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BASED ON THE PROCEEDINGS
OF A UNESCO INTERNATIONAL
CONFERENCE ON BIODIVERSITY
SCIENCE AND POLICY

TRACKING KEY TRENDS in BIODIVERSITY SCIENCE and POLICY

UNESCO biodiversity initiative

United Nations Decade on Biodiversity

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FOREWORD BY GRETCHEN KALONJI, ASSISTANT DIRECTOR-GENERAL FOR NATURAL SCIENCES, UNESCO

Scientific knowledge is a mandatory input for decision-making, most importantly in the sustainable development field where societal concerns require science and policy to cooperate and provide the best available answers to fundamental problems. Progress in this direction is critically dependent on the quality and efficiency of the science-policy interface. To effectively mainstream science into governance policy, policy makers should be provided with credible and legitimate scientific information. In turn, the scientific community should strive to engage in a dialogue with the policy community, so as to ensure that scientific knowledge is relevant and that related advice is provided on a timely basis.

The International Year of Biodiversity (IYB) Science-Policy Conference organized by UNESCO as part of the launch of IYB was designed to give special attention to the voice of the scientific community in order to highlight new knowledge that could be used in the context of biodiversity-related decisions. New scientific findings on biodiversity and ecosystem services, including in relation to global and climate change were presented. The Conference followed on from the UNESCO High-Level Launch of the Year that took place at the Headquarters of UNESCO in Paris on 21 and 22 January 2010, five years after the 2005 International Conference on Biodiversity Science and Governance, also held at UNESCO Headquarters in Paris.

Twenty years after the Rio Summit in 1992, global and national efforts to conserve biodiversity are still far from sufficient, and biodiversity continues to be eroded and lost. The degradation of biodiversity is a threat to our cultures and societies, our economies and our environment. Failure in addressing biodiversity conservation and sustainable and equitable use is partly due to inadequate biodiversity policy responses, which tend to lack sectoral integration; moreover, sectoral policies have largely failed to successfully mainstream biodiversity concerns thus far.

The biodiversity crisis is a multi-faceted one, and the challenges posed by it need multiple solutions. Policy responses based on the best scientific knowledge are essential. But scientific knowledge alone cannot do it all. This is why the UNESCO IYB Conference in 2010 also critically assessed the contribution of education, culture, communication as well as the social sciences, in addition to natural sciences, to tackling the profound causes of biodiversity loss.

Biodiversity is of particular concern to the most vulnerable – the poor, women, and to the world's regions requiring more international attention and aid, in particular in Africa. Local and indigenous communities will be most affected by the loss of biodiversity and associated ecosystem services such as water purification, provision of food, fibers, food and shelter and climate regulation. At the same time, biodiversity loss represents a global challenge. Through its interdisciplinary mandate, UNESCO is determined to work at all levels to strengthen capacities for efficient biodiversity governance.

This is why in November 2011, I decided to launch a UNESCO Biodiversity Initiative to crystallize our work in education, the sciences, culture and communication for the preservation of biodiversity. UNESCO will strive to cooperate at all levels through the "OneUN" Initiative for Biodiversity in support of efforts by governments to implement their respective biodiversity commitments.

2011 marked the launch of the United Nations Decade on Biodiversity (2011-2020). The decade represents an opportunity for all of us to reaffirm the importance of biodiversity and to join forces for its preservation. We are beginning this decade with a renewed agenda, a UN system-wide ambitious Strategic Plan for Biodiversity, to which UNESCO adheres; the Plan includes 20 bold internationally-agreed targets in support of biodiversity, known as the Aichi Targets.

The Conference of the Parties to the Convention on Biological Diversity at its tenth meeting in Nagoya, Japan in October 2010 also agreed on a comprehensive framework in relation to access to biodiversity and the equitable sharing of the benefits arising from its utilization – the Nagoya International Protocol on Access and Benefit Sharing. It is now our shared responsibility to implement the Plan effectively and to embrace wholeheartedly the Nagoya Protocol. We will maximize our efforts and multiply our partnerships for the conservation of biodiversity as well as the sustainable management and the equitable distribution of its benefits.

The UNESCO Biodiversity Initiative will respond to future relevant developments on the international stage relating to the challenge of biodiversity conservation. UNESCO's work in support of the Strategic Plan for Biodiversity 2011-2020 and the Nagoya Protocol will be instrumental to assist Member States indentify plausible future biodiversity conservation scenarios and policy responses.

This publication contains the main findings presented at the 2010 UNESCO IYB Biodiversity Science-Policy Conference and it is intended to demonstrate how different dimensions of the biodiversity problem impinge on each other; and to provide recommendations to counteract the current biodiversity crisis, including from the perspective of climate change.

Collaboration of UNESCO with key UN partners on biodiversity-related issues will be reinforced, including in the context of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), in which UNESCO is deeply involved. Looking ahead, the United Nations Conference on Sustainable Development 'Rio+20' in Rio de Janeiro in June 2012 was as much an opportunity to renew the vision that began in Rio as to learn from the past 20 years and move the sustainable development and the biodiversity agendas forward. Biodiversity was of the main themes addressed in the outcome document, The Future We Want.

In the future years, particular attention will be given to building capacity in the most vulnerable regions, in particular in Africa. Finally we will work towards a better recognition of the role of women, youth and local communities in biodiversity management and decision-making processes.

UNESCO's commitment, now as ever, is to support global efforts to ensure environmental and socioeconomic sustainability and to foster solutions to problems affecting society, including in relation to biodiversity.

INTRODUCTION

The UNESCO conference upon which this book is based unfolded over five days around the following themes:

1. The Biodiversity Knowledge Base: Taxonomy Today and Tomorrow for Environmental Sustainability and Human Well-being
2. Conservation Biogeography: Integrating Biogeography and Conservation Science in a Changing World
3. Priority-setting in Biodiversity Conservation: Strengthening Site-scale Approaches
4. Communication, Education and Public Awareness
5. Mainstreaming Biodiversity into Policy-Making: Towards a Biodiversity Science Policy

Like the conference, the book begins with high-level opening messages by the President of the General Conference of the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the Director-General of UNESCO and the Executive Secretary of the Secretariat of the Convention on Biological Diversity (CBD), and ends with the recommendations, in English and in French, agreed upon by the many conference participants and brought forward to several international fora during the International Year of Biodiversity 2010.

As Director-General Bokova notes, we present new knowledge and ideas here. Yet, that is not to say that some before us were not wise enough to foresee the general lines of today's overlapping and mutually reinforcing issues of the loss of biodiversity and ecosystem services, global climate change, unbridled consumption and population growth. For example, in 1865 George Perkins Marsh wrote the seminal *Man and Nature, or Physical geography as modified by human action*, in which he presciently described changes, both designed and inadvertent, to landscapes, extirpation of animals and introduction of exotic plants already apparent in his day. Half a century later Aldous Huxley – brother of Julian, the first Director-General of UNESCO – railed against "More motors, more babies, more food, more advertising, more money, more everything, forever."[1] and suggested that politicians turn from "progress" to learn from physical biology. One can easily imagine that this sort of discussion went on in the Huxley household, filled as it was by several generations of eminent biologists.

Sadly, it took another half-century and the chronicling of the truly harmful effects of pesticides on both people and nature by Rachel Carson in *Silent Spring* in 1962 to really give impetus to both species conservation and protection of people and nature from the harmful effects of ill-conceived progress.

In the 1980s, the concept of 'synthetic communities' of plants which are a mixture of native, naturalized and exotic species or more rarely assemblages of native species atypical of the landscape in question was introduced. This notion is now part of mainstream ecological theory in relation to the phenomenon known as 'novel ecosystems' – "new assemblages of species that have not co-occurred historically, that largely result from direct and

1. Aldous Huxley, Point Counter Point, Doubleday Doran & Company, USA, 1928, pp. 68-69.

indirect human activity, and that occupy new ecological spaces in the world's landscapes and seascapes", as reflected in the 2011 Pender Island Call for Action on Understanding and Managing Novel Ecosystems.

We live in the Anthropocene, an era in which human action profoundly influences the course of natural phenomena. Today, we should know that humankind and living nature are bound to each other in a symbiotic embrace; we should know that we cannot live inside the glass cities of Yevgeny Zamyatin's One State separated entirely from nature by the Green Wall. Ecology and environmental science, jump-started by large-scale research initiatives in the 1960s and 1970s, have only begun to report on the effects of changing climate, changing nutrient loads from pollution, and changing land use patterns on ecosystem function and services and what these changes imply for society. The interdisciplinary science of conservation biology came into being in the 1980s in order to put biologists' lessons about species dynamics in to practical use. Here, we review the next directions needed in order to maintain healthy ecosystems and viable biodiversity.

The essential first step to understand something and conserve it is to accurately identify and name it. Thus taxonomy, the science that defines groups of organisms on the basis of shared characteristics and gives names to those groups, is where we begin "Biodiversity Knowledge in a Changing World", in chapters by Gilles Boeuf, André Levesque, Gideon F. Smith and Estrela Figueiredo and Randolph Thaman. Without a current assessment of the organisms in any given area based on taxonomy, estimating the amount of diversity present is unrealistic and making informed conservation decisions impossible. As conservation becomes ever more politically important, taxonomic work is of relevance not only to other scientists but also to society in general. Remarkable advances in genetic sequence analysis since the early 1990s have resulted in new tools for taxonomy which have revolutionized progress in identifying cryptic species and species with few visible characters, such as fungi, bacteria, algae and protozoa. Taxonomic collections, in museums and herbaria, provide the repositories of historical records that enable scientists to compare biodiversity from different ages and locations. Sadly, both taxonomists and collections are themselves in danger and need support. Also contributing to taxonomy are the ways that people use or classify organisms in daily life, which is part of the knowledge base underpinning biodiversity.

Marine biodiversity presents special concerns as described by Sara Lourie, as, to misquote Gertrude Stein, "There is no there there." and designating parts of the seemingly indivisible marine realm for conservation presents its own difficulties. The challenges that Josh Donlan presents are even more daunting: how can entire regions be 'rewilded' to connect large habitats that can be used by keystone species, either the originals or close analogues?

In a special section Thomas E. Lovejoy, one of the founders of conservation biology, who introduced both the term "biological diversity" and debt-for-nature swaps, reviews the challenges threatening biodiversity, particularly climate change, and the myriad benefits it brings to society. You can almost imagine Lovejoy sitting down with the Huxley family for a spirited chat. Next Anna Frangou, Richard J. Ladle, Ana C.M. Malhado and Robert J. Whittaker provide a synopsis of the predicted effects of climate change on animal distributions. This contribution illustrates how animals already are adapting to the effects of climate change, and quite effectively so; but it also indicates that this adaptation comes with a price to those species that are less capable of adapting and for biodiversity in general. Both contributions in the special section indicate that we are approaching the tipping point beyond which adaptation will become difficult. Hence we need to act now, bearing in mind that the climate change, biodiversity science and policy agendas are intimately interlinked.

"Counteracting Biodiversity Erosion and Loss" goes on to consider how to prioritize what to conserve and where, through various decision support tools such as biodiversity hotspots, global ecoregions and Important Bird Areas (IBA). This world tour considers the successes of various tools at the site level in different regions. Matthew Foster provides an overview and comparison of different key biodiversity areas, while Leon Bennun provides a global inventory of IBA and Paul Matiku puts IBA to the test in Kenya.

"That's the trouble with you politicians. You don't even think of the important things. Talking about progress … and every year allowing a million tons of phosphorus pentoxide to run away into the sea. … Only two hundred years and they'll be finished. You think we're being progressive because we're living on our capital. Phosphates, coal, petroleum, nitre – squander them all."

"One can imagine the comments of the lunar astronomers. 'Those creatures have a remarkable and perhaps unique tropism toward fossilized carrion.'"

Aldous Huxley, Point Counter Point, Doubleday Doran & Company, USA, 1928. p. 68 and p. 154.

William Darwell explains the prioritization methodology for important areas for freshwater biodiversity, given that it is one of the most threatened by human action as ever more water is channelled for consumption in industry, agriculture and urban use. Glaucia Drummond shares the experience of the Brazilian Alliance for Zero Extinction in identifying key habitat for the most threatened species in that country, while Douglas Evans clarifies Europe's Natura 2000 Network of conservation sites and Karen Manvelyan zooms in on the Caucasus Hotspot, and how new protected areas are being selected there. Monica Barcellos, Martin Sneary, Conrad Say and Ian May describe the Integrated Biodiversity Assessment Tool, developed by a number of major conservation organisations in order to help businesses make better operational decisions that affect or are affected by biodiversity.

Considerations of social and cultural values of biodiversity in the landscape enable the chapters by Danielle Dagenais and Yoshihiro Natori (on the production landscapes known in Japan as Satoyama) to bridge to the subsequent section, "Biodiversity at the Nexus of Science with Society". These two authors focus on how people have helped to nurture landscapes (which are a level of biodiversity), while the section to follow looks at how the landscapes and species have, in turn, contributed to society.

Anahit Minasyan looks at the compelling correlation between linguistic diversity and species diversity demonstrated by the work of UNESCO's Endangered Languages Programme. Marc Patry of the UNESCO World Heritage Convention secretariat reviews the links between nature and culture from several angles, noting that they are inseparable even when we name them one or the other. Martin Price and Ana Persic review current and future priorities of the UNESCO Man and the Biosphere Programme as it expands 40 years' experience putting sustainable development and conservation to the test in biosphere reserves. Robert Kasisi makes a plea for participative management in conservation and notes the importance of biodiversity to intangible cultural heritage, using an example from the Democratic Republic of the Congo. The contribution of citizen science to biodiversity is a dialectic, we are told by Vincent Devictor; it not only provides data about biodiversity for science (and policy making), but it educates citizens about conservation in the process. The linkages between gender and biodiversity related to access and benefit sharing, and indigenous knowledge are noted by Gulser Corat, while Rosalie Ouoba provides a concrete example of rural women's empowerment in relation to their knowledge of biodiversity in Chad. Crossing the Atlantic we are introduced by Jorg Bendix, Bruno Paladines, Monica Ribadeneira-Sarmiento, Luis Miguel Romero, Carlos Antonio Valarezo and Erwin Beck to a research project in Ecuador that is a model

of North-South collaboration, in that it weans the local researchers from an initial connection with German institutions, empowering them to conduct research on their own.

The theme of access and benefit sharing expands now to society at large with a chapter on the economic valuation of biodiversity – Huxley's natural capital – by Anastasios Xepapadeas. This is followed by a case study from The Economics of Ecosystems and Biodiversity (TEEB) report on the valuation of marine protected areas by Salman Hussain. TEEB attempts to put an economic value on every ecosystem service from the Millennium Ecosystem Assessment in the conviction that policy makers will thus be empowered to better consider biodiversity concerns in decision making. Last but not least, David Schaffer shares the outcomes from an international workshop on biodiversity by the InterAcademy Panel on International Issues (IAP) held immediately prior to the UNESCO Conference in Paris. Both the IAP and UNESCO agreed on the need to train more researchers, improve collaboration between the sciences and between institutions, and to improve the science-policy as well as the science-public interface.

In closing we should like to thank the many individuals and organisations that assisted in the conference and these proceedings, including colleagues at UNESCO, CBD and the Muséum national d'Histoire naturelle in Paris. Special thanks are due to all the conference presenters and participants, to Eric Loddé for the graphic design, to Natasha Lazic for unflagging enthusiasm and administrative support and to Mirian Querol for her unflagging eye. Anathea thanks Justice Nancy Kastner and Robert Peasant for providing a welcoming poolside haven for editing. Salvatore thanks the many active scientists and policy-makers who continue showing indulgence and interest in working with him despite his not being formally part of either of these two communities *per se*. But this is the challenge in front us: bridging these two worlds in the interest of the future of biodiversity and of people on earth.

This volume is available as an on-line publication not only in an effort to reduce its environmental footprint, but also because of financial considerations, which lie behind the mix of both French and English chapters without translation from the author's original language. We take responsibility for any errors in the final text.

GENERAL MESSAGES

Address by DAVIDSON L. HEPBURN, President of the General Conference of UNESCO,

Discours de IRINA BOKOVA, Directrice générale de l'UNESCO,

Discours de AHMED DJOGHLAF, Secrétaire exécutif de la Convention sur la Diversité Biologique

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Address by DAVIDSON L. HEPBURN, President of the General Conference of UNESCO

Honorable Minister of Sustainable Development, Forestry Economy and Environment of Congo,
State Secretary for Ecology of France,
Chairperson of the Executive Board,
Deputy-Director-General,
Executive Secretary of the Convention of Biological Diversity, President of incoming COP 10 Bureau of the Conference of the Parties to the Convention on Biological Diversity,
Excellencies, Ladies and Gentlemen,

It is a great pleasure for me in my capacity as President of the General Conference of UNESCO to address the distinguished participants attending this High Profile Event on the occasion of UNESCO's contribution to the launch of the International Year of Biodiversity.

As we are all aware, at its 61st session, the United Nations General Assembly declared 2010 as the International Year of Biodiversity and invited all specialized agencies, funds and programmes of the United Nations to contribute to its success.

In the fall of 2009 when the Member States of UNESCO debated UNESCO's contribution in support of the implementation of the International Year of Biodiversity, they unanimously expressed support for the Year and recommended that UNESCO play an active role in its implementation.

Similarly, several Member States expressed concern for the enormous challenges faced by biodiversity, in particular, in the light of climate change. In this regard, the launch of the International Year of Biodiversity was considered to be timely, as was the need for raising further awareness in relation to the contribution that biodiversity makes to human well-being and the challenge of biodiversity loss, which are among the main objectives of the Year.

Indeed, the international community is becoming increasingly aware that although biodiversity is fundamental to our existence it is also in peril. Many countries possess unique biodiversity but they are also faced with its growing loss.

In Small Island States, for example, the consequence of biodiversity erosion and loss are particularly obvious. We are witnessing the loss of the very services on which livelihood systems depend, such as regulation of climate, purification of clean water, detoxification of soils and sediments. All of these benefits that biodiversity brings are gradually but steadily being lost at an unprecedented rate.

Instead of having to be coerced to import these services, which has huge consequences for developing countries and for societies in general, we should act rationally and responsibly both at an international and national level. Societies should strive for a more sustainable use of natural resources and for a reduction in habitat loss and climate change, including the social and cultural dimensions. This will allow us to preserve the services on which we depend – the services of biodiversity.

"Indeed, the international community is becoming increasingly aware that although biodiversity is fundamental to our existence it is also in peril. Many countries possess unique biodiversity but they are also faced with its growing loss."


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It is heartening to state that during the debate on the International Year of Biodiversity, many UNESCO Member States reiterated their commitment to biodiversity conservation and its sustainable use and the related need for public awareness on the importance of biodiversity and ecosystems.

Member States supported the plans developed by the UNESCO Secretariat in relation to the International Year of Biodiversity and expressed an interest in participating actively in the realization of these activities, paying special attention to the needs of developing and least developed countries. The great participation of governments in today's Paris launch of the Year demonstrates this further.

Several Member States emphasized that UNESCO also provides for a framework to stress the role of women in relation to biodiversity conservation and its sustainable use and, therefore, the equal participation of women, including scientists, should be incorporated in the planned activities. Equally, the participation of local and indigenous communities should also be encouraged.

In essence, UNESCO's plans are intended to take us beyond the 'mere' frame of biodiversity by linking these initiatives with the sustainable development agenda.

I wish to thank the Member States of UNESCO and the civil society for the strong support expressed for UNESCO's action in this area.

Interactions between the scientific community and governments are indeed essentials when addressing this important issue. The proposal to establish an Intergovernmental Group of Experts for biodiversity, somewhat similar to the IPCC for climate change, should be examined with this background in mind. I am convinced that UNESCO would be a very reliable partner who could host the Secretariat of such a body if it were to be established.

Ladies and Gentlemen,
The slogan of the Year: "Biodiversity is life. Biodiversity is our life", hits at the heart of the significance of the Paris launching. Consequently, we cannot afford to miss this opportunity to involve UNESCO totally in the process of the services of Biodiversity. The Organization, with its unique mandate, has the responsibility to develop and implement initiatives in education, the sciences and culture, in partnership with other relevant international and national players.

That is why you are here today. To step out of the box and take some calculated risks toward increasing UNESCO's efforts to curb the loss of biodiversity.

© Parag Naik

Discours de IRINA BOKOVA, Directrice générale de l'UNESCO

Monsieur le Premier Ministre de la Guinée Bissau,
Monsieur le Ministre du développement durable, de l'économie forestière et de l'environnement du Congo,
Monsieur le Ministre de l'écologie, de l'énergie, du développement durable et de la mer de la France,
Monsieur le Président de l'Académie des sciences de Hongrie,
Monsieur le Secrétaire exécutif de la Convention sur la diversité biologique,
Excellences,
Mesdames, Messieurs,

Permettez-moi de vous souhaiter la bienvenue au Siège de l'UNESCO pour l'ouverture de cette Conférence scientifique organisée dans le cadre du lancement de l'Année de la biodiversité.

La semaine dernière, l'UNESCO a organisé une rencontre à haut niveau avec ses partenaires dans le domaine de la biodiversité, et lancé une exposition itinérante destinée à sensibiliser le public, dans les différentes régions du monde, sur les enjeux de cette Année, et sur l'importance de se mobiliser en faveur de la biodiversité.

Je n'ai pu être présente à cette occasion, puisque j'étais en mission à New York où j'ai eu l'occasion d'aborder le thème de l'Année avec le Secrétaire général des Nations Unies et de l'assurer que l'UNESCO ne ménagerait aucun effort pour faire de cette Année un succès.

Dans un message rendu public le 11 janvier 2010, M. Ban Ki-Moon a lui-même appelé «chaque pays et chaque citoyen de notre planète à s'engager dans une alliance mondiale pour protéger la vie sur terre».

« La biodiversité, c'est la vie - La biodiversité, c'est notre vie ». Tel est le slogan de l'Année. Il parle de lui-même et souligne à quel point les humains, partie intégrante de la biodiversité, dépendent aussi d'elle pour leur existence, pour se nourrir, se soigner ou se vêtir.

Même quand nous pensons être détachés de la biodiversité, nous restons connectés de façon intime avec les écosystèmes et les services qu'ils fournissent, tels l'accès à l'eau potable ou la régulation du climat.

Mesdames et messieurs,

La conférence qui vous réunit aujourd'hui a pour objet de faire le point de nos connaissances et de pallier à nos incertitudes. De nombreuses espèces restent encore à découvrir, il nous faut mieux cerner le rôle des espèces dans le fonctionnement des écosystèmes et leurs interactions avec les activités humaines. Des questions fondamentales seront abordées, comme le lien entre biodiversité et développement, les interactions avec le changement climatique ou encore les liens entre science de la biodiversité et décision politique.

“Même quand nous pensons être détachés de la biodiversité, nous restons connectés de façon intime avec les écosystèmes et les services qu’ils fournissent, tels l’accès à l’eau potable ou la régulation du climat.”

L’Evaluation des Ecosystèmes pour le Millénaire, publiée par les Nations Unies, a tiré la sonnette d’alarme en révélant des taux d’extinction des espèces jusque-là inégalés et en faisant le lien entre l’accélération de cette dégradation et le changement climatique. Il s’agit bien d’un enjeu mondial, au même titre que le changement climatique.

Sur cette préoccupante accélération de la perte de diversité biologique, un consensus existe chez les scientifiques. Les menaces qui pèsent sur la biodiversité sont nombreuses et bien connues : destruction des habitats naturels du fait de la déforestation, de l’agriculture intensive ou du morcellement des paysages, surexploitation des ressources marines ou terrestres, propagation des espèces envahissantes, pollution, changement climatique, pour citer les principales.

Nous savons également que ce sont les populations les plus pauvres qui sont les plus atteintes, puisque la satisfaction de leurs besoins fondamentaux dépend largement de la biodiversité. Ce problème menace aussi la survie de cultures autochtones qui ont tissé, au fil des siècles, des liens très forts avec la nature.

Nos connaissances restent toutefois à approfondir, comme restent à développer les moyens de mieux assurer leur prise en compte par les décideurs.

La proposition d’établir un Groupe intergouvernemental d’experts consacré à la biodiversité et destiné à améliorer l’interface entre scientifiques et politiques, à l’image du GIEC pour le climat, doit être appréhendée dans ce contexte.

Il n’appartient pas à l’UNESCO de prendre parti dans la négociation en cours concernant la création de cette instance. En revanche, je souhaite exprimer le souhait de l’Organisation de co-parrainer cette initiative si elle voit le jour et d’en accueillir le Secrétariat.

L’UNESCO contribue de façon très dynamique à l’amélioration des connaissances sur la biodiversité dans le cadre de ses programmes scientifiques intergouvernementaux, la Commission océanographique intergouvernementale, le Programme hydrologique international (PHI) et le Programme sur l’Homme et la biosphère (MAB).

En ce qui concerne en particulier le MAB, ce programme a permis de développer considérablement les connaissances sur les interactions entre l’Homme et les

“Mieux informer, mieux éduquer à tous les niveaux, tels sont les objectifs de la Décennie pour l’éducation au service du développement durable, menée par l’UNESCO, qui vise à encourager un comportement responsable envers l’environnement.”

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milieux naturels et de les tester sur le terrain, grâce aux réserves de biosphère, dont on compte à ce jour 553 dans 107 pays. Constituées en réseau au niveau mondial et au niveau régional, les réserves de biosphère permettent d’échanger expériences et expertises, et sont un support important pour la formation des gestionnaires de ressources naturelles. Ainsi, grâce à l’apport des réserves de biosphère, véritables laboratoires sur le terrain, les actions de conservation progressent dans les sites et au-delà.

La conservation de la biodiversité est aussi un des objectifs de la Convention du patrimoine mondial, culturel et naturel. Parmi les sites inscrits sur la Liste du patrimoine mondial, certains ont en effet été choisis en fonction de leur importance pour la biodiversité, soit dans des sites peu touchés par l’homme, soit au contraire dans des paysages façonnés par l’activité humaine. Leur protection au titre de la Convention du patrimoine mondial joue ainsi un rôle important pour la sauvegarde de la biodiversité dans des sites exceptionnels.

L’UNESCO s’investit aussi dans la formation des gestionnaires. Ainsi, l’école régionale postuniversitaire en République démocratique du Congo permet de former des spécialistes africains à l’aménagement et la gestion intégrés des forêts et territoires tropicaux. Cette école régionale, qui bénéficie d’un important financement de l’Union européenne, sera développée pour répondre notamment aux objectifs de l’initiative de réduction des émissions dues à la déforestation (REDD) qui a été renforcée à Copenhague.

