamurthy, 2003). Hence, there is the need to unequivocally define and partition biodiversity into it's components (Lee, 2005; Sarkar, 2005). Nevertheless, a complete assessment is not regarded as possible (Takacs, 1996). For example, although more than twenty years have passed since the inception of biodiversity, a plethora of definitions on biodiversity still exists (see McAllister, 1991 and Takacs, 1996 for review). Yet none has been ubiquitously agreed upon (Koricheva and Siipi, 2005)[3]. These authors explain that scientists of different disciplines create definitions that suit their objectives without alignment to other fields.

A common feature though of most biodiversity definitions is the recognition of a hierarchical structure of three interlinked levels (Christie et al. 2004; Norse, 1993)[4]. One of the most widely cited definitions of biodiversity is provided by the Convention on Biological Diversity (CBD) (Glowka et al., 1994). It describes biodiversity at the a) genetic level (within species), b) species level and c) ecosystem level.

For this study a more extensive definition is adopted, provided by Heywood and Baste (1995)

2 Taxonomy is the approach to divide the variety of plants, animals and microorganisms into recognizable groups.

3 Trying to find an unifying concept, DeLong (1996) reviewed 85 definitions of biodiversity.

4 Fewer studies mention less (Thomas, 1990) or more levels (Williamson, 1997).

which reveals that each level has it's own hierarchical structure (see also table 1):

> Biodiversity is [...] the total diversity and variability of living things and of the systems of which they are a part. This covers the total range of variation in and variability among systems and organisms, at the bioregional, landscape, ecosystem and habitat levels, at the various organismal levels down to species, populations and individuals, and at the level of the population and genes. It also covers the structural and functional relationships within and between these different levels of organization.

Table 1: Hierarchical Structure of Biodiversity Components

Genetic diversity	Taxonomic (Organismal) diversity	Ecological diversity
Populations	Kingdoms	Biomes
Individuals	Phyla	Bioregions
Chromosomes	Families	Landscapes
Genes	Genera	Ecosystems
Nucleotides	Species	Habitats
	Subspecies	Niche
	Populations	Populations
	Individuals	

Source: After Heywood and Baste (1995).

Characterisation

Treating biodiversity only as an abstract concept as discussed above raises questions about it's applicability. Hence, characterisation includes moving away from the abstractness and turning to the quantification of it's components. It is thus possible to analyse how diversity may have changed over time or to compare different systems according to their respective range of diversity (Williams and Humphries, 1996).

At each level, diversity of different components can be measured. These measures are essentially derived from ecological diversity methods precedent to the inception of biodiversity which have now been incorporated. It is theoretically possible to measure diversity by an infinite number of ways, but most of these measures include three essential elements (Odum, 1971): The number of entities (richness), a measure of abundance (evenness) and a combination of both (diversity index). Originally, these measures were basically applied to species. For example, two systems with 10 species and 100 individuals have the same richness.

But by taking evenness into consideration a different picture emerges. For instance, in one system each species is represented by 10 individuals. In the other system one species comprises 91 individuals and all other species contribute only 1 individual. In this example, the first system is more diverse since the abundances are more even. Diversity indices, such as the Shannon or Simpson index, compare both, richness and evenness, in one single number (Magurran, 1988). It is generally assumed that diversity, measured in this way, is positively correlated to a system's resistance to change (Odum, 1963; Baur and Schmid, 1996; Duffy and Stachowicz, 2006) and negatively correlated to disturbances such as pollution (Magurran, 1988). Although there exists a wealth of other more complex measures of diversity than stated above, many measures of diversity within the concept of biodiversity often only consider richness (see below) (Erwin, 1991).

What follows is a short description of each level with focus on the most widely used measures.

Genetic diversity

In the broadest sense all levels of biodiversity and their components are essentially derived from genetic diversity, this is the variation of the genetic make-up of organisms (Solbrig, 1996). Mallet (1996) further explains that genes express proteins that specify physiology, development, appearance, and behaviour of organisms and thus may form different taxonomic units (e.g. populations and species). These provide the building blocks for ecological systems, such as ecosystems. Hawksworth and Kalin-Arroyo (1995) support this concept, however, state that in the absence of detailed data on most species and populations, it is impractical to measure genetic diversity at anything higher than the species level. Thus, genetic differences are generally assessed among individuals (within populations) or among populations (within species) (Gray, 1997).

The methods distinguishing genetic variety can be grouped into direct and indirect measures (Bisby, 1995). Direct measures identify the variation of nucleotide sequences (A, T, C, G) or the number and frequency of different genes and proteins. Indirect measures analyse phenotypic features that indicate underlying genetic patterns (Gaston and Spicer, 2004). Bisby (1995) emphasises that even taxonomic diversity functions as a proxy for genetic diversity. Thus, genetic variety increases with higher levels of taxonomic diversity (e.g. phyla).

Taxonomic diversity

Basically, taxonomic diversity includes richness of those entities that are recognized by taxonomic or biosystematic classification (table 1) (Bisby, 1995). However, Wilson (1992) denotes the species as the integral unit of biodiversity. Brooks (2002) supports this argument since individuals of one species exhibit similar geographical and ecological preferences. Hence, it can be assumed that individuals of one species can be used to recolonize a different area where that particular species used to occur and function in the same way as their predecessors. This results in taxonomic knowledge being disproportionately biased towards species richness (Millennium Ecosystem Assessment, 2005). This bias is further affirmed by authors designating species richness as maybe the most important and straightforward measure of biodiversity (WCMC, 1994a; Caldecott et al., 1996). The main advantage of species richness is that data is sufficiently available on a global basis. Additionally it is easy to assess and there exists a general understanding of it's meaning (WCMC, 1994a; Gaston, 1996a). Nevertheless, species richness has also been subject to critical scrutiny: Applied alone it is misleading as a proxy for genetic, overall taxonomic and ecological diversity (Carleton Ray, 1988; Purvis and Hector, 2000). Also does it not recognize that species are not equal in their relative contribution to biodiversity (Wheeler, 1995). In fact many authors have proclaimed that *taxic* diversity, i.e. richness of higher taxonomic levels, is incorporated as a measure of biodiversity in order to reflect evolutionary distinctiveness (Harper and Hawksworth, 1994; Drake et al, 1996; Christie et al., 2004). Here, richness of phyla (phyletic diversity) is regarded being the most significant measure (WCMC, 2000). Hence, a system with four species from 2 phyla is less diverse than a comparable system with four species from 4 phyla (Hawksworth and Kalin-Arroyo, 1995). Analysing phyletic diversity besides species richness becomes all the more important recognizing that various species definitions exist that make the species unit arbitrary (Veron, 1995).

Ecological diversity

Within the concept of biodiversity, ecological diversity primarily deals with species abundances, functional diversity, and diversity of ecological systems (see table 1) which emerge from the combination of all species functions (Bisby, 1995). As already indicated above important conclusions about a system's integrity can be inferred by analysing species abundances (Angermeier and Karr, 1994). The more disturbed or threatened a system is, the less balanced are species abundances and few opportunist species tend to dominate the rest

(Margalef, 1997). Various authors purport this to be a much more meaningful measure of diversity compared to species richness (Margalef, 1994; Longhurst, 2006, Naeem, 2006). Other scientists argue that functional diversity is also an important measure of ecological diversity (Steele, 1991b) regarding the functioning of whole systems (Thorne-Miller, 1999). On the one hand, functional diversity can be regarded as the richness of species population interactions with the biotic environment categorised into predation, competition, mutualism, and parasitism (Kawanabe, 1996). For instance, functional diversity of predation can be assessed by simply counting the richness of trophic links or trophic groups (species with similar prey or predators) within a system's food web (Martinez, 1996). On the other hand, there exist various species population interactions with the abiotic environment, such as the flow of water, energy, and materials (ecological processes) (Mooney et al., 1995a). Dif ferent ecological systems group biotic and abiotic interactions along with other features into larger identifiable units (Bisby, 1995). The most frequently used ecological systems are communities (purely biotic interactions) and ecosystems (biotic and abiotic interactions). Classifications of ecological systems on a global scale follow the same dichotomy, however, apply different criteria. Although many terms for ecological systems are used interchangeably some concepts predominate. *Biogeographic regions* are delineated primarily by clusters of similar species or rates of endemism of their component species and thus contain unique species composition (Briggs, 1974). Another approach tries to take biogeography and use aspects of the physical environment to further delineate ecological systems. Therefore, geographical features such as mountains, climatic influences such as heat or precipitation, and other environmental factors such as nutrient availability and salinity are taken into consideration (Udvardy, 1975; Bailey, 1998; Longhurst 2006; Spalding et al., 2006). Biogeographical and physical criteria can be applied on different scales and yield a nested classification of ecological systems which are listed in decreasing scale/increasing resolution: *Realms, Provinces,* and *Ecoregions.* There exists debate though if ecological systems that contain abiotic aspects should be excluded from the concept of biodiversity since they contain abiotic interactions and processes (DeLong, 1996). Lovejoy (1994) proposes to include these systems since living organisms are responsible for such abiotic processes.

2.1.3 Threats to biodiversity

Despite solitary opinions that there exists no imminent danger that threatens life on Earth (Solbrig, 1996) the prevailing scientific opinion states the opposite and that this danger emanates from anthropogenic actions (Grassle et al., 1990, Thorne-Miller, 1999, Secretariat of the CBD, 2006). Market and policy failures are considered the main underlying (indirect) causes of biodiversity loss such as a) ignorance over public consequences of private actions; b) legal arrangements and privileges that encourage people to ignore public consequences of their actions (e.g. perverse incentives and open access resources) and; c) government policy that fails to address such externalities (Perrings, 1995; SBSTTA, 1996). McNeely et al. (1995) describe conversion from one type of community to another and modification of conditions within a biological community as the two major forms of human impact. Heywood and Baste (1995) further distinguish these forms and state that overexploitation, habitat fragmentation and degradation, introduction of alien invasive species, pollution, and global climate change are the major direct human impacts on the environment. Such human influences induced an artificial extinction rate which exceeds the natural extinction rate by a factor in the thousands (Barbault and Sastrapradja, 1995). This is roughly equivalent to a loss of approximately 30,000 species annually (Myers, 1993). If this loss does not slow down up to 40 percent of the world's present species are assumed to go extinct within the next 50 years (WCMC, 1994b). But this artificial extinction rate is likely to grow even larger in the future (Millennium Ecosystem Assessment, 2005).

2.2 Comparing Sea and Land

2.2.1 Similarities, differences and interlinkages

Similarities

Information on similar characteristics between the marine and the terrestrial environment is sparse. Nevertheless, Caldecott et al. (1996) mention five general rules of biodiversity patterns that can be found in both environments: a) warmer areas support more species than colder areas; b) less seasonal areas contain more species than very seasonal ones; c) larger areas contain more species than smaller areas; d) geographically isolated areas contain more endemic species than contiguous areas and; e) the longer an area was isolated the higher the number of endemic species. Gaston (2000) summarises points a) to c) by observing the same, though less pronounced, latitudinal gradient in the sea, as found on land. Similarly, it has been recognised that peak diversity can be found on mid altitudes between 500 and 1000 m on land and at mid depths at around 1000 m in the sea (Gaston and Williams, 1996).

In both environments it can be as well observed that increasing richness of primary producers

enhances productivity (Duarte, 2000; Naeem et al., 1994).
Additionally, the marine as well as the terrestrial environment, face the same categories of threat as described in section 2.1.3. (Sebens, 1994; Naeem, 2006).

Differences

The Earth is covered to 70.8 percent ($362x10^6$ km^2) by oceans which account for 99 percent ($1.370x10^7$ km^3) of the volume that is known to sustain life (de Fontaubert, 1996; WCMC, 1996; UNEP 2006).
The most fundamental difference between marine and terrestrial systems is the prevalence of the aquatic medium in which all marine organisms live (Carr et al., 2003). The properties of water have important physical and biological implications. The density of seawater is 854 times larger and it's viscosity is 60 times greater than that of air which involves physical dispersion, buoyancy and a slower sinking rate of particles from the surface (Steele, 1985; Norse, 1993). This implies that the whole volume of the oceans may support life and allows the existence of many organisms that spend much or all of their life within the water column. A complete aerial existence of species is not observed on land though (Thorne-Miller, 1999). Also greater influences by temperature and salinity may create stratification (density boundaries) which separates the watercolumn and allows distinct biotas to live at different depths (Norse, 1993). Density boundaries belong to the predominant type of boundaries within the oceans. Due to variable energy and fluxes they are less pronounced and more mobile than, for example, geographical boundaries on land (Gray, 1997).
Compared to the terrestrial realm the marine realm is much more light-limited. Only the surface layers are reached and warmed by sun-light. Hence, most primary producers may only exist at the top layers and the biota in deeper oceans depend on the productivity at the surface. Except for seagrasses and kelp forests which constitute a minority, most primary producers in the sea are small, dynamic, and with high turnover rates, unlike terrestrial producers that tend to be larger, older and sessile (Steele, 1991b; Committee on Biological Diversity in Marine Systems, 1995; Groombridge and Jenkins, 2002). Consequently, complex physical structures created by vegetation on land, except for reefs and kelp forests, seem to be not existent within the oceans (Briggs, 1994). However, the large area, three dimensionality of the sea, stratification of the water column, and existence of microhabitats in the deep sea (Grassle, 1989; May, 1994) may compensate for the missing biological structure that supports highly diverse communities on land (Williamson, 1997; Thorne-Miller, 1999).

Yet another profound effect of the fluid nature of the seas is the existence of currents. These enable lateral transport of materials and organisms whereby ocean systems and communities tend to be more open and even distant regions are assumed to be interconnected (Lasserre, 1996; Carr et al., 2003).

Due to the vastness and huge heat capacity of the oceans the magnitude of environmental fluctuations is considered lower in the sea than on land. This damps and reduces the impact of short-term, small scale environmental perturbations but may increase the effect of long-term, large scale environmental changes (Underwood, 2005).

Even though both environments face principally the same categories of threat, different threats vary in their impact on the respective environment. For instance, overexploitation is the primary threat within the sea which may lead to cascading effects on complex food webs while habitat destruction and fragmentation are most severe on land (Bryant et al., 1998; Balmford and Bond, 2005). Mooney et al. (1995b) mention submarine acoustic pollution as being detrimental for social and migratory behaviour of marine mammals and fish, though noise pollution has found little attention on land.

Interlinkages

Although marine and terrestrial ecosystems differ in various aspects they are also strongly interlinked (Stergiou and Browman, 2005b). Rivers constitute one of the main linkages by providing migration routes for diadromous animals (Angermeier and Karr, 1994; Roberts et al., 2002) and downward transport of materials (Hair, 1996). Other connections are provided by air-water interactions as dust blown from land (Mooney et al., 1995b) or through long-lasting geochemical cycles (Snelgrove, 1999a). Norse (1993) exemplifies that the oceans turned salty due to constant input of salts through dust, subsea volcanos and eroding soils via rivers. Hence, marine systems are biological sinks for the terrestrial environment. Because of these reasons Steele (1991a) purports that management and conservation efforts must not be separated. Rather a holistic and integrative approach that adequately represents these linkages is necessary.

2.2.2 Marine ignorance

Researchers agree that scientific knowledge about marine biodiversity is minimal compared with that of land (Gaston and Williams, 1996; Raghukumar and Anil, 2003; Myers and Ottensmeyer, 2005; Duffy and Stachowicz, 2006). For example, virtually nothing is known about functions of many commercial marine species within their community or ecosystem and the impact upon their removal (Earle, 1991). Although there exist general difficulties estimating the total number of global species within one to two orders of magnitude, the number of described marine species (250,000) is much lower than that of described terrestrial species (1,5 million) (Groombridge and Jenkins, 2002). The number of annually described terrestrial species (15,000) exceeds newly described marine species (1,500) by a factor of ten, despite various unknown areas such as the deep sea (Bouchet, 2006). Likewise, the number of articles on terrestrial ecology still exceeds those on marine ecology by a factor of seven (Stergiou and Browman, 2005a). The main reason for this lack of knowledge is that the marine environment remains inaccessible to humans without expensive specialised equipment (WCMC, 2000). Low concentrations of dissolved oxygen, lack of light, low temperatures, and high pressures make the sea and especially the deep sea an hostile environment to sampling efforts (Briggs, 1974; Norse, 1993). Sampling difficulties imply that expensive ships, submersibles, and remote sampling gear are necessary to analyse the area below the shelf, which covers 65.5 percent of the Earth's surface (Snelgrove, 1999a). Satellites may not provide information about the watercolumn (Longhurst, 2006). These challenges are further enhanced by monitoring difficulties of the uninterrupted and internally moving nature of the sea (Krishnamurthy, 2003) and that many marine species are subject to large ontogenetic changes, i.e. larvae may differ substantially from adults (WCMC, 1994b). Hence, the knowledge of marine biodiversity remains well behind that of terrestrial systems (Clarke and Crame, 1997).

2.3 The Convention on Biological Diversity

The Convention on Biological Diversity (CBD) was negotiated in five meetings of the United Nations Environment Programme (UNEP) Ad Hoc Working Group of Experts on Biological Diversity from 1989 onwards (Whiting, 1991; de Fontaubert, 1996). The CBD, along with the Framework Convention on Climate Change (FCCC) and the Convention to Combat Desertification (CCD), was opened for signature at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992[5] and entered into force on 29 December 1993 (Thomas, 1990; McConnell, 1996).

The primary objectives of the CBD are a) the conservation of biological diversity; b) the

5 The 1992 United Nations Conference on Environment and Development in Rio is also referred to as Earth Summit or Rio Summit. Agenda 21 has also been adopted in Rio.

sustainable use of its components and; c) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. These objectives are specified in Articles 6 to 20 which lay down legally binding obligations for the member states. These articles include provisions on, for example, creation of national plans, strategies and programmes to fulfil the CBD's objectives (Article 6), or *in situ* measures to protect biological diversity (Article 8). In addition to these instructions Article 23 establishes the Conference of the Parties (COP) which meets periodically. The main tasks of the COP are to review the implementation of the CBD, to steer it's development as well as to provide guidance to the financial mechanism (see below) (Secretariat of the Convention on Biological Diversity, 2005). The COP has inducted seven thematic work programmes addressing various distinct environments over the globe. Neither within the convention's text, nor within COP decisions or within the thematic work programmes a distinction is made between the importance of the marine or terrestrial environment (Thorne-Miller, 1999). Antecedent to the inception of the marine and coastal programme of work at the fourth COP meeting (COP 4) in 1998[6], global consensus on the importance of marine and coastal biological diversity (Jakarta Ministerial Statement, 1994) led to the marine programme of action, also known as the 'Jakarta Mandate', which has been adopted at COP 2 in 1994[7].

The precautionary principle is one of the guiding principles of the CBD and recognized within the preamble of the convention text.

The special conditions and needs of Small Island Developing States (SIDS) are also conveyed in the preamble of the CBD and received constant adherence since COP 2[8]. As well COP 8 adopted the island program of work[9]. Important implications of these decisions including the Precautionary Principle will be further discussed in section 6.2.

Article 21 of the CBD creates a financial mechanism for the disbursement of financial resources to developing countries for the purpose of the CBD. Article 39 designates the Global Environment Facility (GEF) as the interim financial mechanism.

6 UNEP/CBD/COP/4/5, Annex
7 UNEP/CBD/COP/2/10
8 UNEP/CBD/COP/2/10, para. 8(d)
9 UNEP/CBD/COP/8/1

2.4 The Global Environment Facility

Initially, the GEF was set up in 1991 as a collaborative management arrangement between the United Nations Development Programme (UNDP), UNEP, and the World Bank, providing funds to combat global environmental problems for a pilot phase of 3 years (Bagla, 1998). Developed (donor) countries provide financial resources that are disbursed among developing (recipient) states. The initiative to create the GEF was based on a proposal by France, which was backed by Germany (Sjöberg, 1994). Tension between different GEF constituencies, dissatisfaction on GEF policies and the possibility to serve as a financial mechanism for the Rio conventions led to the 'Restructured Global Environment Facility' in 1994 (Sjöberg, 1999). UNDP, UNEP, and the World Bank were designated as implementing agencies supporting countries in developing and implementing projects. The GEF governance system balances a double majority that respects the one-country, one vote principle and the relative financial contribution of constituencies (Boisson de Chazournes, 2005). According to the GEF's founding document 'Instrument for the Establishment of the Restructured Global Environment Facility' (hereinafter the Instrument), the purpose of the GEF is to:

> operate, on the basis of collaboration and partnership among the Implementing Agencies, as a mechanism for international cooperation for the purpose of providing new and additional grant and concessional funding to meet the agreed incremental costs of measures to achieve agreed global environmental benefits (GEF, 2004).