Mieux informer, mieux éduquer à tous les niveaux, tels sont les objectifs de la Décennie pour l’éducation au service du développement durable, menée par l’UNESCO, qui vise à encourager un comportement responsable envers l’environnement.

Car c’est bien d’éthique qu’il s’agit, et l’UNESCO se doit, de par ses compétences interdisciplinaires et son mandat en matière d’éthique, de promouvoir une réflexion dans ce domaine.

Enfin, l’UNESCO attache une importance particulière aux relations entre diversité biologique et diversité culturelle, y compris la diversité linguistique. On le sait, les langues et les savoirs autochtones sont étroitement imbriqués, et leur maintien a une incidence directe sur l’utilisation et le maintien des espèces animales et végétales.

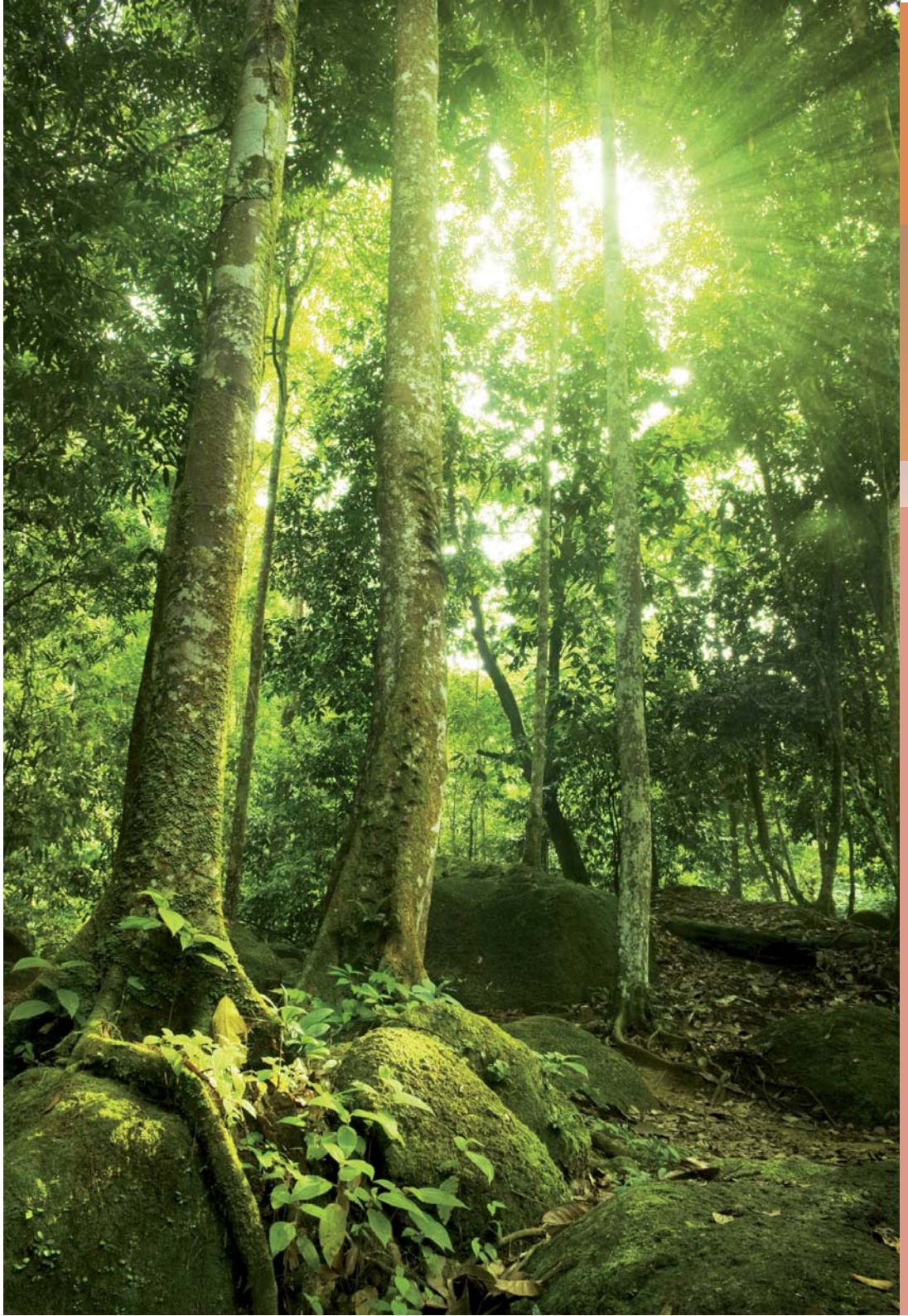
Permettez-moi de me référer à ce que déclara, dans cette même salle, en 2005, l'immense anthropologue Claude Lévi-Strauss, je cite: « Diversité culturelle et diversité biologique ne sont pas seulement des phénomènes du même type. Elles sont organiquement liées, et nous nous apercevons chaque jour davantage qu'à l'échelle humaine, le problème de la diversité culturelle reflète un problème beaucoup plus vaste et dont la solution est encore plus urgente, celui des rapports entre l'homme et les autres espèces vivantes, et qu'il ne servirait à rien de prétendre le résoudre sur le premier plan si l'on ne s'attaquait aussi à lui sur l'autre, tant il est vrai que le respect que nous souhaitons obtenir de chaque homme envers les cultures différentes de la sienne n'est qu'un cas particulier du respect qu'il devrait ressentir pour toutes les formes de la vie. »

Mesdames et messieurs,

En 2010, Année internationale de la Biodiversité, les gouvernements devront se mettre d'accord sur de nouvelles cibles et de nouveaux objectifs relatifs à la biodiversité. En ce qui concerne l'UNESCO, j'entends saisir l'occasion de cette Année pour développer, sur la base des éléments que je viens de décrire brièvement, une initiative renforcée pour aborder, de façon holistique, tous les aspects liés à la gestion et à la sauvegarde de la biodiversité.

L'érosion de la biodiversité n'est pas inéluctable.

L'UNESCO, quant à elle, est prête à s'engager pleinement dans ce combat pour la vie sur Terre.



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Discours de AHMED DJOGHLAF, Secrétaire exécutif de la Convention sur la Diversité Biologique

Excellences,
Mesdames et Messieurs,

En lançant le Grenelle de l'environnement, le Président de la République française M. Nicolas Sarkozy avait déclaré « C'est bien à une révolution que nous invite ce Grenelle de l'environnement, une révolution dans nos façons de penser, dans nos façons de décider, une révolution dans nos comportements, dans nos politiques, dans nos objectifs et dans nos critères ». En présentant les résultats de cette expérience de démocratie environnementale unique en son genre avec ses 273 engagements de la part des représentants des cinq collèges, vous avez déclaré M. Jean Louis Borloo « On sait aussi que la biodiversité doit devenir une nouvelle dimension de l'action publique. C'est une nouveauté, et d'ailleurs une des découvertes majeures de Grenelle. Peut-être parce que ce terme technique est mal connu, ou connoté. Mais on sait aujourd'hui qu'avec l'extinction de certaines espèces, effet du réchauffement climatique mais aussi, trop souvent, d'une gestion inadaptée de l'espace et des ressources, on remet en cause de façon irréversible l'avenir. Il est urgent d'agir de façon coordonnée en ce domaine. » La célébration de l'Année international de la biodiversité participe à l'esprit et la lettre du Grenelle et vise donc à jeter les fondements d'un grenelle universel souhaité par M. Al Gore lui-même au cours de sa participation à la cérémonie de présentation des résultats du Grenelle. Qu'il me soit donc permis, M. le Ministre de vous exprimer ma profonde gratitude pour votre contribution remarquable au lancement de l'Année internationale de la biodiversité, à travers l'événement organisé en ces lieux même, le 21 janvier dernier avec la participation de plus de 1400 participants, y compris les représentants de l'art et du spectacle.

La célébration de l'Année internationale de la biodiversité vise en effet l'établissement d'une alliance globale pour la protection de la vie sur terre, avec la participation active de tous les acteurs de la société civile, tant au niveau national qu'international, y compris donc la communauté scientifique et les familles politiques. C'est l'objet même de notre réunion scientifique d'aujourd'hui, entre la science et les politiques, qui se tient sous l'égide fort à propos et à fort escient de l'UNESCO. Qu'il me soit donc permis de vous remercier, Mme Irina Bokova ainsi que vos collègues pour cette initiative fort heureuse et pour le succès retentissant de la réunion de haut niveau qui a clôturé ses travaux vendredi dernier. Il était donc dans l'ordre naturel des choses que l'UNESCO soit la première organisation onusienne à apporter sa contribution à l'amont de cet événement inédit dans les annales des Nations Unies.

Mme Bokova, in your statement in Doha last November, you said, "An ethical mindset also seeks to find solutions to the global challenges we face: climate change, hunger, shrinking water resources, endangered biodiversity and health epidemics. Education must engender a culture of sharing and responsibility towards our planet. It must open hearts and minds".

This ethical mindset will need to guide the new biodiversity-science-policy interface. More than ever we need to mobilize the scientific community at both local and international levels in support to the three objectives of the Convention on Biological Diversity, the sole Rio convention exclusively devoted to biodiversity and reporting every year to the General Assembly, the supreme organ of the United Nations.

"The establishment of a scientific mechanism to support the implementation of the three objectives of the Convention is indeed an idea whose time has come."

To be able to track and adapt to changes in biodiversity levels requires more than ever improved scientific knowledge of species and their interaction. By some estimates, the number of species on Earth is 100 million or more, if we include microorganisms, and yet classified species number less than two million. To quote E.O. Wilson on the problem this poses for biodiversity research, "It's like having astronomy without knowing where the stars are". Much more work remains to be done if we are truly to come to terms with the sheer abundance of life on Earth.

The two reports on climate change and biodiversity and ocean acidification submitted last month by the Convention on Biological Diversity to the Copenhagen Conference on Climate Change clearly indicated the urgent need to mobilize the scientific community in support of the interaction between climate change and biodiversity. Indeed, 89 per cent of the 110 national reports submitted so far by Parties to the Secretariat have identified climate change as a major driving force behind the unprecedented loss of biodiversity. The reports demonstrate that approximately 10 per cent of species assessed so far have an increasingly high risk of extinction for every 1°C rise in global temperature. As a result, given the warming rates predicted by the Intergovernmental Panel on Climate Change, more than 30 per cent of all known species may disappear before the end of this century. The oceans are a fundamental component of the global carbon cycle and act as a long-term sink for carbon-dioxide emissions. Ocean acidity has increased by 30 per cent since the Industrial Revolution – a change that is about 100 times faster than any change in acidity during the past 50 million years or so. On the other hand, climate change is being compounded by biodiversity loss. Deforestation is currently estimated to be responsible for 20 per cent of annual human-induced carbon-dioxide emissions.

As Victor Hugo said, "No army in the world can defeat an idea whose time has come". The establishment of a scientific mechanism to support the implementation of the three objectives of the Convention is indeed an idea whose time has come. An Intergovernmental Platform on Biodiversity and Ecosystem Services, akin to the Intergovernmental Panel on Climate Change, would build on and complement the work being carried out by the Convention's scientific body, as well as help in the development of information-sharing networks, a key component of internationally coordinated research. It would be an essential tool in support to the post-2010 biodiversity strategy to be adopted in October this year at the tenth meeting of the Conference of the Parties to the Convention, to be held in Aichi-Nagoya, Japan.

A strong science-policy interface is essential for meeting the unprecedented

challenges faced by mankind arising by the continued loss of biodiversity compounded by climate change. As Louis Pasteur said, “Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world.”

Votre participation avec nous ce matin, M. le Premier ministre de Guiné-Bissau se veut être un message qui s’inspire de l’esprit et de la lettre de cette sagesse ancestrale. Elle incarne l’esprit et la lettre de l’objet même de notre rencontre. Il en va de même de l’exposition de votre pays sur l’homme et sa nature qui orne les murs de cette enceinte. Votre participation trace la voie et montre le chemin à suivre dans notre marche commune en vue de la convocation en septembre prochain de la session spéciale de l’Assemblée générale des Nations Unies entièrement consacrée à la biodiversité. Après le lancement de l’Année internationale de la biodiversité, à Berlin, le 11 janvier dernier sous l’égide de Mme Angela Merckel, vous êtes aujourd’hui le deuxième chef d’Etat ou de gouvernement à vous engager pour la célébration de cette année. M. le Ministre Henri Djombo vient de nous rappeler qu’en 1972, deux chefs d’Etat seulement avaient pris part à la conférence de Stockholm et qu’ils étaient 120 le mois derniers à Copenhague. Nous ne pouvons pas nous permettre d’attendre 37 autres années pour inscrire la biodiversité en tant que préoccupation majeure des leaders de ce monde. Je formule donc le vœu que les 192 membres de l’Assemblée générale puissent suivre votre exemple et être représentés au plus haut niveau en septembre prochain, à New York. Pour avoir mérité de la Convention sur la diversité biologique, je demande aux participants d’applaudir bien fort et de saluer la présence parmi nous ce matin de S.E.M. Carlos Gomes Junior, Premier ministre de la Guinée-Bissau.

BIODIVERSITY KNOWLEDGE IN A CHANGING WORLD

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Base des connaissances en biodiversité, la taxinomie aujourd'hui et demain pour la durabilité environnementale et le bien être humain, une introduction

Le terme de biodiversité a été différemment défini et ne représente pas toujours exactement la même chose pour les différents publics, un agronome, un philosophe, un économiste, un systématicien, un sociologue, un homme politique ou le grand public. Il est bien clair que la biodiversité ne saurait être représentée dans sa totalité par le seul inventaire des espèces vivantes peuplant un écosystème particulier. Ceci est la diversité spécifique. En fait la biodiversité est beaucoup plus et, basée sur un inventaire initial, elle va être tout l'ensemble des relations établies entre les divers êtres vivants, entre eux et avec leur environnement. Elle a été définie comme étant toute l'information génétique contenue dans chaque unité élémentaire de diversité, un individu, une espèce, une population, un écosystème…et dans toutes les relations établies entre eux. Le terme est récent, créé en 1985 par W. Rosen aux Etats-Unis puis repris par E.O. Wilson en 1986. Mais il ne sortira des laboratoires d'écologie qu'en 1992 lors du sommet de la Terre à Rio. Il partira alors à la conquête du grand public, des médias et du monde politique. La biodiversité c'est le vivant dans toute sa complexité, c'est la fraction vivante de la Nature (Bœuf, 2008).

Pour le biologiste, trois niveaux se distinguent, les diversités génétique, organismique et écologique (les gènes, les espèces, les écosystèmes). Nous mettons globalement dans le terme « biodiversité » aujourd'hui (Lévêque et Mounolou, 2001): (1) l'étude des mécanismes biologiques fondamentaux permettant d'expliquer la diversité des espèces et leurs spécificités et nous obligeant à davantage « décortiquer » les mécanismes de la spéciation et de l'évolution, (2) les approches plus récentes et prometteuses en matière d'écologie fonctionnelle et de biocomplexité, incluant l'étude des flux de matière et d'énergie et les grands cycles biogéochimiques, (3) les travaux sur la nature « utile » pour l'humanité dans ses capacités à fournir des éléments nutritionnels, des substances à haute valeur ajoutée pour des médicaments, produits cosmétiques, des sondes moléculaires ou encore à offrir des modèles plus simples et originaux pour la recherche fondamentale et finalisée, afin de résoudre des questions agronomiques ou biomédicales et enfin (4) la mise en place des stratégies de conservation pour préserver et maintenir un patrimoine naturel constituant un héritage naturellement attendu pour/par les générations futures. D'un point de vue opérationnel, la biodiversité est une priorité scientifique (comprendre sa genèse, ses fonctions et enrayer son érosion), un enjeu économique (ressources biologiques et génétiques à valoriser et partager), un enjeu éthique (droit à la vie des espèces) et un enjeu social (partage des valeurs et des avantages), tous ces termes apparaissant dans la Convention sur la Diversité Biologique, dont la signature par les gouvernements a été ouverte à Rio en 1992 (Blondel, 2007). Dès le départ, dans la Convention sciences de la nature et sciences de l'homme et de la société se sont donc retrouvées intimement liées.

L'histoire de la vie sur la Terre n'est pas « un long fleuve tranquille » et a connu quelques grandes crises d'extinctions massives, bien étudiées par les géologues et paléontologues. Nous en avons décelé au moins cinq depuis 550 millions d'années (M.A.). La troisième qui explique la charnière entre le permien et le

trias, à 245 M.A., fait disparaître 95 % des espèces, surtout marines (Crasquin, 2007). En 4 M.A., l'impact est très fort sur les communautés, une importante chute de l'oxygène, dans l'eau et dans l'air, en relation avec une augmentation thermique de l'ordre de 6°C et des émissions intenses de CO_2 et de méthane, liés à un volcanisme très intense expliqueraient tout cela (Benton et Twitchett, 2003). La cinquième s'est produite il y a 65,5 M.A. et marque la charnière Crétacé-Tertiaire (dite « K-T »), déclenchée par un impact de gigantesque météorite, et fait disparaître définitivement dinosaures et ammonites. La question posée aujourd'hui, bien documentée par les disparitions massives de milieux, d'oiseaux et de mammifères depuis l'émergence d'Homo sapiens et de ses activités, et surtout fortement accélérée depuis la révolution industrielle, est «… allons-nous vers une sixième grande crise d'extinction ? » cette fois-ci provoquée par une seule espèce (Barbault, 2006). Celui-ci parle d'ailleurs d'anthropocène. Le rythme d'extinction récent des milieux et des espèces a été bien documenté par les travaux du *Millennium Ecosystem Assessment* (2005) qui nous précisent qu'elles disparaissent à un rythme entre 100 et 1000 fois plus rapide que celui naturellement attendu et estimé sur les 10 derniers millions d'années. S'il se poursuit ainsi, nous aurons perdu les 2/3 des espèces actuelles (Barbault, 2006 ; Blondel, 2007 ; Bœuf, 2008), d'ici à la fin du XXI^{ème} siècle ! La biodiversité est menacée par la destruction et la pollution des milieux, la surexploitation de ressources naturellement renouvelables, les introductions anarchiques d'espèces créant des conditions de situations envahissantes et le changement climatique.

Que peuvent apporter la systématique et la taxinomie dans un tel contexte ? Beaucoup !

L'une des questions essentielles aujourd'hui est de parvenir à une estimation objective de la diversité spécifique. Ce n'est pas un défi simple car tout évolue très vite et la destruction massive des milieux entraîne la disparition d'un nombre inconnu d'espèces. Par ailleurs une autre disparition alarmante est celle des «descripteurs humains» de cette diversité, que sont les systématiciens. Les évaluations actuelles des grands organismes scientifiques ne sont pas favorables à l'activité de descriptions d'espèces nouvellement découvertes ! Des groupes entiers n'ont plus de spécialistes en France ni même en Europe ou dans le monde. Cette question est fondamentale (Boero, 2010).

Aujourd'hui, sont déposées dans les Musées d'Histoire naturelle du monde entier environ 1,9 million d'espèces répertoriées, et 300 000 fossiles et donc d'espèces disparues. La notion d'espèce, proposée par K. Von Linné durant le XVIII^{ème} siècle prend tout son sens. On en connaissait environ 12 000 vers 1760 et le rythme actuel de description est de 16 000 par an (dont 10 % pour l'environnement marin). Combien en existe-t-il, nous accompagnant encore aujourd'hui? C'est la question délicate qui ramène à la définition de l'espèce: qu'est-ce qu'une espèce de bactérie? De virus? Ceci n'est pas du tout tranché, mais l'espèce apparaît quelque peu comme une « monnaie » assez aisément utilisable (Blondel, 2007) mais les méthodologies d'échantillonnages et de mise en évidence sont bien différentes entre procaryotes et petits eucaryotes d'un côté et les « macro-organismes » de l'autre (Fraser et al., 2007). Les chiffres globaux du nombre d'espèces actuels fluctuent entre 10 et 30 millions, certains vont même jusqu'à 100 (Barbault, 2006 ; Bœuf, 2008). May proposait en 1992, sept millions d'espèces (hors micro-organismes), et Gaston et Spicer en 2004, 14 millions. Si nous admettons ce dernier chiffre, pour décrire les espèces non encore identifiées, au rythme actuel, il nous faudra entre 700 et 1000 ans! Et les espèces disparaissent beaucoup plus vite que le rythme actuel de description.

La question alors posée est comment mettre en évidence la biodiversité sans impérativement connaître toutes les espèces qui peuplent un écosystème ? On peut effectivement compter des espèces dans un milieu bien délimité et étendre les résultats à de plus grands volumes, en estimer les abondances relatives, séquencer les petits ARN 16S chez les procaryotes, 18S chez les très petits eucaryotes, « séquencer des milieux » (métagénomique), réaliser des « mesures génétiques » comme vérifier le nombre d'allèles sur un même locus, mesurer les fréquences relatives ou le degré d'hétérozygotie… (Purvis et Hector, 2000). Pouvons-nous continuer à décrire la diversité comme nous le faisons aujourd'hui ? Les outils moléculaires sont de plus en plus importants et ceci est actuellement bien pris en compte. Toutes les « méta-approches » sont séduisantes et de plus en plus développées. Les projets de « barcoding » sont en cours et aujourd'hui vitaux dans la nouvelle taxinomie. Tout ceci demande des efforts financiers, une organisation internationale assurant une inter-opérabilité et des compatibilités entre systèmes et un véritable dialogue Nord-Sud.

Les principaux défis sont :

- Déterminer les tendances et les développements les plus pertinents pour les pratiques de la taxinomie et en préciser les retombées
- Développer la taxinomie pour un environnement durable et le bien-être humain
- Fournir une bonne opportunité pour un dialogue ouvert entre systématiciens et biogéographes
- Augmenter les relations avec d'autres catégories de partenaires, gens de terrain, conservateurs et gestionnaires de l'environnement
- Renforcer les liens entre la communauté des taxinomistes et les preneurs de décisions, les enseignants et les chargés de communication
- Identifier les priorités pour l'utilisation des « Fonds spéciaux pour la systématique » préconisés par les parties de la Convention sur la Diversité Biologique (CDB)
- Faire passer ce message pour la déclaration de la Conférence de l'UNESCO comme une entrée vers la CDB et tous autres événements qui vont se tenir sur les mesures de la conservation en 2010.

Les principales implications sont la pertinence de la taxinomie pour la mise en évidence de la biodiversité et le bien-être de l'humain, de nouvelles voies pour amplifier les découvertes et les applications des connaissances dues à la systématique, et de nouveaux outils pour développer enseignement et communication.

Les grands Musées d'Histoire naturelle sont incontournables dans leur intime osmose entre deux activités complémentaires, muséographie et recherche fondamentale. Ils ne sont pas des « universités classiques » ni des centres de recherche isolés, ni bien sûr de seuls musées. L'activité de diffusion vers le public et les sujets de recherche permettent de dépasser les missions classiques de recherche, d'enseignement et de diffusion et de renforcer les aptitudes à l'expertise. Depuis le début des années 70 et la prise de conscience des menaces pesant sur la planète, le rôle des grandes collections a changé : elles constituent un support essentiel et un outil indispensable pour la recherche et permettent une connaissance du passé et l'archivage du présent. Les nouvelles méthodologies (imagerie, ADN ancien…), non invasives, autorisent tous les jours de nouvelles approches et usages fructueux et les valorisent constamment. Ces collections et les taxinomistes sont incontournables pour comprendre le passé, gérer le présent et de plus en plus pour tenter de prévoir l'avenir.

Références

Barbault, R. 2006. *Un éléphant dans un jeu de quilles. L'homme dans la biodiversité*. Paris: Seuil.

Benton, M.J. and Twitchett, R.J. 2003. How to kill (almost) all life: The end-Permian extinction event. *Trends in Ecology and Evolution* 18 (7): 358-365.

Blondel, J. 2007. La biodiversité, le point de vue d'un scientifique. Dans *La biodiversité à travers des exemples*. CSPNB, MEDD/D4E : 4-5.

Bœuf, G. 2007. Océan et recherche biomédicale. *Journal de la Société de Biologie* 201 (1) : 5-12.

Bœuf, G. 2008. Quel avenir pour la Biodiversité ? Dans *Un monde meilleur pour tous, projet réaliste ou rêve insensé ?,* sous la direction de Changeux J.P. et Reisse J., Collège de France/ Odile Jacob, 47-98.

Boero, F. 2010. The study of species in the era of Biodiversity: A tale of stupidity. *Diversity*, 2: 115-126.

Crasquin, S. 2007. Quand la vie faillit disparaître. *La Recherche* : 409.

Fraser, C., Hanage, W.P. and Spratt, B.G. 2007. Recombination and the nature of bacterial speciation. *Science* 315: 476-480.

Gaston, J.J. and Spicer, J.I. 2004. *Biodiversity, an introduction*. 2nd edition Oxford: Blackwell Science, : 191 pp.

Lévêque, C. and Mounolou, J.C. 2001. Biodiversité. Dynamique biologique et conservation. *Dunod*.

May, R.M. 1992. How many species inhabit the Earth? *Scientific American* 267: 42-48.

Purvis, A. and Hector, A. 2000. Getting the measure of biodiversity. *Nature* 405: 212-219.

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A new generation of taxonomic tools

The sequencing of DNA, the blueprint of life, created a revolution in taxonomy. It provided the ability to analyse the specific codes of the genes that are the direct result of selection and speciation events. Molecular biology tools are now routinely used by scientists to study taxonomy and biodiversity and by many other users who need rapid, routine and accurate identification of organisms. If a comprehensive DNA sequence database exists for a group of organisms, there are many tools that can be utilised for rapid diagnostics, detection or identification. These tools range in cost, technological sophistication, and in their ability to deal with single species or a broad range of biodiversity (e.g. soil samples). Robotics, microfluidics, microfabrication, nanotechnology, bioinformatics and computer science all contribute to the development of new tools. These technologies are developing rapidly but the basic principle is the same: the assays characterise sequence similarity. No matter how sophisticated the analysis technology is, DNA sequence similarity remains at the core of these new tools and identification through molecular tools is only as good as the taxonomy, DNA sequence databases and the biological collections from which the data and assays were developed.

Introduction

The advent of molecular biology has created a revolution in taxonomy. Recombinant DNA technologies in the 1980s were used to compare DNA between closely-related organisms that were very difficult to identify (e.g. Curran et al., 1985). It was the advent of PCR and the routine use of DNA sequencing in the 1990s that truly revolutionized taxonomy. Sequence data could be easily compared to reference databases like GenBank and phylogenetic hypotheses based on sequence alignments could be tested with much more robustness than ever before. This had an impact in all areas of taxonomy from viroids to mammals.

In order to illustrate the need and the impact of new taxonomic tools, this discussion is concentrated on oomycetes. This is the group of organisms I know best which also encompasses most of the reasons why molecular taxonomy is so important and why new robust tools are desperately needed. Oomycetes were originally classified in the kingdom fungi but through molecular phylogenetic analyses it became indisputable that they are more closely related to brown algae and diatoms than true fungi. This reclassification helped explain several unique aspects in the biology of these organisms and had a profound impact on those who study their biology. Oomycetes are found in marine and terrestrial environments. Many species can grow as saprophytes with little impact on human activities but oomycetes are economically important because they can be virulent pathogens. The Irish potato famine was caused by *Phytophthora infestans* and many other oomycetes are obligate or facultative plant pathogens, including several species that are on international plant quarantine lists. Some genera are well known pathogens of fish while others can be pathogens of nematodes, insects or algae. *Pythium insidiosum* belongs to a genus with many plant pathogenic representatives but is an animal pathogen that can cause serious infections in humans. Some *Pythium* species are used as biological control agents against oomycete plant pathogens. Because of their economic impact and of the regulations restricting their movement, some oomycetes have been studied extensively and rapid detection tools have been developed for several species. The oomycetes provide good examples of the kinds of taxonomic or detection tools that can be developed for accurate diagnostics. The message that I want to convey in this paper is that the computer science concept of “garbage in – garbage out” is applicable to the development of new taxonomic tools. The new technologies have amazing potential, however for molecular identification or detection of organisms, proper taxonomic information

and coverage is necessary for the development and validation of new tools. Without that, results from new tools, no matter how sophisticated these tools are, can be very misleading.

Identification and detection by sequencing

Pythium and *Phytophthora* are two oomycete genera commonly found in soil. One gram of soil can easily contain thousands of propagules and dozens of species. Identification by morphology is very challenging for many species. For identification the strain needs to be isolated from roots or soil and grown in pure culture with the proper stage of the life cycle observable. For several closely related species only a few specialized scientists can differentiate by microscopic examination the 10-40 μm diagnostic structures. Because of their high economic impact and the fact that several species are regulated, DNA technologies were used very early on to separate these species. Cooke et al. (2000) published a comprehensive DNA sequence database and phylogeny of the genus *Phytophthora* based on the internal transcribed spacer (ITS) which included all the known species at the time. Lévesque and de Cock (2004) produced the same resource for the genus Pythium. Because the DNA sequence databases are comprehensive for these genera and because the ITS provides good resolution, it is possible to identify known species by sequencing and easier to determine if strains are putative new species.

Providing comprehensive DNA sequence databases on agreed-upon markers using properly identified reference strains for the broadest species coverage possible is the goal of the DNA Barcode of Life (Hebert et al., 2003). Currently, GenBank is the main source of sequences for identification by sequencing but there are many poorly-identified strains that have data in GenBank (see Lévesque and de Cock, 2004, for *Pythium* examples). The strains with sequences in GenBank are often no longer available for verification and the chromatograms cannot be checked for quality of the base calling. The goal of the International Barcode of life (iBOL) project is to create databases that will alleviate these problems (Ratnasingham and Hebert, 2007). GenBank data, with such standardization and additional quality assurance for taxonomic purposes, can have the "barcode" label. The iBOL project has the goal of sequencing 500K species and 5M specimens of a wide range of kingdoms in the near future.

After a comprehensive and well-referenced DNA barcode database has been developed, identification of a species or specimen by sequencing is straightforward but it requires a fairly clean or pure sample to extract DNA from. Sequencing DNA from a mixed sample with traditional Sanger sequencing used to require cloning the PCR product mixture by bacterial transformation in order to generate individual clean sequences, a very tedious process similar to what was done in traditional shotgun genome sequencing. Second generation sequencing can skip this most tedious and work-intensive cloning step, providing the ability to produce millions of sequences from one or a few samples in a couple of days. Soil samples can have thousands of microbial species and this kind of technology is being used more routinely for ecological research (Roesch et al., 2007). These ecological studies are showing how limited our reference databases are. Sequences cannot be matched or identified because many known species have not been sequenced yet but also because there are many unculturable species in soil.

Environmental detection of a single or a few species

Quite often users want to know about the presence or absence of one or a few species directly from environmental samples. This is particularly relevant for regulated species. Quantitative PCR (qPCR) is the most common and rapid technique for such purpose and several robust instruments, including portable ones, are available for this technology. Developing a qPCR assay without a comprehensive database covering all the closely-related species or a wide range of strains for the species of interest can lead to assays that will be prone to false positive or false negative results. *Phytophthora ramorum* was found in Europe and North America around the time when a fairly comprehensive database for *Phytophthora* had just been made available (Cooke et al., 2000; Werres et al., 2001). Several laboratories developed qPCR assays (Bilodeau et al., 2007; Hayden et al., 2006; Hughes et al., 2006; Martin et al., 2004; Tomlinson et al., 2007; Tooley et al., 2006) but validated them individually with a fairly inconsistent range of species and strains to asses the potential for false positives and negatives. An international effort was undertaken to validate all these assays through a blind ring trial using a comprehensive and well characterized collection of *Phytophthora* species and DNA extracts from field samples (Martin et al., 2009). Outside the medical and veterinary field, this is probably one of the most comprehensive DNA test validations ever completed. It was obvious from these results that it is essential to have comprehensive biological collections to develop

these kinds of assays. Recent advances of qPCR for molecular ecology were recently reviewed (Smith and Osborn, 2009).

Multiplex detection with DNA arrays

A technique like qPCR can provide answers on the presence or absence of a few species in a few hours. However, there are many instances where a rapid and cheap test is required to address a large number of possibilities. Such a test is a DNA array which contains a wide range of species-specific oligonucleotides that can be hybridized with a labelled PCR product amplified from a mixed environmental sample using primers that match a wide range of species. The first such array for an entire genus was developed for *Pythium* (Tambong et al., 2006) and has been used for ecological studies (Le Floch et al., 2007). Many other arrays have since been developed for specific applications (e.g. Agindotan and Perry, 2007; Justé et al., 2008) including very large arrays for a very wide range of bacterial species (Bodrossy, 2003).

The new technologies

The first meeting on microfabrication and DNA technologies was held in 1995 in San Francisco. At this meeting some newly-formed companies presented revolutionary prototypes that became mainstream technology soon afterward (e.g. Affymetrix arrays and Cepheid micro PCR). However many other ideas and promises, such as fully integrated handheld point of care devices, are still in the development stage. The challenges for creating the fully integrated lab on a chip are numerous, many pertaining to the difficulties of integrating high quality DNA extraction from a wide range of samples (Ince and McNally, 2009). Many laboratories are working on developing fully-integrated arrays that would do DNA extraction, PCR, labelling, detection and strain typing of infectious diseases on a handheld device (Charlton et al., 2009; Mikhailovich et al., 2008). A miniaturized DNA array for *Phytophthora* spp. was set in a way that each species-specific oligonucleotide dot is over a gap between electrodes in a microchip. If silver labelled DNA is hybridized to a particular dot, the current can go over the gap and the computer immediately picks up a signal (Julich et al., 2009).

The term next generation DNA sequencing is being used to describe massively parallel DNA sequencing that has increased capacity by orders of magnitude. The current technologies still rely on some form of amplification to prepare the reactions. The limits and efficacy of this approach are being pushed further rapidly. There are near-market technologies that will sequence individual DNA molecules without amplification (e.g. Branton et al., 2008; Eid et al., 2009). The cost of genome sequencing has decreased by about 1,000-fold over the past ten years and this trend is continuing. Taxonomists will have information from many complete genomes for comparisons and ecologists will be able to gather millions of sequences from a single sample at a very cost-effective price. Data analysis and bioinformatics will be the new challenge. The data generated by current second generation technologies are already a major bioinformatics endeavour requiring facilities that are out of reach for many laboratories.

When these novel sequencing technologies are being used to sequence environmental DNA to study microbes, it is becoming more obvious than ever that we know very little about our biodiversity and that many of the microbial species have never been cultivated. Molecular biology is making use of many of the novel micro-scale engineering technologies that have emerged over the past few decades (e.g. microfabrication, microfluidics, nanotechnology) but technologies to isolate or maintain microbes have not evolved significantly since the Pasteur era. A paradigm shift is needed if we want to be able to isolate all this biodiversity and maintain it as live cultures. Microfabrication techniques have been used to isolate so-called unculturable bacteria by maintaining the chemical signalling that allows them to grow in a natural environment (Du et al., 2009; Kim et al., 2008). More efforts are needed in this area of microbiological research to maintain and characterize that vast number of unknown microbial species.

Conclusion

Molecular biology is revolutionizing taxonomy and biosystematics. Most of the DNA-based taxonomic tools provide rapid and sensitive protocols that can bypass the time-consuming steps necessary to produce the diagnostic morphological stages in vitro. When taxonomic databases are comprehensive and assays are properly validated with extensive collections, DNA tools can be specific, multiplexed and provide results that can be easy to interpret. The cost of DNA-based tools keeps coming down and most protocols are amenable to scaling up and high throughput by staff that do not need training in taxonomy.

Recently it was reported that black cherry (*Prunus serotina*) was an invasive species in Europe but not in its native North American range because of the complex of different *Pythium* species harboured in its root system (Reinhart et al., 2010). No *Pythium* taxonomists were involved in this study that provided evidence for a new role for *Pythium* in invasiveness. Having such studies without the involvement of one of the few oomycete taxonomists would not have been possible before the publication of the comprehensive ITS database of all known *Pythium* species.

However, the fact that somebody with minimal taxonomic and technical training can run molecular diagnostic assays can be problematic. A large amount of background information, as well as knowledge of the limitations of several reagents and instruments, are needed for the development and application of any molecular test. Interpretation of the results also requires knowledge of the system (e.g. hydroponic culture) from which the sample came in order to make a recommendation about a treatment or about the need for further sampling and tests. This is analogous to flying a sophisticated airplane: once it is on automatic pilot everything is fine but if it has to be put on manual control or if the navigation system fails, experience is desperately needed to complete the flight safely.

Isolation by in vitro culturing is no longer required for rapid detection with DNA and this is problematic in some situations. When DNA is detected, it is not certain if the DNA comes from living or dead cells - which can be an issue for certain diagnostic applications. However for many users detecting the presence of simply DNA or RNA is acceptable. When a new outbreak of a pathogen appears, e.g. an organism with a new antibiotic resistance mechanism, there are often no recently isolated strains available to trace back the phenomenon because diagnostics are now done without isolation by culture. Laboratories that are trying to study the virulence and resistance mechanisms of this new outbreak will have very few strains to work with and their work might be compromised.

There are many parallels and technology transfers between the fields of genomics and molecular taxonomy but the requirement for biological collections is much higher in molecular taxonomy than genomics. One human DNA sample for genomics will provide over 3 billion bp of sequences whereas the same total amount of information from taxonomy barcodes of 1,000 bp would represent 3 million strains or specimens that need to be housed in biological collections. New taxonomic tools can only be as good as the state of the taxonomic information they are based on and the biological collections that are being used to develop the tools or interpret the data. Therefore, as efforts and investments are being made in developing new taxonomic tools, an effort as least as significant is needed to support the biological collections and the specialists that curate and study them.

The cost of new taxonomic tools is coming down but DNA-based techniques are still prohibitively expensive for many laboratories, particularly in developing countries where most of the biodiversity is still unknown. One significant factor in the price reduction is the miniaturization of technologies with fewer reagents required and smaller instruments which are cheaper to buy and operate. This miniaturization can also come at a cost for the users however, particularly those studying ecology or involved in preventing the introduction of invasive alien species. These users need to process and properly sample large volumes whereas miniaturization is steadily reducing the amount of DNA that can be processed in a single assay. Robideau et al. (2008) demonstrated this when they showed that as the amount of cranberry fruits being processed for disease identification was increased, the number of false negative results increased simply because the DNA of certain pathogens was not represented in the small aliquot of DNA extract used for PCR detection.

The current situation with new molecular tools and taxonomy can be compared to the early days of intercontinental travelling. Our knowledge of the global biodiversity is still limited, much like the maps of the world were when travellers were first sailing around the different continents. As the ships ventured further, the maps got better and travelling got easier. Molecular tools are being used by taxonomists to facilitate species discovery and maps of biodiversity are being drawn with DNA sequence information. There is one major difference, however, between the experiences of the early world travellers and modern taxonomists. When these early travellers were sailing, the continents were not shrinking and the land was not vanishing, meaning there was no rush to complete the map of the world before it disappeared. We, however, must hurry up to map the world's biodiversity because species are disappearing at an alarming rate.

References

Agindotan, B. and Perry, K.L. 2007. Macroarray detection of plant RNA viruses using randomly primed and amplified complementary DNAs from infected plants. *Phytopathology* 97 (1): 119-127.

Bilodeau, G.J., Lévesque, C.A., de Cock, A.W.A.M., Duchaine, C., Brière, S., Uribe, P., Martin, F.N. and Hamelin, R.C. 2007. Molecular detection of *Phytophthora ramorum* by RT-PCR using TaqMan, SYBR®Green and Molecular Beacons. *Phytopathology* 97: 633-642.

Bodrossy, L. 2003. Diagnostic oligonucleotide microarrays for microbiology. In: E. Blalock (ed.), *A Beginner's Guide to Microarrays*. New York: Kluwer Academic Publishers: pp. 43-92.

Branton, D., Deamer, D.W., Marziali, A., Bayley, H., Benner, S.A., Butler, T., Di Ventra, M., Garaj, S., Hibbs, A., Huang, X., Jovanovich, S.B., Krstic, P.S., Lindsay, S., Ling, X.S., Mastrangelo, C.H., Meller, A., Oliver, J.S., Pershin, Y.V., Ramsey, J.M., Riehn, R., Soni, G.V., Tabard-Cossa, V., Wanunu, M., Wiggin, M. and Schloss, J.A. 2008. The potential and challenges of nanopore sequencing. *Nature Biotechnology* 26 (10): 1146-1153.

Charlton, B., Crossley, B. and Hietala, S. 2009. Conventional and future diagnostics for avian influenza. *Comparative Immunology, Microbiology and Infectious Diseases* 32 (4): 341-350.

Cooke, D.E.L., Drenth, A., Duncan, J.M., Wagels, G. and Brasier, C.M. 2000. A molecular phylogeny of Phytophthora and related oomycetes. *Fungal Genetics and Biology* 30 (1): 17-32.

Curran, J., Baillie, D.L. and Webster, J.M. 1985. Use of genomic DNA restriction fragment length differences to identify nematode species. *Parasitology* 90 (1): 137-144.

Du, W., Li L., Nichols, K.P. and Ismagilov, R.F. 2009. SlipChip. *Lab Chip* 9: 2286-2292.

Eid, J., Fehr, A., Gray, J., Luong K., Lyle, J., Otto, G., Peluso, P., Rank, D., Baybayan, P., Bettman, B., Bibillo, A., Bjornson, K., Chaudhuri, B., Christians, F., Cicero, R., Clark, S., Dalal, R., deWinter, A., Dixon, J., Foquet, M., Gaertner, A., Hardenbol, P., Heiner, C., Hester, K., Holden, D., Kearns, G., Kong, X., Kuse, R., Lacroix, Y., Lin, S., Lundquist, P., Ma, C., Marks, P., Maxham, M., Murphy, D., Park, I., Pham, T., Phillips, M., Roy, J., Sebra, R., Shen, G., Sorenson, J., Tomaney, A., Travers, K., Trulson, M., Vieceli, J., Wegener, J., Wu, D., Yang, A., Zaccarin, D., Zhao, P., Zhong, F., Korlach, J. and Turner, S. 2009. Real-time DNA sequencing from single polymerase molecules. *Science* 323 (5910): 133-138.

Hayden, K., Ivors, K., Wilkinson, C. and Garbelotto, M. 2006. TaqMan chemistry for *Phytophthora ramorum* detection and quantification, with a comparison of diagnostic methods. *Phytopathology* 96 (8): 846-854.

Hebert, P.D., Cywinska, A., Ball, S.L. and deWaard, J.R. 2003. Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London*. Series B: Biological Sciences 270 (1512): 313-321.

Hughes, K.J.D., Tomlinson, J.A., Griffin, R.L., Boonham, N., Inman, A.J. and Lane, C.R. 2006. Development of a one-step real-time polymerase chain reaction assay for diagnosis of *Phytophthora ramorum*. *Phytopathology* 96 (9): 975-981.

Ince, J. and McNally, A. 2009. Development of rapid, automated diagnostics for infectious disease: Advances and challenges. *Expert Review of Medical Devices* 6 (6): 641-651.

Julich, S., Kielpinski, M., Urban, M., Riedel, M., Wagner, S., Werres, S., Fritzsche, W., Möller, R. and Henkel, T. 2009. PCR and microarray chip technologies for *Phytophthora* diagnosis. In: *qPCR 2009 Event Proceedings (www.qpcr2009.net),* Freising, Germany. pp. 41-42.

Justé, A., Thomma, B.P.H.J. and Lievens, B. 2008. Recent advances in molecular techniques to study microbial communities in food-associated matrices and processes. *Food Microbiology* 25 (6): 745-761.

Kim, H.J., Boedicker, J.Q., Choi, J.W. and Ismagilov, R.F. 2008. Defined spatial structure stabilizes a synthetic multispecies bacterial community. *Proceedings of the National Academy of Sciences of the United States of America* 105 (47): 18188-18193.

Le Floch, G., Tambong, J., Vallance, J., Tirilly, Y., Lévesque, C.A. and Rey, P. 2007. Rhizosphere persistence of three *oligandrum* strains in tomato soilless culture assessed by DNA macroarray and real-time PCR. *FEMS Microbiology Ecology* 61 (2): 317-326.

Lévesque, C.A. and de Cock, A.W.A.M. 2004. Molecular phylogeny and taxonomy of the genus . *Mycological Research* 108: 1363-1383.

Martin, F.N., Coffey, M.D., Zeller, K., Hamelin, R.C., Tooley, P., Garbelotto, M., Hughes, K.J.D., Kubisiak, T., Bilodeau, G.J., Levy, L., Blomquist, C. and Berger, P.H. 2009. Evaluation of molecular markers for *Phytophthora ramorum* detection and identification: Testing for specificity using a standardized library of isolates. *Phytopathology* 99 (4): 390-403.

Martin, F.N., Tooley, P.W. and Blomquist, C. 2004. Molecular detection of *Phytophthora ramorum*, the causal agent of sudden oak death in California, and two additional species commonly recovered from diseased plant material. *Phytopathology* 94 (6): 621-631.

Mikhailovich, V., Gryadunov, D., Kolchinsky, A., Makarov, A.A. and Zasedatelev, A. 2008. DNA microarrays in the clinic: infectious diseases. *Bioessays* 30 (7): 673-682.

Ratnasingham, S. and Hebert, P.D.N. 2007. BOLD: The Barcode of Life Data System: Barcoding. *Molecular Ecology Notes* 7 (3): 355-364.

Reinhart, K.O., Tytgat, T., Van der Putten, W.H. and Clay, K. 2010. Virulence of soil-borne pathogens and invasion by *Prunus serotina*. *New Phytologist* (online release).

Robideau, G.P., Caruso, F.L., Oudemans, P.V., McManus, P.S., Renaud, M.A., Auclair, M.E., Bilodeau, G.J., Yee, D., Desaulniers, N.L., DeVerna, J.W. and Lévesque, C.A. 2008. Detection of cranberry fruit rot fungi using DNA array hybridization. *Canadian Journal of Plant Pathology* 30: 226-240.

Roesch, L.F.W., Fulthorpe, R.R., Riva, A., Casella, G., Hadwin, A.K.M., Kent, A.D., Daroub, S.H., Camargo, F.A.O., Farmerie, W.G. and Triplett, E.W. 2007. Pyrosequencing enumerates and contrasts soil microbial diversity. *ISME Journal* 1 (4): 283-290.

Smith, C.J. and Osborn, A.M. 2009. Advantages and limitations of quantitative PCR (Q-PCR)-based approaches in microbial ecology. *FEMS Microbiology Ecology* 67 (1): 6-20.

Tambong, J.T., de Cock, A.W., Tinker ,N.A. and Lévesque, C.A. 2006. Oligonucleotide array for identification and detection of species. *Applied and Environmental Microbiology* 72 (4): 2691-2706.

Tomlinson, J.A., Barker, I. and Boonham, N. 2007. Faster, simpler, more-specific methods for improved molecular detection of *Phytophthora ramorum* in the field. *Applied and Environmental Microbiology* 73 (12): 4040-4047.

Tooley, P.W., Martin, F.N., Carras, M.M. and Frederick, R.D. 2006. Real-time fluorescent polymerase chain reaction detection of *Phytophthora ramorum* and *Phytophthora pseudosyringae* using mitochondrial gene regions. *Phytopathology* 96 (4): 336-345.

Werres, S., Marwitz, R., Man In'T Veld, W.A., De Cock, A.W.A.M., Bonants, P.J.M., De Weerdt, M., Themann, K., Ilieva, E. and Baayen, R.P. 2001. *Phytophthora ramorum sp. nov.*, a new pathogen on *Rhododendron* and *Viburnum*. *Mycological Research* 105 (10): 1155-1165.

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A place for taxonomy in 2010, and beyond?

Introduction

In several respects the first decade of the 21st Century has been a proverbial Golden Age for biological taxonomy and systematics as far as the realisation of the primary value of this field of scientific endeavour is concerned. However, the term 'Golden Age' no longer simply refers to organism collectors gaining increasingly easy physical access to previously inaccessible localities where myriad species new to science will be discovered. Explicit in this statement is the much wider and stronger understanding of, and appreciation for, the value and services that can be derived from collections of preserved biological material and their associated data. This of course implies that herbaria and natural history museums must be appropriately staffed and the collections actively researched and curated.

Taxonomy in the 21st Century

The renewed understanding of the value of collections demonstrated over the past few years coincided with the establishment of a variety of widely-supported country-level initiatives, including for example the development of National Biodiversity Strategies and Action Plans (NBSAPs) and the implementation of the Global Strategy for Plant Conservation (GSPC), both brought about by a large number of governments becoming signatories to the widely-supported Convention on Biological Diversity. Further to these organized activities, the acceptance of human-accelerated climate change and the early detection and eradication of alien invasive organisms, have also significantly enhanced the scientific and public understanding of the importance of systematics.

Many things have changed over the past few years. Taxonomists are increasingly embracing modern technologies, such as delivering identification tools over the Internet, accessing images remotely and collaborating with, for example, population geneticists and molecular geneticist to unravel phylogenies. However, some things have not changed. Taxonomy and taxonomists are still widely perceived as involving themselves with activities that emphasise their lack of communication skills, and displaying a preference for being stuck in dusty corners of herbaria and natural history museums while chiselling away at a monumental monograph of a group that hardly warrants (yet another?) treatment. But the need for taxonomic products has not changed. In fact, it has been enhanced over the past few years. For example, there is still a dire need for governments to be empowered to adequately look after their natural resources; for this there is no alternative to having robust checklists of their fauna flora and mycota. The step beyond this would be to populate such inventories with nomenclatural, descriptive and geographical information. And of course identification tools for end-users. Taxonomists remain the best-placed group of scientists to produce these, and more.

Several emerging issues regarding the value and uses of their work should, and must, be taken into account by taxonomists. These include advocating the usefulness of biological collections as essential reference materials for providing a range of services for the broader scientific community and other end-users of primary biological data. Furthermore, they should enhance and fast-track efforts to train and skill the next generation of systematists and biological data analysts through joint capacity-enhancing activities. This should result in a scaling up of their joint efforts to discover, describe and document the disappearing biotas of the world. Through establishing an increasingly-supported, coordinated network of collaborating taxonomists and systematists working on large scale projects, it will be possible to achieve some of these outputs. This will ultimately result in adequately beneficiated biological collections that are well able to demonstrate their value through targeted, priority-driven analyses of data derived from them.

Taxonomists are legitimately expected to deliver products that must be useful to both scientists and society at large. Such products should include:

- Monographs of taxonomic groups
- Up-to-date checklists of the biodiversity of a region
- Inventories enriched with diverse information including endemic status of taxa, geographical distribution ranges, and additional natural history information
- Narratives of the natural history of species (conservation status, range changes, etc.)
- Identification tools, ideally simplified for easy use
- Scientifically curated collections for reference purposes
- A cadre of young trained and skilled taxonomists

To enable taxonomists to deliver these products, there is a reciprocal expectation that they will be enabled to do so. Their needs include:

- Adequately-staffed collections, including collections managers
- Access to collections that are physically curated to a high standard
- Access to electronic images of relevant specimens and collections
- Library holdings with a wide range of relevant literature and electronic access to libraries and periodicals
- Jointly developed electronic shells (databases, websites, etc.) that can be populated with robust content
- Regular field work
- Access to funding for prioritised research projects

Conclusion

For taxonomists the past few years have heralded a period during which there has been a much improved appreciation for the importance and value of their high-level, information-driven outputs and services. This remarkable improvement is somewhat paradoxical given that their science is not necessarily fast, cost-effective and based on high throughput, as is the case with most modern methodologies. But in many respects in the global debate on the relevance of science, the challenge remains theirs; they must maintain an active association with, and attachment to, global science-based biodiversity endeavour. For example, the increasing availability of modern technologies, such as molecular identification tools, is speeding up the detection of species, but proper taxonomic information and coverage remains pivotal. Essentially, the validation of the names of organisms can only be achieved if the underlying taxonomy is reliable. In all of this, the participation of taxonomists imperative.

References

Germishuizen, G., Meyer, N.L., Steenkamp,Y. and Keith, M. (eds). 2006. *Checklist of South African Plants*. SABONET Report Series No. 41. Pretoria, South Africa: South African Botanical Diversity Network.

Gibbs Russell, G.E. 1985. Analysis of the size and composition of the southern African flora. *Bothalia* 15: 613–629.

Hall, A.V. 1978. Endangered species in a rising tide of human population growth. *Transactions of the Royal Society of South Africa* 43: 37–49.

Huntley, B.J., Siegfried, R. and Sunter, C. 1989. *South African environments into the 21st century*. Tafelberg, Cape Town: Human and Rousseau.

Klopper, R.R., Smith, G.F. and Chikuni, A.C. 2002. The Global Taxonomy Initiative in Africa. *Taxon* 51: 159–165.

Low, A.B. and Rebelo, A. (eds). 1996. *Vegetation of South Africa, Lesotho and Swaziland*. Pretoria, South Africa: Department of Environmental Affairs and Tourism.