Today the GEF disburses funds within a replenishment period of four years in six focal areas[10] under the auspices of the respective international agreements.

The Assembly comprises all 177 member states individually and reviews and evaluates the general policies and operation of the GEF. The Council represents it's developing and developed member countries in constituencies in a balanced way and according to their contribution. It is responsible for adopting and evaluating operational policies and programmes for the GEF. The Council is served by a functionally independent Secretariat which coordinates the implementation of GEF activities and carries out the decisions of the Council (Namasta et al., 2005). As stated in Article 21 of the CBD the GEF functions under the authority and guidance of the COP. The COP determines “the policy, strategy, programme priorities and eligibility criteria for access to and utilization of financial resources” as laid

10 The focal areas and responsible international agreements (in brackets) are: Biodiversity (CBD), Climate Change (FCCC), International Waters (no convention), Land Degradation (CCD), Ozone Depletion (Montreal Protocol), and Persistent Organic Pollutants (Stockholm Convention).

down in the Memorandum of Understanding between the secretariats of the CBD and the GEF[11]. Similarly the Instrument (GEF, 2004) states that GEF resources used for purposes of the conventions must be in conformity with the policies, program priorities and eligibility criteria decided by the COP. The Council has the right to set specific priorities with regard to direct utilization of GEF funds that do or do not refer to any agreement (Dolzer, 1998)[12].

Resource Allocation Framework (RAF)

At a special meeting in 2005 the Council[13] agreed to implement the RAF for the fourth replenishment period (GEF-4) which will be evaluated at the mid-term review in November/December 2008[14]. The overall purpose of the RAF is to determine maximum country allocations for a replenishment period, currently for the biodiversity and the climate change focal area. Before inception of the RAF, funds were disbursed on a purely project-by-project basis. The origins of the RAF can be traced back to the twentieth Council meeting in 2002[15] where constituencies called for a performance-based allocation system (PBA)[16]. Such a framework's purpose is to enhance the effectiveness and transparency of the application of resources. Therefore, factors corresponding to the institution's tenet are explicitely applied[17]. The RAF was primarily created due to a request of the United States, being one of the largest donors (Clémençon, 2006) and due to the general notion that demand for GEF funds exceeds supply[18]. The RAF aligns itself with PBAs of other institutions[19] by including two basic elements[20]: An index of a country's "performance" combined with an index of a country's "need". The GEF Performance Index (GPI) measures a country's capacity to deliver potential global environmental benefits based on its current and past performances. The GEF Benefits Index (GBI) measures a country's potential to deliver global environmental benefits for the biodiversity (GBI_{bio}) and climate change (GBI_{CC}) focal areas[21]. The "need"-aspect of the GBI_{bio} is demonstrated by a country's amount of and threat to biodiversity. It is therefore calculated

11 GEF/C.5/8
12 see also the Instrument, para. 20(e)
13 GEF/C.26/CRP.1
14 GEF/R.4/32, para. 14
15 GEF/C.20/4, para. 18/19 and Annex B; but see as well: GEF/R.3/38 para. 4 and 19.
16 The re-naming into Resource Allocation Framework took place at a GEF Seminar convened in Paris, 2004.
17 GEF/C.22/11, para. 23
18 Ibid. para. 16
19 e.g. by the International Development Association (IDA) of the World Bank, International Fund for Agricultural and Development (IFAD), and Asian Development Bank (ADB).
20 GEF/C.24/8, para. 38
21 GEF/C.26/2/Rev.1 para. 4

by two sub-indices which in turn are based on different indicators: The terrestrial sub-index represents a country's terrestrial biodiversity and threat to terrestrial biodiversity and is based on four indicators. The marine sub-index reflects a country's marine biodiversity (see chapter 3 for full explanation). Due to a lack of detailed marine sub-national data only one indicator is applied to the marine sub-index. Therefore, the terrestrial sub-index outweighs the marine sub-index by 80 percent to 20 percent.

This has been criticised by various GEF member states at the third Assembly in 2006[22] and at country consultations[23], in particular by SIDS, as a lack of importance given to marine biodiversity, to adversely impact allocations and to discriminate SIDS status. Concerns about the GBI_{bio} and the conflict of the RAF with the spirit of the conventions have also been raised by several Council members[24,25].

Thus, there exists the urgent need to explore possibilities to incorporate additional indicators of marine biodiversity, in order to justify a more equitable weighting.

22 Joint Summary of the Chairs, Meeting of the GEF Assembly, August 29-30, 2006, para. 26 and 41.
23 GEF/C.30/11, para. 12
24 Joint Summary of the Chairs, Meeting of the GEF Council, June 3-8, 2005, Annex A, para. 116
25 Joint Summary of the Chairs, Meeting of the GEF Council, June 6-9, 2006, para. 97.

Chapter 3

Resource Allocation Framework

In order to provide the necessary methodological background for this study, it is important to outline the construction of the current RAF. Special emphasis is attributed to the construction of the GBI_{bio} since this part will be modified most strongly in subsequent chapters.

3.1 Methodology of the RAF for biodiversity

The RAF for the biodiversity focal area calculates a country's allocation within 6 main steps[26]:

1. Indicators and the calculation of the GBI_{bio}

A set of 5 indicators of biodiversity, divided into 4 indicators for a terrestrial part and 1 for a marine part, comprise the basis of the current GBI_{bio}. Indicators of the terrestrial part calculate a terrestrial sub-index, while the marine indicator already constitutes the marine sub-index. Both sub-indices finally calculate the GBI_{bio} (Figure 1).

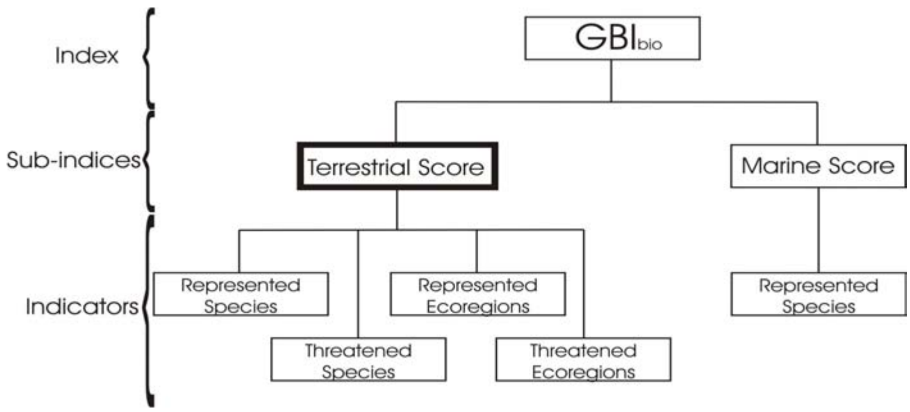


Fig. 1: Simplified structure of the relationship between RAF indicators, sub-indices, and the $GBI_{bio.}$ The larger contribution of the terrestrial over the marine sub-index calculating the GBI_{bio} has been indicated by a thicker frame. For reasons of simplicity the following components have been excluded: Weightings of indicators and role of Country Ecoregion Components (CEC). Further explanation in text.

26 GEF/C.27/Inf.8/Rev.1

Terrestrial indicators and sub-index

In the first step the terrestrial ecoregions by Olson et al. (2001), representing distinct biotas around the world, are divided along country borders into Country Ecoregion Components (CEC). 867 global terrestrial ecoregions thus divide into approximately 1,700 CECs.

In the second step each CEC is scored according to four indicators:

Represented Species

Species habitat range maps, provided by the World Conservation Union (IUCN) and World Conservation Monitoring Centre (WCMC), are overlaid with CECs. The total habitat area of one species receives a theoretical score of 1. This score is divided proportionally according to the habitat range found within each CEC. For instance, the Sulawesi Flying Fox, *Acerodon celebensis*, can be found on whole Sulawesi. However, Sulawesi is divided into two terrestrial ecoregions. 56 percent of the habitat *of A. celebensis* lies within the Lowland Rainforest ecoregion of Sulawesi, and 44 percent of the habitat can be found within the Montane Rainforest ecoregion (see Figure 2). Thus the two CECs[27] receive theoretical scores of 0.56 and 0.44 for that species respectively. For each CEC the species scores are summed for all species included in the RAF[28] and normalized to 10,000. The final CEC score for represented species is the unweighted average of all normalized scores of the seven groups.

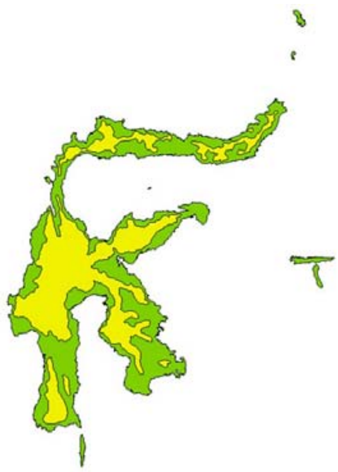


Fig. 2: Terrestrial species range map of *Acerodon celebensis* across Sulawesi and adjacent islands. Ochre: *A. celebensis* habitat within the Sulawesi Montane Rainforest ecoregion. Green: *A. celebensis* habitat within the Sulawesi Lowland Rainforest ecoregion. The species range map was kindly provided by the Development Research Group of the World Bank.

27 In this example CEC equals full ecoregion since both ecoregions belong to Indonesia.

28 The RAF includes approximately 11,000 terrestrial species, divided into seven taxonomic groups: Mammals, birds, amphibians, reptiles, freshwater fish, flowering plants and non-flowering plants.

Threatened Species

The calculation of the threatened species score is identical with the computation of the represented species score, with two adjustments. Firstly, only data for mammals, birds and amphibians are used. Secondly, threatened species fall into one of six categories, classified by IUCN[29]. Instead of 1, threat scores applied to these six categories are used for species and divided according to the habitat share in each CEC[30]. These scores are again summed, normalized and averaged for the final threatened species score.

Represented Ecoregions

The terrestrial ecoregions developed by the World Wildlife Fund (WWF) provide the most detailed resolution of ecological system diversity with a complete global coverage (Olson and Dinerstein, 2002). Similarly to precedent indicators each ecoregion receives a score of 1 which is divided proportionally according to the ecoregion share, i.e. CEC area
, within each country.

Threatened Ecoregions

Analogue to the threatened species indicator, each ecoregion receives a threat score provided by WWF classification[31]. This score is also divided according to the ecoregion share within each country (CEC).

In the third step, a score for each CEC is calculated from the four indicators (see above):

$$(1)\quad \textbf{\textit{CEC Score}} = \textbf{0.55}\cdot \textbf{\textit{Represented Species}} + \textbf{0.2}\cdot \textbf{\textit{Threatened Species}} + \textbf{0.15}\cdot \textbf{\textit{Represented Ecoregions}} + \textbf{0.1}\cdot \textbf{\textit{Threatened Ecoregions}}$$

Finally, the terrestrial sub-index is determined by creating the sum of all terrestrial CEC scores for a nation.

Marine indicator and sub-index

The marine score is only determined by a simplified version of the terrestrial represented species indicator since detailed sub-national data on precise species ranges, threatened species, and ecoregions in general was not available. The global information system FishBase provides data on the presence of approximately 15,000 commercial fish species in Exclusive

29 Extinct in the wild, critically endangered, endangered, vulnerable, near threatened, and least concern.
30 10, 10, 6.7, 1, 0, and 0
31 4 (highest threat), 2, and 1 (lowest threat).

Economic Zones (EEZ). Species range maps, similar to the terrestrial represented species indicator, are inferred by assuming that a fish species occurs in the whole EEZ where it was recorded. Thus it's range is delineated by national maritime boundaries. For example, the EEZ of Mauritius accounts for 36 percent of the habitat range of the Cockatoo waspfish, *Ablabys taenianotus*, and two Indian EEZs (India plus Andaman and Nicobar Islands) account for 64 percent of the habitat range (Fig.3). Theoretically, Mauritius receives a score of 0.36 and India a score of 0.64 for *A. taenianotus*. Subsequently, scores for all species within an EEZ are summed and normalized.

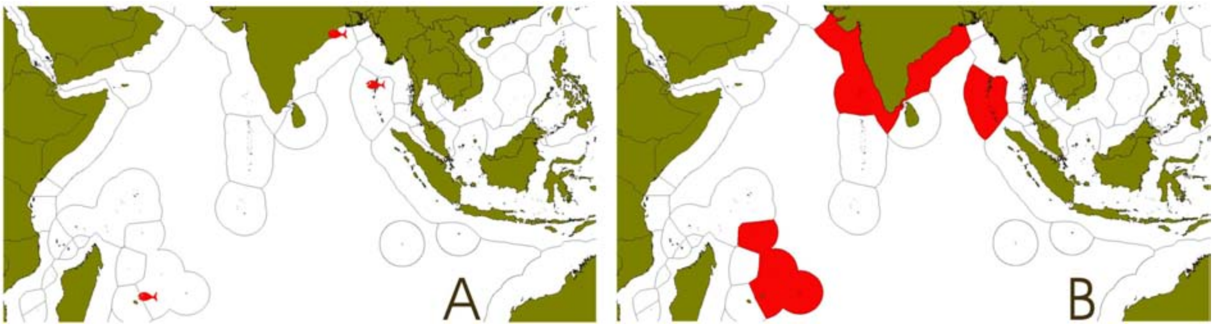


Fig. 3: Marine species locations and range map of *Ablabys taenianotus*. Black lines indicate Exclusive Economic Zones provided by Deckers and Vanden Berghe (2007). A) Red objects represent species recordings of *A. taenianotus* provided by FishBase (Pauly and Froese, 2007). B) Red areas: assumed species ranges (total EEZs) for incorporation into the RAF.

Calculation of the GBI_{bio}

The GBI_{bio} measures a country's potential to generate global environmental benefits for biodiversity and reflects selected components of a country's biodiversity and threat to these components. It is the weighted average of a country's score for the marine and terrestrial sub-indices. The terrestrial score is weighed by 80 percent and the marine score by 20 percent:

$$(2)\quad \textit{GEF Benefits Index for Biodiversity} = 0.8 \cdot \textit{Terrestrial Score} + 0.2 \cdot \textit{Marine Score}$$

All following steps are illustrated in Figure 4.

2. Calculation of Country Score

The Country Score is the weighted product of the GBI_{bio} and the GPI[32].

$$(3)\quad \textit{Country score} = GBI_{bio}^{\,0.8} \cdot GPI^{\,1}$$

32 The higher exponent of the GPI compared to the GBI_{bio} increases the influence of a country's performance on a country score.

As already indicated the GPI measures a country's potential for the successful implementation of GEF projects. It is calculated for each country as the weighted average of three indicators: a) the project portfolio performance indicator (PPI); b) the country's environmental policy and institutional assessment indicator (CEPIA) and; c) the broad framework indicator (BFI) including assessment of public performance:

$$(4)\quad \textbf{\textit{GEF Performance Index}} = \mathbf{0.1} \cdot \textbf{\textit{PPI}} + \mathbf{0.7} \cdot \textbf{\textit{CEPIA}} + \mathbf{0.2} \cdot \textbf{\textit{BFI}}$$

The last two indicators are derived from the World Bank's Country Policy and Institutional Assessment (CPIA). The CPIA rates the capacity of member countries to support poverty reduction, sustainable development, and effective use of development assistance and can be seen as the PBA of the World Bank. It is implemented annually for middle-income countries that are financed by the International Bank for Reconstruction and Development (IBRD) and for low-income countries supported by the International Development Association (IDA). CPIA data for IDA countries has been fully disclosed, however, no CPIA data for IBRD are subject to public disclosure within the near future[33]. Three-quarters of GEF resources go to non-IDA countries though[34]. If either the CEPIA or the BFI are missing, the weightings of the remaining indicators are proportionally increased. If both, the CEPIA and the BFI, are missing then the Rural Sector Assessment Indicator by IFAD is used as a substitute. If only the PPI is available, the GPI is not calculated and a country is allocated in the group (see step 6).

3. Calculation of Country Share

The country share is determined by dividing the country score by the sum of country scores for all countries:

$$(5)\quad \textbf{\textit{Country Share}} = \frac{\textbf{\textit{Country Score}}}{\textbf{Sum}\ \textbf{\textit{of Country Scores for all countries}}}$$

4. Country Preliminary Allocations

A preliminary allocation is calculated by the product of a country's country share and the total GEF resources available under the biodiversity focal area subtracted with 5 percent to support the Small Grants Program (SGP) and another 5 percent to support global projects[35]:

$$(6)\quad \textbf{\textit{Country Preliminary Allocation}} = \textbf{\textit{Country Share}} \cdot \textbf{\textit{Total RAF resources}}$$

33 GEF/C.25/Inf.10, Annex 2, para. 4.

34 GEF/C.23/7 para. 17

35 The total amount available for the GEF biodiversity focal area is US$ 1,000 million. After subtraction the total amount available for the RAF for biodiversity is US$ 900 million.

5. Allocations adjusted to ceilings and floors

No country will be allocated more than 10 percent of the total resources for biodiversity for a replenishment period and no country will be allocated less than US$ 1 million.

6. Individual and Group Allocations

The highest-ranked countries whose cumulative adjusted allocations equal 75 percent of all resources receive individual allocations equal to allocations calculated until step 5. The remaining countries are placed in a group. They do not receive individual allocations but have collective access to the group allocation which are the total RAF resources under biodiversity minus all individual allocations[36].

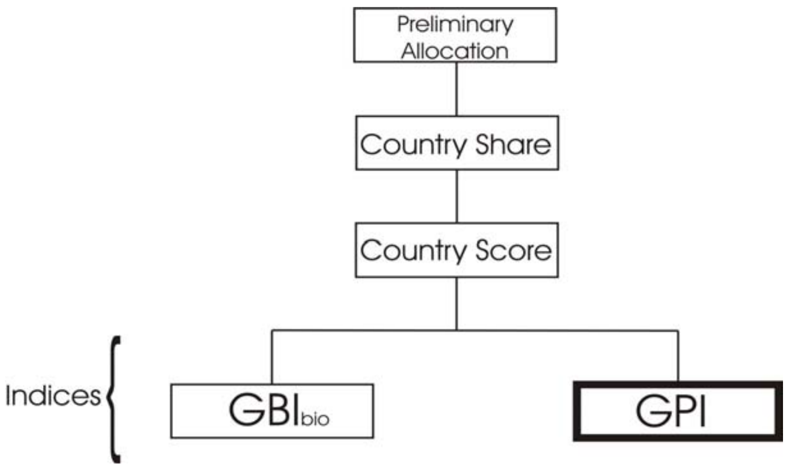


Fig. 4: Simplified illustration of the RAF from indices to preliminary allocation for the biodiversity focal area. Higher contribution of the GPI over the GBI_{bio} has been indicated by a thicker frame. For reasons of simplicity the following components have been excluded: Detailed illustration of the GPI and higher elements, adjustment to ceilings and floors (step 5), determination of individual and group allocations (step 6). Further explanations in text.

36 Currently, the Group consists of 93 countries with a collective access to US$ 146.8 million. Each group country can access up to US$ 3.5 million in GEF-4.

Chapter 4

Material and Methods

For complementing the current GBI_{bio} in the most meaningful and illustrative way, it has been decided to classify and incorporate new marine datasets as counterparts to the terrestrial indicators (see section 3.1). Thus, the calculation of new allocations is orientated as much as possible on the current RAF. This does not imply that other RAF structures are less feasible.

4.1 Exploration and selection of new marine datasets

The primary method to learn about global marine biodiversity datasets that may be suitable for incorporation into the RAF was to implement consultations and interviews with more than forty experts from more than twenty research institutions, universities and NGOs around the world (appendix 1). After consultation with the GEF Secretariat what kind of data is most suitable, two subsequent filters with different criteria were applied to determine possible datasets.

Criteria for the first filter included datasets which are

a) global in their approach, i.e., possess comparable data for all countries and;
b) similar to terrestrial datasets used for the RAF or can be applied in a similar manner. This way new marine datasets were categorised into already familiar units (see terrestrial indicators) and their incorporation is straightforward.

The second filter included the final recommendation of datasets which are

a) readily or soon available for a possible incorporation into the RAF for GEF-5;
b) not underrepresenting any regions due to low data availability and;
c) sub-national, i.e. data should not be based on country units or be limited by national

boundaries (e.g. EEZs).

If any of the criteria are not met, the dataset has been excluded from detailed analysis and possible incorporation into a new RAF (see section 5.1 for analysed datasets).

4.2 Processing final marine datasets

4.2.1 Represented species using OBIS and the Kansas Geological Survey Mapper (KGSMapper)

From each of the two subphyla[37] within the OBIS taxonomic order, three classes with most species records were selected. From each class the one species with most location records and with a distribution range of records predominantly found within EEZs of developing countries was ascertained. Altogether six species, the South African fur seal*, Arctocephalus pusillus pusillus,* the Waved albatross, *Phoebastria irrorata*, the African weakfish, *Atractoscion aequidens*, the copepod, *Calanus agulhensis*, the Lesser Flying squid, *Todaropsis eblanae*, and the stony coral, *Acropora valida* were selected for further analysis (Table 2).

By a link on each OBIS species page, species records (point data) were fed into the KGSMapper and thus converted into a global 0.5° cell grid (raster data) with specimen cells (true occurrences derived by OBIS) and empty cells (no specimen) (Figure 5a).

Table 2: Selected species from the OBIS database, their taxonomic location within OBIS, and predominant distribution range.

Subphylum	Class	Species per class	Species name	Location records	Location range of records
Vertebrata	Mammalia	159	*Arctocephalus pusillus* subsp. *pusillus*	2440	South Africa
	Aves	751	*Phoebastria irrorata*	457	Ecuador
	Pisces	21407	*Atractoscion aequidens*	98356	West/South Africa, East Australia
Invertebrata	Arthropoda	12880	*Calanus agulhensis*	16309	South Africa
	Mollusca	15412	*Todaropsis eblanae*	7424	West Africa, Europe, East Australia
	Cnidaria	7088	*Acropora valida*	1089	East Indian Ocean to West Pacific

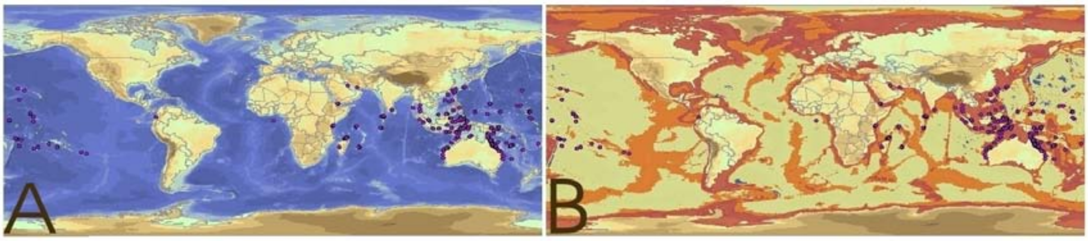
Source: OBIS (2007).

37 Vertebrates and Invertebrates.

Determining distribution ranges

Within four main steps a species distribution range was determined by using the KGSMapper. Based on the environmental data of 40 physical, chemical and biological variables within six categories[38] available for all 0.5° cells the most influencing environmental variables to map a distribution range were determined.

Therefore, in the first step each variable from the six categories was tested to map the range of suitable habitat. This means that the KGSMapper, based on selected environmental variables of the specimen cells, highlights all non-specimen cells with statistically similar environmental conditions globally. Automatically, the KGSMapper plots all cells having values within 1 standard deviation (SD) of the mean of the environmental variable at specimen cells (deep red), those within 2 SD (orange) and those within the total value range of selected variables (ochre) (Figure 5b)[39]. From each tested variable within the six categories the correlation between true occurrences and suitable habitat was assessed. Therefore, the ratio of specimen cells and total cells of the first standard deviation of the suitable habitat plot was determined (Figure 5c). The higher the ratio the stronger was the influence of the environmental variable. From each category the most influencing variable with the highest



C

TABLE 1: Cell-Specimen location statistics, all records			
	Total Cells	Cells (with specimens)	Cells (no specimens)
0-1 Standard deviation	49654	168	49486
1-2 Standard deviation	41691	22	41669
> 2 Standard deviation	87522	11	87511
Outside Entire Range	1730	1	1729
Total	180597	202	180395

Fig. 5: Determining the influence of the KGSMapper 'Mean Bathymetry' environmental variable to the stony coral Acropora valida. A: Before applying the parameter. Purple dots represent specimen cells (occurrences) provided by OBIS. B: After applying the parameter. The mean of specimen cells lies at 1081 m with a standard deviation (SD) of 1,367 m. Displayed are all cells within 1 SD of the mean (1,081 ± 1,367) of the selected parameter (deep red), within 2 SD (1,081 ± 2,734) (orange), and outside 2 SD (ochre). C: Summary statistics table for B, provided by the KGSMapper. Red circles illustrate the values incorporated into the determination process of the most influencing variables. In this example the ratio is 0.0034 (168/49654).

38 1. Bathymetry, 2. Bottom (e.g. O_2, nutrients, salinity), 3. Surface (same as 2. plus wind and tides), 4. Sea Surface Temperature (SST) and bottom temperature, 5. Aragonite, 6.Chlorophyll a concentrations. See appendix 9 for full list.

39 Thus, the deep red area contains the most suitable conditions while the ochre area contains the least suitable.

ratio was selected for further analysis.

In the second step the most influential environmental variables from all categories for determining a species' distribution range were assessed. Therefore, the variable with the highest ratio plotted the initial habitat map. Other selected variables, in sequence of descending ratios, were subsequently added to plot suitable habitat maps until the new ratio did not increase substantially anymore (cf. Fig. 5c but now with multiple variables). A threshold value of 25 percent increase has been set. As soon an additional variable contributes less than a 25 percent increase of the ratio, the variable and all subsequent variables were excluded from further analysis. All precedent variables belonged to the final set to map the suitable habitat range for further processing[40] (Fig. 6). The final suitable habitat range was exported as a shapefile via a link provided on the website. The shapefile was imported[41] into and further processed by the GIS Program MapInfo© v.7.0.

In the third step, a species distribution range was inferred by removing those isolated cells and cell accumulations of the suitable habitat plot that do not contain at least one specimen record[42]. The underlying assumption was that marine species freely migrate along pathways (connected cells) of suitable habitat. However, they cannot cross areas of unsuitable habitat (empty cells) to reach another area of suitable habitat again[43]. The remaining cells were the raw distribution range of a species.

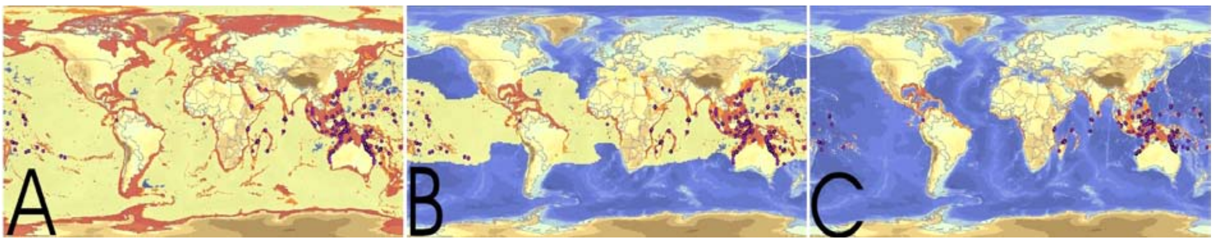


Fig. 6: Determination of a final set of environmental variables for *A. valida*. A: First variable is applied (minimum bathymetry). Ratio is 0.004 B: The second variable is added (max. sea surface temperature). Ratio is 0.019. Addition of the third variable only yields a 15 percent increase of the ratio. C: All area outside 1 SD has been removed.

40 After the final set has been determined, outliers were excluded by removing specimen cells outside 1 SD and the habitat range is plotted again.

41 This implies conversion into a MapInfo© v.7.0 compatible file format (*.tab).

42Isolation means cells that do not share at least one border. This implies diagonal located cells as well. Specimen cells that do not contain suitable habitat were also excluded.

43 In other words, a distribution range is the area of suitable habitat minus the area where a species does not occur or cannot migrate to.

In the fourth step, the raw distribution range was adjusted to the coastline by deleting cell area that overlaps with land area[44]. Finally, the distribution range was split along borders of EEZs[45] and the share within each EEZ assessed by dividing the species range within a country's waters by the total range:

$$(7)\quad \textbf{\textit{Country share}} = \frac{\textbf{\textit{Species range within EEZ}}\,[\textbf{\textit{km}}^2]}{\textbf{\textit{Total species range}}\,[\textbf{\textit{km}}^2]}$$

Where possible, the results were compared to published ranges of the same species. The results can be inferred from section 5.1.1.

4.2.2 Represented ecoregions using the MEOW dataset

Raw ecoregions were provided in shapefile format by Spalding et al. (2006)[46]. The ecoregions only apply to the area from the coastline out to 200 m of depth, i.e., for instance, the area of the continental shelf. However, the provided raw ecoregions were closed objects that exceeded the coastline and the 200 m edge clearly to the outer boundaries of the EEZ due to reasons of visibility.

Hence, raw ecoregions were modified with the GIS program MapInfo© v.7.0. A 200 m depth contour line amalgamation of the GEBCO 2003 CD-ROM contours and the contours of the Pacific provided by SOPAC was used to split ecoregions and delete all area beyond this border. Furthermore, the remaining ecoregion area overlapping with land area was split and deleted using the coastline already applied for the precedent dataset in section 4.2.1.

The processed marine ecoregions were then separated along maritime boundaries. The share within each EEZ was assessed by dividing the ecoregion area within country waters by the total ecoregion area (cf. formula 7) (Fig. 7). The final indicator for incorporation into the GBI_{bio} consisted of the sum of ecoregion shares for a country[47] (see section 5.2.1 for results).

Special situations occurred when an EEZ was disputed or shared among two or more countries and the ecoregion could not be unequivocally attributed to one country. In case of conflict zones (dispute on national sovereignty of the EEZ) the ecoregion share was not attributed to any country and was counted as a “lost” share. If an ecoregion occurred within a

44 As a coastline served an amalgamation of the data on the General Bathymetric Chart of the Oceans (GEBCO) 2003 CD-ROM (IOC et al., 2003) and the coastline provided by the South Pacific Islands Applied Geoscience Commission (SOPAC, 2007), since the GEBCO data contains many gaps within the Pacific.

45 Global maritime borders are available from the Vlaams Instituut Voor De Zee (VLIZ) (Deckers and Vanden Berghe, 2006)

46 Due to pre-publishing licence constraints from 232 marine ecoregions globally only 145 have been provided. From this set 96 marine ecoregions have been processed and incorporated into a new formula that was tested on 73 countries (see section 4.3).

47 See appendix 10 for a full list of countries, marine ecoregion area (a), ecoregion shares (b), and final data (c).

joint EEZ (e.g. between Japan and South Korea) the ecoregion share was divided equally among countries.

Another constraint was given by the missing maritime boundaries of Brunei Darussalam within the EEZ dataset. The EEZ of Brunei Darussalam lies fully within the Malaysian EEZ and contains a part of only the Palawan/North Borneo marine ecoregion. Hence, the problem was solved by subtracting the shelf area of Brunei Darussalam's EEZ (SeaAroundUs, 2007) from the Palawan/North Borneo marine ecoregion share belonging to Malaysia[48].

Occasionally, very small gaps along GEBCO coastlines occurred (<500 m). These were closed manually by a straight connection. Two types of very rare but large gaps were contained in the GEBCO 200 m depth contour line. One type of gap were interruptions of the depth contour along coasts of continents spanning more than one country[49]. These gaps were treated as not containing any ecoregion area, i.e., empty space which is not attributed to any country[50].

The other gap were missing 200 m depth contours for small islands under the jurisdiction of larger countries[51]. Each of these islands constituted a marine ecoregion of it's own. Thus, the

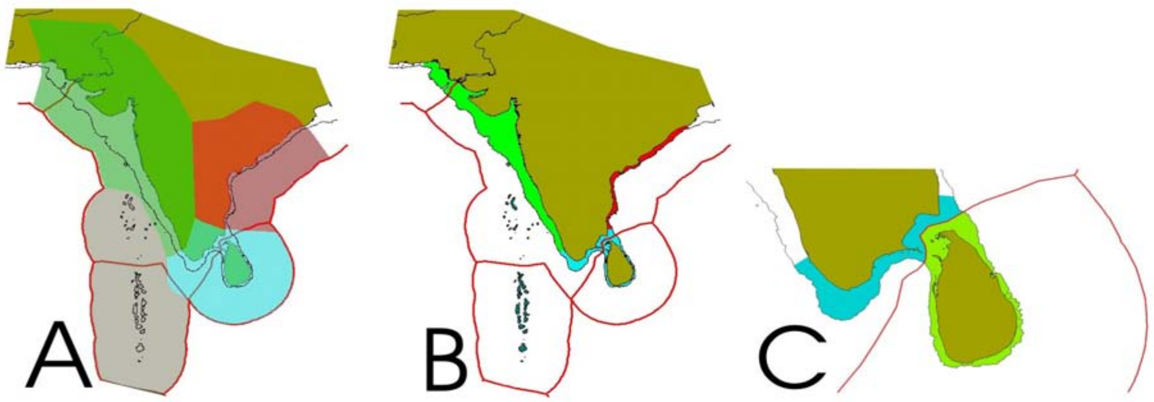


Fig. 7: Processing raw ecoregions of India and adjacent countries. Brown area represents land, thick red lines indicate EEZ borders, and light black lines illustrate the position of the 200 m depth contour line. A: Unprocessed marine ecoregions within the Indian EEZ: Western India (green), East India (red), Maldives (greyblue), and South India and Sri Lanka (bright blue). B: Same ecoregions have been adjusted to the 200 m depth contour line and to the coastline. C: South India and Sri Lanka marine ecoregion split along the shared EEZ border. The area within India's EEZ (blue) (~ 37,000 km²) represents a share of about 0.55 and the area within Sri Lanka's EEZ (green) (~31,000 km²) a share of 0.45. For a shapefile containing maps of all 96 analysed and processed marine ecoregions see appendix 17.

48 The SeaAroundUs Project website also truncates EEZ area at the 200 m depth contour line to infer shelf areas and is thus assumed to be a reliable source to estimate Brunei's ecoregion share.

49 Panama-Costa Rica (~600 km) and Chile-Peru (~200 km).

50 In both cases also the 500 m depth contour line could have been taken as a substitute for the missing 200 m depth contour line. However, the rationale not to use the next deeper contour line is that deeper contours may run differently from the 200 m contour. This way, a certain country may receive wrongly a larger ecoregion share and thus incorrectly a larger benefit.

51 Northern Galapagos Islands (Ecuador), Trinidad and Martin Vaz Island (Brazil), and Sao Pedro and Sao Paolo Islands (Brazil).

marine ecoregions fully belonged to the respective EEZs and therefore, the countries received a maximum share of 1 for the marine ecoregion.

4.2.3 Threatened ecoregions using the NCEAS dataset

Threat values of marine ecoregions were provided by NCEAS ranging from a minimum value of 0.15 for the least threatened ecoregion up to 13.84 for the most threatened ecoregion. This indicator should contribute to the marine sub-index to the same degree as the indicator for terrestrial threatened ecoregions to the terrestrial sub-index which ranges from 1 to 4. Therefore, all marine ecoregion threat values were first proportionately scaled down to a range between 0 and 4. The largest original value (13.84) was taken as a benchmark which received the maximum score of 4. According to the 'rule of three' new marine ecoregion threat scores were then calculated by:

$$(8)\quad \textbf{\textit{Ecoregion new threat}} = \frac{\textbf{\textit{Ecoregion old threat}}}{\mathbf{13.84}} \cdot \mathbf{4}$$

Analogous to the terrestrial score, the new threat scores were grouped in four distinct categories (Table 3). The threat scores were not grouped into three distinct categories as terrestrial threatened ecoregions (1, 2, and 4) since it is assumed to overmanipulate the data and to draw arbitrary boundaries[52].

Table 3: Defining categories for new marine ecoregion threat scores

Value range	Category
0 < x ≤ 1	1
1 < x ≤ 2	2
2 < x ≤ 3	3
3 < x ≤ 4	4

Then ecoregion threat shares for the set of 96 marine ecoregions were determined by multiplying the threat category with a country's ecoregion share as described in section 4.2.2:

$$(9)\quad \textbf{\textit{Ecoregion threat share}} = \textbf{\textit{Ecoregion share}} \cdot \textbf{\textit{Ecoregion threat category}}$$

Eventually, the sum of marine ecoregion threat shares for each of the 73 countries constituted the final indicator for incorporation into the GBI_{bio}[53] (see section 5.2.1 for results)

52 No threat score was available for the Sao Pedro and Sao Paolo Island ecoregion (Brazil, s.a.). This ecoregion was automatically located in the lowest category.

53 For a full account of threatened ecoregion data see appendix 11a, b, and c.

4.3 Incorporation of final marine indicators into a new RAF

New preliminary allocations were calculated by incorporating the marine ecoregions and threat to marine ecoregion indicators for a representative set of countries.

4.3.1 Selecting a representative set of countries for testing a new RAF

In the light of incompletely provided data, a representative sample from all 150 countries within the RAF had to be determined. Therefore, the total amount of RAF eligible countries was subdivided, taking all different variables and particularities that may have an effect on allocations into consideration. The intention was that for this set of countries trends of changing allocations for the proposed RAF are correctly illustrated. This approach should also enable extrapolation of results to other states. The final sample comprised 73 countries[54] subdivided into 17 sea-locked (SIDS), 40 coastal, and 16 land-locked countries (Table 4).

54 The exact steps and intermediate results of the calculation can be found in appendix 7.

Table 4: Subdivision of a 73 RAF eligible country sample according to geographic status, region, relationship of the RAF marine to terrestrial sub-index, and size of GBI_{bio}.

Global category	Region	Biodiversity class	# of countries	Country names*
sea-locked	African	**mar.** > terr.	2	Maldives, Seychelles
		mar. < **terr.**	1	São Tomé and Príncipe
	Caribbean	**mar.** > terr.	1	Bahamas
		mar. < **terr.**	5	Cuba, Dominican Republic, Grenada, Haiti, St. Kitts and Nevis
	Pacific	**mar.** > terr.	6	Fiji, Palau, Papua New Guinea, Solomon Islands, Tonga, Tuvalu
		mar. < **terr.**	2	Nauru, Western Samoa
coastal	African	**mar.** > terr.	6	Equatorial Guinea, Eritrea, Gambia, Ghana, Guinea-Bissau, Mozambique
		mar. < **terr.**	10	Benin, Cameroon, Dem. Rep. Congo, Djibouti, Guinea, Kenya, Liberia, Madagascar, Tanzania, Togo
	Asian	**mar.** > terr.	3	Indonesia, Philippines, South Korea
		mar. < **terr.**	8	Bangladesh, Cambodia, China, India, Malaysia, North Korea, Pakistan, Vietnam
	Latin American	**mar.** > terr.	2	Chile, Nicaragua
		mar. < **terr.**	11	Belize, Brazil, Colombia, Ecuador, El Salvador, Guyana, Mexico, Peru, Suriname, Uruguay, Venezuela
land-locked	African	mar. < **terr.**	10	Burkina Faso, Burundi, Chad, Ethiopia, Lesotho, Malawi, Niger, Swaziland, Uganda, Zambia
	Asian	mar. < **terr.**	5	Afghanistan, Bhutan, Lao People's Dem. Rep., Mongolia, Tajikistan
	Latin American	mar. < **terr.**	1	Bolivia

* Alphabetical order.

At first, all RAF eligible countries were grouped into three global categories representing sea-locked countries[55], land-locked countries, and continental coastal countries. Dividing the total country number of larger categories (coastal and land-locked) by the total number of the smallest category (sea-locked) yielded a ratio of 1 sea-locked to 1.06 land-locked to 2.48 coastal countries within the RAF. In order to determine a number of countries to be included in the new RAF and not to exceed available data a number of 16 sea-locked states thus yielded 17 land-locked and 40 coastal states. This sample represents roughly half of all RAF eligible countries.

All following calculations were implemented with rounded integer values. This resulted in final numbers that deviate slightly from the initial number for global categories determined in the first step. The impact on final allocations is assumed to be minimal[56].

Secondly, the global coverage of the available data was large enough to allow a finer subdivision of countries into regions[57]. Sea-locked states were subdivided into Pacific, Caribbean and African SIDS, while land-locked as well as coastal states were subdivided into African, Latin American and Asian countries, respectively. From each region of a category a sample of countries was selected. Therefore, the total sample size of the category determined above, e.g. 16 sea-locked states, was divided by the total size of the category within the RAF, e.g. 33 sea-locked states. The result was multiplied by the total size of the region within the RAF, e.g. 14 Pacific sea-locked states:

$$(10)\quad \textbf{\textit{Sample size of region}} = \frac{\textbf{\textit{Sample size of global category}}}{\textbf{\textit{Total size of global category}}} \cdot \textbf{\textit{Total size of region}}$$

Applied this way, the sample size of each region is in true proportion to other regions within the same category. However, the sum of regions of a category did not exceed the threshold value set in the first step. For example, all 33 sea-locked states within the RAF divided into 14 Pacific, 13 Caribbean, and 6 African states. Applying this approach to 16 sea-locked states yielded a proportionally correct ratio of 7:6:3 sea-locked states for the same regions.