Mittermeier, R.A., Gill, P.R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and Da Fonseca, G.A.B. (eds.). 2005. *Hotspots revisited. Earth's biologically richest and most endangered terrestrial ecoregions*. Mexico City, Mexico: CEMEX.

Mucina, L. and Rutherford, M.C. (eds.). 2006. *The vegetation of South Africa, Lesotho and Swaziland*. Strelitzia 19. Pretoria, South Africa: South African National Biodiversity Institute.

Sadie, J.L. 1978. The demographic forces in South Africa. *Transactions of the Royal Society of South Africa* 43: 11–23.

Scheepers, J.C. 1983. The present status of vegetation conservation in South Africa. *Bothalia* 14: 991–995.

Siebert, S.J. and Smith, G.F. 2005. Plant Red Data List assessments in southern Africa: Financial costs of a collaborative project. *Taxon* 54: 1051–1055.

Simon, J.L. 1986. Disappearing species, deforestation and data. *New Scientist* 110 (1508): 60–63.

Smith, G.F. 2006. Herbaria in the real world. *Taxon* 55: 571–572.

Smith, G.F. and Figueiredo, E. 2009a. Capacity building in taxonomy and systematics. *Taxon* 58: 697–699.

Smith, G.F. and Figueiredo, E. 2009b. E-taxonomy: An affordable tool to fill the biodiversity knowledge gap. *Biodiversity and Conservation* 19: 829–836.

Smith, G.F. and Klopper, R.R. 2002. A southern perspective on the All Species Project and the global taxonomic imperative. *Taxon* 51: 359–361.

Smith, G.F., Roux, J.P., Tolley, K. and Conrad, F. 2007. Taxonomy and barcoding: Conflict or companions? *South African Journal of Science* 102: 517–518.

Smith, G.F., Steenkamp, Y., Klopper, R.R., Siebert, S.J. and Arnold, T.H. 2003. The price of collecting life. Overcoming the challenges involved in computerizing herbarium specimens. *Nature* 422: 375–376.

Smith, G.F. and Wolfson, M.M. 2004. Mainstreaming biodiversity: The role of taxonomy in bioregional planning activities in South Africa. *Taxon* 53: 467–468.

Steenkamp, Y. and Smith, G.F. 2003. Needs of users of botanical information in South Africa: Outcomes of a national workshop for the stakeholders and end-users of botanical information and herbaria. *Taxon* 52: 303–306.

Steenkamp, Y. and Smith, G.F. 2006. Introduction to A checklist of South African plants. In Germishuizen G., N.L., Meyer, Y., Steenkamp and Keith, M. (eds), A checklist of South African plants. *Southern African Botanical Diversity Network Report* 41: iv–ix. Pretoria, South Africa: SABONET.

Van Wyk, A.E. and Smith, G.F. 2001. *Regions of floristic endemism in southern Africa. A review with emphasis on succulents*. Hatfield, South Africa: Umdaus Press.

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Ethno-biodiversity, taxonomy and bioinformatics for all ages: Engaging and educating the next generation of taxonomists as a foundation for sustainable living on Planet Earth – Challenges and opportunities

Introduction

Ethnobiodiversity is defined as the knowledge, uses, beliefs, management systems, taxonomies and language that a given culture, including the modern scientific community, has for biodiversity. Taxonomy, as a component of ethnobiodiversity, is the science of identifying, describing, classifying, naming and determining the interrelationships between living things. Bioinformatics is the science of recording, compiling, processing and making this information available to the widest range of users. For millennia, ethnobiodiversity, taxonomy and bioinformatics have been a basis for human understanding of biodiversity as a foundation for sustainable habitation of Planet Earth. They are, however, like biodiversity itself, highly threatened, creating a parallel "ethnobiodiversity extinction crisis".

It is argued that: 1) the biodiversity extinction crisis, whether due to overexploitation, habitat destruction and degradation, invasive species or disease, climate change, pollution or other causes, is a much more serious long-term threat to the sustainable future of people on the planet than climate change and sea level rise; 2) the conservation, sustainable use and equitable sharing of access to biodiversity, the three main objectives of the United Nations Convention on Biological Diversity (CBD), constitute the most practicable means of mitigating and adapting to climate change and other natural and economic calamities at international, national and local levels; and, 3) without addressing the ethnobiodiversity crisis, of which strengthening taxonomy and bioinformatics must play central roles, the achievement of the goals of the CBD will be problematic, if not impossible. Some examples of existing initiatives and outputs and potential areas for the conservation and enrichment of ethnobiodiversity and the strengthening and mainstreaming of taxonomy and bioinformatics are provided, based on experiences in the Pacific Islands.

The ethnobiodiversity crisis and the taxonomic impediment

One facet of the ethnobiodiversity conservation crisis is the serious shortage of taxonomists to successfully inventory and characterize the Earth's biodiversity and to provide the biodiversity data to underpin biodiversity conservation efforts. This has been referred to as the "taxonomic impediment" (Hoagland 1996). Although we have countless academics, planners, fundraisers, conflict resolvers and conservation consultants, there are very, very few taxonomists who can assess the status of biodiversity and communicate this to appropriate stakeholders.

Many world-class professors and alpha-taxonomists from museums and other research organizations are dying or retiring (or being retired) and not replaced. The epitome of this is the recent forced retirement from the Hawai'i's Bishop Museum of seven staff, including Dr. Jack Randall, the world's foremost authority on tropical fishes, who is still productive, having just produced two massive volumes on the fishes of the Hawaiian Islands and the tropical Pacific Islands, and is currently working on a book on the fishes of Easter Island.

It is now far easier to fund DNA analyses, climate change modelling and scholarships for accounting, economics, e-commerce, computing, law, medicine and other fields than it is to fund people in areas that could strengthen taxonomy. If

the situation is serious in developed countries, the situation is far worse in developing countries, which often have no trained taxonomists, no biodiversity collections, and few if any guidebooks on their flora, fauna and mycota. This is particularly concerning because developing countries are among the world's most important and seriously-threatened biodiversity hotspots and are often countries with an almost obligate dependence on the sustainable use of biodiversity as the foundation for economic, cultural and political survival.

The way forward: Demystification and mainstreaming of biodiversity and ethnobiodiversity conservation, taxonomy and bioinformatics

To address the biodiversity and ethnobiodiversity extinction crises and the "taxonomic impediment" is, however, not just about formal training of taxonomists to catalogue unidentified biodiversity and developing bioinformatics to provide information to conservationists. It is also about using bioinformatics and the most up-to-date educational strategies to demystify and mainstream concepts of biodiversity conservation, ethnobiodiversity and taxonomy to insure that everyone clearly understands their seminal importance. We need a massive systematic campaign so that everyone can define these interdependent concepts on their own terms, whether they are fluent in Latin, French, English, Chinese or any other vernacular language. We need people to be able to define biodiversity and learn taxonomy, at many different levels of sophistication, in meaningful terms in their own languages.

We must use innovative and culturally-inclusive approaches and the best bioinformatics to protect, teach and enrich taxonomy for people of all ages; for organisms of all ages, past and present (e.g., of dinosaurs, extinct birds, etc.); for populations, both endemic and non-endemic; and for all places, both natural and cultural. Only thus can we simultaneously address the current biodiversity and ethnobiodiversity extinction crises and the taxonomic impediment at all levels of society.

For developing countries and rural and outer island communities with no museums, no modern taxonomists and often no connection to the Internet, taxonomy and bioinformatics are particularly critical to underpin biodiversity conservation. In these areas the conservation and use of local taxonomies, where possible in concert with modern taxonomy, will be required, and bioinformatics may have to employ a synthesis of some of the most cutting-edge technologies and models with some of the most time-tested models, such as oral transmission, production of inexpensive guides or checklists in vernacular languages with associated digital photos, or putting solar powered laptops and digital cameras into the hands of local taxonomists, with the appropriate training and support, so that they can conduct their own biodiversity surveys and link their own taxonomies, names and metadata to the biodiversity of their reefs, lagoon, rivers, forests and garden areas.

Best practice and suggested activities

There are an increasing number of recent initiatives or outputs that have clearly played a role in demystifying and mainstreaming biodiversity conservation, taxonomy, and bioinformatics. Such initiatives, from a Pacific Islands perspective, include: 1) increases in undergraduate and postgraduate programmes, in-service courses and workshops in biogeography, conservation biology, invasive species management, taxonomy and bioinformatics; 2) regional and local community-based initiatives on the inventory, conservation and monitoring of terrestrial, marine, freshwater and agricultural and forest biodiversity; 3) biodiversity surveys involving local students and local community experts alongside expedition taxonomists; 4) publication or establishment of biodiversity guides, booklets, checklists, videos, movies, websites and other materials that combine both scientific and local vernacular taxonomies and other information on biodiversity; 5) development of national, local or conservation initiative-based open-access biodiversity databases; and, 6) increasingly effective biodiversity conservation partnerships between international and local NGOs, government, educational and scientific organizations, the private sector and local communities.

There is insufficient space here to give credit to these efforts individually. Suffice it to say that we must use all of these avenues to:

- Insure that the general public, policy makers, and the developmental elite clearly know what biodiversity is, that it is seriously threatened, and that it is a foundation for sustainability
- Create understanding and appreciation of the importance of ethnobiodiversity and taxonomy among all ages and at all levels in society as a precondi-

tion for addressing the biodiversity loss

- Train armies of parataxonomists and make sure our children know the names and types of plants animals and other organisms and the ways ecosystems function. This could include requiring that all students take "natural history", or perhaps, more appropriately "life history" courses that focus on the taxonomies and economic, cultural and ecological importance of biodiversity. Curricula should focus not only on "natural biodiversity", but also on the "humanized biodiversity" of cities, highly degraded areas, invasive species, agricultural areas, home gardens, atolls and other habitats that have biodiversity inheritances that require conservation and sustainable management. Without a cohort of young people who have knowledge and are interested in biodiversity, there will be no pool from which we can derive potential future practicing taxonomists
- Support local and indigenous taxonomists and traditional biodiversity users to record, preserve, strengthen, disseminate, and use their own taxonomies and "stories" as vital links between "our" and "their" taxonomies and bioinformatics as bases for the conservation and sustainable use of their biodiversity. This would include working with traditional healers, fishers and reef gleaners, gardeners and horticulturalists, craftspeople, shell sellers, marketers of fresh produce and other persons involved in the conservation and sustainable use of biodiversity, and assisting them to produce guides, posters, checklists, videos, maps place name and biodiversity distribution maps, and other outputs to support local biodiversity conservation and education efforts
- Involve local students, local community members and the best indigenous or local taxonomist in our biodiversity surveys and expeditions
- Adapt bioinformatics as the open-access superhighway for getting taxonomic information (both primary and metadata) to stakeholders of all ages, all educational levels, rich and poor, rural and urban. This includes the provision of taxonomic and biodiversity information and the results of biodiversity surveys in many different ways, so that stakeholders and practitioners – whether they be other taxonomists, researchers, conservationists, school teachers, local communities, citizen scientists or younger school children – have materials and activities that serve as their windows to biodiversity. This would include increasing emphasis on guidebooks, biodiversity lists and popular publications (both in print as well as on DVD and on-line), especially in on-line, open-access sources. Co-authorship with local collaborators is to be promoted
- Promote and convince policymakers of the critical need for field and museum biodiversity collections and for teaching taxonomists and bioinformaticians. Very few of our top taxonomists actually teach, particularly at the undergraduate level, not to mention in schools
- Strongly support international taxonomic and bioinformatic initiatives such as GBIF and BioNet and their partner and linked organizations and biodiversity information portals (web link) to energize taxonomic and bioinformatic capacity building
- Strongly lobby for more funds for degrees in biology, marine science, biogeography, anthropology, environmental law, and environmental science, with increasing emphasis on biodiversity and taxonomy or parataxonomy
- Encourage all conservation NGOs to include, as an integral component of their conservation project proposals, scholarship funding for the formal education of conservation taxonomists and other areas related to biodiversity conservation, ethnobiodiversity, taxonomy and bioinformatics

In conclusion, as suggested above, we must use innovative and culturally-inclusive teaching and awareness-raising and bioinformatic approaches to protect, teach and enrich biodiversity conservation, taxonomy and bioinformatics for people of all ages and persuasions, all stakeholders, all countries, all ecosystems and populations, both endemic and non-endemic, and for all places, both natural and cultural. Only thus can we simultaneously address the current biodiversity and ethnobiodiversity extinction crises and the taxonomic impediment at all levels of society.

References

Hoagland, K.E. 1996. The taxonomic impediment and the Convention on Biodiversity. *Association of Systematics Collections Newsletter*, 24(5): 61–62, 66–67.

Thaman, R.R. 2009. Sustainability. In Gillespie, R.G. and Clague, D. (eds.). *Encyclopedia of Islands*, Berkeley, CA: University of California Press: p. 888-896.

Thaman, R.R. 2008. Pacific Island agrobiodiversity and ethnobiodiversity: A foundation for sustainable Pacific Island life. *Biodiversity: Journal of Life on Earth (Special issue: The value of biodiversity to food and agriculture)* 9 (1&2): 102-110.

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Conservation biogeography: The view from the sea

Marine biogeography

The Earth from the sky is a blue planet. The ocean covers more than 70% of the world's surface, and reaches depths of nearly 11 km. Over 275,000 marine species have been described and many more remain undiscovered. Yet, because humans are not marine creatures, and few have the opportunity to spend time underwater, most people are blind to the sea, the diversity it harbours, and the threats that it faces.

Approximately 40% of the global human population lives within 100 km of the sea, and marine ecosystems provide an estimated minimum of US$ 20.9 Tr in goods and services every year (Costanza et al., 1997), yet we treat the sea as a sewer, a dump, and an inexhaustible supply of fish. The ecological responses tell it all – loss of over 90% of top predators, collapsing fisheries, ecosystem shifts from large vertebrates to jellyfish, and dead zones with anoxic waters that kill everything in sight. A recent study estimated that almost every square kilometre of the oceans is subject to threat, with over 40% of them suffering from medium high to very high impact (Halpern et al., 2008).

In contrast to the land, the sea is dominated by the physical fact of the high density of water. This allows organisms to be buoyant with little energy expenditure, and enables fully pelagic life-cycles and life-styles that would be untenable on land. Many sessile or benthic taxa have pelagic larvae, and most primary production consists of microscopic phytoplankton, which are at the mercy of currents and have high rates of turnover. The three-dimensional seascape is dependent upon variations in temperature, salinity, chemistry, currents, upwellings, and other water movements that are dynamic over a variety of spatial and temporal scales. The fluidity and relative lack of physical barriers means that much of the sea is interconnected, physically, ecologically and genetically. The huge size of the marine environment also provides potential for species to have vast ranges, and for individuals to move over enormous distances. These characteristics of the sea have important implications for biogeography, the way threats to biodiversity can spread, and for the efficacy of conservation approaches (Lourie and Vincent, 2004). For example biogeographic regions in the sea are three-dimensional and their boundaries are highly dynamic in space and time, and thus difficult to map. On land, in comparison, rooted plants are used to define two-dimensional bioregions and transitions are generally swift and comparatively stable.

Biogeography has the potential to make a significant contribution to conservation planning in the marine realm. Firstly, data on species distributions can help inform systematic conservation planning, particularly when coupled with spatial data on humans and their activities. Secondly, biogeographic research can provide answers to the question 'why are things where they are?' which can help make conservation actions more effective. The substantial challenges associated with studying the marine realm, however, mean that our understanding of marine species and their biogeography lags behind similar work on land. Furthermore, the nature of the sea means that some of the conservation approaches developed on land may not transfer effectively to a marine setting.

Conservation planning

There are a number of different approaches to conservation planning which reflect different biogeographical concepts: hotspots (numbers), representation (composition), ecoregions (pattern functionally defined) and key areas (ecological attributes) (Jepson et al. in press).

Hotspots

The simplest conceptual approach is 'hotspots' – determining where there is most of something. With nearly 100,000 km^2 of coral reefs (34% of the world's total) and over 2,000 species of reef fish, South-east Asia, especially the 'Coral Triangle', is unquestionably a hotspot of species richness (Allen, 2008). The bull's-eye pattern of high diversity in SE Asia, attenuating across the Pacific and Indian Oceans, is repeated in many groups. It is estimated that this relatively small area of the Indo-Pacific harbours 83% of the world's coral species and 58% of reef fishes (Hughes et al., 2002). That said, the large signal of species richness is primarily due to a concentration of overlapping distributions of wide-ranging species (e.g. sargeant major, *Abudefduf bengalensis*), rather than an abundance of endemics, or restricted range species (e.g. spikefin goby, *Discordipinna griessingeri*).

From an ecological perspective, however, it may be that biodiversity 'coldspots' (species-poor regions) are more vulnerable. Firstly, the low diversity of these locations implies limited potential for functional redundancy, thus extinctions of one or a few species are more likely to be associated with loss of critical ecosystem function, and secondly, they contain disproportionately large numbers of endemics (Hughes et al., 2005).

To address the issue of endemism, Roberts and colleagues mapped the distributions of 3,235 species of fish, corals, lobsters and snails. They showed that restricted range species in the sea grouped into centres of endemism, as they do on land (Roberts et al., 2002). The endemism hotspots were generally not concordant with species richness hotspots. They then overlaid a map-based indicator of threats to coral reefs (a precursor to the Halpern et al., 2008 study) resulting in a combined endemism hotspot-threatspot map that was influential in directing Conservation International's marine programme.

While the hotspot approach is relatively simple, politically appealing, and analytically transparent (assuming high quality and availability of data), there is a risk that such an approach may disenfranchise communities, in 'non-hotspot areas', who also need to be engaged in the conservation effort.

Representation

A second approach to conservation priority-setting is to ensure adequate and comprehensive representation of each habitat type or biogeographic zone. Devising appropriate classifications of the marine environment, however, in order to plan for, and assess representation is no easy task. Marine classifications are based on a variety of data, including: direction, velocity and persistence of currents, temperature and ice-cover, geomorphology, statistical interpretations of remotely sensed oceanographic data, sonar soundings, faunal records, percent endemism and biotic associations. 'Rooted' ecosystems in the sea – e.g. coral reefs, sea grass, hydrothermal vent faunas, oyster beds and soft-coral gardens are easier to map than pelagic zones, notwithstanding the challenges involved in locating them.

When the International Union for the Conservation of Nature (IUCN) published the first review of the global spread of marine protected areas, full assessment of its representativeness could not be completed because of a lack of an agreed global biogeographical regionalisation (Kelleher et al., 1995). Since then, a review of the available global and regional marine classification systems has been undertaken by a team of conservation professionals with input from biogeographers and regional experts. The resulting Marine Ecoregions of the World scheme, covers shelf areas and is a composite of previous systems, with nested realms, provinces and ecoregions (Spalding et al., 2007). It is being applied in global and regional conservation planning and assessment by the World Wildlife Fund (WWF), the Nature Conservancy and other international NGOs, and has been adopted as a support tool for implementation of the Convention on Biological Diversity's programmes of work. A similar consensus framework, the Global Open Oceans and Deep Seabed classification, was published recently for pelagic and benthic biomes of the high seas (UNESCO, 2009). With these tools, some progress can be made to assess representativeness of marine conservation action at global levels. At smaller scales the representation principle has been used successfully, for example in underpinning priority-setting and zoning in the Great Barrier Reef, Australia (Fernandes et al., 2005), and representation has been a key goal stimulating development of other national and regional classifications.

Ecoregions

More recently, emphasis has been placed on an 'ecosystem approach' to marine conservation, i.e. going beyond hotspots and representation to consider the ecological functioning of areas. Using ecological units for an overall spatial classification can be considered an 'ecoregional approach'. The WWF used ecoregions as a basis for their Global 200 analysis. In the marine realm, ecoregions were defined, mapped, and assessed for different biodiversity criteria (e.g. species richness, endemism, higher taxonomic uniqueness, unusual ecological or evolutionary phenomena, global rarity of habitat type). Ecoregions were then ranked as globally outstanding, regionally or bioregionally outstanding, or locally important, and finally they were assessed for levels of threat in order to come up with a final list of 43 Priority Marine Ecoregions (Olson and Dinerstein, 2002).

Key areas

The 'key areas' approach does not depend on a prior classification step, but simply focuses on specific locations where significant ecological processes take place, for example breeding grounds for whales, turtle nesting beaches, upwelling areas, migration corridors, or where particular threatened species exist. Large Marine Ecosystems (LMEs) (Sherman et al., 2007), although not technically a conservation priority-setting scheme, can be considered as an example of a key areas approach because LMEs are usually focused on particularly productive areas. The concept of key areas is also used for conservation planning at smaller scales e.g. within WWF's ecoregions.

Status of Marine Conservation

Conservation International currently works in three seascapes (having moved on from its hotspots approach), WWF works in 20 of its 43 priority marine ecoregions, and 16 of 64 LMEs have Global Environment Facility-supported projects. Many of these priority areas overlap (Figure 1). Conversely, significant areas have no large-scale priority attention, nor the funding that is associated with it.

The implicit assumption of global priority-setting is that local site-based conservation within high global priority areas is an appropriate allocation of resources. Funding and resources for local site-based conservation are thus filtered by the global framework and may not necessarily take into account the social realities that govern the success of designated marine protected areas.

In fact, designated marine protected areas occur in both priority areas and elsewhere. There are around 5,045 designated marine protected areas (MPAs) worldwide (www.wdpa.org, accessed Nov. 2009). These cover about 4% of the total continental shelf area, or 0.7% of the ocean's surface (Wood et al., 2008). This compares to approximately 11.5% of the land surface under protection. Of these MPAs, even fewer are 'no-take' zones representing less than 0.1% of the world's ocean surface, and none are on the high seas. Even worse, estimates of the effective management of MPAs suggest that most are no more than paper parks. As of 2006, for example, less than 0.01% of the world's coral reefs were within MPAs estimated as no take, with no poaching, and at low risk (Mora et al., 2006).

Conclusion and recommendations

This paper has highlighted some of the larger initiatives in marine conservation planning, and ways that biogeographical information can contribute. The nature of the sea, and the processes that drive biogeographical patterns, need to be kept in mind as we consider the way forward for marine conservation.

Most marine conservation still appears to be rooted in the idea of designating place-based protected areas, undoubtedly because most conservation planning theory stems from terrestrial work. While place-based approaches can – if well managed and conceived of as part of a network – contribute to biodiversity conservation, factors beyond our control (and often beyond our immediate thoughts) can render them less effective. Such factors include: the three-dimensionality, dynamic nature and high connectivity of the ocean, its 'downstream' location from the land, and climate change effects (e.g. species range shifts). Other factors that are more within our control include: demand for marine resources, the open access nature of much of the sea, perverse subsidies in the fishing industry, human-mediated contributions to climate change, low capacity for ocean governance and conflict resolution, and generally poor knowledge of marine issues. An effective marine conservation approach needs to consider the linkages within and among ecosystems, not just isolated protected areas within an exploited and degraded matrix.

Biogeographical science offers data and spatial tools (even as simple as drawing maps with pencil and paper) for discovering, assessing, monitoring, and communicating species diversity – basically making the marine world more 'visible' to us land-bound creatures. These data and tools can be used for setting conservation priorities. They can also further our understanding of ecological and evolutionary processes, strengthen the conservation voice in political discourse, and educate and inspire the public to care about marine biodiversity and the need for a conservation ethic.

Biogeographical patterns and processes exist at the full range of spatial scales. I have focused primarily at the global scale. The biodiversity crisis we are currently facing is indeed a global issue – point source damage is being replicated across the world, and some threats have global impacts. To counter these, however, action at all levels is required. Both top-down and bottom-up approaches are needed simultaneously, and approaches that focus on entire ecosystems are needed in conjunction with more locally-focused efforts. Scales of action must be also matched with appropriate support at all institutional levels from individuals to inter-governmental agreements.

To conclude, what I believe is necessary is a sea-change in human attitudes towards the marine realm. Historical views, particularly the ideology of the oceans as open access and limitless are no longer helpful. Let us replace them with a truer understanding of the sea. UNESCO, with its focus on integration of education, science and culture, can play a key role. We have no excuse today for turning a blind eye to the oceans.

References

Allen, G.R. 2008. Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. Aquatic Conservation: *Marine and Freshwater Ecosystems* 18: 541-556.

Costanza, R. et al. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., Cameron, D., Jago, B., Hall, J., Lowe, D., Innes, J., Tanzer, J., Chadwick, V., Thompson, L., Gorman, K., Simmons, M., Barnett, B., Sampson, K., De'Ath, G., Mapstone, B., Marsh, H., Possingham, H., Ball, I., Ward, T., Dobbs, K., Aumend, J., Slater, D. and Stapleton, K. 2005. Establishing representative no-take areas in the Great Barrier Reef: Large-scale implementation of theory on marine protected areas. *Conservation Biology* 19 (6): 1733-1744.

Halpern, B.S, Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R. 2008. A global map of human impact on marine ecosystems. *Science* 319: 948-952.

Hughes, T.P., Bellwood, D.R. and Connolly, S.R. 2002. Biodiversity hotspots, centres of endemicity, and the conservation of coral reefs. *Ecology Letters* 5: 775-784.

Hughes, T.P., Bellwood, D.R., Folke ,C., Steneck, R.S. and Wilson, J. 2005. New paradigms for supporting the resilience of marine ecosystems. *Trends in Ecology and Evolution* 20 (7): 380-386.

Jepson, P.R., Whittaker, R.J. and Lourie, S.A. 2011. The shaping of the global protected area estate. In *Conservation Biogeography*. Ladle, R.J. and Whittaker, R.J. (eds.), Oxford: Blackwell.

Kelleher, G., Bleakley, C. and Wells, S. (eds.) 1995. *A global system of marine protected areas*. Washington D.C.: Great Barrier Reef Marine Park Authority, World Bank, World Conservation Union.

Lourie, S.A. and Vincent, A.C.J. 2004. Using biogeography to help set priorities in marine conservation. *Conservation Biology* 18 (4): 1004-1020.

Mora, C., Andrèfouët, S., Costello, M.J., Kranenburg, C., Rollo A., Veron, J., Gaston, K.J. and Myers, R.A. 2006. Coral reefs and the global network of marine protected areas. *Science* 312: 1750-1751.

Olson, D.M. and Dinerstein, E. 2002. The Global 200: Priority ecoregions for global conservation. *Annals of the Missouri Botanical Garden* 89: 199-224.