Thirdly, the regional samples were further subdivided by taking 'biodiversity classes' into

55 All sea-locked countries in this category are SIDS.

56 The final number of sea-locked states account for 17 instead of 16. For land-locked states, 16 instead of 17 countries were determined. The total number of countries is still 73.

57 This subdivision considers that regions may have different effects RAF calculations due to: A) Geographical particularities during incorporation of new datasets. For example, Caribbean sea-locked states may behave differently to Pacific sea-locked states when determining marine ecoregion shares due to their smaller EEZ in average. B) Differences in current sub-indices scores. For example, countries of different regions have varying distances to major centres of biodiversity. Thus, Latin American countries may exhibit very high terrestrial sub-indices, compared to other countries worldwide.

consideration. A biodiversity class illustrated the relationship between the marine and terrestrial sub-index of the original RAF[58]. There existed two classes: A) The marine score exceeds the terrestrial score and B) the terrestrial score exceeds the marine score. A sample set of countries within a region with a marine score exceeding the terrestrial score was calculated analogous to determining the sample size of a region (cf. formula 10):

$$(11) \quad \textbf{\textit{Sample mar.}} > \textbf{\textit{terr. score}} = \frac{\textbf{\textit{Sample size of region}}}{\textbf{\textit{Total size of region}}} \cdot \textbf{\textit{Total region size mar.}} > \textbf{\textit{terr. score}}$$

The same formula has been applied to countries with terrestrial scores exceeding marine scores.

Eventually, the equal representation of small and large countries was taken into consideration by selecting alternately countries with highest and lowest values for the GBI_{bio}[59] until the number of countries of a biodiversity class was reached.

4.3.2 Calculation of a GPI proxy

One GPI value has been calculated that serves as a proxy for all 73 countries tested in a new RAF scenario[60].

Since the GEF's PPI indicator as well as CPIA scores for IBRD countries were not available, a 90 percent GPI approximation for only IDA eligible countries has been calculated. The missing PPI value accounts for '0' in this calculation:

$$(12) \quad \textbf{90 \textit{percent GPI}} = \textbf{0} + \textbf{0.7} \cdot \textbf{\textit{CEPIA}} + \textbf{0.2} \cdot \textbf{\textit{BFI}}$$

For countries where an IDA score was not available, the rural sector indicator of the IFAD was used as a substitute for the CEPIA and the BFI indicators:

$$(13) \quad \textbf{90 \textit{percent GPI}} = \textbf{0} + \textbf{0.9} \cdot \textbf{\textit{IFAD}}$$

Finally, all resulting country GPI values were averaged to create a GPI proxy of 3.03[61]. This proxy was used to test the formula on the full set of 73 countries.

58 This step has not been applied to land-locked countries since their marine score is always zero.

59 Biodiversity is generally positively correlated to area. Thus the underlying assumption is that the biodiversity index, GBI_{bio}, is positively correlated to size of a country.

60 This has two underlying reasons: 1. As indicated much GPI data is subject to public disclosure restraints so that for several countries no GPI could be calculated (e.g. Bahamas, Fiji, North Korea, South Korea, Tuvalu). Thus applying any value for them is arbitrary. 2. Calculating and incorporating individual GPIs would blur the effect of the inclusion of marine indicators on single countries.

61 see appendix 12 for a detailed breakdown of the GPI based on CPIA scores for IDA countries and IFAD scores.

4.3.3 Normalization of final data

Data of the current RAF has been provided normalized, i.e., each indicator for all RAF eligible countries adds up to 10,000[62]. For the country sample the current marine represented species indicator added up to 3882.026 which constituted the benchmark for normalizing both new indicators[63]. Therefore, the sum of the already normalized marine represented species indicator was divided by the sum of both new un-normalized marine ecoregion indicators, respectively. The resulting 'normalization factors' for both indicators[64] were used to multiply every country value of a new indicator to reach the normalized score (see appendix 2).

4.3.4 Incorporation of indicators into a modified RAF

Normalized scores of the new indicators for sample countries and the GPI proxy were the building blocks of the RAF tested in this study (see appendix 3b). The calculation of a new preliminary allocation was analogous to the original RAF (see chapter 3) but contained some slight modifications.

In the first step a new marine score was computed by including three instead of one marine indicators, i.e., original represented species, new represented ecoregions, and new threatened ecoregions. The weighting between these three indicators was taken from the computation of the four terrestrial indicators. To compensate for the missing indicator of marine threatened species, all other weights have been proportionally increased. Therefore, the sum of weightings for the four terrestrial indicators (1) was divided by the sum of weightings for the same indicators except threatened species (0.8). The result was multiplied by the original weighting of the indicator to be increased (e.g. 0.55 for represented species). Eventually, the marine score was the weighted sum of three indicators[65]:

$$(14)\quad \textbf{\textit{Marine score}} = \mathbf{0.69} \cdot \textbf{\textit{Represented Species}} + \mathbf{0.19} \cdot \textbf{\textit{Represented Ecoregions}} + \mathbf{0.12} \cdot \textbf{\textit{Threatened Ecoregions}}$$

62 In this case, normalization means the proportional increase of numbers until their sum reaches a desired value, e.g. 10,000.

63 Normalization of new marine indicators is necessary, since otherwise the marine represented species indicator would dominate calculations.

64 Normalization factor of 53.234 for marine represented ecoregions; 19.073 for threatened marine ecoregions.

65 For easier perceptibility weightings are rounded but still create a sum of 1. However, applied values are 0.6875 for represented species, 0.1875 for represented ecoregions, and 1.25 for threatened ecoregions.

In the next step, a new GBI_{bio} value was computed by the new marine score and the original terrestrial score. However, a new weighting of 0.5 for the terrestrial and 0.5 for the marine score was applied:

$$(15)\quad \textbf{\textit{GEF Benefits Index for Biodiversity}} = \mathbf{0.5} \cdot \textbf{\textit{Terrestrial Score}} + \mathbf{0.5} \cdot \textbf{\textit{Marine Score}}$$

Subsequently, the Country Score was computed by multiplying the new GBI_{bio} with the averaged GPI for all countries:

$$(16)\quad \textbf{\textit{Country Score}} = \textbf{\textit{GBI}}_{\textbf{\textit{bio}}}^{\mathbf{0.8}} \cdot \mathbf{3.03}$$

As already described in chapter 3, the Country Share was calculated by dividing the Country Score by the Sum of Country Scores for the sample set. In order to yield new preliminary allocations in roughly the same range as current preliminary allocations, the Country Share was multiplied only by a fraction of US$ 438 million of total RAF resources[66]:

$$(17)\quad \textbf{\textit{Preliminary Allocation}} = \textbf{\textit{Country Share}} \cdot \mathbf{438{,}000{,}000}$$

Including the representative set of 73 countries implies that new preliminary allocations are only approximate values. The main information content lies within the positive and negative change of allocations and their magnitude.

4.3.5 Comparison with the current RAF

Preliminary allocations of an unmodified RAF were calculated for the sample, in order to enable direct comparison to the new RAF values (s.a.). Therefore, old preliminary allocations were calculated as described in chapter 3 combined with some of the modifications of the precedent section: The same sample of 73 countries was analysed and the same GPI of 3.03 as well as the same amount of total RAF resources (US$ 438 million) was applied. However, no modifications were undertaken for the marine score (see appendix 3c).
This enabled comparison of the impact of a new GBI_{bio} on preliminary allocations on the basis of modifying only the composition of the marine score and the relative weighting to the terrestrial score (see appendix 3a).

66 This value was determined by dividing the sample size of 73 countries by the total number of RAF eligible countries and to multiply the result by the total RAF resources available (US$ 900 million).

Chapter 5

Results

This chapter lists the results of the quest for global marine datasets of biodiversity or threat to biodiversity and provides trends of changing preliminary allocations generated by incorporation of new datasets of marine biodiversity.

5.1 Exploration of global datasets on marine biodiversity

The exploration of new data yielded seven global datasets which were tested on the five criteria of the two filters[67] (see also section 4.1). These are in order of appearance: OBIS, the Sea Around Us Project (SAUP), the Global Marine Species Assessment (GMSA), MEOW, NCEAS, the Marine Trophic Index (MTI), and the Environmental Vulnerability Index (EVI). In the following sections (5.1.1 to 5.1.4) these datasets are opposed to selected criteria and a summary table is provided on page 47.

5.1.1 Marine represented species

OBIS (Ocean Biogeographic Information System)

Criterion 1a: Is the dataset global in it's approach?

Yes. OBIS is a global internet portal that aims to be the primary authoritative source of data on the distribution of all marine species in the world (Grassle et al., 2005). It provides mainly global location records for approximately 82,000 marine species[68] combined from 28 authoritative datasources and 216 databases. It collaborates with further 20 partner organisations[69]. Since it's inception in 2002 the number of global species records steadily

67 1a) global comparable data approach; 1b) similar to terrestrial part of the RAF; 2a) available until GEF-5; 2b) equal representation of all regions; 2c) sub-national.

68 indexed according to taxonomic hierarchy.

69 see appendix 13 for a full list of organisations.

increases (Figure 8). Until 2010 it intends to have at least one global record for each marine species described (Costello et al., 2007). Currently, groups with most species records are fishes (21407 species), molluscs (15412), arthropods (12880), and cnidarians (7088). Likewise, various vertebrate species (birds, mammals, fishes, and reptiles) are adequately sampled and thus also well represented within OBIS (Costello et al., 2007).

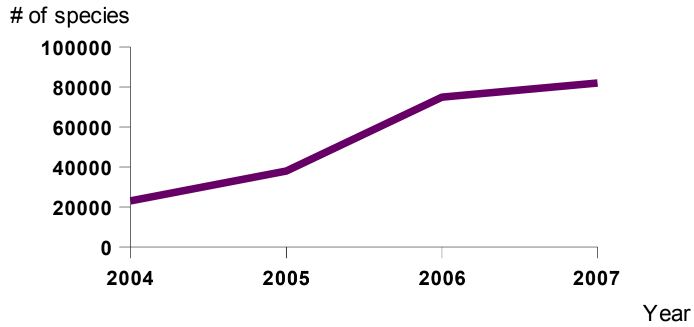


Fig. 8: Number of species with location records within OBIS

Criterion 1b: Is the dataset similar to terrestrial indicators used in the RAF?

Yes. The KGSMapper models species distribution ranges similar to the terrestrial represented species indicator by plotting species records against a set of environmental parameters. Unlike the polygon maps used for the terrestrial indicator, range maps are predictions and displayed on a 0.5° cell grid (55 km at equator). Analogous to terrestrial represented species, countries can receive scores based on the share of a distribution range occurring within their EEZ. The strength of the KGSMapper is that it predicts where a species cannot occur anymore (Costello, pers. communication). Based on the methodology described in section 4.2.1 the modelled distribution ranges are provided in Figure 9.

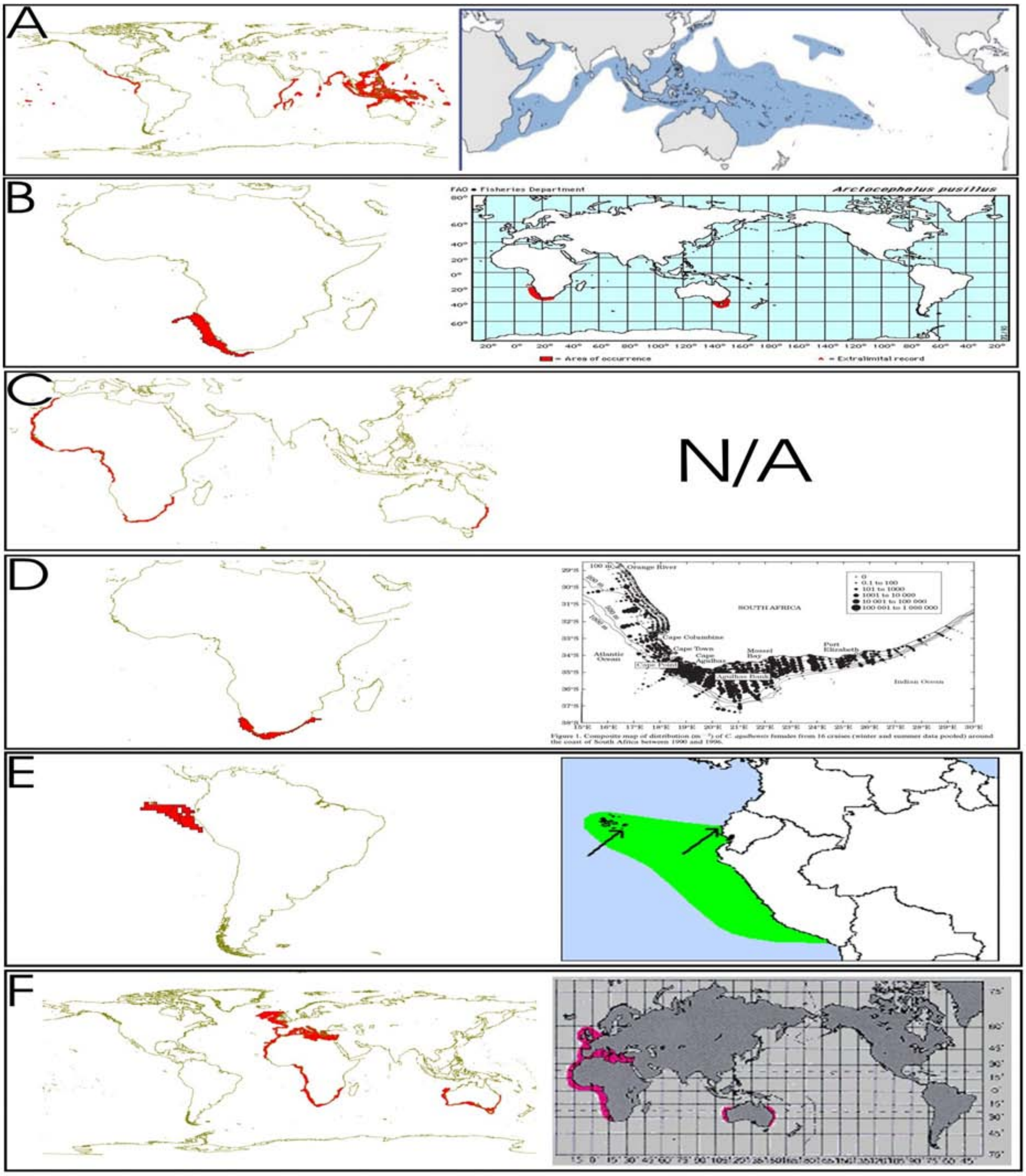


Fig 9: Comparison of modelled species ranges (left) and published species ranges (right). Modelled species ranges (red) are drawn thicker for better visibility compared to the coastline (brown lines). A: Distribution range of the stony coral, *Acropora valida*, distributed across the Indian and Pacific Ocean. Published range (blue) by AIMS (2007). B: Distribution range of the South African fur seal, *Arctocephalus pusillus pusillus*. Published range (red) (Jefferson et al., 2007) shows two *A. pusillus* sub-species. *A. p. doriferus* can be found at Tasmanian coasts and *A. p. pusillus* at South African coasts. C: Distribution range of the African weakfish, *Atractoscion aequidens*. Although no published range maps are available Froese and Pauly (2007) describe the East Atlantic, Western Indian Ocean (off Mozambique and South Africa) and the Pacific Ocean (Eastern coast of Australia) as the primary habitat areas. D: Distribution range of the copepod, *Calanus agulhensis*. Published range (black dots) on South Africa's Agulhas Bank are derived from Huggett and Richardson (2000). E: Distribution range of the Waved albatross, *Phoebastria irrorata*, off the Ecuadorian coast. Published range (green) by Birdlife International (2007). F: Distribution range of the Lesser Flying squid, *Todaropsis eblanae*. Published range (red) from Cuttlefish and Squids of the World in Color (2007). Modelled ranges in shapefile format can be found in appendix 16 for more detailed analyses.

Based on these distribution ranges, Table 5 summarises analysed species, the number of countries they occur in and those two countries that contain the largest share of the species range[70].

Table 5: Analysed species, number of occurring states, and largest shareholding countries of habitat range.

Species	Number of countries	Largest shareholding countries [%]
Acropora valida	57 + conflict zone	Indonesia [31.59] Australia [11.56]
Arctocephalus pusillus pusillus	2 + outside EEZ	Namibia [59.62] South Africa [35.27]
Atractoscion aequidens	22 countries	Morocco [14.27] South Africa [13.82]
Calanus agulhensis	2 countries	South Africa [94.22] Namibia [5.78]
Phoebastria irrorata	2 + outside EEZ	Ecuador [40.96] Peru [35.91]
Todaropsis eblanae	47 + outside EEZ	Australia [15.68] Greece [7.87]

A globally valid distribution range determined with OBIS location point data can already be inferred from 20 global specimen records within the KGSMapper (Costello, pers. communication). However, multiple OBIS location points may fall on one global record. Within OBIS there exist 6917 species with more than 100 location points and 10663 species with more than 50 location points[71]. See appendix 4 for a detailed breakdown of OBIS groups, their amount of species with location data, and the amount of species with over hundred and over fifty location points.

Criterion 2a: Is the dataset available until GEF-5?

Yes. The idea of OBIS was developed in 1997. The internet portal was created in 1998. OBIS is committed to unrestricted, free, and open access to all data it publishes.

Criterion 2b: Are all regions equally represented?

Uncertain. On the one hand, there is a the large number of species accessible via OBIS, and it

70 For a full breakdown of distribution ranges into countries see appendix 14.

71 This gives an approximation of how many species can be used to map distribution ranges and simultaneously recognizes the possibility of multiple OBIS location points to fall on one KGSMapper global record.

is the aim to geographically record every marine species globally (Lesue, 2002; Grassle et al., 2005). On the other hand, Costello et al. (2007) mention that the northern hemisphere has been better sampled than the southern hemisphere.

Criterion 2c: Is the dataset sub-national?

Yes. Neither OBIS species location points, nor the 0.5° cell grid or the environmental parameters of the KGSMapper orientate themselves on national boundaries.

SAUP (Sea Around Us Project)

Criterion 1a: Is the dataset global in it's approach?

Yes. The SAUP dataset provides global distribution maps of 1037 marine species[72] from around the world (Sea Around Us, 2007).

Criterion 1b: Is the dataset similar to terrestrial indicators used in the RAF?

Yes. Similarly to OBIS and the KGSMapper it predicts distribution ranges on a 0.5° cell grid. These ranges are based on species location data from FishBase, distribution ranges from the the Food and Agriculture Organization (FAO), and a set of specifically preferred environmental parameters[73].

Distribution ranges are provided either in maps of predicted environmental suitability (low to high) (Figure 10a) or by approximation of abundances (Figure 10b).

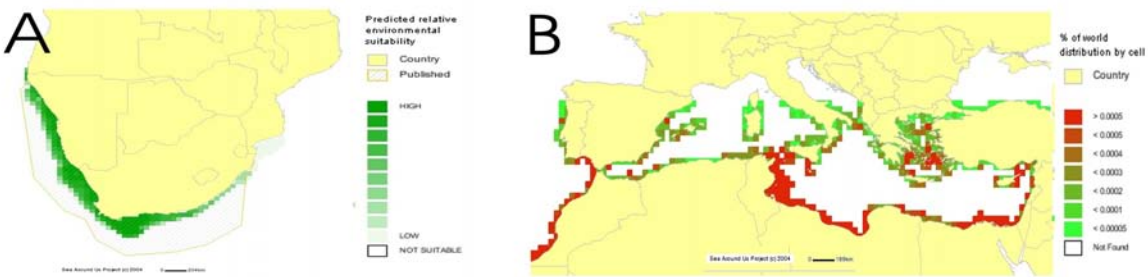


Fig. 10: Predicted distribution ranges by SAUP (2007). A: Range map of the South African fur seal, *A. pusillus pusillus*. Shades of green indicate high environmental suitability (deep green) or low suitability (light green). B: Range map of the African threadfish, *Alectis alexandrinus*. Shades of red indicate a high rate of occurrences (max. value indicate a share of >0.05% of global abundance) while shades of green indicate a low rate (min. value 0.01-0.005%).

72 700 fishes, 114 marine mammals, 115 crustaceans, 100 mollusks, 4 echinoderms, and 4 species of sea squirt.

73 Parameters may vary between species but the basic set for all species includes latitude and longitude as well as depth. Additional parameters may be sea surface temperature, or distance to preferred habitat.

Criterion 2a: Is the dataset available until GEF-5?

Yes. Range maps are already available on the website, but they have not been provided as GIS data for further analyses.

Criterion 2b: Are all regions equally represented?

No. This dataset mainly provides distribution maps of commercially used species. Thus, modelled ranges strongly depend on quality fishery statistics which are poor in diverse and tropical countries (Cheung, pers. communication). Additionally, many datasets are still in error so that they can not be applied yet (Watson, pers. communication).

Criterion 2c: Is the dataset sub-national?

Yes. Similarly to the KGSMapper this dataset uses biological relevant parameters to map distribution ranges (s.a.).

Other datasets

J.E.N. Veron from the Australian Institute of Marine Science (AIMS) currently works on an updated dataset illustrating global distribution maps of coral species (Veron, pers. communication). However, this dataset will not be further analysed here, since the GEF Secretariat is already familiar with the existence of this dataset[74] and neither the updated nor the old dataset were available for analyses.

5.1.2 Marine threatened species

GMSA (Global Marine Species Assessment)

Criterion 1a: Is the dataset global in it's approach?

Yes. The August 2005 established GMSA aims at evaluating the conservation status of every marine vertebrate and selected invertebrates and plants[75]. Therefore, all essential information of species ecology, function, threats, human uses, and distribution maps are compiled. Eventually, this analysis will include extinction risks according to IUCN red list categories[76] of 20,000 globally distributed marine species. It therefore adds to the 1,380 marine species currently assessed by the IUCN redlist (Carpenter and Livingstone, 2007).

74 The GEF Secretariat, in consultation with the large NGOs, has decided not to use this dataset in the current RAF, since it would bias allocations towards coral rich countries.

75 Vertebrates: Primarily fishes. Invertebrates: Corals, mollusks, echinoderms. Plants: macro-algae, seagrass, mangroves.

76 Extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened, and least concern.

Criterion 1b: Is the dataset similar to terrestrial indicators used in the RAF?
Yes. Once completed the GMSA complements the same type of data as used for the terrestrial threatened species indicator. Likewise, the GMSA datasets provides species distribution ranges based on, for example, depth or association with habitat structures as coral reefs. These ranges may be utilized for a marine represented species indicator analogous to current IUCN maps for the terrestrial represented species indicator (Figure 11).

Criterion 2a: Is the dataset available until GEF-5?
No. From it's inception in 2005 until the finalization of this dataset a period of at least 6 years has to be scheduled[77] (Livingstone, pers. communication).

Criterion 2b: Are all regions equally represented?
Yes. All different marine and coastal regions are subsequently assessed in workshops for their species conservation status. Consequently, the global approach permits equal representation of all regions.

Criterion 2c: Is the dataset sub-national?
Yes. Species distribution ranges are only inferred by species point data delivered by scientific expeditions or fishery catches and are not limited by national maritime boundaries.

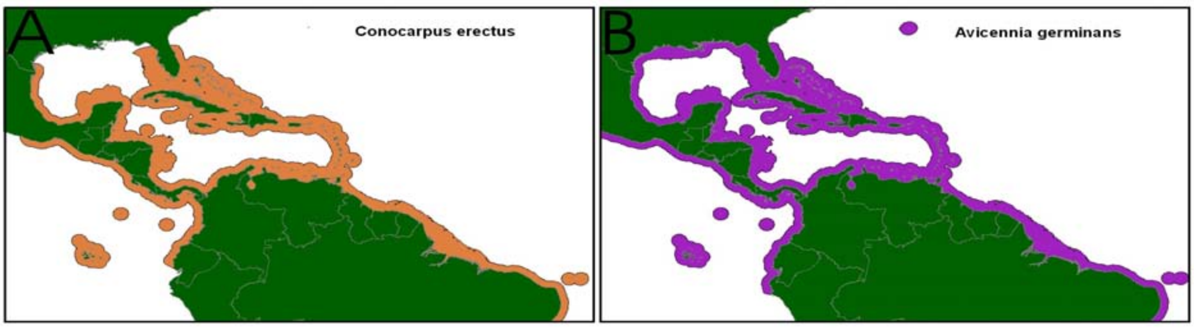


Fig. 11: GMSA raw distribution ranges. A: Range map of the mangrove associated species *Conocarpus erectus*. B: Range map of the mangrove *Avicennia germinans*. Species range maps were kindly provided by the GMSA.

77 This implies finalization shortly after the beginning of GEF-5 and thus enables incorporation into the RAF for GEF-6.

5.1.3 Marine represented ecoregions

MEOW (Marine Ecoregions of the World)

Criterion 1a: Is the dataset global in it's approach?

Yes. This dataset was created by a joint cooperation of WWF and The Nature Conservancy (TNC) and constitutes a global biogeographic classification of the world's coastal and shelf area. It represents a full global synthesis of findings from over 230 works on global and regional marine classifications. Primarily those concepts provided by Briggs (1974), Longhurst (2006), and on Large Marine Ecosystems (LME) (for example Sherman and Tang, 1999) were decisive. The hierarchical classification is categorised into 12 realms (largest scale), 62 provinces, and 232 ecoregions (smallest scale).

Criterion 1b: Is the dataset similar to terrestrial indicators used in the RAF?

Yes. This dataset may represent the marine counterpart of terrestrial represented ecoregions of the RAF provided by Olson et al. (2001) since it uses a similar terminology[78] and classification[79] (WWF, 2007). The results of incorporating marine ecoregions into a new RAF are provided in section 5.2.2.

Criterion 2a: Is the dataset available until GEF-5?

Yes. While an early draft circulated as an information report for member states of the CBD (Spalding et al., 2006), the final version has been published in August this year (Spalding et al., 2007).

Criterion 2b: Are all regions equally represented?

Yes. Figure 12 depicts the equal global coverage of all coastal and shelf regions. However, all area below the 200 m depth contour line has been excluded. Below that threshold other biogeographic patterns predominate that have not yet been assessed (Spalding, pers. communication).

Criterion 2c: Is the dataset sub-national?

Yes. Realms, provinces and ecoregions depend on biogeographic[80] features as well as on

78 Terrestrial: Realms, Biomes, Ecoregions. Marine: Realms, Provinces, Ecoregions.

79 e.g. realms in both environments are based on Udvardy's description (Udvardy, 1975) or both ecoregion types are defined by distinct assemblages of homogeneous species composition.

80 endemism or similar species aggregations.

various geographical (e.g. isolated islands, semi-enclosed seas), hydrological (currents, upwellings), or chemical (nutrients, salinity) influences.

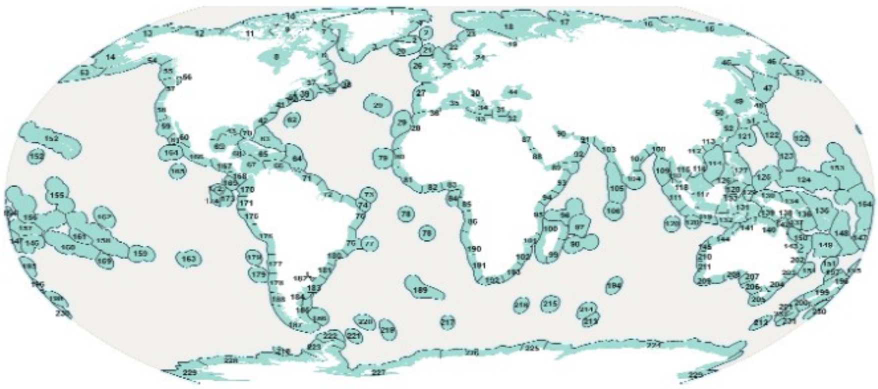


Fig. 12: Marine ecoregions of the world from Spalding et al. (2007). Boundaries are drawn further out than the 200 m contour line for reasons of clarity.

5.1.4 Marine threatened ecoregions

NCEAS (National Center for Ecosystem Analysis and Synthesis)

Criterion 1a: Is the dataset global in it's approach?

Yes. This dataset provides the first global assessment of vulnerability of marine ecosystems (Halpern, unpublished article). Firstly, 23 different types of marine ecosystems were identified that occur globally[81]. Secondly, 38 different types of threats[82] were described. Thirdly, 135 experts from 19 countries worldwide were consulted to provide their knowledge on the degree (e.g. scale and frequency) and impact (e.g. solitary or cascading effects) of these threats on the ecosystems. Eventually the results were translated on a scale of vulnerability and mapped.

Criterion 1b: Is the dataset similar to terrestrial indicators used in the RAF?

Yes. As part of the NCEAS global threats project the marine ecoregions, provided by Spalding et al. (2007), were evaluated and their levels of threat[83] assessed (Halpern, pers. communication). The NCEAS dataset therefore represents the marine counterpart to terrestrial threatened ecoregions. The results of incorporating threat categories of marine ecoregions into a new RAF are provided in section 5.2.2.

81 e.g. beaches, mangroves, coral reefs, kelp forests, icy coasts, shelf slopes, deep sea vents, canyons, etc.
82 e.g. nutrient input, exploitation, climate change, invasives, diseases, mineral extraction, hypoxia, etc.
83 These range from 0.15 for the lowest threatened ecoregion up to 13.84 for the highest threatened ecoregion.

Criterion 2a: Is the dataset available until GEF-5?

Yes. Currently NCEAS is still preoccupied rectifying the final values and the report. Disclosure of data and literature can be expected later this year though.

Criterion 2b: Are all regions equally represented?

Yes. The vulnerability analysis of the 23 marine ecosystem types was mapped on a global 1 km^2 grid that even covers remote areas such as Pacific SIDS (Halpern, pers. communication). Likewise, except for two the threat status of all 232 marine ecoregions has currently been assessed[84].

Criterion 2c: Is the dataset sub-national?

Yes. The analysis of marine ecosystems explicitly adopts the ecosystem approach which is not restrained by political borders. The same applies for the threat status of marine ecoregions.

MTI (Marine Trophic Index)

Criterion 1a: Is the dataset global in it's approach?

Yes. In order to serve as an indicator of biodiversity to the CBD[85], Pauly (2005) describes the MTI[86] to deliver comparable data for all marine areas in the world. The MTI was created from the notion that marine fisheries are increasingly dependent on lower trophic level catches[87] (Pauly et al., 1998). This is illustrated by the change of mean trophic level of catches. Hence, high MTI values indicate high levels of evolved biodiversity and sustainable fishery activities. Decreasing and/or low values represent low levels of biodiversity[88] and depletion of higher trophic level fish stocks (Pauly and Watson, 2005).

Criterion 1b: Is the dataset similar to terrestrial indicators used in the RAF?

Yes. It may be regarded as similar to the threatened ecoregions indicator since it assesses the sustainability of fisheries within regions such as LMEs or EEZs. However, it only reflects one kind of threat, i.e., human related overexploitation.

84 Not included are the Black Sea as well as the Sao Pedro and Sao Paulo Islands marine ecoregions.
85 UNEP/CBD/COP/7/30
86 Formerly known as the mean trophic level of fisheries catches.
87 That implies a shift of catches from large predatory fishes to smaller invertebrates and planktivorous fishes.
88 This may translate into low levels of taxonomic diversity (e.g. lower species richness) and ecological diversity (e.g. simplification of complex food webs and other types of interactions).

Criterion 2a: Is the dataset available until GEF-5?

Yes. All MTI data can be readily accessed over the Sea Around Us website (Sea Around Us, 2007).

Criterion 2b: Are all regions equally represented?

No. Similar to the SAUP represented species indicator presented above, this dataset also requires good fishery statistics that are broken down into constituent species or groups. This is not yet the case for eight out of fourteen Pacific SIDS which thus have no MTI value.

Criterion 2c: Is the dataset sub-national?

Yes, LMEs are sub-national units[89]. However, the MTI is also applied to EEZs.

EVI (Environmental Vulnerability Index)

Criterion 1a: Is the dataset global in it's approach?

Yes. The EVI was developed to provide globally comparable data on the vulnerability of different countries. Therefore, all countries were tested on a set of 50 indicators that reflect vulnerabilities on a scale from 1 (low vulnerability) to 7 (high vulnerability)[90].

Criterion 1b: Is the dataset similar to terrestrial indicators used in the RAF?

Yes. Theoretically, nine from the 50 indicators[91] reflect marine vulnerability within the EVI and can be applied to score an EEZ (s.b.) for it's vulnerability.

Criterion 2a: Is the dataset available until GEF-5?

Yes. The dataset has already been published in 2004 (Kaly et al., 2004).

Criterion 2b: Are all regions equally represented?

No. In order to calculate a valid overall EVI score at least 80 percent of all indicators must be available for one country (Kaly et al., 2004). Applying this threshold to the set of nine

89 since for delineation of LMEs bathymetry, hydrography, productivity and 'trophically dependent species' are critically parameters.

90 Subdivided into indicators of weather and climate (e.g. temperature), geology (volcanos, tsunamis), geography (e.g. isolation), resources and ecosystem services (e.g. endemism, extinctions, overexploitation), and human impacts (e.g. tourism, growth).

91 SST, country fragmentation, country isolation (distance to next continent), MTI, overfishing, oil spills, coastal population within 100 km from coast, Marine Protected Areas (MPAs), and fishery effort.

indicators mentioned above, a valid vulnerability assessment is only possible for 83 of 115 RAF eligible sea-locked and coastal states (see appendix 5).

Criterion 2c: Is the dataset sub-national?

No. All EVI values and indicators apply for countries. Thus, the marine indicators apply for EEZs.

Previous results from section 5.1.1 to 5.1.4 are summarised in table 6.

Table 6: Marine datasets and their results to selection criteria. Optimal datasets that conform to all criteria are bold.

RAF terrestrial indicator	Dataset	1a) globality	1b) similarity	2a) GEF-5	2b) equality	2c) sub-nationality
Represented species	OBIS/KGS	√	√	√	uncertain	√
	SAUP	√	√	√	x	√
Threatened species	GMSA	√	√	x	√	√
Represented ecoregions	**MEOW**	√	√	√	√	√
Threatened ecoregions	**NCEAS**	√	√	√	√	√
	MTI	√	√	√	x	√ (LME) x (EEZ)
	EVI	√	√	√	x	x

5.2 Incorporation of marine indicators into a modified RAF

5.2.1 Marine represented ecoregions and threatened ecoregions

The un-normalized sum of marine represented ecoregion and marine ecoregion threat shares for sea-locked states of the sample are provided in table 7. The unnormalized sum for coastal states can be extracted from tables 8a and 8b. Normalized values for each country can be inferred from appendix 2.

For land-locked countries all marine ecoregion values account for 0.

Table 7: Sea-locked states and respective sums of the marine represented ecoregion and threatened ecoregion shares within their EEZs.

Region	Country	Ecoregion Sum	Ecoregion Threat Sum
African	Maldives	0.793	1.586
	São Tomé and Príncipe	0.985	1.969
	Seychelles	1.000	2.000
Caribbean	Bahamas	0.861	1.721
	Cuba	0.684	2.000
	Dominican Republic	0.119	0.327
	Grenada	0.095	0.382
	Haiti	0.069	0.206
	St. Kitts and Nevis	0.033	0.131
Pacific	Fiji	1.182	3.546
	Nauru	0.002	0.006
	Palau	0.629	1.258
	Papua New Guinea	4.346	10.053
	Solomon Islands	0.890	2.669
	Tonga	1.061	4.245
	Tuvalu	0.534	1.822
	Western Samoa	0.315	1.259

Table 8a: Coastal states and respective sums of the marine represented ecoregion and threatened ecoregion shares within their EEZs.

Region	Country	Ecoregion Sum	Ecoregion Threat Sum
Africa	Benin	0.037	0.111
	Cameroon	0.143	0.429
	Congo, Dem. Rep.	0.016	0.047
	Djibouti	0.057	0.171
	Equatorial Guinea	0.153	0.443
	Eritrea	0.445	1.336
	Gambia	0.100	0.399
	Ghana	0.653	2.572
	Guinea	0.366	1.098
	Guinea-Bissau	0.278	0.835
	Kenya	0.500	1.195
	Liberia	0.139	0.416
	Madagascar	1.942	4.884
	Mozambique	2.184	4.612
	Tanzania	0.560	1.681
	Togo	0.014	0.042
Asia	Bangladesh	0.319	0.956
	Cambodia	0.177	0.531
	China	2.362	8.974
	India	3.333	12.213
	Indonesia	10.285	29.111
	Malaysia	1.065	3.876
	North Korea	0.111	0.445
	Pakistan	0.425	1.397
	Philippines	1.661	5.085
	South Korea	0.576	2.306
	Vietnam	1.844	5.704

Table 8b: Coastal states and respective sums of the marine represented ecoregion and threatened ecoregion shares within their EEZs.

Region	Country	Ecoregion Sum	Ecoregion Threat Sum
Latin America	Belize	0.332	0.997
	Brazil	8.009	21.028
	Chile	5.201	13.642
	Colombia	0.531	1.700
	Ecuador	3.883	7.649
	El Salvador	0.225	0.676
	Guyana	0.270	0.811
	Mexico	6.537	16.746
	Nicaragua	0.637	1.910
	Peru	2.030	6.089
	Suriname	0.286	0.857
	Uruguay	0.705	1.622
	Venezuela	0.939	3.620

5.2.2 Modified formula and changing allocations

Appendix 3a directly compares the tentative preliminary allocations for all sample countries between the unmodified RAF (section 4.3.5) and the modified RAF (section 4.3.4). Appendix 3b and 3c further illustrate the underlying calculation for both models from the GBI_{bio} up to preliminary allocations.

Chapter 6

Discussion

The main points of this chapter are to a) critically evaluate the current RAF; b) justify the equal weighting within the GBI_{bio} from a scientifical and political point of view; c) analyse the results of new allocations and extrapolate them as far as possible and; d) scrutinize the proposed RAF as well as new marine datasets.

6.1 Positive and negative aspects of current RAF

Within this section the current RAF will be critically evaluated.

6.1.1 Analysis from a methodological point of view

The purpose of the RAF is to allocate GEF resources according to a country's performance (GPI) and need (GBI). On the 'Need'-aspect much international debate concentrated on the unequal weighting between the terrestrial and the marine score. However, there are various other aspects of the RAF besides the weighting that are worthwhile mentioning and analysing. There exist several positive aspects of the RAF and especially of the GBI_{bio} that are methodologically sound:

A) Probably the most striking advantage of the RAF is the application of sub-national data. This explicitly recognizes that species, ecosystems, and biota in general are not delineated in their range by national boundaries such as EEZs. Therefore, ecoregions and species ranges may occur in several countries at once.

B) The RAF recognizes that neither species or populations nor the systems they occur in are isolated entities for themselves but rather heavily interwoven. This is accomplished for the terrestrial score by using CECs as the fundamental unit which is scored according to represented and threatened species.

C) At least for the terrestrial score, the RAF uses the best available knowledge of species and ecological systems on a global level. It therefore merges data from the most authoritative sources such as WCMC, IUCN, and WWF to build it's indicators.

D) In the face of the unmanageable task to inventory and map all terrestrial species in the world, the RAF correctly uses only certain species groups as a proxy for overall taxonomic diversity (Bisby, 1995). These groups are taken from a wide variety of vertebrate species and plants.

E) By applying detailed species ranges for the terrestrial species indicators, the RAF removes one potential bias of species scores and thus of allocations towards larger countries. For example, a very large and a very small country which equally share a species range map would receive a score of 0.5, respectively. Without a range map and following the idea of the GBI_{bio}, the whole area of the large and small country would be assumed to be the range of the species. Consequently, the large country receives a greater score for that species. This would bias the species score towards large countries (s.b., disadvantages bullet point E).

F) Many indices of diversity tend to be complex (non-linear) and difficult to understand for a broad audience that includes the public as well as policy-makers. The RAF, on the contrary, is easy to comprehend. It is a transparent and flexible formula due to three main reasons. Firstly, it does not compute the GBI_{bio} in one long formula but rather splits it's calculation in various hierarchical levels that clearly illustrate the various components they consist of. This structure made it possible in the first place to quickly identify one of the major constraints of the formula, namely the unequal weighting between the terrestrial and marine diversity score. Secondly, all sub-indices and indices are computed linearly by using only basic mathematical operators. Hence, addition or removal of indicators follow simple rules. Thirdly, all components from indicators up to the GBI_{bio} are weighted so that their sum always yields a certain normalized number. Thus, the contribution of each component to the whole can easily be identified. Summarized, above reasons make the RAF and also the GBI_{bio} accessible to a wide range of stakeholders and thus provides the best chance for collective improvement.

Nevertheless, there exist various limitations within the RAF that need to be improved for the future:

A) By weighting the terrestrial score more strongly than the marine score the RAF only acknowledges that there exists more data on terrestrial than on marine diversity. Yet it does not recognize that marine biodiversity is beyond the body of scientific knowledge probably equally high in overall biodiversity and threat to biodiversity on a global scale (see section 6.2.1). Therefore, the RAF is wrongly biased towards terrestrial biodiversity since it implicitly assumes a higher terrestrial overall biodiversity.