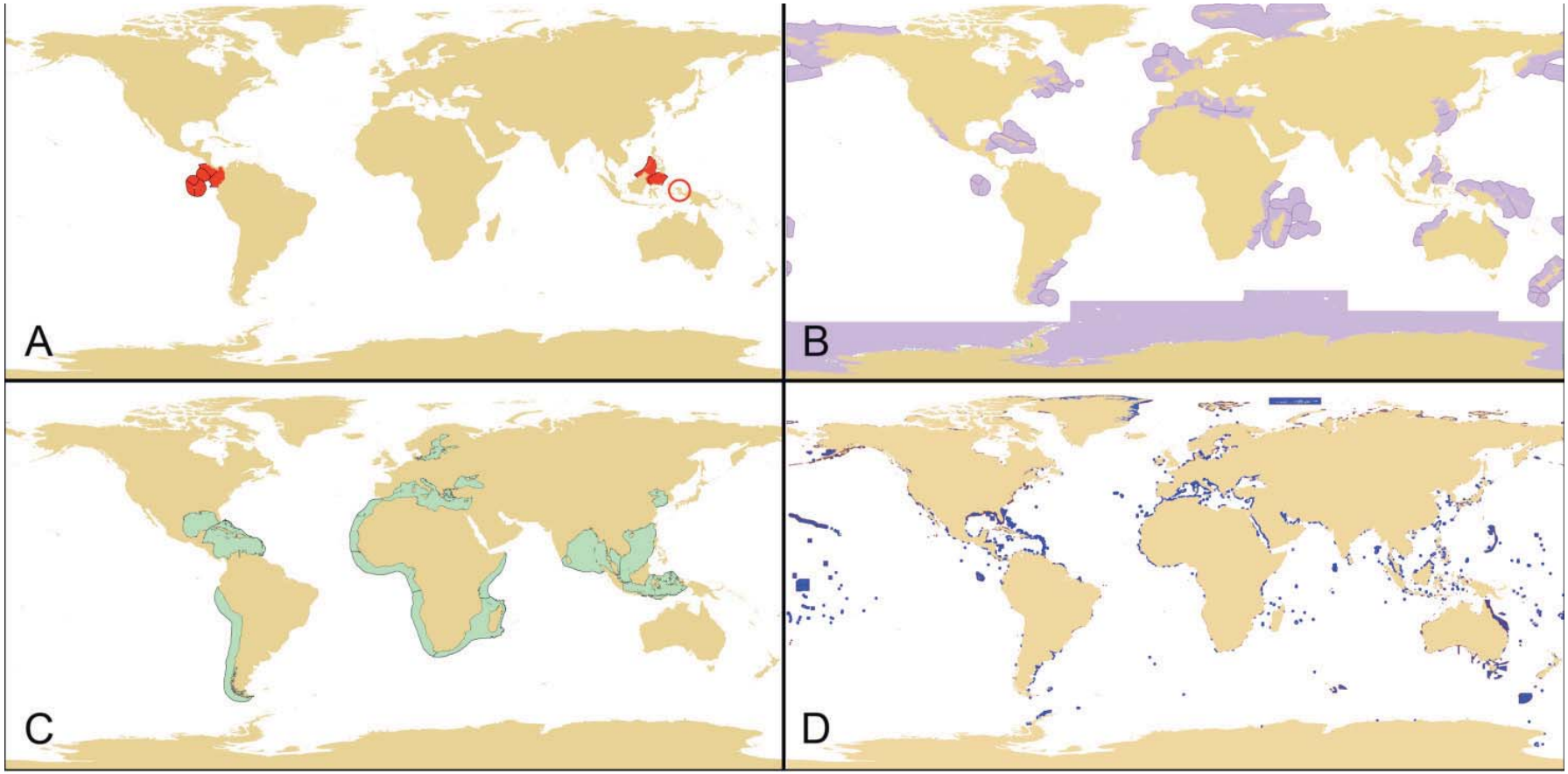
Roberts, C.M., McClean, C.J., Veron, J.E.N., Hawkins, J.P., Allen, G.R., McAllister, D.E., Mittermeier, C.G., Schueler, F.W., Spalding, M., Wells, F., Vynne, C. and Werner, T.B. 2002. Marine biodiversity hotspots and conservation priorities for tropical reefs. *Science* 295: 1280-1284.

Sherman, S., Aquarone, M.-C. and Adams, S. 2007. *Global applications of the Large Marine Ecosystem concept 2007-2010*. NOAA Technical Memorandum NMFS-NE-208.

Spalding, M.D., Fox, H.E., Allen, G.R., Davidson, N., Ferdaña, Z.A., Finlayson, M., Halpern, B.S., Jorge, M.A., Lombana, A., Lourie, S.A., Martin, K.D., McManus, E., Molnar, J., Recchia, C.A. and Robertson, J. 2007. Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. *Bioscience* 57 (7): 573-583.

UNESCO, 2009. Global Open Oceans and Deep Seabed (GOODS) – Biogeographic Classification. (IOC Technical Series, 84.) Paris: UNESCO-IOC.

Wood, L.J., Fish, L., Laughren, J. and Pauly, D. 2008. Assessing progress towards global marine protection targets: shortfalls in information and action. *Fauna & Flora International* 42 (3): 340-351.



Comparison among currently-funded global marine conservation priorities and distribution of marine protected areas A) Conservation International's Seascapes (3 compared to original 10 hotspots), B) World Wildlife Fund's Priority Marine Ecoregions (20 of original 43), C) Large Marine Ecosystems (16 of total 64), D) designated MPAs from World Database on Protected Areas (total 5,045). Note that symbols for small MPAs do not accurately reflect their actual area (original figure).

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Rewilding as a "call for action" strategy for biodiversity conservation in the 21st century

Biodiversity loss continues at an alarming rate. Human economics, politics, demographics, and pollution now pervade every ecosystem; even the largest protected areas require management to prevent loss of biodiversity and the services it provides. Over the past decades, biodiversity conservation has conveyed a gloom and doom message to the public, with an overarching goal of merely slowing the rate of extinction and ecosystem degradation. New, positive paradigms have surfaced as a result, including payment for ecosystem services, which strives to connect biological diversity with human welfare. The rewilding movement, which emerged over a decade ago, has increasingly captivated the public and practitioners. Contrary to welfare, rewilding appeals to human emotions—it is biological in design but inspirational in nature. Ecological history is also playing an increasingly important role. While its definition is dynamic, rewilding focuses on ecosystem function, evolutionary potential, and proactive restoration action. Complementary to other conservation strategies, rewilding fits into many initiatives under the auspices of the United Nations, the Convention of Biological Diversity, and the Global Environment Facility. Rewilding provides a flexible platform for biodiversity conservation that is science-based but grounded in proactive action that counters the prevailing gloom and doom message of nature conservation. Recent results from rewilding programs around the globe suggest a vista with widespread policy implications.

Introduction

Biodiversity provides us with the critical goods and services on which we depend on for livelihoods, inspiration, and peace of mind. Far more than any other species in the history of life on Earth, humans alter their environments by eliminating species, and changing biodiversity function and services in drastic ways. We will surely continue to do so for the foreseeable future, either by default or by design. Earth is now nowhere pristine, in the sense of being substantially free from human influence, and indeed, most landmasses have sustained many thousands of years of human occupancy and impacts. The effects of economics, politics, demographics, and chemicals pervade every ecosystem; even the largest protected areas require management to prevent loss of biodiversity and the services it provides. Human-induced environmental impacts are now unprecedented in their magnitude and cosmopolitan in their distribution, and they show alarming signs of worsening.

Biodiversity conservation—our effort to reverse the loss of biological diversity—is currently too easily characterized as a "doom and gloom" discipline. The movement and its programs have acquiesced to a default goal of exposing and merely slowing the rate of biodiversity loss. Together these attributes minimize excitement for conservation and even actively discourage it. There is a growing consensus that biodiversity conservation needs to move away from managing loss and toward actively restoring biodiversity and ecosystem services, along with the biological and geophysical processes responsible for those services. Alternative, pro-active approaches have emerged as a result over the past decade, including rewilding and ecosystem services, the latter striving to connect biological diversity with human welfare. Dynamic and evolving, rewilding—which appeals to human emotions—has increasingly captivated the public and conservation practitioners.

Rewilding

The term rewilding emerged out of an atypical partnership starting in the late 1980s between the eminent conservation biologist Michael Soulé and the wilderness activist Dave Forman, which led to The Wildlands Project.[1] Rewilding was defined as the scientific argument for restoring big wilderness based on the regulatory roles of large predators (Soulé and Noss, 1998). There are three pillars of rewilding:

- Large, protected core reserves
- Connectivity
- Keystone species

Over the past decade, a strong scientific justification has emerged for rewilding and the need for connected networks of protected areas with ecologically effective populations of carnivores and large herbivores (Soulé and Terborgh 1999; Terborgh and Estes, 2010). Yet, while rewilding is biological in design, it is also inspirational in nature. Rewilding has sparked a number of visionary conservation initiatives around the globe over the past decade, including programs such as The Yellowstone to Yukon Conservation Initiative in North America, The Wild Country Project in Australia, and the European Greenbelt.

Rewilding has also captured the imagination of the general public. The concept is increasingly present in the popular media, and the term is evolving as the public and conservation practitioners have become captivated and motivated by the pro-active nature of rewilding. Rewilding insinuates an emotional call for actions to set something right : steps to address the major wounds or ecological insults caused by abusive land uses of the pass that require redress, ideas which can be traced back to ecologist Aldo Leopold and others.

Everything we know, or believe to be true, about nature is founded on a knowledge history

In addition to science and emotion, rewilding is now turning to history for guidance and inspiration. Starting in the late 1970s, scientists began unraveling the influence of extinct large animals on the ecology of extant species and ecosystems. For the first time, for example, the ecology of many large-seeded plants in the Americas were viewed as anachronistic due to the missing large animals that once influenced their biology (Janzen and Martin 1982). Scientists and practitioners are now considering the roles of history in conservation practice. Some have called for using "deep history" as a guide to restore missing functions and services in ecosystems with the introduction of related species as analogues or substitutes for extinct species. While challenges and risks are present, there are clear scientific, economic, and social justifications for considering such bold conservation actions (Donlan et al., 2006). And while controversial, rewilding projects that embrace history are now happening around the globe, and are producing positive outcomes for biodiversity and the people that rely on their services.

"Rewilding is an idea whose time has come" – 27 December 2008, Sunday Times

Bringing back large animals to ecosystems where they have been absent for long periods of time is gaining public support. On a nature reserve a few hours outside of Amsterdam, scientists have introduced 3,000 Heck cattle, red deer, and Konik horses in an attempt to represent the large herbivores and their important ecological processes that were once present throughout Europe. The results are not only challenging what scientists once viewed as natural, but the biodiversity outcomes have been impressive, including the first breeding pair of white-tailed eagles in the Netherlands since the Middle Ages (Curry, 2010). In Siberia, scientists are trying to restore the mammoth steppe—once one of the world's most extensive ecosystems—by introducing Yakutian horses, muskox, wood bison, and other large herbivores. They hope to eventually introduce the endangered Siberian tiger and thus the important process of predation. This Pleistocene Park also has important implication for climate change: frozen Siberian soils lock up over 500 gigatons of organic carbon (over twice as much as the world's rainforests). As the permafrost melts, microbial activity will release these carbon stores into the atmosphere, exacerbating climate change. Restoring the ancient grassland ecosystem, it is thought, could prevent permafrost thawing and help combat climate change (Zimov, 2005). Giant bolson tortoises are critically endangered and restricted to a single site in central Mexico. They were recently introduced to the United States where they have been absent for over 8,000 years, an action that will help secure the species' future (Traphagen, 2007). In the Indian Ocean,

other giant tortoises from the Seychelles Islands are being reintroduced to islands in the Mauritius as proxies for the tortoises extant there hundreds of years ago. Those tortoises are restoring keystone processes and services to the islands, including the dispersal of endangered plants (Griffiths et al., 2010). Other aspiring rewilding projects are underway, from repatriating beaver and lynx to the United Kingdom to endangered pine trees in the United States to European bison in Latvia.

Rewilding and Biodiversity Policy

The Convention on Biological Diversity Conference of the Parties has adopted a revised and updated Strategic Plan, including new biodiversity targets for the post-2010 period. Biodiversity is the living foundation for sustainable development. Science, history, and the relationships between humans and biodiversity combine to form our strategies to secure and foster intact biodiversity and its services. In the face of current threats, along with increased threats from oncoming climate change, strategies will need to embrace more proactive, aggressive, and action-oriented approaches. Those strategies must also garner public support, and in return deliver benefits back to the public. Increasing evidence suggests that rewilding, as a complimentary strategy to existing approaches, can help deliver the post-2010 targets. Rewilding, in its many different forms, provides a platform to inspire and promote nature and human well-being around globe.

"The greatest impediment to rewilding is an unwillingness to imagine it" – Michael Soulé

References

Curry, A. 2010. Where the wild things are: A prehistoric park challanges our more cherished ideas about wilderness and conservation. Waukesha, WI, USA: *Discover Magazine*. March 2010. pp. 59-62.

Donlan, C. J., Berger, J., Bock, C.E., Bock, J.H., Burney, D.A., Estes, J.A., Forman, D., Martin, P.S., Roemer, G.W., Smith, F.A., Soulé, M.E., and Greene, H.W. 2006. Pleistocene Rewilding: An optimistic agenda for 21st century conservation. *American Naturalist* 168:660-681.

Griffiths, C. J. Jones, C.G., Hansen, D.M., Puttoo, M., Tatayah, R.V., Muller, C.B. and Harris, S. 2010. The use of extanct non-indigenous tortoises as a restoration tool to replace extinct ecosystem engineers. *Restoration Ecology* 18:1-7.

Janzen, D. H. and Martin, P.S. 1982. Neotropical anachronisms: The fruits the gomphotheres ate. *Science* 215:19-27.

Soulé, M. and Noss, R. 1998. Rewilding and biodiversity: complementary goals for continental conservation. *Wild Earth* 8:18-28.

Soulé, M.E. and Terborgh, J. (eds.) 1999. *Continental conservation: Scientific foundations of regional reserve networks*. Washington, D.C.: Island Press.

Terborgh, J. and Estes, J. (eds.) 2010. *Trophic cascades: Predators, prey, and the changing dynamics of nature*. Washington, D.C.: Island Press.

Traphagen, M. 2007. Re-wilding a giant American reptile. *Wildlife Conservation*, July: 43-47.

Zimov, S.A. 2005. Pleistocene Park: Return of the mammoth's ecosystem. *Science* 308: 796-798.

Large herbivores, including Heck cattle, red deer, and Konik horses, have been introduced to the nature reserve Oostvaardersplassen, a few hours outside of Amsterdam.
Photo Credit: Y Rohwer.

SPECIAL SECTION
BIODIVERSITY AND GLOBAL CHANGE

“One of the biggest challenges for accurately modelling changes in biodiversity under climate change is the lack of knowledge about the number of species on Earth

Anna Frangou, Richard J. Ladle, Ana C. M. Malhado and Robert J. Whittaker

THOMAS LOVEJOY

WHAT FUTURE for biodiversity?

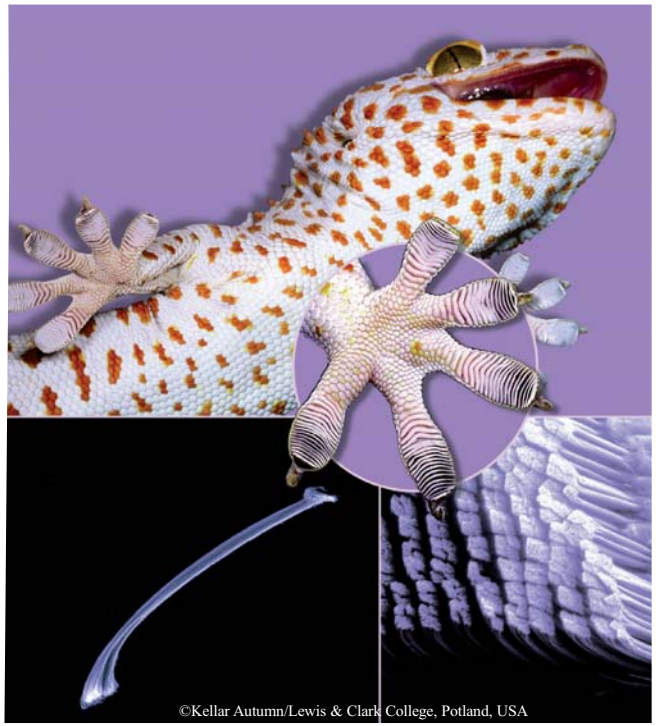
The following article was first published in UNESCO's journal, *A World of Science* (vol. 10, no. 1) in January 2012. It recalls some of the major challenges facing biodiversity, with an emphasis on climate change, and is based on a presentation Thomas Lovejoy made to the UNESCO Conference on Biodiversity Science and Policy which launched the International Year of Biodiversity in January 2010. It was Thomas Lovejoy who coined the term 'biological diversity' back in 1980 and it is to him that we owe the concept of debt-for-nature swaps, conceived during his time as director of the World Wildlife Fund's conservation programme (1973–1987).

As we embark upon the International Decade of Biodiversity (2011–2020), it is remarkable that we still have such an incomplete overall sense of the variety of life forms with which we share a four billion-year heritage.

Certainly, the outlines of life on Earth have become clearer in recent decades. The two sturdy trunks (plants and animals) of the Tree of Life of my childhood classroom in the 1950s have been replaced in one presentation by something akin to a low spreading bush, with three terminal branches on one side representing plants, fungi and animals. The rest represents a variety of microorganisms, many deriving from the early history of life. Many have strange appetites and metabolisms that make them potentially useful for industrial purposes and remediation. We now know there are entire biological communities which depend on the primal energy of the Earth (chemosynthesis), rather than on solar energy through photosynthesis, and that organisms live kilometres below the surface of the Earth.

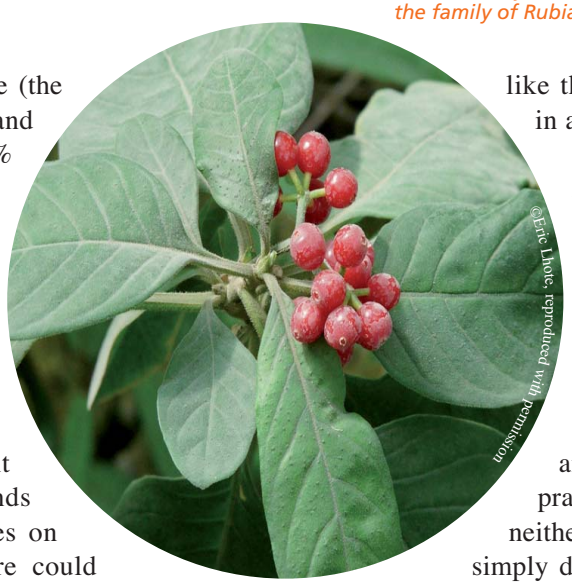
The exploration of life on Earth: one of the great scientific challenges

Yet, even the more obvious groups like plants and animals remain only partially explored and described by science. Joppa et al. (2011)[1] take a new approach based upon the number of species described per taxonomist per year; they



The paws of a gecko have the best-known adhesive. This small reptile can develop a force of contact of over 100 kg. More and more, scientists are looking to biodiversity for inspiration in developing innovative products, in what is known as biomimicry.

*This small tree (*Psychotria bacteriophyla*) in the family of Rubiaceae grows in tropical forests.*



estimate, for example, that about 18% of the Rubiaceae (the family that includes coffee) remain to be discovered and that, generally for flowering plant families, about 15% remain undescribed. In many cases, this is because the unknowns have small ranges, which means that the number of endangered species per plant family (and in total) is currently underestimated.

Basically, the exploration of life on Earth remains one of the great scientific priorities and challenges: a grand adventure of immense direct and indirect value to society. As US myrmecologist (ant specialist) Edward O. Wilson periodically reminds us, we do not in the end know the number of species on Earth to perhaps even an order of magnitude. There could be ten million, thirty million or one hundred million species, depending on microbial diversity, soil biodiversity and the like.

Clearly, as the 2005 *Millennium Ecosystem Assessment*[2] revealed with greater clarity than understood before, ecosystems and their constituent biodiversity provide multiple human benefits, ranging from direct harvest benefits to flows of benefits like watersheds, pollination and disaster mitigation – such as the protection mangroves offer from storm surges. Most of the benefits are treated as being free and so are undervalued by society.

We do not know the number of species on Earth. There could be ten million, thirty million or one hundred million species.

The Bushmaster's venom, or the value of biodiversity

There is a group of completely unacknowledged services provided by biodiversity: knowledge services. It is useful to think of biological diversity as an enormous library, with each species representing a unique set of solutions to a particular and unique set of biological problems. Humans have a huge stake in flourishing life sciences.

Edward O. Wilson once calculated that the amount of information (as a computer would count) in a single strand of DNA from a chromosome of a species like the domestic mouse was equivalent to the information in all editions of the *Encyclopedia Britannica* combined.

A compelling example of value to the life sciences involves the Bushmaster, a poisonous viper native to the tropical forests of Latin America (*see photo*). Its venom is quite effective and generally ends in death for the prey by driving blood pressure to zero. Scientists at Brazil's Butantan Institute in São Paulo studied the mechanism and uncovered a previously unknown system of blood pressure regulation in mammals, the angiotensin system. That was interesting but not instantly practical because snake venom taken as an oral medicine is neither poisonous nor practical because the digestive system simply denatures the protein, much as an egg white becomes a solid when cooked. Knowledge of the angiotensin system, however, made it possible for pharmacologists at the Squibb Company to devise a compound to work on it. That was given the brand name Capoten and was the first of the angiotensin-converting enzyme (ACE) inhibitors. Today, there are a number of ACE inhibitors and hundreds of millions of people live longer, healthier and more productive lives, oblivious to the benefit conferred by a nasty snake in a faraway rainforest.

An important footnote to this example is that, in the absence of major pharmaceutical industry research in Brazil at the time, the benefits all flowed to developed country corporations rather than to Butantan. The molecule of the Bushmaster's venom was not the medicine. (Nor does that snake species occur only in Brazil.) Had the venom been usable directly as medicine, there are at least some ways today in which the benefit would flow to Brazilian entities. If Brazilian scientists had teamed with foreign pharmaceutical chemists, the benefit flow would have been shared. The important lesson here is that advances often depend on free sharing of scientific information and that a strong national industry could have created an opportunity for Brazil to capture benefit nationally more easily.

Another example of a knowledge service: PCR

In 1993, the American Kary Mullis received the Nobel Prize in Chemistry for conceiving of the Polymerase Chain Reaction. Known by its acronym of PCR, it is widely included in press stories with almost no reference to what it is or its history. PCR is an extraordinary magnifying reaction that allows tiny amounts of DNA to be multiplied thousands of times over in a very short time. This has revolutionized diagnostic medicine because, in most instances, it is no longer necessary to culture the suspected disease agent until it can be identified. It has revolutionized forensic medicine. It has made all kinds of science dependent on genetic information either possible or more powerful – including the Human Genome Project – with major benefits to humanity. The Indian economist Pavan Sukhdev believes a proper analysis of the benefits from PCR could total a trillion dollars or more.

Today, hundreds of millions of people live longer, oblivious to the benefit conferred by a nasty snake in a faraway rainforest.

©Christopher Murray/Wikipedia

The reaction has two parts – heat separating the two strands of a chromosome and an enzyme causing the two separate strands to build their missing partner – repeated over and over again very rapidly. At the time of Kary Mullis's conception, however, there was no known enzyme that could trigger the second part because it had also to be heat-resistant; so, no chain reaction. Eventually, such an enzyme was found in the bacterium *Thermus aquaticus*, recovered from a Yellowstone hot spring in the USA. That was the knowledge service that makes the entire trillion dollar benefit possible.

Capturing the value of biodiversity in decision-making

Much of the value of the biodiversity library is not captured in the decision-making process; nor, for that matter, does it capture many other contributions of nature. If there is to be a sanguine outlook for the future of biodiversity on our planet, that must change. The Economics of Ecosystems and Biodiversity project[3] addresses that specifically and suggests ways in which a lot of that value can be incorporated in economic decision-making. Led by Pavan Sukhdev, its reports were submitted to the Conference of the Parties to the Convention on Biological Diversity in Nagoya in October 2010.

A classic example is that of whether to clear mangroves to create an opportunity for shrimp aquaculture. In the standard economic analysis, there would be no question about going ahead with the shrimp farm. If, however, the subsidies were subtracted, suddenly the choice would not be clear at all. If, in addition, the benefits the mangroves contribute to fishery productivity were added to the equation, the desirability of leaving the mangroves intact would become abundantly clear. That doesn't even include the protection of coastlines and coastal settlements that mangroves provide.

One of the difficult aspects is the use of discount rates – according to which, the less immediate a benefit, the lower its value –, which tend to undervalue benefits to future generations or to the poor, who depend on ecosystems for a significant part of their 'income' (between 39% and 89% of the total, according to studies of specific populations). Another anachronism is that expenditure on disaster relief or medical treatment gets counted in gross domestic product, whereas disaster prevention provided by ecosystems and the benefits of cleaner air or water do not.

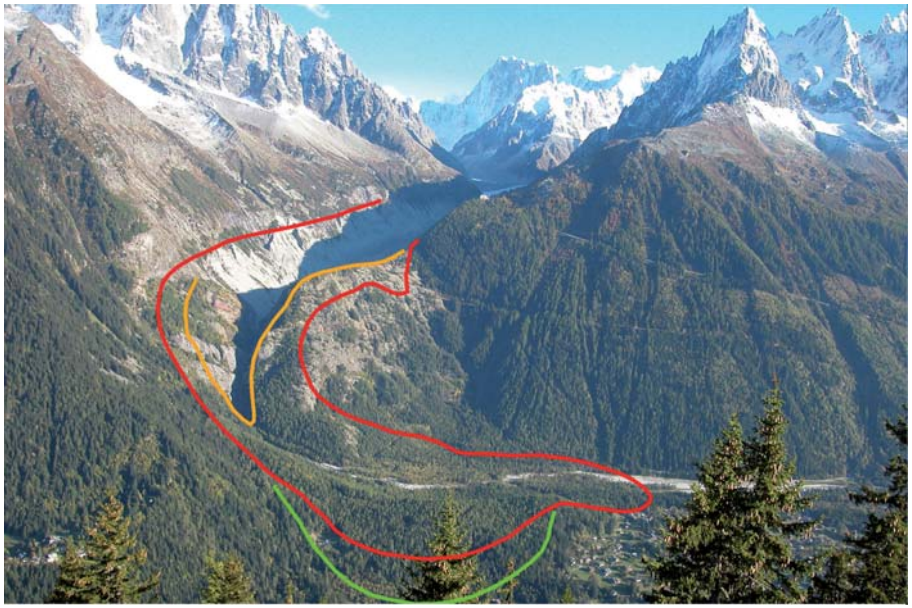
I have long been interested in the possible economic analogy to the two forms of biological growth: one whereby the organism simply gets larger and consumes more (such as an alligator) and the other in which the organism does not grow in size, does not consume more but rather grows in complexity[4]. In discussing this with Pavan Sukhdev, I offered the example of a caterpillar becoming a butterfly and the slogan 'an economy like a butterfly' emerged. Perhaps more practical is the notion of moving in that direction from the high consumption growth pattern towards a lower consumption intensity. It would seem wise to do that in a creative fashion before we are left with no choice but to force it upon ourselves.