B) It has to be kept in mind that the RAF generally uses data that only illustrates a fraction of a fraction of what biodiversity actually is (see section 2.1). Firstly, it only uses two measures to illustrate overall biodiversity of a country, a sophisticated measure of species richness and ecoregions. It does not explicitly apply any measures of genetic diversity, higher taxonomic diversity, and ecological diversity such as functional diversity within systems, evenness, or ecological systems of other levels. These are all measures of equal importance since they indicate different aspects of biodiversity (Féral, 2002). Secondly, the represented species indicators only use a tiny part of the total amount of species[92]. Both constraints can be explained by the low availability of data on a global level.

C) Commercial fish species is the only indicator used for the marine score although additional data existed during the creation of the RAF. For example, the global database on coral distribution is currently updated and available later this year (Veron, pers. communication). There may be a risk of biasing the marine score towards certain countries by including corals. It seems to be equivocal though not to incorporate such data due to this reason. This dataset is of high quality, the exact counterpart to terrestrial species maps of the GBI_{bio}, and balances the much larger bias of the RAF towards the terrestrial part.

D) It is scientifically questionable to assume an EEZ as a distribution range of a fish species as currently applied for the marine score. As has been illustrated for the terrestrial part species are rarely limited by political boundaries[93]. The same applies for marine species since they are often not distributed over a whole EEZ, e.g. range restricted reef fishes. Similarly, ranges must not be restricted by EEZ borders, e.g. straddling stocks.

E) The current marine indicator is heavily biased towards countries with large EEZs. For instance, a strictly tropical species is recorded in the 2 million km² large EEZ of Papua

92 e.g. 11,000 terrestrial species in RAF compared to 1.5 million terrestrial species totally. From this total the bulk is constituted by insects, an important group totally omitted in the RAF.

93 except maybe where national and geographical boundaries fall together.

New Guinea and only in the northern part of the much larger 9 million km² EEZ of Australia. The current marine indicator assumes both complete EEZs as species range, although half of the Australian EEZ belongs to temperate waters where that species does not occur anymore. Thus Australia, would wrongly receive a much larger score for that species' habitat.

F) A country's performance weighs more than a country's biodiversity. This has to be seen against the background that the RAF's fundamental purpose is to fund biodiversity. This weighting has been justified by more adequately mirroring original pre-RAF allocations.

6.1.2 Analysis from a political point of view

Most of international debate arose from the inclusion of the GPI. General issues of the GBI_{bio} will be taken into focus for this part. Some elements might be seen as advantages:

A) As already noted before the RAF is in alignment with PBAs of other institutions by also including a measure of a country's need for resources. A high need to support a country results from high biodiversity and threat to biodiversity. On the one hand the RAF may therefore serve as an incentive to protect biodiversity in order to receive more funding. On the other hand it may also provoke less conservation action since funds theoretically increase with higher threatened species and ecoregions.

B) The GBI_{bio} roughly aligns with at least two of the three objectives of the CBD since it provides funds for diversity and threat to diversity. These two aspects are linked with conservation and sustainable use of biodiversity components.

Disadvantages directly related to the unequal weighting will be more thoroughly discussed in section 6.2.2. There exist more general issues though which will only be mentioned marginally here. It should be remarked that the creation of the RAF can be primarily derived from an initiative by the United States to which the Council concurred in order to ensure a continuous participation of the USA (Clémençon, 2006). Additionally, indicative allocations may create an incentive for states to rather use funds nationally instead of sharing funds for regional or global projects.

6.2 Rationale of equal weighting

This study proposes an equal weighting between the marine and terrestrial sub-index of the GBI_{bio}. Mathematically seen, increasing the number of marine indicators in the RAF from one to three only explains a weighting of 60 percent for the terrestrial sub-index and 40 percent for the marine sub-index within the GBI_{bio}[94]. This does not distract from the abundance of scientifical and political arguments that justify an equitable weighting for both sub-indices.

6.2.1 Scientific arguments

Taxonomic and other types of diversity

Measuring biodiversity is the major element of the GBI_{bio}. Nonetheless, it does not correctly reflect the contribution of marine and terrestrial diversity to global biodiversity.

As already noted before, there exists strong discussion on how many species generally exist on Earth. This is also the case for extrapolations of species numbers for the terrestrial and the marine realm, respectively. Basically, this discussion can be split into two attitudes within the scientific literature. There exist those who proclaim a lower overall species richness in the oceans than on land (May, 1988; Singh, 2002; Bouchet, 2006). Others purport marine species numbers that rival terrestrial ones (Grassle, 1991; Snelgrove, 1999a). Primarily the discussion focusses on benthic meiofauna[95] between depths of 1000 and 3000 m. Grassle and Maciolek (1992) analysed species richness data from bottom samples off the east coast of the United States. They have extrapolated a global deep sea sediment species richness of 10 million species, a number that competes with estimates for tropical rainforests. Poore and Wilson (1993) state that this study does not take higher richness of some deep sea areas in the Pacific into consideration and still constitutes a strong underestimate. Lambshead (1993) even raises this number to over 100 million species of global marine meiofauna. These high numbers can be explained by a high habitat patchiness created by a) burrows and mounds; b) sinking detrital pulses from phytoplankton blooms, creating 'feeding oases'; c) carcass falls; d) bioturbation and; e) occasional benthic storms (Grassle, 1989; Raghukumar and Anil, 2003). These estimations caused debate, mainly by May (1992) who analysed Grassle and Maciolek's (1992) data differently. He concluded that global benthic meiofauna accounts for less than 500,000 species. Similarly, Briggs (1994) scrutinizes Grassle and Maciolek's (1992)

94 A number of three from a set of seven indicators corresponds roughly to a 43 percent fraction.
95 Animals with a size range between 1 mm and approx. 50 µm

estimations and even purports an overall marine species richness of approximately 200,000 species. Conversely, Reaka-Kudla (1997) mentions a number for only coral reefs of about 950,000 species. Hawksworth and Kalin-Arroyo (1995) even describe species richness of coral reefs being roughly the same as tropical rain forests. Thus, although it is not possible to estimate marine species richness relative to terrestrial species richness with any degree of certainty, there exists ample scientific evidence that marine and terrestrial species richness may be roughly the same (Carleton Ray, 1988; Grassle et al., 1990; Snelgrove, 1999b; Thorne-Miller, 1999).

Different patterns of taxonomic diversity between the marine and terrestrial environment occur at different levels of the taxonomic hierarchy[96]. Clearly there exist many more orders, classes, and phyla in the marine than in the terrestrial environment (Briggs, 1974; McAllister et al., 1994; van der Spoel, 1994; WCMC, 1996). For instance, from an overall number of 33 animal phyla, 32 have marine representatives while only 18 phyla also occur on land[97] (Boersma et al., 2004). Moreover, there exist 21 animal phyla endemic to the sea, while this is only the case for one terrestrial phylum[98] (May, 1994, Mooney et al., 1995b). Equally, the evenness between phyla[99] is much larger in the sea than on land, where spiders and insects comprise over 90 percent of all species (WCMC, 2000). Some authors even describe phyletic diversity as the fundamental level of diversity since it reflects many other kinds of biodiversity (Pielou, 1975; Mooney et al., 1995a). It may serve as a proxy for genetic diversity, since it represents more distantly related broad categories of life. Thus, genetic diversity is also higher within the marine environment than on land (Gray, 1997). It also represents basic body plans or groups of life forms (May, 1992). For example, marine species groups exist that do not have any terrestrial counterpart, such as a greater number of ancient groups of marine primary producers or sessile animals (Duffy and Stachowicz, 2006). This has important implications for marine functional diversity (Lasserre, 1996, Cury et al., 2001). Hence, marine food webs are more complex[100] and have more trophic levels than terrestrial webs (Thorne-Miller, 1999). Furthermore, filter feeders such as zooplankton specialised in

96 roughly with increasing level: Species, Genus, Family, Order, Class, Subphylum, Phylum, Kingdom.
97 The predominance of higher marine taxa can be explained that life originated in the seas and only a fraction of all phyla succeeded to colonize the land (Gaston and Spicer, 2004).
98 A similar picture emerges taking all phyla into consideration: From 96 phyla recognized by Gaston and Spicer (2004), 69 have marine and 55 terrestrial representatives while 23 are marine and 13 are terrestrial endemics.
99 e.g. number of species between phyla.
100 i.e., more trophic linkages between groups of organisms.

extracting food from a liquid medium are not found on land and thus also increase food web complexity (Carleton Ray, 1988).

Due to human ignorance of the sea, it is also likely that ecosystem diversity is higher in the marine realm than on land, since many marine systems are hidden from human discovery (Norse, 1993). Actually, because of reasons stated above, some authors conclude that it cannot be determined which realm is higher in biodiversity (Angermeier and Karr, 1994). Yet others proclaim that in any other measure of biodiversity except for species richness (see section 2.1.2 for a short overview) the marine environment is more diverse than the terrestrial environment (Earle, 1991; Krishnamurthy, 2003). This is already reason enough for Harper and Hawksworth (1994) to call for an equal allocation of resources for global conservation of marine and terrestrial life on Earth.

Threat status

It is important to discuss threat to global marine biodiversity, since threat is the other main element of the GBI_{bio}. Despite other opinions, the entire marine environment from coasts to the open ocean is at risk (Norse, 1993). As already indicated before the marine environment is the final destination for various hazardous substances that originate from land. Halpern et al. (unpublished) put forward that four out of five primary threats to the marine environment comprise effects from land-based activities[101]. These threats have a cumulative effect especially in coastal areas (Carr et al., 2003). Additionally, due to highly complex marine system structures, such as food webs, extinctions may lead to cascading effects (Culotta, 1994). This phenomenon is rarely observed on land and may lead to loss of more fundamental biodiversity (McKinney, 1998).

Moreover, Cowen et al. (2000) object to the view that marine populations are open, interconnected, and widespread, a characteristic which is assumed to render many marine species extinction-proof. These findings are consistent with those of Roberts et al. (2002) who have found out that many marine species groups have in fact very restricted ranges[102]. However, if openness and interconnectivity is given, long-distance transport of pollution is implied as well. Myers and Ottensmeyer (2005) refer to three additional reasons that make risk of extinction a larger problem in the marine realm: a) marine pollinators do not exist, so

101 Temperature rise, coastal development, point source organic pollution, increased sediment input.
102 Corals, fishes, lobsters, and snails were analysed with the latter three being more restricted than assumed.

that many sessile species fully rely on the very vulnerable process of large-scale spawning; b) larvae tend to settle at already colonised areas, so that successful establishment depends on a whole suit of organisms and; c) due to the large heat-capacity, the marine environment is more sensitive and vulnerable to large scale, long-term threats such as climate change (Steele, 1985).

Thus, the global alteration of marine ecosystems is at least as significant as that of terrestrial ecosystems. Equally, marine species are as susceptible to these changes as terrestrial species (Naeem, 2006; UNEP, 2006). This implies that marine biodiversity is threatened just as terrestrial biodiversity is (Thorne-Miller, 1999).

Primary production

Yet another aspect is primary production which is only indirectly related to biodiversity[103] or to the RAF but also illustrates the global importance of the marine biota. Although an elusive topic, there exists general agreement that both, marine and terrestrial net primary productivity, account for the fixation of approximately 50 x 10^{15} g carbon per year[104] (WCMC, 2000; Groombridge and Jenkins, 2002). Additionally, the most productive natural ecosystems in both realms, coral reefs and rainforests, have similar rates of production per unit area (2,000 to 5,000 g C m^{-2} y^{-1})[105] (WCMC, 1996; Margalef, 1997). From this point of view, both environments contribute roughly equally to global climate.

Pacific case studies

For the majority of SIDS a higher terrestrial weighting within the RAF does not reflect their natural status. Most SIDS in the Pacific have not only a higher richness of marine flora and fauna than on land[106], they even belong to the richest marine environments in the world (Sebens, 1994; Thaman, 1994; Caldecott, 1996). The global centre of highest marine diversity can be found in the Indo-Australian region, basically comprising the Coral Triangle[107] (Bellwood and Hughes, 2001). Due to the exceptionally large marine diversity of the Solomon

103 Few studies positively relate species richness to productivity, e.g. Naeem et al. (1994) or Duarte (2000).

104 This has to been seen against the background that marine producers only constitute 0.2 percent of the global biomass of primary producers. This illustrates the conversion of sun energy into an extremely high turnover rate. Therefore, marine producers compensate not to invest energy into the accumulation of biomass due to missing structural components in the water column on which they can build on.

105 Averaging all land and marine ecosystems, terrestrial productivity per unit area exceeds marine productivity by a factor of three (300 g C m^{-2} y^{-1} for land compared to 100 g C m^{-2} y^{-1} for oceans).

106 This is also illustrated by SIDS land area that only covers 2.7 percent of their EEZ area (see appendix 15).

107 Including East Borneo, the Philippines, the northern part of New Guinea, and Timor L'Este.

Islands (Karlson et al., 2004), the original range of the Coral Triangle has recently been extended to also include this area (s.b.) (Green and Mous, 2006). It has to be borne in mind though that marine diversity decreases longitudinally, i.e., east- and westward from the centre of marine diversity (Gaston and Spicer, 2004). Thus, PICs in the mid-Pacific, although still very rich from a global perspective, have a decreased marine richness. Species numbers are even lower for islands in the East Pacific (Hughes et al., 2002). Table 9 summarises case studies that compare described marine taxa richness for selected states, all states within the Pacific, and globally. The table shows that a large share of marine diversity can be found within Pacific Island States. Several issues have to be kept in mind though:

A) Some values are only tentative, e.g. for marine mammals or crustaceans.
B) Numbers describe both, endemic and non-endemic species to the Pacific.
C) Mollusc species for New Caledonia (FRA) already exceed Pacific values. This can be explained by the study of Bouchet et al. (2002) being one of the most extensive undertakings of modern time.
D) Coral species data for the Pacific was only available for the Solomon Islands. It represents the second highest assessment of coral species worldwide[108] (Veron and Turak, 2006).
E) Species richness of reef fishes for selected Pacific SIDS indicate the longitudinal pattern of decreasing richness. Highest values are met by Indonesia with a number of 2032 reef fishes (Allen, 2006).

108 With only one site in Eastern Indonesia being higher: Raja Ampat Islands with 535 coral species.

Table 9: Species richness for taxa within the Pacific compared to total global estimates.

		Species numbers per region			
Category	Taxa	Selected States*	All Pacific Islands	Global	Pacific share
Vertebrates	Mammals	12 (FIJ)[††]	90[†]	120[†]	75 %
	Reef fishes	2,000 (PNG)[‡] 1,159 (SLB)[‡‡] 1,059 (MHL)[§]	3,392[†]	6,000[†]	57 %
	Seabirds		55[†]	290[†]	19 %
Invertebrates	Sponges		1,000[†]	7,000[†]	14 %
	Mollusks	2,738 (FRA)[§§]	2,600[†]	23,324[¥]	12 %
	Crustaceans		2,000 (Indo-Pacific)[†]	5,729[¥]	35 %
	Echinoderms		452[†]	1,971[†]	23 %
	Corals	494 (SLB)[‡‡]		2,963[¥]	
Plants	Seagrasses		14[†]	58[†]	24 %
	Mangroves		34[†]	49[†]	70 %

* FIJ=Fiji; FRA=New Caledonia; MHL=Marshall Islands; PNG=Papua New Guinea; SLB=Solomon Islands.
† Vertebrates (Eldredge, 1995a); Shore fishes (Pyle, 1995); Seabirds (Flint, 1995); Sponges (Kelly-Borges and Valentine, 1995); Mollusks (Kay, 1995); Crustaceans (Eldredge, 1995b); Echinoderms (Pawson, 1995); Seagrasses (Coles and Long, 1995); Mangroves (Ellison, 1995).
†† Nair et al (2003).
‡ Thaman (1999).
‡‡ Allen (2006).
§ National Biodiversity Team of the Marshall Islands (2000).
§§ Bouchet et al. (2002).
¥ OBIS (2007).

6.2.2 Political arguments

Economical valuation

Several studies call for an economic valuation of ecosystems in order to fully understand and incorporate their importance in policy making and decisions (Alexander et al., 1997; Pimentel et al., 1997; UNEP 2006).

The only study currently existing is provided by Constanza et al. (1997). By reviewing available literature on valuation of ecosystem functions and services[109], they have estimated a total value of approximately US$ 33 trillion per year for all services on Earth. Moreover,

109 Over 100 studies with valuation techniques based mainly on estimating the 'willingness-to-pay' of individuals for ecosystem services.

considering only marine ecosystems, a value of US$ 21 trillion[110] is reached which is 1.8 times greater than the estimate for terrestrial ecosystems (US$ 12 trillion). The conclusion is, although not directly related to biodiversity *per se*, that humans value ecosystem services arising from marine biodiversity higher than those from terrestrial biodiversity. This needs to be accounted for in policy decisions (Roush, 1997). Interestingly, the study by Constanza et al. (1997) does not take any account of the open ocean and it's role for climate control (Thorne-Miller, 1999). Despite the illustrative usefulness to guide decisions, several constraints have to be borne in mind such as moral issues to value the invaluable, applying market prices for non-market commodities, and insufficient knowledge on accurate valuations (Ehrenfeld, 1988; Daily et al., 2000; Koricheva and Siipi, 2005).

Conflict with the spirit of the CBD

It is fundamental to explain that the unequal weighting of the GBI_{bio} contradicts various essential elements of the CBD that contribute to the whole character of the Convention. This has also important implications for recipient countries.

As already stated the RAF implicitly assumes that terrestrial diversity is higher and more important than marine diversity. Apart from the fact that this cannot be proven, this issue contravenes the notion of the CBD which does not apply any higher importance neither to terrestrial nor to marine biodiversity (Thorne-Miller, 1999; SPREP, 2000). It has thus to be assumed that both kinds of diversity, beyond scientific data, are equally important and must be treated as such.

Applying an equal weight within the GBI_{bio} aligns with the precautionary principle, one of the guiding principles of the CBD and the RAF[111].

The precautionary principle was created in the late 1970's in West Germany[112]. It was created to provide the basis to control hazardous substances whose detrimental effects were evident but the exact causal relationships has not yet been scientifically established (Fisher et al., 2006). More detailed, the principle consists of four fundamental elements (de Fur and Kaszuba, 2002): a) There is a credible or known threat of harm; b) the situation presents a

110 For coastal and open ocean services.
111 GEF/C.27/Inf.8/Rev.1, Annex 1, para. 4
112 german: 'Vorsorgeprinzip'

lack of scientific certainty or evidence[113]; c) detailed cause and effect relationships are not proven yet and; d) there exists a duty to act. The formal structure of the principle allowed various interpretations and it has been manifested in many international treaties and declarations (Foster et al., 2000; von Schomberg, 2006). For example, the more general version of the CBD states (Goklany, 2001):

> [...] where there is a threat of significant reduction or loss of biological diversity, lack of full scientific knowledge should not be used as a reason for postponing measures to avoid or minimize such a threat,

The principle applies especially well to biodiversity. Firstly, global biodiversity, terrestrial as well as marine, is heavily threatened as outlined roughly in precedent sections (2.1.3; 2.2.1; 6.2.1). Secondly, for both environments there exists a great deal of scientific uncertainty about threats and their impacts on biodiversity (Tickner and Kriebel, 2006). For example, the full consequences of species introductions, habitat destruction, increasing UV radiation, and climate change for the marine environment is still far from being fully assessed (Myers, 1993; Mooney et al., 1995b). Also, for more obvious marine threats such as overexploitation and pollution, scientific knowledge is generally incomplete. Especially the impact on the intricately intertwined interactions between species and long-term effects on marine biodiversity are poorly understood (Cooney, 2006). Similarly, a precautionary approach is also warranted given the vast ignorance on other aspects of biodiversity, such as unknown species, functions, and services (Krishnamurthy, 2003; Balmford and Bond, 2005; Peel, 2006). So as long as it is not scientifically solved which environment is more threatened or diverse, an equal weighting of the GBI_{bio} would recognize the uncertainty in both realms and thus conforms to the precautionary principle (Madin et al., 2004; Ricci et al., 2003).

The current GBI_{bio} reduces funds for all recipient states with significant marine biodiversity, i.e., countries with a marine sub-index score exceeding the terrestrial score[114] (see section 6.3.1). This results in an unjustified discrimination in the allocation of resources for one-fourth of all RAF eligible countries, including a large amount of coastal countries as well as SIDS.

113 scientific uncertainty implies many variable forms (for good review see Stirling, 2007). However, here it simply applies to situations of incomplete knowledge or where available scientific information is simply insufficient. This is also included more detailed in point c).