Ecosystems have enjoyed a stable climate for 10,000 years

In 1896, the Swedish scientist Svante Arrhenius addressed an extremely important question: why is the Earth a habitable temperature for humans and other forms of life? Why isn't the Earth too cold? The answer in his famous paper was the greenhouse effect and the heat-trapping capacity of certain gases, most notably carbon dioxide (CO_2). It is interesting – in a world that still includes people who deny this venerable and well-tested science – that, with pencil and paper, Arrhenius calculated what the temperature would be for a world with double the pre-industrial levels of CO_2. His result came very close to what the modern super-computer models project.

It would seem wise to move from a high consumption growth pattern towards a lower consumption intensity in a creative fashion before we are left with no choice.

The Mer de Glace on Mont Blanc is the longest glacier in France (7 km), even after retreating by 2 km over the past 150 years. In this photograph from 2003, the lines show the area covered by the Mer de Glace in 1644 (green) and 1821 (red), during the Little Ice Age, and in 1895 (orange). Between 1821 and 1895, the glacier retreated by 1.2 km.



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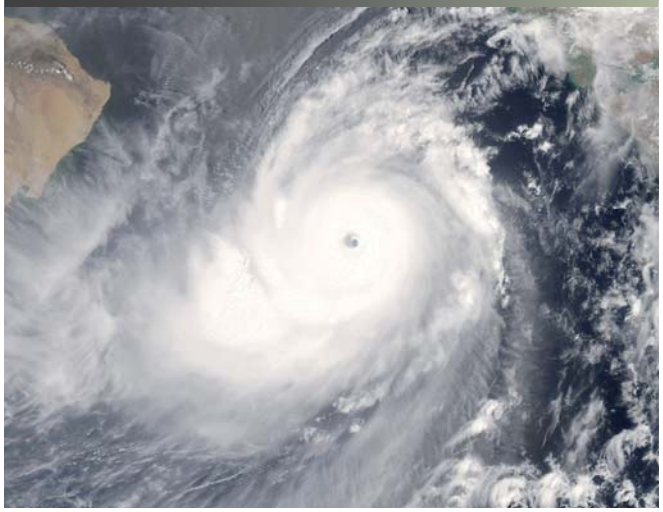
What Arrenhius would not have known was the actual temperature of the planet over the last hundred thousand years and, in particular, that the planet has had a very stable climate for the past 10,000 years. That period includes all recorded human history, plus some unrecorded history, as well as the origins of agriculture and human settlements. In other words, the entire human enterprise is based on the assumption of a stable climate. That is why, in part, people talk so much about the weather. Over that same 10,000-year period, all ecosystems have adjusted to a stable climate. That has begun to change.

Atmospheric concentrations of CO_2, which were at 280 parts per million (ppm) in pre-industrial times, are now close to 400 ppm. Despite a brief downturn in emissions because of the global recession, emissions are now climbing faster than the worst-case scenario described in the last report of the Intergovernmental Panel on Climate Change in 2007. The planet's climate system is responding with an overall temperature increase of about 0.8°C since 1850.

That increase is already causing dramatic, visible changes in physical aspects of nature, most notably between the solid and liquid phases of water. The summer extent of ice on the Arctic Ocean has diminished dramatically in recent years and the first ice-free Arctic Ocean period is projected to be less than 20 years off. Glaciers are retreating in most parts of the world. Soon, the USA's Glacier National Park, a biosphere reserve, will have glaciers only in name. As for France's alpine glacier known as the Mer de Glace, it is the subject of major efforts to slow its melting. All tropical glaciers will be gone in less than 15 years; some, as in Bolivia, are the main source of water for cities, as in the case of La Paz. That will of course have effects on downslope ecosystems.

Sea-level is rising, originally because of the thermal expansion of water resulting from warmer air temperatures but now because of ice melt, particularly at the poles and in Greenland. The IPCC has consistently underestimated



Tropical Cyclone Gonu showed up in an unusual place on 4 June 2007. NASA's Aqua satellite captured this image of the cyclone approaching the northeastern shore of Oman, a region better known for hot desert conditions.

sea-level rise, in part because of its very conservative approach. Sea-level rise, coupled with the natural subsidence of the land, is turning the Blackwater Wildlife Refuge of Maryland's Eastern Shore in the USA into a marine refuge (*see map*). A greater frequency of major storms and intense tropical cyclones is also being experienced around the world.

Biodiversity is responding to climate change

Not surprisingly, the biology of our planet is also responding to climate change. The first signals have been changes in life-cycle timing. Flowering plants are blooming earlier in the spring in the temperate and boreal regions. Animals are changing their annual cycles, with some bird species, such as tree swallows (*Tachycineta bicolor*) in North America, migrating, nesting and laying eggs earlier than before.

Species are also beginning to change the places where they occur. In North America, Edith's Checkerspot (*Euphydryas editha*), an extremely well-studied butterfly species that does normally roam, has clearly moved northward and upslope. Similar shifts have been observed in some other butterfly species. A recent analysis of many cases shows the distributional changes are happening three times faster than previously recognized.

Indeed, it is clear that this is no longer a matter of anecdotal examples; the change and movement in nature is statistically robust. Virtually everywhere scientists have looked, nature is on the move. It is happening in the oceans with changing plankton and fish distributions. In Chesapeake Bay in the USA, the sea grass habitats so important for blue crabs and other life forms are very sensitive to rising temperatures: the southern boundary of eel grass, a particular type of sea grass, is steadily moving north year after year.

Change is occurring not just in boreal and temperate regions. In Costa Rica's legendary Monteverde cloud forest, change has been detected not so much in temperature but in moisture. Cloud formation is now occurring more frequently at higher altitudes – a very serious change for an ecosystem almost totally dependent on condensation from clouds for its source of moisture. The first terrestrial extinction from climate change may be the Golden Toad of Monteverde (*Bufo periglenes, see photo*).

What will the future hold?

These changes are relatively minor ripples in the fabric of life on Earth. The more important question is: what does it look like ahead? One thing is clear: change will be not only be related to temperature but also to moisture. This is typified by the recurrent drought in the American southwest, which persists despite La Niña cycles, and by drying in the Prairie pothole region in the Midwest – the latter being critical to the great North American flyway for migratory waterfowl (*see map*). Decoupling events are occurring when two linked aspects of nature are responding to different timing mechanisms: daylight versus temperature. While the amount of daylight remains the same, the atmosphere is warming at a faster rate than species can evolve to cope with the consequences. Found only in North America, Snowshoe hare (*Lepus americanus*) are now being caught against a snowless background with their bright white winter pelage – making them totally obvious for predators. Black Guillemots (*Cepphus grille*) nesting on the Arctic Ocean shore of Alaska fly to the edge of the Arctic Ocean ice to feed on Arctic cod. Now, with more of this ice melting in summer than before, they must fly farther on the round trip from their nests – so far, in fact, that at least one nesting colony has failed.

Looking ahead for species with well-understood requirements, it is possible to project where those conditions might occur. For the Sugar Maple (*Acer saccharum*), so well known for its autumn foliage, as well as for maple syrup and sugar, its home will be in Canada once CO_2 levels climb to twice that of the pre-indus-

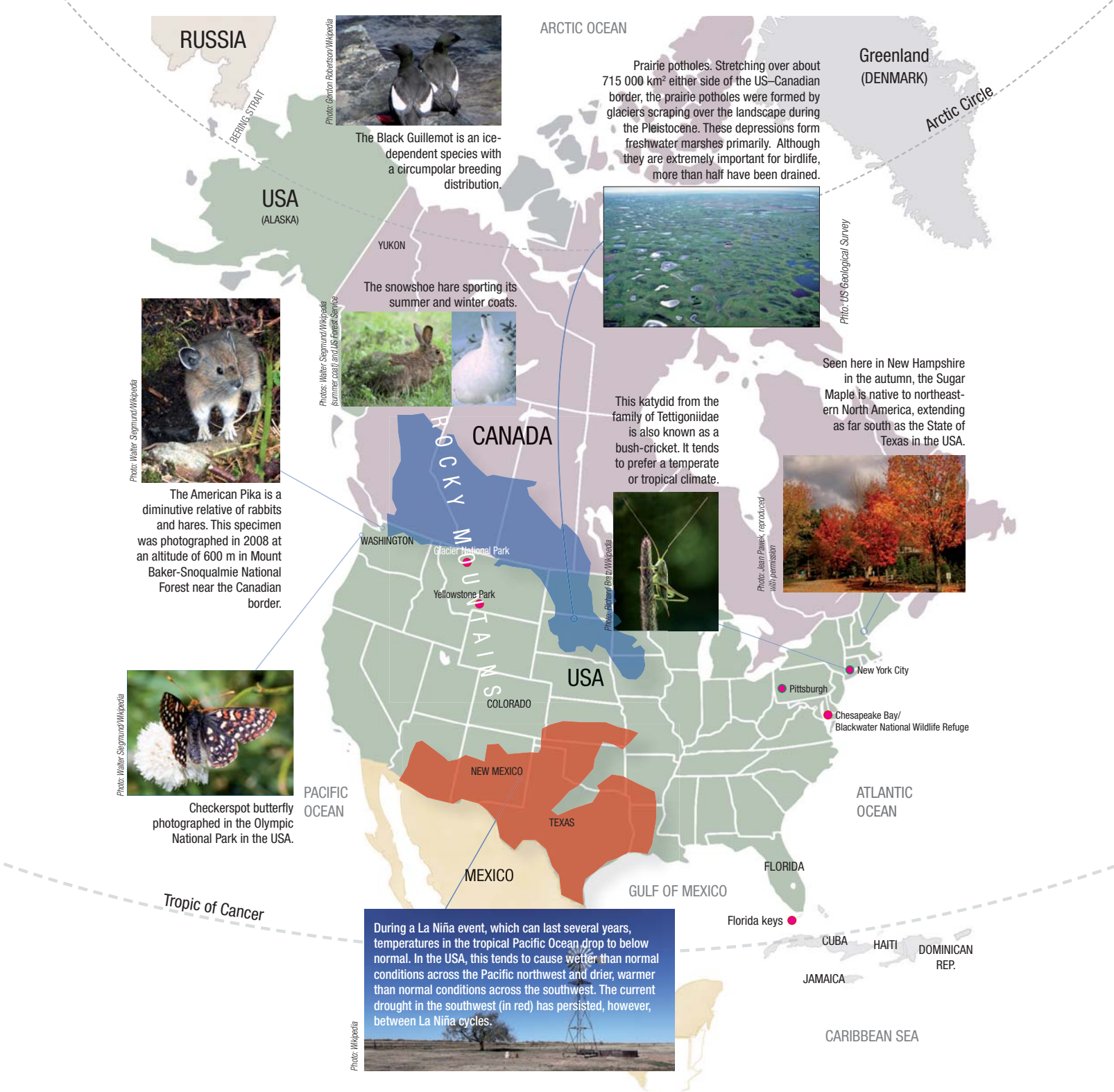


Photo: Gordon Robertson/Wikipedia

The Black Guillemot is an ice-dependent species with a circumpolar breeding distribution.

Prairie potholes. Stretching over about 715 000 km² either side of the US–Canadian border, the prairie potholes were formed by glaciers scraping over the landscape during the Pleistocene. These depressions form freshwater marshes primarily. Although they are extremely important for birdlife, more than half have been drained.

Photo: US Geological Survey

The snowshoe hare sporting its summer and winter coats.

Photos: Walter Siegmund/Wikipedia (summer coat) and US Forest Service

Photo: Walter Siegmund/Wikipedia

The American Pika is a diminutive relative of rabbits and hares. This specimen was photographed in 2008 at an altitude of 600 m in Mount Baker-Snoqualmie National Forest near the Canadian border.

This katydid from the family of Tettigoniidae is also known as a bush-cricket. It tends to prefer a temperate or tropical climate.

Photo: Richard Bize/Wikipedia

Seen here in New Hampshire in the autumn, the Sugar Maple is native to northeastern North America, extending as far south as the State of Texas in the USA.

Photo: Jean Pawek, reproduced with permission

Photo: Walter Siegmund/Wikipedia

Checkerspot butterfly photographed in the Olympic National Park in the USA.

During a La Niña event, which can last several years, temperatures in the tropical Pacific Ocean drop to below normal. In the USA, this tends to cause wetter than normal conditions across the Pacific northwest and drier, warmer than normal conditions across the southwest. The current drought in the southwest (in red) has persisted, however, between La Niña cycles.

Photo: Wikipedia

trial area. In fresh waters, cold water species like trout will certainly have their ranges changed, if not reduced or even eliminated.

Species which live at high altitudes, like the American Pika (*Ochotona princeps*), isolated populations of which can be found at high points in the Rocky Mountains, will move upward like the Checkerspot until, finally, there is no further up to go. A projection for endemic vertebrates in the rainforests of Eastern Australia shows a major loss of species with a warming climate; some of the species seem very sensitive to warmer temperatures physiologically.

Coastal species will be affected by sea-level rise but may successfully move inland. Species on low-lying islands, like the Key Deer in the Florida Keys, will have nowhere to go. Those on higher islands may in the end run out of a suitable microclimate and be unable to move on.

More worrisome, ecosystem failure is already being recorded. One example concerns tropical coral reefs, which are particularly sensitive to warmer water. That causes the fundamental partnership of the coral ecosystem between the coral animal and an alga to break down. The coral expels the alga, which leads to a 'bleaching event' in which the diversity, productivity and benefits to local communities crash – almost as if the lights go out. Only first recorded in 1983, bleaching events are occurring with greater frequency every year, making the future prospects for tropical reefs quite grim.

Ecosystem failure is already being recorded. More frequent bleaching events are making the future prospects for tropical reefs quite grim.

Clownfish among coral on reefs at Baa Atoll in the Maldives, which joined UNESCO's World Network of Biosphere Reserves last year.

Landscapes have been highly modified by human use, basically creating obstacle courses which could prevent species dispersal in reaction to climate change and cause extinction.

Will bricks and mortar prevent some species from dispersing?

On land, another case of ecosystem failure – or at least major ecosystem transformation – is being observed in the coniferous forests of western North America. From Alaska to Colorado, there is massive coniferous tree mortality from longer summers and milder winters, tipping the balance in favour of the native bark beetles which at high density kill the trees, which feed on dead trees. The growing mass of dry, rotting wood is creating an enormous fire hazard and forest management problem, making it hard to imagine what those ecosystems will become.

Looking ahead, it appears that there will be greater and more complex ecosystem disruption. One cause will be the interaction between species dispersal and human modification of landscapes.

Climate change, of course, has always been a part of life on Earth. Glaciers came and went in the great Pleistocene (*circa* 2.5 million – 11,700 years ago) ice ages, with little apparent loss of biodiversity. Species clearly were able to track their required conditions.

Today, however, landscapes have been highly modified by human use, basically creating obstacle courses to dispersal. The degree to which some human modification acts as a barrier will vary with a species' biology. I once observed a katydid (*see map on previous page*) on the rooftop terrace of a six-storey building in lower Manhattan in New York and, more recently, an invasive species, the Brown Marmorated Stinkbug (*Halyomorpha halys*[5]), on the 20th floor of a Pittsburgh skyscraper but, for others, modified landscapes could prevent dispersal and cause extinction.

There is clear evidence from present-day minor shifts, as well as from much greater past change, that biological communities do not move as a unit. Rather, it is the individual species that moves, each at its own rate and in its own direction, as specific conditions are tracked. The result is that, with greater climate change such as could lie ahead, the ecosystems we currently know will disassemble and the surviving species will assemble into ecosystems hard to imagine in advance. The challenge to manage that process would be enormous.

What if the climate changes abruptly, as in the past?

It is also clear that whatever change could lie ahead will be more abrupt than that which we have observed in recent decades. That certainly is the case in the climate system. For example, the southwestern USA, known for citrus fruit-growing, is already gripped by a drought that is proving exceptional not only in terms of duration but also in its severity and geographical extent.

The global 'conveyor belt' that distributes heat around the oceans has been known to shut down in geologic times. The climate 'jumped' most recently at the end of the last ice age about 12,000 years ago, when the melting North American Ice sheets released masses of freshwater into the North Atlantic, causing the conveyor belt to stop and average temperatures in the North Atlantic region to plunge by 5°C within a decade.

Acid rain on the oceans

Major systemic change is already occurring, the most notable sign being the acidification of the oceans. Mostly overlooked until 2005 (although it could be deduced from high school chemistry), the excess CO_2 absorbed by the oceans has produced enough carbonic acid in the process to change the pH of the oceans by 0.1 pH unit.[6] That seems a trivial amount, except that the pH scale is logarithmic, so this means the oceans are 30% more acidic than in 1950.

The acidification of the oceans is of enormous consequence for all marine organisms that build shells and skeletons of calcium carbonate. The carbonate equilibrium is affected by temperature and pH and is weaker in water that is more acidic or colder. The failure of oyster spawning in the State of Washington in the USA has been attributed to rising acidity. Many of the tiny organisms that exist in astronomical numbers at the base of food chains will be imperiled, such as the pteropods – tiny snails with a modified 'foot' that can flap like a wing and maintain the organism at a given level in the water column – and the entire food chain with them. Acidification is truly a profound change for the oceans that comprise two-thirds of the planet.

Could Amazon dieback be around the corner?

Another major change that may be on the horizon involves the possibility of dieback of the Amazon rainforest in the southern and southeastern part of the Amazon. First projected by the Hadley Centre (UK) model to occur at about 2.5°C of global warming, a revised projection dating from about 2005 indicates it could occur at even 2.0°C.

More recently, the World Bank invested US$1 million in a study that modelled the effects of climate change, deforestation and fire on the Amazon. This was the first time they had been modelled together; the results suggest a tipping point to Amazon Dieback could occur at 20% deforestation, when the current figure is 18%. Disturbingly, what was then the greatest drought in the recorded history of the Amazon occurred in 2005 – only to be followed by an even greater one in 2010. These are perhaps signals of what could lie ahead.

Even a global temperature rise of 2°C will be hard on biodiversity

In the meantime, most of the discussions and negotiations have focused on stopping at an average of 2°C global warming this century. Under current approaches, global emissions will have to peak in 2016 if warming is to stop at 2°C. Yet even this is clearly too much for many of the ice systems and for the ecosystems of the planet. The obvious things to do to assist ecosystem resilience are to restore natural connections in the landscape (such as by creating ecological corridors like that linking Yellowstone Park to the Yukon's Territorial Parks in North America) and to reduce other stresses to avoid negative synergies with climate change. But even these stresses will pale in comparison to the effects of continued global warming.

Most of the negotiations have focused on 2°C of global warming; 1.5°C seems a much safer target.

In sum, a global average temperature rise of 2°C (roughly 450 ppm of CO_2) is too much. Something in the order of 350 ppm of CO_2 – roughly equivalent to a temperature rise of 1.5°C – seems a much safer target to settle for.

A lot of excess carbon could be removed by restoring ecosystems

The energy agenda is clear and urgent but, in addition, there is a critical need to remove substantial amounts of excess CO_2 from the atmosphere to avoid the warming it would otherwise cause. That might seem Quixotic[7] but, in fact, the history of life on Earth shows that twice in the history of the planet, there have been extremely high concentrations of CO_2 and, twice, these have been brought down to pre-industrial levels biologically. The first drawdown occurred with the appearance of plants on land, by their photosynthesis and the accumulation of plant biomass. Simultaneously, soil formation reduced CO_2 – not just the physical process but also aided and abetted by the soil biota. The second drawdown occurred with the appearance of modern flowering plants, which performed the same role more efficiently.

Those two major alterations to atmospheric composition took tens of millions of years, which might make biological potential seem irrelevant. It would be, except that perhaps 200–250 billion tons of carbon have accumulated in the atmosphere over the past three centuries because of the destruction and degradation of ecosystems via deforestation, the deterioration of grasslands and agricultural practices that lose soil carbon. Greater recourse to crop rotation, for instance, could reduce soil erosion, which releases a lot of stored carbon into the atmosphere. Roughly half of the current excess CO_2 is of modern biological origin and a significant portion of it can be removed by ecosystem restoration on a planetary scale.

The numbers are approximate but about 50 ppm of CO_2 could be sequestered over a 50-year period – the difference between 350 ppm and current levels of close to 400 ppm. That could be achieved by sequestering about half a billion tons of carbon per year in reforestation and better forest management, another half billion per year through restoration of grassland and degraded pasture lands – resulting in better grazing – and a third half billion per year by managing agro-ecosystems to restore soil carbon – resulting in greater soil fertility. Such an approach to managing the planet is obviously more complex than simply making this statement and must take into account the needs of feeding at least another two billion people over and above the current population but the potential is clear. Such a solution also has the great advantage of making biodiversity and ecosystems more resilient in the face of the climate change and other stresses that will affect them.

About 50 ppm of CO_2 could be sequestered over a 50-year period via reforestation and better forest management, restoration of grassland ,and degraded pasture lands and agro-ecosystems.

Since this is not enough, given current emission trends, clearly non-biological ways need to be sought to remove CO_2 not just from smokestacks but also from the atmosphere. Economically feasible means need developing to this end. For instance, one could imagine a process by which CO_2 would combine with other molecules to become an inert substance like concrete.

The reduction of CO_2 is infinitely preferable to almost any scheme for geo-engineering aimed at reducing temperature, except locally. Geo-engineering schemes that would reduce the planet's temperature in the end address the symptom, not the cause. They do nothing to combat ocean acidification and, being planetary in scale, their downside will, by definition, also be planetary in consequence. In addition, any time the intervention ceases, the temperature of the planet will go right back up to where it would have been otherwise.

Far preferable will be to manage our living planet as just that, a living planet, by using Earth's living systems to regreen it and make it more habitable for all life forms.

The reduction of CO_2 is infinitely preferable to almost any scheme for geo-engineering. Geo-engineering schemes address the symptom, not the cause.

This article may be consulted freely on UNESCO's portal in English, French and Spanish. Simply replace the 'e' at the end of the following link to a World of Science *by an 'f' for French or an 's' for Spanish:*
http://unesdoc.unesco.org/images/0021/002150/215081E.pd
For details: www.unesco.org/science/en/a-world-of-science

The eruption of Iceland's Eyjafjallajökull volcano in April 2010 paralysed European air traffic for days.

As the debris ejected by volcanic eruptions has a cooling effect by blocking the sun's rays, some imagine geo-engineering the climate system by injecting aerosols into the stratosphere to slow global warming.

1. *Joppa, L. N. Roberts, D. L. and S. L. Pimm (2011). How many species of flowering plants are there? Proceedings of the Royal Society (B) 278: 554-559.*
2. *UNESCO contributed to this assessment. See* A World of Science, *July 2005*
3. *See: www.teebweb.org/*
4. *known obscurely as 'growth by intussusception'*
5. *Its native range covers China, Japan and the Republic of Korea.*
6. *From a pH of 8.2 in 1950 to 8.1 today.*
7. *Don Quixote is a character of 17th century Spanish literature, an idealist on a crusade for justice.*

ANNA FRANGOU, RICHARD J. LADLE, ANA C. M. MALHADO AND ROBERT J. WHITTAKER

WILDLIFE in a warming world

The following article was first published in UNESCO's journal, *A World of Science* (vol. 8, no. 1), in January 2010. It begins by anticipating that the International Year of Biodiversity will provide an ideal platform for restating the case for conservation at a time when species are disappearing at an alarming rate. Although conservationists are likely to point the finger at habitat destruction, invasive species, overfishing of the seas and pollution, it is the all-encompassing impact of climate change on ecosystems and species that will probably garner the most headlines, the authors predict. Beyond the rhetoric and awareness-raising, there remains an enormous scientific challenge. Politicians and policy-makers need detailed and geographically precise information on how ecosystems and species will respond to climate change if they are to make rational decisions about land-use, resource management and conservation. In order to meet this challenge, scientists are developing an exciting range of new techniques and models to reduce the uncertainties to a level where important real-world decisions about conservation can be made with confidence, the authors write. They then go on to highlight some key problems in predicting the consequences of climate change for ecological communities and discuss some of the innovative solutions being developed to overcome these problems.

An emphasis on climate change in the International Year of Biodiversity is understandable. For one thing, even with the unlikely scenario that greenhouse gas emissions are brought under swift control, global warming is now regarded as unavoidable. The latest projections from the Intergovernmental Panel on Climate Change (IPCC) in 2007 provide scenarios for a 1.8°C–4°C warming this century as compared with late 20th century baselines, alongside changes in precipitation patterns (rainfall and snow) and the seasonality of weather. Global warming this century may even exceed the most pessimistic of the IPCC's projections if carbon emissions are not rapidly brought into check. It is predicted that the impact on biodiversity will be profound and global (*see table*).

Secondly, climate change has become the dominating environmental agenda of the new century. Aligning biodiversity conservation with climate change is therefore far more likely to engage the interest of decision-makers and politicians than biodiversity conservation alone. This will also provide an effective

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Illegal logging in Giam Siak Kecil–Bukit Batu, a biosphere reserve since May 2009. This peatland area encompasses two wildlife reserves that are home to the Sumatran tiger (insert)*, elephant, tapir and sun bear. They are among the first victims of deforestation. Unfortunately, illegal logging is uncovering and drying out the peat which has formed over thousands of years from decomposed plants. Peat contains huge quantities of carbon dioxide which are released into the atmosphere when it burns[1]. Forest fires of peatlands in particular are the major source of Indonesia's greenhouse gas emissions (about 70–75%).*

vehicle for reminding the public that extinctions and ecosystem collapse were not halted with the signing of the Convention on Biological Diversity in 1992.

What do we mean by conservation biogeography?