114 see table 4 on page 31 and table 13 on page 70 for a list of such countries.

Especially the special status and needs of SIDS are neglected within the RAF. The international community has recognized SIDS special status within Agenda 21[115], the Barbados Declaration[116], Johannesburg Declaration[117], Mauritius Declaration[118] and Strategy[119], and within the CBD[120] and COP decisions[121], as being based upon the extraordinarily high, unique, and extremely fragile marine biodiversity. In addition SIDS are financially highly vulnerable due to very weak economies, a lack of institutional capacity, remoteness from international markets, very high transportation costs, and high income fluctuations[122]. Therefore, SIDS are frequently referred to, along with Least Developed Countries (LDC), as being those most in need for financial support[123]. Furthermore, the COP has requested the GEF to provide financial resources to developing states, taking into consideration the special needs of SIDS[124]. However, the concern has been expressed by the last COP that the RAF will actually do the opposite by limiting allocation of resources to SIDS[125]. This fear is verified by the results which clearly show that the current RAF constrains SIDS funding possibilities compared to the proposed RAF (Fig. 13). Thus, the current RAF does not align with COP decisions.

6.3 Analysis of results

Altogether 35 countries had increasing allocations and 38 had decreasing allocations. It has to be reiterated that the results are based on a sample set of countries that were selected according to certain criteria[126]. Therefore, preliminary values are only tentative, but trends are expected to be definite.

6.3.1 General implications

Including two more marine indicators and applying an equal weighting of the GBI_{bio} yields three main consequences of the new tested RAF (Fig. 13).

115 UN/A/CONF.151/26/Rev.1 (Vol.I), para. 17.123 to 17.126
116 UN/A/CONF.167/9, part one, III, para. 1 to 4
117 UN/A/CONF.199/20, para. 24
118 UN/A/CONF.207/11, para. 3
119 UN/A/CONF.207/11, Annex II, Opening Statement of Paul Raymond Bérenger, Mauritius Prime Minister (retired).
120 Preamble and Article 20, para. 6.
121 UNEP/CBD/COP/4/5, III
122 UNEP/CBD/COP/8/1, Annex A, para. 10.
123 e.g. UNEP/CBD/COP/6/26, Annex C, para. 2.2
124 UNEP/CBD/COP/7/20, para. 2
125 UNEP/CBD/COP/8/13
126 See section 6.4.2 for why a representative sample has to be selected in the first place.

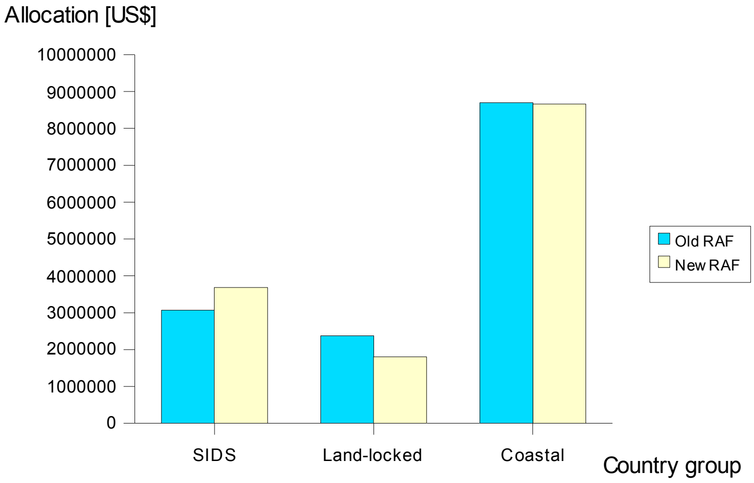


Fig. 13: Average RAF preliminary allocations for the 73 country sample for the current RAF (blue) and for the new RAF (yellow).

Sea-locked states or SIDS have a clear overall upward trend in preliminary allocations by approximately 20 percent. Conversely, coastal states decrease slightly by 0.4 percent and land-locked countries decrease strongly by 24 percent.

For further analyses of the data four major observations require explanation: a) all countries with a higher marine than terrestrial score under the new GBI_{bio} experienced increasing allocations; b) countries with a higher terrestrial score experienced both, increasing and decreasing allocations; c) allocations decreased by approximately 24 percent for all land-locked countries and; d) larger countries tend to have decreasing allocations while this trend seems to be reversed for small countries.

A) The most evident explanation for this pattern appears to be the predominance of the marine sub-index over the terrestrial sub-index. Although this is true it cannot be always ascribed to the incorporation of new marine indicators. In fact, few countries have decreasing marine scores under the proposed RAF. The underlying reason is the change of weightings *within* the marine score due to new indicators. Thus, a very high marine represented species score may be pulled down due to marine ecoregion scores that are very low. For example, the marine represented species score of the Bahamas decreased with incorporation of the two marine ecoregion indicators by approximately 12%. This sacrifice of the marine score still leads to a higher allocation for the Bahamas under the proposed RAF. This is explained by increasing the weight of the still much higher marine score, which is justified by the incorporation of new indicators in the first place. On the contrary, the reverse can also be true. Very low marine scores, due to a low marine represented species score, can be boosted by very high marine ecoregion values. The most extreme example is Tonga with a marine score that doubles with additional data.

B) Countries which have a terrestrial score higher than the marine score may have after inclusion of new indicators increasing or decreasing allocations. The most straightforward explanation would be that new marine indicators increased the marine score to levels that exceed the terrestrial score. Actually, this is only the case for two coastal countries[127]. This implies that increasing allocations for these kinds of countries must not be compulsory dependent on new marine indicators. It rather depends on applying an equal weighting within the GBI_{bio}. This was tested by running the original RAF formula on the same sample set without any new marine indicators but with an equal weighting of the marine and terrestrial score (see appendix 6a/b). The results reveal that seven coastal countries with higher terrestrial scores still received increasing allocations[128]. The extreme example is Belize with an increasing allocation of 0.47 percent, yet the marine score is 40 percent lower than the terrestrial score. This can be explained by the balance between countries with a higher terrestrial than marine score and vice versa. 75 percent of all RAF eligible countries have terrestrial scores exceeding marine scores. This also shifts the threshold between the marine and terrestrial score, at which countries receive higher or lower allocations, to the terrestrial side. This means that countries with a higher terrestrial score may still receive increasing allocations. Conversely, patterns change if there would be an equal number between countries with a higher marine score and countries with a higher terrestrial score. In that case changing weights from an 80-20 percent situation to 50-50 percent results in increasing allocations for all countries with higher marine scores and decreasing allocations for all countries with higher terrestrial scores[129]. To fully provide the whole mathematical explanation is beyond the scope of this thesis. The same applies to an equally weighted GBI_{bio} with *new* marine indicators. In this case, there are 13 countries with higher terrestrial scores and still increasing allocations. This can be explained by new marine indicators that serve as a buffer.

127 Uruguay and El Salvador.
128 Belize, Benin, El Salvador, India, Mexico, North Korea, and Suriname.
129 with all other conditions being equal as well, e.g., size of countries.

Hence, new indicator values raise marine scores above the threshold from which countries receive increasing allocations[130]. One of the best examples is the island state São Tomé and Princípe. Originally, the marine score was half the size of the terrestrial score. Compared to the original RAF, an equally weighted GBI_{bio} without new indicators decreased allocations by 5 percent. New marine indicators elevated the marine score to a level only slightly below the terrestrial score. Thus, allocations for São Tomé and Princípe increased by 20 percent. Since new marine indicators add a new dimension of complexity and unpredictability it is not possible to draw a threshold value to foretell the fate of these kinds of countries.

C) It has been observed that all allocations for land-locked countries decrease by a value of 23.92 percent. This can be explained that the same conditions apply for all land-locked states. Since they have no coastline their marine score accounts for zero. This, of course, cannot be changed by any new marine indicators. Equally decreasing the percentual contribution of the terrestrial score for each country, yields an equal percentual decrease in allocations. Since the marine score is and stays the same, there is no additional parameter that influences the outcome of allocations.

D) Larger coastal countries tend to have decreasing allocations compared to smaller countries. This has been recognized after categorising coastal countries into three size classes of large (> 1 million km²), medium (100,000 – 1 million km²), and small (< 100,000 km²) countries. A greater number of large countries had a downward trend of allocations (3 up, 5 down). There was a slight increasing trend for medium sized states (10 up, 8 down), and for small countries there was a strong upward trend (10 up, 4 down). Generally, this can be explained that large countries tend to have much larger terrestrial than marine scores and small countries have more similar scores. By decreasing the terrestrial score from 80 to 50 percent, large countries loose much more of their original GBI_{bio} score. Smaller countries are not that heavily impacted. The pattern of much higher terrestrial scores for large countries may be explained by combined effects of various geographical and biogeographical causes:

   i. Following the idea that species richness increases with area, larger countries tend to have much higher terrestrial than marine richness. These countries have a much larger terrestrial area than EEZ. Small countries more frequently have an EEZ area that is of similar size to the land area.

130 With the marine score still being lower than the terrestrial score.

This can be explained by land of big countries being more often large in 'two dimensions'. These countries have a long coastline but also a large landward dimension, e.g. Brazil. However, their EEZ may only be large along one dimension (coastline), since the seaward extension is fixed by the 200 nm border. The reverse applies for small countries such as Suriname with a landward border 390 km far from the coastline[131]. Therefore, the marine and terrestrial score is more similar, and it receives an increasing allocation.

ii. The current marine represented species indicator enhances distribution ranges so that an incorrect wider species range is inferred (see section 6.1.1). This reduces country shares and marine species scores tend to be even smaller than they actually are.

iii. Land species tend to be more range restricted and endemic than marine species. For such species countries may receive larger terrestrial species scores. It is also assumed that a few highly scored terrestrial species weigh more than many widely distributed marine species.

iv. Large countries may have more restricted EEZs due to location of maritime boundaries from other states. For example, China's EEZ is compressed by adjacent maritime borders of Taiwan, North Korea, South Korea, and Japan. Thus, it's terrestrial area exceeds the EEZ area by a factor of nine.

v. Some large countries such as Brazil, Colombia, and Peru are located at or near the terrestrial centre of biodiversity (Neotropics).

These are assumed to be the main reasons for the aforementioned pattern. Nevertheless, more country-specific reasons, which are not explained here, are expected to occur as well.

6.3.2 Extrapolation of results

From the deeper insights into the results gained in the previous section it is possible to predict changes of allocations for countries not included in the sample:

A) Allocations for all countries increase with a marine score exceeding the terrestrial score in the current RAF (Table 10).

131 Almost same distance as the EEZ seaward border (200 nm = 370 km).

B) Allocations for all land-locked countries will decrease (see appendix 18 for a list of RAF eligible land-locked countries).

Table 10: Countries, not included in the sample, with marine scores higher than terrestrial scores of the current RAF.

Category	Countries (alphabetical order)
Sea-locked	Antigua and Barbuda, Barbados, Cape Verde, Cook Islands, Kiribati, Marshall Islands, Mauritius, Micronesia, Vanuatu
Coastal	Egypt, Mauritania, Namibia, Panama, Senegal, Sierra Leone, South Africa, Yemen

As has been indicated it is much more difficult to infer a pattern of changing allocations for countries with marine scores below terrestrial scores[132]. There are too many factors that would influence the real outcome in an unpredictable manner, for example, the relationship between the current marine and terrestrial score and the unknown influence of marine ecoregions since they couldn't be provided. Additionally, analyses are based on a sample set of countries and are only tentative. Extrapolation from tentative values includes an extremely high degree of uncertainty and is deemed arbitrary. With this in mind, a simple extrapolative approach has been tried. Sample countries with higher terrestrial scores were grouped in size categories of small, medium, and large (s.a.). In each category the percentage has been assessed of countries with increasing allocations. This value represents a very rough probability how allocations may change eventually. For small countries there exists a 47 percent, for medium sized countries a 42 percent, and for large countries a 38 percent chance of increasing allocations. This calculation and a list illustrating all RAF eligible countries that fall under one of these categories but were not included in the sample are provided in appendix 8.

From these results it is an unsolvable task to predict which group countries with increasing allocations may eventually receive individual allocations and vice versa. It is only possible to tell that a higher increase of allocations yields a higher probability of an individual allocation. This also depends heavily on actual values of the GPI which were not applicable for this study. Taking the most extreme yet purely hypothetical example, even the huge increase of Tonga's GBI_{bio} may not guarantee individual status if the GPI is too low.

132 This includes sea-locked and coastal countries but excludes land-locked states.

6.4 Analysis of proposed RAF

Within this part the methodological approach of the proposed RAF will be scrutinized, and it will be explained why a representative set of countries was a necessity.

6.4.1 Positive and negative aspects for proposed RAF

The advantages of an equally weighted GBI_{bio} are illustrated in section 6.2. Nevertheless, there exist several other positive implications of the proposed RAF that mainly relate to the inclusion of the two marine indicators:

A) The number of indicators of the terrestrial and marine part is more balanced. Although marine data was limited during the creation of the current RAF, there is already now enough data available to increase this number to three.

B) The marine ecoregion indicators incorporated into the proposed RAF constitute essentially the same units as their terrestrial counterparts. This complements the GBI_{bio} in the most meaningful way and enables direct comparison between contributions of analogous indicators. This aids to keep the RAF formula transparent.

C) Since selected marine indicators conform to all five criteria, they are the most suitable datasets for incorporation into the proposed RAF. This enhances acceptability of proposed datasets unlike non-equivalent indicators.

D) As proposed datasets improve, the quality of the proposed RAF increases as well (e.g. section 6.5.1).

E) With analogous indicators on the terrestrial and marine side yet another formula can be proposed that does not separate the GBI_{bio} into a terrestrial and marine score. Such a formula could combine the un-normalized sum of analogous datasets, for instance, terrestrial and marine ecoregions, in one indicator. Applied for each dataset the GBI_{bio} would consist four merged indicators. Although this may compromise transparency it recognizes that the marine and the terrestrial environment are intimately linked[133]. However, the state of available marine data for this study did not allow such an integrated approach.

Although the current RAF and GBI_{bio} can substantially be improved, there exist various negative aspects and omissions of the proposed approach:

A) The new GBI_{bio} still consists out of fewer marine than terrestrial indicators.

133 UNEP/CBD/COP/2/10, Annex I, para. ii

B) The current marine represented species indicator could not be replaced by another dataset on species ranges, due to the sheer size of these datasets.

C) The current state of marine data is not sufficient to allow the same quality of the GBI_{bio} for the marine side as for the terrestrial side. For instance, no dataset is available for a marine threatened species indicator. Nor it is possible to use marine CECs as the fundamental unit for the marine score, despite the inclusion of marine ecoregions[134]. Therefore, the proposed GBI_{bio} still uses an EEZ as the fundamental unit which is scored according to new marine indicators.

D) Land-locked countries do generally receive lower preliminary allocations under an equally weighted GBI_{bio}.

E) The proposed formula still separates the marine and terrestrial score due to reasons of data quality and availability (s.b.).

F) The results of the proposed RAF do not show real indicative allocations but only trends between old and new allocations. This has intentional as well as un-intentional reasons.

   i. Some methodological parts of the current RAF were purposefully either modified or excluded in the proposed RAF. The aim was to remove all other variables that would influence allocations except for the weighting between the terrestrial and marine score as well as the incorporation of new marine indicators. This pertains application of an average GPI value of 3.03, no adjustment of allocations to floors and ceilings, and no group or individual allocations. These modifications allow new RAF allocations being solely based upon the impact of new marine indicators and a new weighting. This increases transparency on how the proposed GBI_{bio} may change the current RAF.

   ii. Due to pre-publishing license issues, the MEOW dataset could not be fully provided. Therefore, new calculations had to be based upon a representative country sample.

6.4.2 Rationale of a representative set of countries

This thesis had to use a *representative* set of countries in order to reflect likely changes of RAF allocations as well as possible. Three aspects have to be understood therefore. Firstly, also with the proposed RAF formula the GEF resources stay the same (US$ 3.1 billion).

134 OBIS species ranges were too coarse and marine ecoregions too small, especially for SIDS (see section 6.5).

Secondly, GBI and GPI compute a country score which in turn calculates a country share of resources[135]. Thirdly, the RAF for the biodiversity focal area is essentially based on geographic data and indicators[136].

Hence, modifications of the GBI_{bio} will shift country shares and allocations from certain countries to other countries based on their geographical particularities.

For illustrative purposes, the following simplified hypothetical scenario is assumed: A new RAF with new indicators is tested on both, a) once on a set of SIDS and land-locked countries and; b) once on SIDS only.

Scenario a): Incorporating new marine indicators leads to an increased GBI_{bio} and country score for all SIDS (formula 3). Conversely, land-locked countries experience a decreased GBI_{bio} and country score. Since country scores increase for SIDS and decrease for land-locked countries, SIDS receive a greater share of the 'sum of country scores' and land-locked countries receive a smaller share (formula 5). Eventually, a higher country share for SIDS implies higher allocations while land-locked countries receive lower allocations. Summarised, SIDS benefit from land-locked countries.

Scenario b): Testing the same new RAF on only SIDS still increases their respective country scores. Since there are no countries with decreasing scores, country shares of SIDS essentially stay the same and no change in allocations would be recognizable.

So to provide a true indication on how allocations may change for a sample as many different variables as possible for all RAF eligible countries must be taken into consideration. These were not only geographical circumstances such as sea-locked, coastal or land-locked status but also regional classification into continents, relationship of the marine and the terrestrial sub-index, and consideration of the original GBI_{bio} in order to recognize different size classes of countries.

Additionally, a representative set enabled extrapolation of results to other not tested countries.

6.5 Analysis of datasets

This part discusses why certain datasets are more suitable and preferable over others. Additionally, further advantages, disadvantages and scope for improvement for the OBIS,

135 See formulas 3 and 5.
136 e.g. species ranges or ecoregions.

MEOW, and NCEAS datasets and their incorporation into the proposed RAF are analysed[137].

6.5.1 Marine represented species

Perhaps the most striking features of OBIS that make this dataset more suitable for the RAF than others are a) the large size of species records for which location data is held; b) the broad taxonomic coverage it encompasses and; c) the explicit, though ambitious aim to map the distribution of all marine species globally. Yet another innovative aspect is the integration of environmental parameters to plot maps of a species' distribution on a global 0.5° cell grid, which is currently the standard resolution for such a procedure (Guinotte et al., 2006). The approach applied in this study was implemented after consultation with the developers of the KGSMapper who try to develop a very similar automated procedure. The advantages of OBIS and plotted distribution ranges are (cf. Fig.9):

A) Close visual similarity with published species ranges[138].
B) It provides a much higher resolution than assuming a total EEZ as species range. Thus, it is also applicable for more range-restricted species, e.g., for strict shelf species where the continental shelf does not reach the outer boundaries of the EEZ.
C) Questionable areas can be excluded by removing outliers so that a distribution range does only depend on optimal habitat parameters. Even though OBIS data is provided by authoritative sources and controlled by an editorial board, wrong location data can still be included[139].
D) OBIS constantly improves in quality as new organisations and datasets provide their data. Thus, not only new species are added but also current species will contain more location points which yields more reliable distribution maps.
E) Once an automated approach is developed new species can quickly be incorporated.

Despite a substantial improvement of the current represented species indicator, there exist several caveats that must be taken into consideration for a possible role as an indicator:

A) Due to the immense size of the OBIS dataset more in depth analyses were not feasible. Hence, it is not clear if species location data is biased towards a certain type of countries or hemisphere. Opinions seem to diverge on this issue. Costello et al. (2007)

137 These has to be seen complementary to the criteria the datasets were tested on. Fulfilled criteria are advantages and unmet criteria are disadvantages.

138 It was not possible to infer any mathematical degree of correlation since published ranges were only available as simple images, and from different sources with varying degrees of quality and detail.

139 This can be explained by species being wrongly identified.

mention a developed country bias, while Grassle et al. (2005) describe a global coverage with large potential for the most remote island nations in the Pacific (Gordon, 2000). Additionally, it is unclear how many OBIS species can be used to plot a species range, since the majority falls under the minimum threshold of 20 global records within the KGSMapper[140]. The current maximum estimation lies at approximately 11,000 species which is as much as for the terrestrial part. It is also not inferred if certain species groups are similarly influenced by particular environmental parameters[141].

B) The raster display of marine species ranges by the KGSMapper is much more coarse than the high quality polygons used for the terrestrial represented species indicator. This implies that only the global distribution of species can be plotted satisfactorily, yet, they do not correctly represent their local distribution. Nonetheless, these are the most detailed maps currently available for the marine realm that cover a sufficiently large amount of species and taxa[142].

C) Once a global map of suitable habitat is plotted, it is a scientifical challenge to distinguish between areas of suitable habitat and an actual distribution range. The approach applied in this thesis is expected to be conservative since it assumes that species cannot migrate even past one cell of unfavourable conditions. But coral larvae, for example, may drift large distances and settle again on distant patches of suitable habitat. It is arguable though if a species did really migrate that far, as long it is not recorded on other patches of suitable habitat.

D) Gaps in modelled ranges compared to published ranges may occur (e.g. West Africa in Fig. 9F). Either relevant datasets have not been incorporated that locate the species at a particular gap, or that species may simply not exist there.

E) Various organisations and papers primarily apply temperature and depth as a fixed set of environmental parameters that explain a marine species range (Worm et al., 2005; Guinotte et al., 2006; Kaschner et al., 2007; SAUP, 2007). This must not be the case for all taxa. Therefore, this study tries to provide a framework that recognizes the most influencing parameters for a species. Thus, this methodology can be applied for many

140 i.e., the minimum amount of records with which still a reliable distribution map can be plotted.

141 This would allow the utilization of fixed parameters for larger groups of species.

142 Only the GMSA may be able to provide maps that are equally detailed as the current terrestrial species indicator and cover a broad range of species and taxa.

different taxa (Fig. 9)

F) Due to time reasons the statistics table readily provided by the KGSMapper was used to determine the threshold that did not increase the fit of a distribution map substantially[143] (Fig. 5). Since this table analyses all cell areas of the globe, i.e., also suitable areas too far away to migrate to, a high threshold of 25 percent was selected subjectively. It is possible though to extract detailed spreadsheets from every plot. They allow a thorough, time consuming analysis of how the fit has increased for every subsequent plot for only suitable habitat cell patches that contain at least one specimen cell. For such analyses a smaller threshold value can be chosen.

G) There exist species groups whose distribution range cannot be adequately captured by the applied method. For example, zooxanthellate animals[144], such as shallow water corals, will have distribution ranges that extend clearly their maximum depth limit below which light penetration is too scarce for survival[145]. This is the case for the shallow water coral *A. valida*. It's distribution range clearly covers waters deeper than it's natural depth range (Fig. 14A). However, it is a big strength of the KGSMapper to exclude cells that exceed a manually set threshold for an environmental parameter. The distribution range of *A. valida* can be refined by excluding all cells of suitable habitat below 20 m (Fig. 14B). Light and depth restriction is the most prominent example since it is an easily measured and simple, yet crucial correlation. The same relationship may be exhibited by strict shallow reef associated species, since they only occur within light-limited reefs. Obviously, there are more crucial linkages between groups of organisms and environmental parameters. Temperature may play an important role for tropical or polar species. With regard to the KGSMapper it is assumed that the cell size is fine enough to capture the larger scale gradients of, for

143 Therefore the ratio of specimen cells to total cells of the suitable habitat within 1 SD of the means of selected environmental parameters was analysed for subsequent plots.

144 Mainly sessile animals in symbiosis with photosynthesising microbes (zooxanthellae) that provide carbohydrates to the host.

145 This can be explained by the 0.5° cells being too coarse to capture small-scale depth gradients: OBIS provides exact location points (latitude, longitude) of species records. These are converted onto the KGSMapper grid. With regard to depth, each cell may cover habitat with a large depth range. However, each cell has a distinct depth value that is a compromise between the shallowest and the deepest depth. If an OBIS record of a shallow water coral at 20 m falls on a KGSMapper cell with a distinct depth of 60 m (e.g. the mid point of a cell that covers a depth range from 20 m to 100 m, which is likely to be the case for many PICs), then this record is wrongly attributed to a deeper depth. This implies two serious consequences if this applies to a majority of cells. First, the mean depth for all locations is shifted downwards. Secondly, plotting suitable area based on this mean within, for example, 1 SD also predicts a deeper area. Eventually, this leads to a species being predicted where it cannot occur anymore.

instance, temperature, oxygen, salinity, and other parameters.

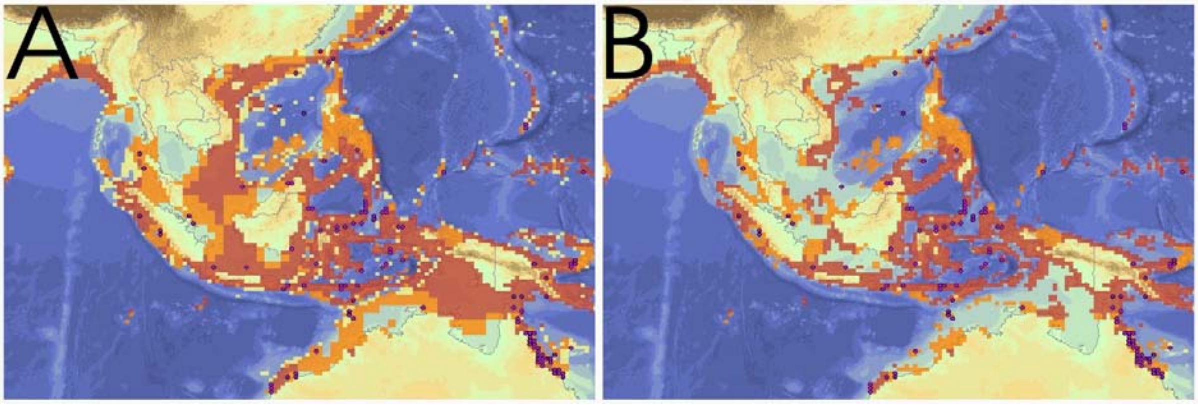


Fig. 14: Range maps of *A. valida* with specimen cells (pink dots) and suitable habitat plot (red and orange area). A: Range map according to Minimum Bathymetry and Maximum Monthly SST. B: Range map with same parameters as A, but excluding all cells below 20 m depth.

6.5.2 Marine represented ecoregions

Despite being the ideal counterpart to terrestrial ecoregions there exist several implications of the marine ecoregion approach that have to be critically inspected. These arise from issues of ecological systems in general but also derive from the special characteristics of the oceans. Nevertheless, regarding the paucity of other datasets that may indicate biodiversity on a global scale, it is not recommended to remove these indicators from the RAF.

Bisby (1995) recognizes three caveats that relate to defining ecological systems:

A) There exist many classifications of ecological units, each applying different criteria for delineation. However, there does not exist one fundamental criterion that unites these approaches. Additionally, all classifications must be seen as abstractions for practical purposes because of the immense complexity that governs within and between systems. Thus, any kind of ecological system is only a simplified aspect of biodiversity.

B) All boundaries between ecological systems are necessarily arbitrary since no system is perfectly separated from the other. For example, ecotones are areas with an environmental gradient that generates a blurred transition from one uniform species composition to the next.

C) Every coarse ecological system totally fails to capture the vast richness and variation of ecological linkages and associations within the system. Such systems represent only a rough or unsuitable proxy for other types of biodiversity (Spalding, pers. comm.).

There exist also issues that apply to marine ecoregions (Spalding et al., 2006, 2007):

A) The current state of marine ecoregion data is minuscule for the open and deeper ocean areas and is only sufficiently large for coastal regions. Hence, the MEOW dataset only delineates ecoregions down to a depth of 200 m. It is not clear when the MEOW dataset will cover deeper areas as well (Spalding, pers. comm.) but it will have drastic implications for especially PICs. Since most island nations in the Pacific are of volcanic origin their coastal area above 200 m is small and most of their EEZ is constituted by deep waters. Eventually, Pacific SIDS may possess more ecoregions than other countries with shelfs extending to the outer limits of the EEZ.

B) Compared to land there exist less conspicuous structural habitat types (only kelp forests, coral reefs, seagrasses, and mangroves that represent a small area of the whole ocean). Therefore, marine ecoregion boundaries also depend on currents, upwellings and similar oceanographic features. Due to the dynamic nature of such features, these boundaries tend to be mobile and should be seen as an average location for a blurred zone of transition.

C) Due to the horizontal stratification of the water column and occurrence of distinct biotas within these zones, classifying the deep sea leads probably to a separation into benthic and pelagic ecoregions.

6.5.3 Marine threatened ecoregions

Since this dataset is not published yet, available literature is extremely scarce which makes it difficult to discuss this dataset here. For example, nothing has been published or provided on how ecoregion threat values were derived from the original 1 km² analysis of the NCEAS threat and impact project. Still this dataset is favourable over the MTI or the EVI since it applies to all selection criteria. There are many advantages of the original analysis. Those pertaining only threatened marine ecoregions are:

A) The high quality due it's large coverage of threats and ecosystems incorporated into the analysis, the very high spatial resolution of the original analysis, expert opinions from around the globe, and a comprehensive methodology[146].

B) The replicability of the analysis by expert consultations, so that threat status on ecoregions can be updated regularly.

C) The compatibility to the MEOW dataset.

146 Each threat (sum: 38) on each ecosystem (sum: 20) was analysed for five impact and vulnerability factors.

Caveats correlate mainly with those for represented marine ecoregions. Additionally to that, some smaller issues were posed by a bias towards academical knowledge (compared to political and traditional knowledge) and a high variation of expert responses regarding certain threats on ecosystems.

6.6 Deterioration of *biodiversity*

Before the term of *biodiversity* was created, it's predecessor (ecological) diversity was a strictly scientific branch of ecology. Although people had already an intuitive idea of what is described by diversity, e.g. a coral reef is diverse, it became an issue to define what actually is diverse on such a coral reef. This issue was aggravated by the fact that ecologists developed an excess of indices and models to measure diversity, so that the concept of diversity remained rather inaccessible and obscure to many. Hence, it was also sometimes referred to as a “non-concept” (Magurran, 1988).

When conservation biologists designed *biodiversity* the scientific elements were still retained (see section 2.1). However, the cornerstone was laid for an intentional far-reaching introduction of the term to the rest of the world[147]. Quickly, *biodiversity* developed to a buzzword in media, public, and policy with a scientific connotation that provides respectability. Still the question was not solved what biodiversity actually is. This ignorance was turned into the actual strength of *biodiversity* as being virtually everything about life on Earth. If *biodiversity* is everything, then every person can find in it what is cherished most. Quickly, the concept of *biodiversity* narrowed and was generally viewed as species richness. Further, for the majority the concept started to embrace only easily recognizable charismatic species. By associating *biodiversity* with such an ideal picture people got converted from being indifferent about *nature* to being supporters of *biodiversity.* This constitutes a broad support within society for biologists to preserve the biotic world. Today *biodiversity* is hoped to be, similar to *ecology*, a well-defined and stand-alone scientific branch but with a broader relevance to the public, so that it's many values can quickly be communicated (Takacs, 1996).

147 Simultaneously it started to replace the less prominent term of *nature*.

Chapter 7

Conclusions

As has been discussed in this study, the current as well as the proposed RAF contain various caveats. Therefore, this chapter a) reiterates the need for an equal representation of marine and terrestrial biodiversity within the GBI_{bio}; b) underscores the importance of further modifications and review of the proposed RAF and; c) describes different pathways of lobbying for a more equitable RAF.

7.1 General conclusions

Firstly, this study demonstrates that there exist at least two marine datasets that can readily be incorporated as indicators for global marine biodiversity into the RAF for the biodiversity focal area. Therefore, the null hypothesis is rejected.

Secondly, although only three marine indicators are available, it is proposed that the marine and terrestrial score within the GBI_{bio} are evenly weighted by 0.5 (50 percent), respectively. This is justified by an equal weighting

A) acknowledging that on a global level there exist ample scientific evidence that marine biodiversity is at least equally high as terrestrial biodiversity. Realizing this also conforms with the global scope of the CBD which addresses known as well as unknown biodiversity, despite the paucity of data.
B) recognizing that marine biodiversity is much more threatened than assumed and most probably equally threatened as terrestrial biodiversity in many parts.
C) perceiving that there exists a large body on solitary distributed case studies on marine biodiversity that have not been incorporated into global databases.

D) recognizing that the marine environment is not economically valued lower than the terrestrial environment.
E) acknowledging that marine biodiversity is not regarded as less important than terrestrial biodiversity within the CBD.
F) conforming to the precautionary principle which is the guiding principle of the RAF.
G) removing a terrestrial bias of allocations by equitably acknowledging coastal as well as sea-locked countries with significant marine biodiversity.

Thirdly, it is concluded that the current GBI_{bio} is a very crude and simplified measure of biodiversity as well as heavily biased towards terrestrial biodiversity. Nevertheless, it has a very sound and transparent structure. This creates the potential that the RAF may significantly improve over time. For example, the current constraints can easily be fixed by adjusting weights or to incorporate better biodiversity data. It is arguable though when further data is available and if global biodiversity data is actually ready at all to create a formula that ranks countries according to their biodiversity. Consequently, there exists the urgent need to incorporate every completed dataset on global biodiversity in order to improve the RAF. This leads to the point that incorporation of new indicators and development of the RAF is a process that won't be finished in any near future[148]. With every new replenishment period, allocations are likely to be calculated with a modified and more inclusive RAF.

Eventually, further scientific work is required to explore potential datasets of marine and terrestrial diversity that are not included in this study. One such example might be phyletic diversity for which data availability and quality must be investigated. Additionally, a different structure for the current GBI_{bio} and it's impact should also be analysed. For instance, analogous marine and terrestrial indicators can be merged, e.g., one represented species indicator instead of two separated[149]. This approach may not change the results significantly compared to the proposed RAF. But, it removes the issue of the uneven weighting and recognizes that the marine and terrestrial environment are intimately linked (see section 2.2.1)

148 Unlike many other PBAs that are simply re-run with additional data but without new indicators.
149 This was not regarded as feasible within this study, since the data was too incomplete to meaningfully modify the RAF more than has already been done.

7.2 Revision of proposed RAF

This model only represents a proposal how new marine indicators can be incorporated into a new RAF. Peer-reviewing is essential to modify and improve this proposal so that the suitability for the RAF is increased. As primary peer-reviewers the South Pacific Regional Environmental Programme (SPREP), the Pacific Islands Forum Secretariat (PIFS) and the Foundation of the Peoples of the South Pacific – International (FSPI) are recommended. Some aspects peer-reviewers should pay particular attention to, pertain: a) evaluating the incorporation of additional marine indicators and; b) the formula must be re-run completely to infer true new allocations.

7.2.1 Peer-reviewing of proposed datasets

Especially the OBIS dataset combined with the KGSMapper needs an in depth review of the approach. Due to the large size of the dataset only a rough introduction on a possible incorporation could be provided and much work still remains to be done. Nevertheless, it is one of the most promising datasets to replace the current marine represented species indicator. The first step is for the GEF to decide if extrapolation of distribution ranges based on environmental parameters is an acceptable, meaningful enough indicator to calculate allocations[150]. This decision may also depend on the probably lower species number for which ranges can be modelled compared to the number of the current marine represented species indicator. However, the number of mappable OBIS species is likely to be similar to the current analogous terrestrial species indicator[151]. The potential bias towards the northern hemisphere needs also to be accounted for although such a bias is a characteristic of almost all global biodiversity data. The greatest advantage is that the quality of modelled species ranges is much higher compared to the current marine indicator .

Further research is required on the methodology of the KGSMapper. The increase in fit of range maps can be focussed only on suitable habitat cell patches that contain specimen cells and exclude those that don't. Additionally, it is important if determination of the most influencing parameters is preferable over a fixed set of parameters. An automated approach to determine most influencing environmental parameters is scientifically valid, but a fixed set of

150 Normally, ranges are delineated by outer occurrences of specimen combined with geographical boundaries. Both are approaches not necessarily well implementable in the ocean due to the more distributed nature of marine biota and due to a lack of clearly visible boundaries.

151 approximately 11,000.

parameters for all or certain taxa may be an equally valid alternative. It also is a challenging task to develop an approach that distinguishes an actual distribution range from a global plot of suitable habitat for all taxa.

More straightforward is the incorporation of the MEOW dataset. Nevertheless, there exist aspects that need to be considered for a future utilization within the RAF for biodiversity. The dataset used for this study is a preliminary pre-publishing version. Therefore, any future tests of this dataset should rely on the final version of the data recently published in August, 2007. Another issue arises from the application of coastlines, the 200 m depth contour line, and maritime boundaries to which marine ecoregions have to be adjusted. One of the most authoritative sources of coastlines and depth contour lines is the recent version of the GEBCO Digital Atlas used for this thesis[152]. Nonetheless, gaps for coastlines and especially the 200 m depth contour for large areas in the Pacific were identified. Although this has been the only gap realized so far, it raises the question if an amalgamation of datasets from various regional sources constitute a better, more detailed alternative. SOPAC, for example, may be one of these sources for the whole Pacific and has been used to complement the GEBCO data. Similarly, more detailed sources on EEZ data may exist. The open source dataset provided by VLIZ does not include the EEZs of Brunei Darussalam and Bosnia Herzegovina, although it has been stated that this omission will be solved[153] (Deckers and Vanden Berghe, 2006).

Unlike the marine ecoregions the NCEAS threat and impact dataset was provided already in it's final version. Issues may arise from adjusting the data from a fluent threat range between 0 and 13 to distinct categories from 1 to 4. This approach is justified since otherwise the marine score would be more biased to threatened ecoregions than the terrestrial score. This process may have overmanipulated the data and expert knowledge as well as further consultation with NCEAS is required to solve this issue. Furthermore, this dataset is intimately linked to the MEOW dataset. Thus, all changes in marine ecoregions must be reflected in analogous changes of the NCEAS dataset on threatened marine ecoregions.

152 The National Oceanic and Atmospheric Administration (NOAA) is another standard source of global coastlines and contour lines.

153 VLIZ has been recognized up to now as the only open source of global maritime boundaries.

7.2.2 Re-application of the proposed formula

After necessary modifications and improvements of the marine datasets are implemented the formula must be run again in order to infer true allocations. This is accomplished by testing the formula with the full dataset on all countries globally[154], true GPI scores, ceilings and floors of maximum and minimum allocations, and categorising countries with access to group and individual allocations.

7.3 Stakeholder engagement

As this thesis has shown there exist marine indicators of biodiversity as well as theoretical arguments that justify an even weighting between the marine and terrestrial score within the GBI_{bio}. Various opportunities at different political levels must be realised so that the necessary institutional influence increases the chances of an equal weight. Probably the most important key event where decisions about the future structure of the RAF will be taken is the mid-term review in November/December 2008[155] or beginning of 2009[156]. At the mid-term review not only resources are re-allocated using additional data on current indicators but the current RAF will be examined by the GEF Evaluation Office[157]. Therefore, the results of further scientific studies that explore possible datasets and their incorporation into the RAF needs to be provided to the Evaluation Office. The task of the Evaluation Office is to provide the best solutions of this issue to the GEF Secretariat and Council. Meanwhile, different entities should exert pressure on the GEF in order to emphasise the need of an equitable GBI_{bio}.

Within the last CBD COP meeting in 2006 the parties have recognized the concerns of member states towards the discrimination by the RAF of certain countries. The next COP meeting will be in May, 2008, in Bonn, Germany. It is proposed that the COP based on this and further scientific studies about the RAF takes on a proactive role. The COP should provide further guidance for a) incorporation of additional indicators on marine biodiversity and; b) an equal weight of both biodiversity sub-indices that avoids discrimination of global marine biodiversity and especially SIDS.

154 RAF eligible and non-RAF eligible countries.
155 GEF/R.4/32, para. 14
156 Since the fourth replenishment started on February 8, 2007 and the review is implemented after two years.
157 GEF/C.31/Inf.9, para. 14

The results[158] clearly show that the current GBI_{bio} is not only biased against SIDS but against all countries which have significant marine biodiversity[159]. Similarly, some countries with lower marine scores are discriminated as well. This should provide the incentive at Council (e.g. in November 2007) and Assembly (2010) meetings that GEF recipient as well as donor constituencies and member states are inclined to support SIDS in their endeavour to opt for an equally weighted, more fair RAF.

Also the NGO sector must take over a much more progressive role. Especially WWF, now being one of the main data providers of both biodiversity sub-indices, should strive for an equal representation of their data within the RAF. For the WWF as well as for other marine data providers, one ideal forum are future GEF workshops that discuss the development of the RAF. Generally, all marine as well as terrestrial datasets within the RAF must be subject to constant improvement[160]. Even though it is a huge challenge, it will be a success for conservation biology and for the quality of the RAF to assemble further global datasets for biodiversity.

Concluding remark

Although the RAF was created by the GEF Secretariat it is not only up to them to find ways for modification and improvement. The scientific side of the RAF is a concept which is best served by a collective improvement of all stakeholders, i.e., contributors, creators, recipients, and the relevant convention. This involvement may pave the way for the most meaningful RAF for all parties.

158 Table 11 and 10

159 i.e., those countries that have currently a higher marine score as terrestrial score within the GBI_{bio}.

160 This is not only a necessity for a better RAF but mainly for the respective conservation aims of the projects.

Chapter 8

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