Climate is a crucial factor for almost every aspect of an organism's ecology, physiology and behaviour, so the implications of changing climate are inherently complex to model. This presents an enormous challenge to scientists wishing to predict how individual organisms and ecosystems will respond, yet there is no one method that will provide unambiguous answers. Much of the focus of biogeographical science has been on answering two key questions: (1) how will the current geographical range of species be affected under different climate change scenarios? (2) how many species, and which ones, will be unable to adjust their geographical range in alignment with changing climate and therefore become threatened with extinction?

The study of geographical ranges comes under the remit of one of the oldest biological disciplines, biogeography. Biogeography is the study of the distribution of life on Earth and the processes accounting for these geographical patterns. Biogeography is less well-known than the related sciences of ecology and evolution but this may be about to change. In the past two decades, biogeography has been transformed from a rather descriptive historical science into a dynamic discipline with important things to say about the future of life on this planet. It owes this transformation to amazing technical advances, including digital databases of species distributions and high-powered computers capable of simulating complex biogeographical processes. This transformation has been paralleled by an increasing awareness of the importance of biodiversity for maintaining healthy ecosystems and the dawning realization that climate change may represent the single biggest challenge to 21st century conservation.

For these reasons, and as part of the International Year of Biodiversity, the International Biogeography Society and UNESCO are jointly sponsoring a one-day symposium in January, in Paris (France), on the theme of Conservation Biogeography. Conservation biogeography provides a rallying point and conceptual framework for biogeographers, physiologists, mathematical modellers, ecologists and behavioural scientists to develop, among other things, predictive tools to assess the impact of climate change on biodiversity. Two general approaches have emerged: mechanistic and species distribution models.

Mechanistic models

Mechanistic models seek to quantify relationships between key physiological or behavioural processes and the external environment. For example, many freshwater fish such as trout or salmon are adapted to fast-flowing 'cool' rivers and are physiologically intolerant of higher water temperatures. Such critical temperature thresholds can be experimentally assessed and the future range of the species can be forecast under different climate change scenarios. One of the key limitations of mechanistic models is that detailed physiological information is not available for many species, especially those that are already rare and may be at most risk from climate change.

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The Fynbos vegetation seen here is unique to the Cape Floral Region in South Africa. The region represents less than 0.5% of the area of Africa but is home to nearly 20% of the continent's floral biodiversity. Some 32% of species are endemic. A biodiversity hotspot and one of six floral kingdoms, this World Heritage site will probably face generally warmer and drier conditions by 2050. If higher concentrations of CO_2 tend to favour plant growth, this advantage will be cancelled out for the Fynbos vegetation by the greater frequency of fires. Up to 65% of Fynbos vegetation may be lost if global temperatures warm by 2.3°C.

Species distribution models

The most commonly used method of forecasting climate-induced range changes is a family of models known as species distribution models. These relate the presence or absence of a species to some aspect of the environment, typically climate. A basic species distribution model has three components (*see graphic*). Firstly, the climate and habitat within the observed geographical distribution of a species are analysed statistically. This produces a unique *bioclimatic envelope* (also known as 'climate space') represent-

The following table illustrates some of the most startling forecasts as to the potential impact of climate change on biodiversity.

Many of these predictions should be treated with caution, however, given the many uncertainties and assumptions involved in the modelling process (*see text for details*).

Average Temperature increase over pre-industrial levels (°C)*	**Impact of climate change on unique or widespread ecosystems or populations** *Studies compiled by the IPCC*	Country or region
<1.0	Marine ecosystems affected by continued reductions in krill possibly impacting Adelie penguin populations; Arctic ecosystems increasingly damaged	Antarctica, Arctic
1.3	8% loss of freshwater fish habitat, 15% loss in Rocky Mountains, 9% loss of salmon	North America
1.6	Bioclimatic envelopes eventually exceeded, leading to 10% transformation of global ecosystems; loss of 47% wooded tundra, 23% cool conifer forest, 21% scrubland, 15% grassland/steppe, 14% savanna, 13% tundra and 12% temperate deciduous forest. Ecosystems variously lose 2–47% of their areal extent; 9–31% (mean 18%) of species committed to extinction	Globe
1.6	Suitable climates for 25% of eucalypts exceeded	Australia
1.7	All coral reefs bleached	Great Barrier Reef, Southeast Asia, Caribbean
1.7	38–45% of the plants in the Cerrado committed to extinction	Brazil
1.7	2–18% of mammals, 2–8% of birds and 1–11% of butterflies committed to extinction	Mexico
1.7	16% freshwater fish habitat loss, 28% loss in Rocky Mountains, 18% loss of salmon	North America
1.9	7–14% of reptiles, 8–18% of frogs, 7–10% of birds and 10–15% of mammals committed to extinction as 47% of appropriate habitat in Queensland lost. Range loss of 40–60% for golden bowerbird	Australia
1.9	Most areas experience 8–20% increase in the number of ≥7day-periods with forest fire weather index >45: increased fire frequency converts forest and maquis to scrub, leads to more pest outbreaks	Mediterranean
2.1	41–51% loss in plant endemic species richne ss	South Africa, Namibia
2.1	Alpine systems in Alps can tolerate local temperature rise of 1–2°C, tolerance likely to be negated by land-use change	Europe
2.1	13–23% of butterflies committed to extinction	Australia
2.1	Bioclimatic envelopes of 2–10% of plants exceeded, leading to endangerment or extinction; mean species loss of 27%	Europe
2.2	3–16% of plants committed to extinction	Europe
2.2	15–37% of species committed to extinction	Globe
2.2	8–12% of 227 medium to large mammals in 141 national parks critically endangered or extinct; 22–25% endangered	Africa
2.3	Loss of Antarctic bivalves and limpets	Southern Ocean
2.3	Fish populations decline, wetland ecosystems dry and disappear	Malawi, African Great Lakes
2.3	Extinction of 10% of endemic species (100% potential range loss); 51–65% loss of Fynbos; including 21–40% of Proteaceae (a family of flowering plants) committed to extinction; Succulent Karoo area reduced by 80%, threatening 2 800 plant species with extinction; five parks lose >40% of plant species; 24–59% of mammals, 28–40% of birds, 13–70% of butterflies, 18–80% of other invertebrates, 21–45% of reptiles committed to extinction; 66% of animal species potentially lost from Kruger National Park	South Africa
2.3	2–20% of mammals, 3–8% of birds and 3–15% of butterflies committed to extinction	Mexico
2.3	48–57% of Cerrado plants committed to extinction	Brazil
2.3	Changes in ecosystem composition, 32% of plants move from 44% of area with potential extinction of endemic species	Europe
2.3	24% loss of freshwater fish habitat, 40% loss in Rocky Mountains; 27% loss of salmon	North America
2.4	63 of 165 rivers studied lose >10% of their fish species	Globe
2.5	Bioclimatic range of 25–57% (full dispersal) or 34–76% (no dispersal) of 5197 plant species exceeded	Sub-Saharan Africa
2.5	Sink service of terrestrial biosphere saturates and begins turning into a net carbon source	Globe
2.5	Extinction of coral reef ecosystems (overgrown by algae)	Indian Ocean
2.5	42% of land area with bioclimate unlike any currently found there; in Hampshire, declines in curlew and hawfinch and gain in yellow-necked mouse numbers; loss of montane habitat in Scotland; potential bracken invasion of Snowdonia montane areas	United Kingdom
2.5	Major loss of Amazon rainforest with large losses of biodiversity	South America, globe
2.5	20–70% loss (mean 44%) of coastal bird habitat at four sites	USA

(continued)

2.6	Most areas experience 20–34% increase in the number of ≥7day-periods with a forest fire weather index >45: increased fire frequency converts forest and maquis to scrub, causing more pest outbreaks	Mediterranean
2.6	4–21% of plants committed to extinction	Europe
2.7	Bioclimatic envelopes exceeded leading to eventual transformation of 16% of global ecosystems: loss of 58% of wooded tundra, 31% cool conifer forest, 25% scrubland, 20% grassland/steppe, 21% tundra, 21% temperate deciduous forest, 19% savanna. Ecosystems variously lose 5–66% of their areal extent	Globe
2.8	Extensive loss/conversion of habitat in Kakadu wetland due to sea-level rise and saltwater intrusion	Australia
2.8	Multimodel mean loss of Arctic summer ice extent of 62% (range 40–100%), high risk of extinction of polar bears, walrus, seals; Arctic ecosystem stressed	Arctic
2.8	Cloud-forest regions lose hundreds of metres in height, potential extinctions with 2.1°C average temperature rise for Central America and 2.5°C for Africa (N.B. 1990 reference year)	Africa, Central America, Tropical Africa, Indonesia
2.8	Eventual loss of 9–62% of the mammal species from Great Basin montane areas; 38–54% loss of waterfowl habitat in Prairie Pothole region	USA
2.9	50% loss existing tundra offset by only 5% eventual gain; millions of Arctic nesting shorebird species variously lose up to 5–57% of breeding area; high-Arctic species most at risk; geese species variously lose 5–56% of breeding area	Arctic
2.9	Latitude of northern forest limits shifts north by 0.5° latitude in Western Europe, 1.5° in Alaska, 2.5° in Chukotka and 4° in Greenland	Arctic
2.9	Threat of marine ecosystem disruption through loss of aragonitic pteropods	Southern Ocean
2.9	70% reduction in deep-sea cold-water aragonitic corals	Ocean basins
2.9	21–36% of butterflies committed to extinction; >50% range loss for 83% of 24 latitudinally restricted species	Australia
2.9	21–52% (mean 35%) of species committed to extinction	Globe
2.9	Substantial loss of boreal forest	China
3.0	66 of 165 rivers studied lose >10% of their fish species	Globe
3.0	20% loss of coastal migratory bird habitat in Delaware	USA
3.1	Extinction of remaining coral reef ecosystems (overgrown by algae)	Globe
3.1	Alpine systems in Alps degraded; risk of extinction of alpine species	Europe
3.1	High risk of extinction of golden bowerbird as habitat reduced by 90%	Australia
3.3	Reduced growth in warm-water aragonitic corals by 20%–60%; 5% decrease in global phytoplankton productivity	Globe
3.3	Substantial loss of alpine zone and its associated flora and fauna (e.g. alpine sky lily and mountain pygmy possum)	Australia
3.3	Risk of extinction of Hawaiian honeycreepers as suitable habitat reduced by 62–89%	Hawaii
3.3	4–38% of birds committed to extinction	Europe
3.4	6–22% loss of coastal wetlands; large loss migratory bird habitat particularly in USA, Baltic and Mediterranean	Globe
3.5	Predicted extinction of 15–40% endemic species in global biodiversity hotspots	Globe
3.5	Loss of temperate forest wintering habitat of monarch butterfly	Mexico
3.6	Bioclimatic limits of 50% of eucalypts exceeded	Australia
3.6	30–40% of 277 mammals in 141 parks critically endangered/extinct; 15–20% endangered	Africa
3.6	Parts of the USA lose 30–57% neotropical migratory bird species richness	USA
3.7	Few ecosystems can adapt; 50% all nature reserves cannot fulfill conservation objectives; bioclimatic envelopes exceeded, leading to eventual transformation of 22% of global ecosystems; loss of 68% wooded tundra, 44% cool conifer forest, 34% scrubland, 28% grassland/steppe, 27% savanna, 38% tundra and 26% temperate deciduous forest; ecosystems variously lose 7–74% of their areal extent	Globe
3.9	4–24% plants critically endangered/extinct; mean species loss of 42% (spatial range 2.5–86%)	Europe
4.0	Likely extinctions of 200–300 species (32–63%) of alpine flora	New Zealand
>4.0	38–67% of frogs, 48–80% of mammals, 43–64% of reptiles and 49–72% of birds committed to extinction in Queensland as 85–90% of suitable habitat lost	Australia

The escalator effect

Accurately determining the distribution of a species can be very problematic in many parts of the world; we simply don't have data for enough taxa in enough places. This problem was highlighted recently by Kenneth Feeley and Miles Silman from Wake Forest University in the USA, in a study of almost 1000 Amazonian and Andean plant species.*

Until the recent advent of global positioning systems, recording the coordinates of specimens' geographical location (termed georeferencing) was often inaccurate. If the region involved was more or less flat, such imprecision was probably not that important, as climate tends not to vary much over a few tens of kilometres. But in mountainous terrain, this can be a huge problem because temperature and precipitation regimes change very significantly as you climb. If the location of a specimen is off by even a few hundred metres, or if the recording (interpolation) of climate variables between sparsely distributed climate stations is inaccurate, then the bioclimatic envelope you assign a species will be incorrect.

Feeley and Silman demonstrated that the use of standard distributional data caused the elevational ranges of the species studied to be overestimated by an average of around 400 m compared to analyses based on better-quality georeferenced data. This is equivalent to overestimating temperature tolerances by more than 3°C. These errors could easily lead researchers to underestimate the sensitivity of species to climate change and therefore fail to take appropriate action.

However, other studies have suggested that mountains often contain 'hidden pockets' of suitable climate space which threatened species could use as refuges. Mountain systems have often played a key role in the survival of species through periods of past climate change. Perhaps they may do so again in the coming centuries.

*published in the Journal of Biogeography in 2009

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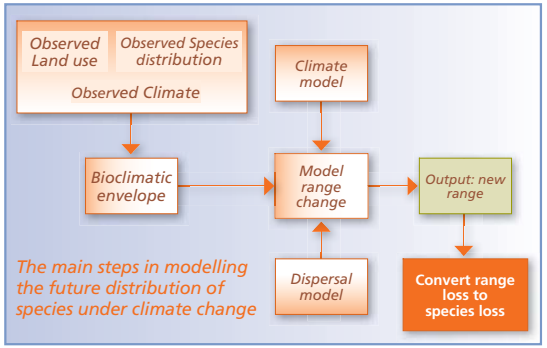
Photo: Capucine monkeys in South America



The main steps in modelling the future distribution of species under climate change

ing the physical conditions that allow that species to flourish. Secondly, the ability of the species to reach new habitats (dispersal) is quantified. Thirdly, one or more climate change scenarios are chosen as the basis for forecasting the geographical distribution of the species' future 'climate space'. Typically, a set of high, medium and low impact (change) scenarios are chosen and applied to one or two significant points in the future. These points are typically 'round number' years, such as 2050 or 2100.

These three components are used to model the future *potential* distribution range of the species. By comparing the current and future ranges of each species, it is possible to determine how ranges will contract or expand, how much overlap there is between current and future distributions, and whether a species has the capacity to move between these areas. If there is no geographical overlap between current and future ranges and dispersal is unlikely, the species may be destined for eventual extinction. When repeated for whole sets of species, these species distribution models can be translated into overall patterns of changing diversity, at least in principle.

There will be winners and losers

It is important to remember that species ranges will both contract and expand under climate change. Put another way, there will be 'winners' and 'losers'. The biggest losers of all will be the species which no longer have any suitable climate and habitat within their dispersal range. Such a case could occur on mountains where the bioclimatic envelope moves upwards and, eventually, may even disappear off the top. This is referred to as the 'escalator' effect and has prompted renewed interest in mountain fauna and flora *(see box)*.

When species distribution models predict the collective loss of range of many species, it is reasonable to suppose equally large reductions in population size. Many species will be reduced to small, fragmented populations incapable of long-term survival. However, given the lag involved between the change in climate and the processes of species range contraction, expansion and ecosystem restructuring, it is likely that

The Bigfoot problem

Like the Yeti reputed to roam the Himalayas,* Bigfoot is a mythical beast that generates great popular interest. Although there have been regular claims of sightings of a 'scientifically undescribed large primate' in the forests of western North America, there is still no hard evidence that this 'species' has ever existed.

A group of scientists led by Dr Jeff Lozier from the University of Illinois recently demonstrated the paradox that poor data may lead to good models. They used data collected on the basis of the claimed sightings and footprint records collated by the Bigfoot Field Researchers Organization. Having 'cleaned' the data, they were able to use a species distribution model to model Bigfoot's bioclimatic envelope. The models** produced a convincing map showing where Bigfoot roams. The researchers also calculated a bioclimatic envelope model for the black bear (Ursus americanus), which had a striking similarity to the Bigfoot map. Could it be that most records claimed to be Bigfoot were actually bears?

The point here is that it was possible to develop a good model of Bigfoot distribution that appeared statistically robust and even to project that model onto a future climate surface to forecast shifts in its distribution. Yet, the general scientific consensus is that there is no Bigfoot in the first place. In short, questionable data produce superficially good but scientifically questionable models.

* *Sightings of elusive beasts have been reported around the world. Examples are Almas (Mongolia), Barmanou (Afghanistan and Pakistan), Bigfoot, also known as the Sasquatch (North America) Chuchunaa (Siberia), Hibagon (Japan), Mono Grande (South America), Orang Mawas (Malaysia), the Yeti and Yeren (China). [Source: Wikipedia]*

** *published in the* Journal of Biogeography *in 2009*

Photo: Wikipedia

Could this be the first victim of climate change? Endemic to the cloud forests of Monteverde (Costa Rica), the golden toad (Bufo periglenes) has not been seen since 1989. The causes of its extinction are not clear but the most likely contender is an outbreak of a highly pathogenic fungus whose growth was encouraged by rising temperatures.

many of the extinctions will occur long after the initial change in climate has occurred. Scientists therefore refer to the animal or plant species involved as being 'committed to extinction'. This poorly understood term has caused simplistic and sensationalist newspaper headlines along the lines of *One million species extinct by 2050!* Of course, species do not blink out of existence as soon as their environment becomes unsuitable. Rather, populations shrink and fragment, until a complex interaction of genetic and environmental fluctuations eventually causes the disappearance of some species from all sites in their range. This process may take decades, or even centuries and, if we view this in a positive light, may give conservationists vital breathing space in their fight to keep extinctions to a minimum.

No model is perfect

No model is perfect. The hope is that the key processes can be modelled in sufficient detail to make broadly accurate forecasts. For example, if a species were able to evolve a higher tolerance to a warming atmosphere, its future range may be much greater than predicted. However, the anticipated speed of climate change is likely to exceed the evolutionary flexibility of many species.

One of the biggest challenges for accurately modelling changes in biodiversity under climate change is the lack of knowledge about the number of species on Earth. This problem is particularly acute for hyper-diverse tropical ecosystems like the Amazon rainforest and for poorly known animal groups such as arthropods (insects, spiders and the like). Consequently, scientists can only make crude extrapolations about the possible consequences of climate change on the total biodiversity in these ecosystems. This is especially true for forecasts of future extinctions. The more species you assume exist in regions like the Amazon, awaiting discovery and cataloguing, the more species there are to become extinct (see overleaf *An uncertain future for Amazonia*). When conservationists or the media talk about extinction in terms of hundreds of thousands, or even millions, they are including in the forecast the extinction of species that have not yet been described: perhaps 5 million, perhaps 30 million, perhaps more! This is perfectly acceptable if the audience has a clear understanding of the issue. If not, it can once again open conservationists to accusations of exaggeration and doom-mongering.

Imperfect knowledge about the geographical distribution of animals and plants is another major challenge for scientists. The observed distribution of species is an essential component of all models but the distribution of species is at best an approximation, especially for rare and cryptic species that may be difficult

Amazona aestiva *(left) and* Amazona farinosa

An uncertain future for Amazonia

The Amazon Basin harbours the largest continuous area of tropical forest on Earth: over 5 million km^2. According to some estimates, it contains one-fifth of the planet's plant and animal species. Of the original forest, it is thought that around 20% has already been cleared, mainly for agriculture. Although the annual rate of deforestation is decreasing, new forest areas are continually being opened up to exploitation.

Less well-known is the important role the Amazon plays in controlling global and regional climate. Evaporation and condensation over Amazonia are important drivers of global atmospheric circulation and largely determine the patterns of precipitation seen across South America.

Using mid-range estimates for the emission of greenhouse-gases, scientists have predicted that temperatures in the Amazon will rise by between 1.8 and 5.1°C this century. Some predictions suggest that temperatures may even increase by up to 8°C if large areas of forest die-off are replaced by savanna.

The impact of climate change on the plants and animals of the Amazon is by no means clear. Most efforts have so far focused on understanding and predicting the impact on the forest ecosystem rather than on individual species. This has been done mainly through the use of sophisticated computer simulations that seek to model critical variables like the sum of evaporation and plant transpiration rising from the land to the atmosphere (evapotranspiration). Most models predict that, whereas small-scale deforestation can actually increase local rainfall, more widespread deforestation tends to reduce rainfall significantly. Moreover, if rainfall drops below a critical level, the forest may start to disappear, as scrub and savanna gain ground. Some models have predicted that the removal of another 30–40% of the forest could push much of Amazonia into a permanently drier climate regime.

Although these forecasts are disturbing, they may not be truly representative of what will actually happen. Ecosystems are intrinsically complex and difficult to simulate and the results of in-depth experimental studies, such as the creation of artificial droughts, suggest that the Amazon forest may be more resilient than previously thought. One of the key insights has been the discovery of deep root systems allowing many tree species to access water far beneath the forest surface and redistribute this into the soil at the surface by a process known as hydraulic lift. Another factor is the ability of trees to acclimatize to higher temperatures and a lesser availability of water. In the long term, this may result in those species most able to cope with the changing climate replacing less adaptable species. Lastly, there is also the possibility that the higher levels of carbon dioxide in the atmosphere may improve the ability of plants to use the available water efficiently. A recent, highly controversial study has claimed that, during the 2005 Amazon drought, large areas of forest actually greened-up as trees fed off the increased sunlight while continuing to access water through their deep roots. Moreover, studies of the pollen record suggest that Southern Amazonia was still forested 10,000 years ago, despite the climate being considerably drier at the time than today.

Although great strides are being made in understanding the potential consequences of climate change in the Amazon basin, there are still considerable uncertainties over the extent and intensity of change. The fate of the millions of species that live in the forest, many unrecorded by science, is even less clear, especially when the effects of continuing deforestation, fires, pollution and overhunting are factored into an increasingly complicated equation.

to survey. This is well illustrated by the rediscovery of species that have been considered extinct, sometimes after a gap of many decades since the previous record. For example, the large-billed reed warbler (*Acrocephalus orinus*) was known from just a single specimen collected in the Sutlej Valley of Himachal Pradesh in India in 1867. In March 2006, it was trapped again, this time at Laem Phak Bia in Phatchaburi Province in south-west Thailand, a staggering 3,100 km from the type locality. This illustrates how difficult it can be to know the range of relatively cryptic species of plants and animals in areas of the world where resources for biological surveys and inventories are limited. More generally, the data used by species distribution models normally take the form of species range maps. These maps are necessarily generalizations: species don't occur at every point in these ranges. This means that the envelope drawn around the data points reporting their presence will inevitably contain numerous places where the species is actually absent. To increase consistency, scientists standardize the mapping of species ranges by first dividing the landscape into grids of cells of a fixed size. A grid cell will be considered as containing the species if the species is reported somewhere within that cell but if the cell size is large, it may only occur in a small part of that cell, leading to range maps that greatly overestimate the total area occupied. Conversely, the use of very small grid cell sizes can provide more precise and accurate representations of the range but at the cost of enormous increases in sampling effort, not to mention the cost and time invested in acquiring the data.

The recorded presence of a species in a grid square is ultimately based on scientific records which, depending on who made the observation, have varying degrees of certainty attached to them. Clearly, expert surveys or voucher specimens lodged in herbaria and museums have a high degree of certainty. Such surveys, however, are less likely to have covered the entire potential range of that species. Other problems appear if the data were collected over a long period of time. In this case, although the total amount of data is greater, so too is the risk of recording a species as being present in areas that have not been home to it for some time. Thus, ranges may easily be inaccurately known, being either overestimated, underestimated or displaced from their true locations. Furthermore, some species may still be in the process of redistributing themselves after the last major climatic shock, the ice age. Controlling for the influence of climate history is thus one of the major challenges in any attempt to model the potential influence of climate change on the future distribution of species.

Dispersal also plays an important role in determining how species will respond to climate change. For instance, water-dispersed plant species are inherently more likely to spread quickly if new climate space opens up *downstream* in large catchments than if they need to migrate *upstream*. But it is much harder to predict the rate of spread into a new climate space of plants whose seed dispersal is dependent on large fruit-eating birds and mammals which may themselves be affected by climate change.

Citizen surveys and other novelties

Despite the numerous challenges, we can be optimistic that quality of data will improve dramatically over the next decade. Important moves are currently afoot to fill knowledge gaps about the number and distribution of Earth's species. Probably the most ambitious bioinformatics project is the Encyclopedia of Life,[2] the aim of which is to 'make available via the Internet virtually all information about life present on Earth.' This encyclopedia works through a series of linked websites, one of which is planned for every species that has been formally described. Each species' website will be flexible and constantly evolving so that it can easily incorporate new information on ecology, genetics and conservation as it is generated. By 2014, the project hopes to have created a million species pages, a rich resource for conservation biogeography if it can improve access to knowledge and the quality, accuracy and speed of data collection. A closely related project, the Catalogue of Life[3] aims to develop a definitive list of all known organisms on Earth.

There are also several biodiversity information system initiatives that can generate range maps. The most ambitious is the Global Biodiversity Information

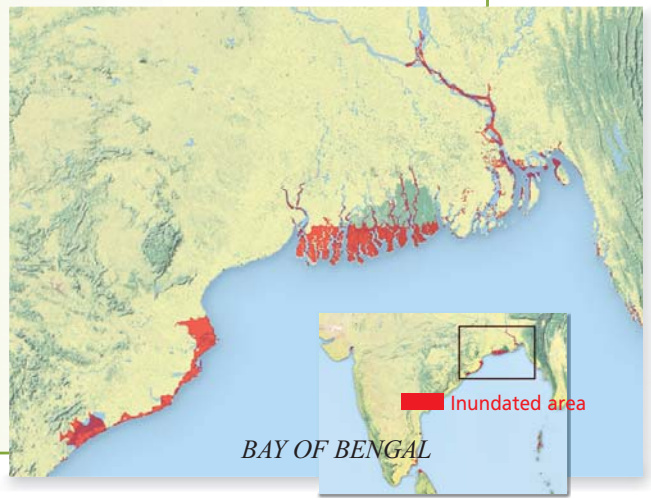
That sinking feeling

Straddling India and Bangladesh, the Sundarbans encompass the largest mangrove forests in the world: 10,000 km^2 of land and water in the delta of the converging Ganges, Brahmaputra and Meghna rivers in the Bay of Bengal. The Sundarbans are intersected by a complex network of tidal waterways, mudflats and small islands of mangrove forests.

There is a continuous natural subsidence in the Sundarbans which causes sea level to rise by about 2.2 mm every year. Were sea level to rise by 45 cm worldwide, 75% of the Sundarbans mangroves could be destroyed. The IPCC predicts sea-level rise of up to 60 cm by the end of the century. However, this prediction excludes changes in ice cover in Greenland and Antarctica, judged too uncertain to quantify at the time its last report was published in 2007.

Further destruction of the Sundarbans mangroves would diminish their critical role as natural buffers against tropical cyclones: about 10% of all tropical cyclones strike the Bay of Bengal. Measures can be taken to help the Sundarbans adapt to higher sea levels: by conserving the remaining mangrove forests in protected areas; and by restoring or rehabilitating mangrove forests through replanting selected mangrove species, such as along freshwater canals or on reclaimed land, as has been done on Sagar Island.

The Sundarbans National Park in India and the part of the Sundarbans in Bangladesh are both World Heritage sites.



Projected impact of 1 m of sea-level rise on the Sundarbans

Source: Adapted from UNESCO (2007) Case studies on Climate Change and World Heritage Map: https://www.cresis.ku.edu/

Facility[4], which already includes more than 180 million records. Although this amazing initiative is rapidly expanding, the coverage for many countries remains insufficient. For example, the facility's database contains fewer than one million records from collections or observations in Brazil, the most biodiverse country in the world.

Rich in biodiversity, the Sundarbans' mangrove forests host 260 bird species, including the Indian roller (Coracias benghalensis) pictured here. They are also home to Indian otters, spotted deer, wild boar, fiddler and mud crabs and five marine turtle species. The Sundarbans are also a refuge for the threatened estuarine crocodile, Indian python and Bengal tiger.

Photo: S.Dasgupta/flickr

For some types of organism, scientists have taken advantage of an enormous base of public interest. One example is the American Christmas bird count. Although these 'citizen science' surveys run higher risks of error and sampling bias, they provide the possibility of generating extensive data sets of contemporary records and thus constitute a rich resource for researchers. With careful data handling, such schemes are already proving their worth as the basis for scientific publications. They have the added benefit of connecting scientists with citizens and strengthening the public profile of the conservation movement. We need to encourage other such initiatives and schemes in more parts of the world and for more types of animals and plants.

The theory and practice of species distribution models also need to improve. In these pages, we have tended to focus on the uncertainties associated with these models. In their defence, they are themselves a very recent development and scientists are working hard to improve their predictive capacity. One promising avenue is the use of consensus forecasting, an approach based on running numerous simulations involving different models then using the overall 'consensus' to identify the most likely future scenarios.

Our predictive power will get better

The consequences of climate change on the Earth's flora and fauna will be complex and profound. If societies are to make rational decisions about how to deal with the repercussions, they will need systematic, geographically precise information about what will happen to species and ecosystems. Species distribution models are currently the best method available for doing this, albeit with numerous unavoidable uncertainties, many of which are due to insufficient or poor-quality data.

The good news is that our ability to predict how species distribution will change, which species will decline and which will become extinct is bound to improve. Global and national initiatives to collect, collate and make available biodiversity data are under way across the globe. New tools and technology are making it easier than ever to collect huge quantities of more accurate data. Furthermore, scientists are constantly improving their understanding and ability to model the fundamental processes controlling the geographic distribution of species. A stronger predictive science base is, however, only one element in developing better policies to mitigate and avoid biodiversity losses in the face of 21st century global environmental change. The sheer scale of the challenges of biodiversity conservation requires action at all levels of the international community and policy-making bodies, as well as the continued involvement of the public.

1. *1 ha of peat stores about 5000-6000 t/C/ha and Indonesia has about 20 million ha of peat.*
2. *www.eol.org*
3. *www.catalogueoflife.org*
4. *www.gbif.org*

This article may be consulted freely on UNESCO's portal in various languages. Simply replace the 'e' at the end of the following link to A World of Science *by an 'a' for Arabic, 'f' for French, 'r' for Russian and 's' for Spanish:*
http://unesdoc.unesco.org/images/0018/001865/186519e.pdf
For details: www.unesco.org/science/en/a-world-of-science

Elephants crossing the river in Giam Siak Kecil-Bukit Batu Biosphere Reserve in Indonesia

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Important Bird Areas thus focus on conservation at the level of sites: discrete areas of habitat that can be delineated and, at least potentially, managed for conservation. Sites form the basis of protected area networks and are thus a major focus of conservation investment by government, donors and civil society.

Leon Bennun

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III

COUNTERACTING BIODIVERSITY EROSION AND LOSS

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Key Biodiversity Areas: Background, criteria and coverage

Background

Over the past several years various nature conservation organizations have proposed various schemes for identifying priorities for conservation at the global scale, such as biodiversity hotspots, endemic bird areas, crisis ecoregions, global 200 ecoregions, frontier forests, etc. (see Figure 1). While these global approaches to setting priorities give an idea of what regions at the global scale might be important or urgent for conservation actions, they do not give us fine scale information on where, within these regions (and beyond these regions), areas of urgent conservation attention are to be found. To that end, a methodology began to take shape to standardize how to identify biodiversity conservation priorities at the site scale.

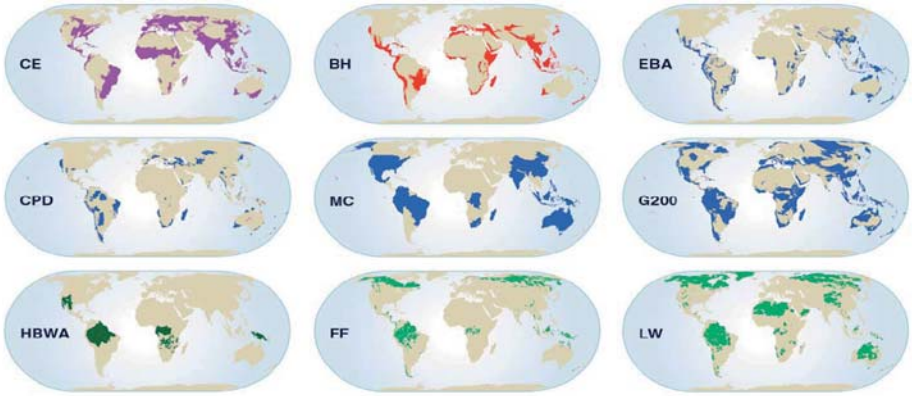

Fig1. Maps of the nine global biodiversity conservation priority templates: CE, crisis ecoregions (21); BH, biodiversity hot spots (11), updated by (39); EBA, endemic bird areas (15); CPD, centers of plant diversity (12); MC, megadiversity coutries (13); G200, global ecoregions (16), updated by (54); HBWA, high-biodiversity wilderness areas (14); FF, frontier forests (19); LW, last of the wild (20). (taken from Brooks et al. 2006).

The development of this method began with identifying important sites for birds, given the fact that a large amount of data are available for birds, owing to the large number of practitioners, both experts and amateurs. For more than two decades, the BirdLife International partnership has been working to identify these sites, Important Bird Areas (IBAs), around the world (Collar 1993–4). IBAs have been identified by local conservation organizations but based on the same global methodology in all countries, making the resulting priorities comparable. This concept of identifying important areas for a taxonomic group began to be used by other organizations for other groups, such as Important Plant Areas (IPAs led through the Plantlife International partnership; Anderson 2002), and Important Freshwater Biodiversity Areas (led through the IUCN Freshwater Programme; Darwall and Vié 2005). However, it soon became apparent that in order to have the greatest conservation impact it would be desirable to bring these approaches under one umbrella and develop criteria for the identification of important areas for multiple taxonomic groups. In 2004, experts in various taxonomic groups, and from various organizations, held a workshop in Washington, DC to discuss and agree on a set of criteria and thresholds for identifying these Key Biodiversity Areas, or KBAs. As described by Eken et al. (2004), "Sites of global significance for biodiversity conservation identified using globally standard criteria and thresholds, based on the needs of biodiversity requiring safeguard at the site scale". The concept of KBAs has been applied for various terrestrial and freshwater taxa, but is also being used to identify important areas in the marine realm (Edgar et al., 2008). The KBA concept and criteria are fully outlined in the IUCN Best Practices Protected Areas Guidelines Series Number 15 (Langhammer et al., 2007), available online at www.iucn.org[2].

2. http://data.iucn.org/dbtw-wpd/edocs/PAG-015.pdf

Process

The process to identify KBAs starts at the local level with local partners, but using globally consistent criteria. This allows for substantial local buy-in and ownership and also ensures that the best data are used in the analysis. The KBA process is also meant to be iterative, with new data incorporated as it becomes available. Additionally it is important to note that throughout the process there is acknowledgement that several options exist to safeguard KBAs, including, but not limited to, national parks, community-managed reserves, indigenous reserves and private reserves. Furthermore, KBA identification is just one tool in the biodiversity conservation arsenal; they are critical areas for conservation at the site-scale, but additional actions are needed at wider scales, such as the wider landscape or seascape, to take into account such phenomena as climate induced migrations/shifts and wider ecological processes on which species depend (Boyd et al., 2008).

Criteria

KBA criteria are based on the concepts of vulnerability and irreplaceability which are widely used in systematic conservation planning. While vulnerability can be thought of as a measure of the options in time available for the conservation of biodiversity, irreplaceability can be thought of as a measure of the options in space. With increasing levels of vulnerability and irreplaceability there is greater urgency for conservation action (Margules and Pressey 2000). The IUCN Red List of Threatened Species serves as the primary basis for incorporating vulnerability into KBA assessments. Over 40,000 species have now been assessed by IUCN using standardized criteria and the associated information is available at www.iucnredlist.org. Sites that hold significant populations of Critically Endangered, Endangered or Vulnerable species are triggered as KBAs. For example, Hellshire Hills in Jamaica qualifies as a KBA because of the presence of three threatened species: one mammal and two birds (CEPF, 2010).

The irreplaceability criteria are divided into several sub-criteria, the first of which is presence of restricted range species. A site may qualify under this sub-criterion if it holds 5% of the population of a species with a limited distribution, provisionally set at 50,000 square kilometers. Morningside in Sri Lanka qualifies as a KBA based on the presence of 11 amphibians, three lizards and three freshwater crabs – all endemic to this single site. While there is often not detailed population data available for species, experts often use surrogates for population, such as range size, especially when it is obvious that a site holds at least 5% of the population (e.g. when half of the entire range of a species is in a single site, or when a fish is known from only one pond).

The second sub-criterion of irreplaceability is the presence of a congregation of species. Here a species may trigger the congregation sub-criterion if it is known to congregate in numbers exceeding 1% of the global population at the site. Again, surrogates or estimates are often used for population numbers, given the general lack of detailed data on species populations. Buguey Wetlands KBA, in Luzon, the Philippines, holds significant numbers of five congregatory bird species and thus qualifies as a KBA. While this criterion has been largely applied for birds, it will also become applicable as KBAs are further identified for spawning congregations of fish and other taxa.

The third sub-criterion of irreplaceability is bioregional restricted assemblage. To qualify as a KBA under this sub-criterion, a site must hold a significant component of the species restricted to a specific bioregion. The threshold is still in development for this criterion, but in Paraguay, a site in the Chaco bioregion triggered this sub-criterion if it held over 50% of the species restricted to the Chaco. At Pirizal, for example, there are 15 species endemic to the Chaco bioregion (>50%) and thus Pirizal qualifies as a KBA (Guyra Paraguay, 2008).

As mentioned previously, those sites that are extremely vulnerable and irreplaceable are the most urgent priorities for conservation action. The identification of this set of sites is the aim of the Alliance for Zero Extinction (www.zeroextinction.org). These sites are KBAs that are completely irreplaceable and extremely vulnerable; they hold the last remaining population of one or more Critically Endangered or Endangered species. If we are serious about wanting to halt biodiversity loss, then these are the sites that we most urgently need to safeguard – if we lose one of these sites, we lose at least one species to extinction.

Coverage

IBAs, which are the avian subset of KBAs, have been identified in nearly all countries with only a few still with incomplete inventories (see Figure 2). Given that IBAs have been underway for over twenty years, the other taxonomic groups have a ways to catch up, but are advancing rapidly. IPAs, for example, have been completed for 13 countries and are partially complete or in progress in an additional 13 (see Figure 3). Much of the focus of the IPA program to date has been in Europe and parts of Asia. As KBAs are expanded around the world, the identification of KBAs triggered by plants will undoubtedly result, and the network of IPAs will likewise expand. Similarly, the identification of globally important freshwater sites has recently been started and is focusing on southern and eastern Africa (see Figure 4). However, there is a new project beginning this year which will aim to identify Freshwater KBAs across the entire continent of Africa. As with plants, the expansion of the network of KBAs will undoubtedly include data on freshwater species as triggers in many cases and so the expansion of the network of important freshwater sites will similarly grow. To get a picture of the global coverage of KBAs for multiple taxonomic groups beyond birds

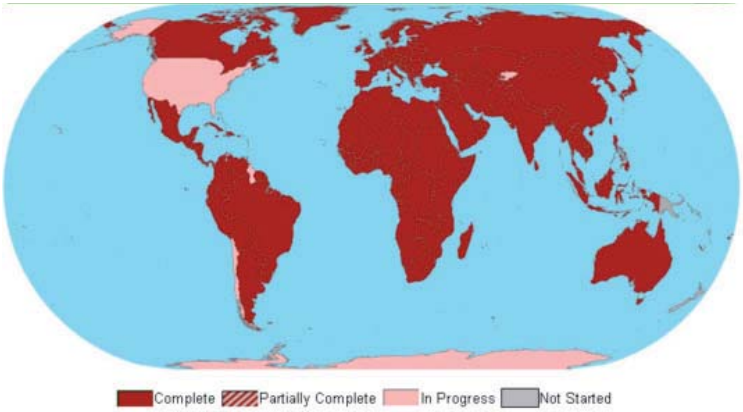

Fig2. Global coverage of Important Bird Areas (IBAs).

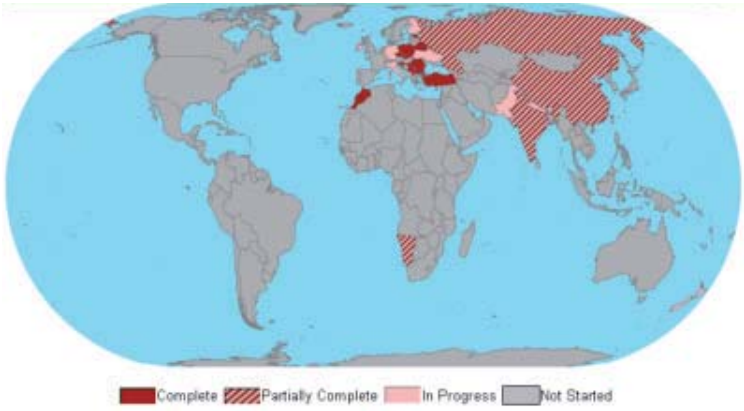

Fig3. Global coverage of Important Plant Areas (IPAs).

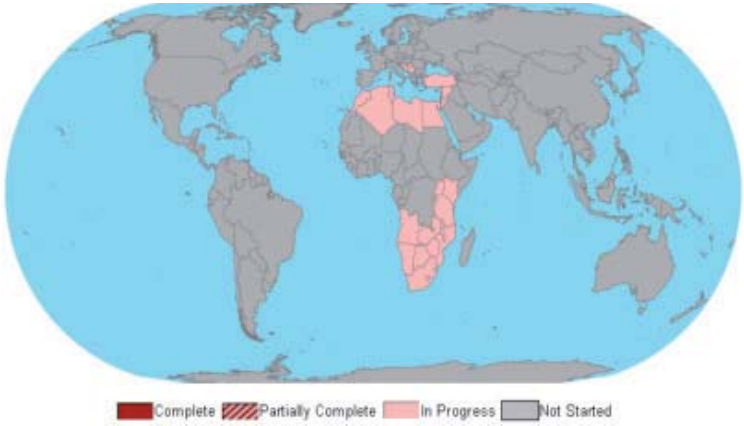

Fig4. Global coverage of Globally Important Freshwater Sites.

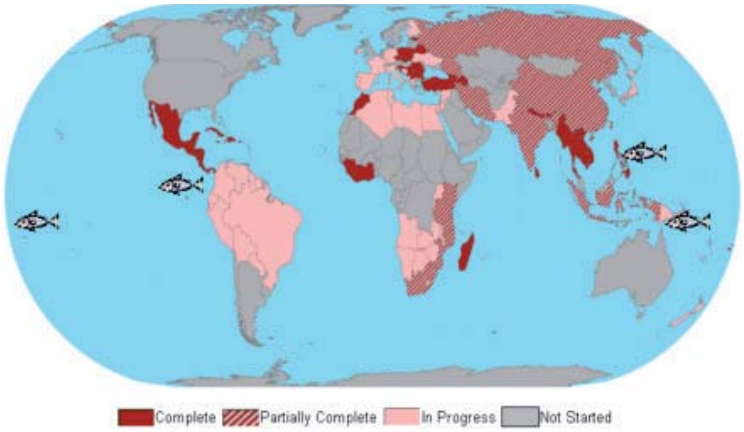

Fig5. Global coverage of Key Biodiversity Areas (KBAs) identified for multiple taxonomic groups.

To best illustrate the global coverage of KBAs, we can add the IBAs to the map in green underneath the map from Figure 5 (Figure 6). Those countries shown in green have KBAs identified, but only for birds (IBAs). So, one can see that there is actually quite decent coverage of KBAs around the world, but we have a ways to go still in order to expand the taxonomic breadth beyond birds. That said, we cannot wait for perfect data, and should make every attempt to ensure that these globally important sites for biodiversity conservation are recognized and incorporated into future policy measures, such as the Convention on Biological Diversity.

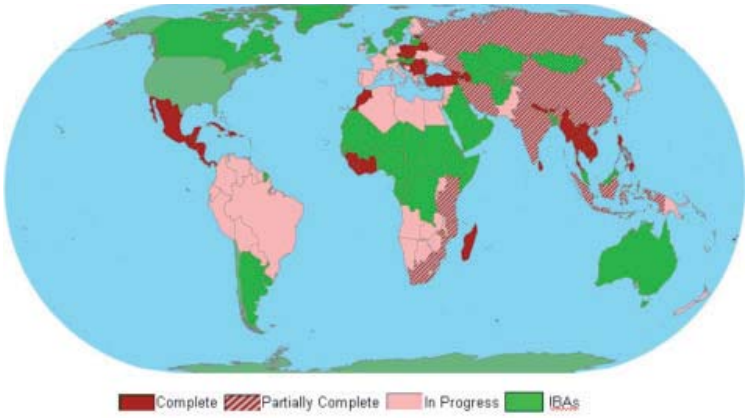

Fig6. Combined global coverage of Key Biodiversity Areas.

(IBAs), we can take the maps for IPAs and Globally Important Freshwater Sites and combine them with information on other multi-taxa KBA processes (Figure 5). Sixty-eight countries have KBAs identified for multiple taxonomic groups with another 58 partially complete or in progress. Additionally, marine KBA identification is progressing in four marine regions: Melanesia, the Philippines, Pacific Islands, and the Eastern Tropical Pacific.

Conclusions

The key biodiversity area methodology provides a globally standard method for identifying sites of global conservation importance. To maximize the utility of the results for conservation action, the KBA process is led by local experts to incorporate the best available knowledge, and to ensure that local stakeholders have a chance to participation in the prioritization exercise. Key biodiversity areas are not the only tool that should be used for conserving biodiversity, but rather form a core set of areas that should be considered for site-scale conservation action. Beyond the site scale, it is recognized that biodiversity requires adequate management of the matrix of land uses in the wider landscape or seascapes. Finally, there is wide coverage of key biodiversity areas around the world, and this dataset continually improves, both in geographic coverage, and in the depth of biodiversity it represents. While there is plenty of space for the key biodiversity area dataset to expand, this should not deter governments and other policy makers from using the best available KBA data currently available.

References

Anderson, S. 2002. *Identifying Important Plant Areas*. London, UK: Plantlife International.

Boyd, C., Brooks, T.M., Butchart, S.H.M., Edgar, G.J., Fonseca, G.A.B. da, Hawkins, F., Hoffmann, M., Sechrest, W., Stuart, S.N. and van Dijk, P. 2008. Spatial scale and the conservation of threatened species. *Conservation Letters* 1: 37-43.

Brooks, T.M., Mittermeier, R.A., Fonseca, G.A.B. da, Hoffmann, M., Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D. and Rodrigues, A.S.L. 2006. Global biodiversity conservation priorities. *Science* 313: 58-61.

Critical Ecosystem Partnership Fund (CEPF) 2010. Ecosystem Profile for the Caribbean Biodiversity Hotspot.

Collar, N.J. 1993–1994. Red Data Books, action plans, and the need for site-specific synthesis. *Species* 21-22: 132-133.

Darwall, W. and Vié, J.C. 2005. *Identifying important sites for conservation of freshwater biodiversity: Extending the species-based approach*. Gland, Switzerland and Cambridge, UK: IUCN.

Edgar, G.J., Langhammer, P.F., Allen, G., Brooks, T.M., Brodie, J., Crosse, W., Silva, N. de, Fishpool, L.D.C., Foster, M.N., Knox, D.H., Mccosker, J.E., Mcmanus, R., Millar, A.J.K. and Mugo, R. 2008. Key biodiversity areas as globally significant target sites for the conservation of marine biological diversity. *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Eken, G., Bennun, L.A., Brooks, T.M., Darwall, W., Fishpool, L.D.C., Foster, M., Knox, D., Langhammer, P.F., Matiku, P., Radford, E., Salaman, P., Sechrest, W., Smith, M.L., Spector, S. and Tordoff, A. 2004. Key Biodiversity Areas as site conservation targets. *BioScience* 54: 1110-1118.

Guyra Paraguay, 2008. *Áreas Importantes para la Conservación de las Aves de Paraguay*. First Edition. Asuncion, Paraguay.

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., Silva, N. de, Edgar, G.J., Eken, G., Fishpool, L.D.C., Fonseca, G.A.B. da, Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S.L., Salaman, P., Sechrest, W. and Tordoff, A.W. 2007. *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. Gland, Switzerland: IUCN.

Margules, C. R and Pressey, R. L. 2000. Systematic conservation planning. *Nature* 405: 243.

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Important Bird Areas on land and sea: A global inventory of key sites for conservation

Introduction

The concept of Important Bird Areas (IBAs) has been developed, refined and applied for over 30 years, by the BirdLife International Partnership and its predecessor organisation, the International Council for Bird Preservation. Work on IBAs arose out of a policy need namely implementation of the European Union's 'Birds Directive', which requires that member states classify the most important areas for bird species of concern as Special Protection Areas.

The underlying logic of IBAs is straightforward. Biodiversity (and the bird component of it) is not evenly distributed: some places are much more important for conservation than others. Identifying and conserving those places is an effective conservation approach, as it allows disproportionately many species to be conserved in a relatively small area. IBAs thus focus on conservation at the level of sites: discrete areas of habitat that can be delineated and, at least potentially, managed for conservation. Sites form the basis of protected area networks and are thus a major focus of conservation investment by government, donors and civil society (BirdLife International, 2004a).

In the IBA approach, the distribution of key bird species defines the key sites. Clearly, not all bird species can be conserved effectively through a site-based approach – it is not appropriate for species that range over large areas at very low densities, for example. And sites should usually not be viewed as islands, but rather as a network within which connectivity is an important consideration. However, site conservation is relevant for the vast majority of birds, including globally threatened species: only for less than 1% of the 1,203 threatened species is broader-scale conservation action appropriate (Figure 1).

Criteria for identifying IBAs

IBAs form the subset of overall Key Biodiversity Areas (KBAs, Eken et al., 2004, Langhammer et al., 2007) identified for birds (Figure 2). Important Bird Areas are identified using a standardised set of data-driven criteria and thresholds, ensuring that the approach can be used consistently worldwide. The four categories of IBA criteria are defined according to threat and irreplaceability, the two main considerations used in planning networks of sites for biodiversity conservation (Margules and Pressey, 2000). These categories are (1) globally-threatened bird species; (2) restricted-range bird species, those with ranges smaller than 50,000 km^2 (Stattersfield et al., 1998); (3) biome-restricted assemblages communities of birds characteristic of a distinct biome, such as the Chaco in South America; and (4) congregations (large aggregations of one or more species, e.g. of migratory waterbirds). Category 1 refers to threat, while categories 2, 3 and 4 all reflect different aspects of irreplaceability.

IBA identification and documentation

BirdLife International is a partnership of grassroots, membership-based conservation organisations around the world, whose mission is "to conserve wild birds, their habitats and global biodiversity, by working with people towards sustainability in the use of natural resources" (BirdLife International, 2004c). BirdLife's strategy to achieve this integrates species, site and habitat conservation with sustaining human

needs, and is implemented by the BirdLife Partnership in some 112 countries and territories worldwide. The site-based component of this approach, the Important Bird Areas Programme, complements the programmes that focus on species and habitats.

Wherever possible, IBAs are identified and documented through a bottom-up national process led by the BirdLife Partner organisation in-country. This ensures that the best local knowledge feeds in to the process, and builds engagement and capacity for taking IBA conservation and monitoring work forward at the next stage. The process is supported by the decentralised BirdLife Secretariat, which is also responsible for checking and maintaining standards and consistency in application of the criteria. Extensive information is collated on each site, including the status of the bird species that triggers designation, threats to the site and priority conservation actions. These data are managed globally in BirdLife's World Bird Database and made available through the Data Zone on BirdLife's website.

At the start of 2010, at least 115 national IBA inventories had been published, in numerous of languages. This information is compiled into major printed regional directories covering Europe, the Middle East, Africa, Asia and the Americas (Grimmet and Jones, 1989; Evans, 1994; Heath and Evans, 2000; Fishpool and Evans, 2001; BirdLife International, 2004a; BirdLife International and Conservation International, 2005; BirdLife International, 2008; Devenish et al., 2009). In January 2010, the World Bird Database contained information on 10,431 confirmed IBAs. For land, the global IBA inventory is thus nearly complete, though a few gaps remain where work is in progress (Figure 3). The process of digitising site boundaries is also ongoing. Over 90% of IBAs now have boundaries delineated in a Geographical Information System.

Marine Important Bird Areas

With the terrestrial inventory nearly complete, the focus of site identification is now shifting to the oceans. Many coastal and island IBAs are already identified for seabirds, especially as nesting colonies under the congregatory species category. However, as seabirds spend most of their lives at sea, there is an obvious need to expand the IBA approach to reflect this. Marine IBAs of four types are currently being identified (Osieck, 2004):

1. Seaward extensions to breeding colonies: while many seabird breeding colonies have already been identified as IBAs, their boundaries have been, in almost all cases, confined to the land on which the colonies are located. The boundaries of these sites can, in many cases, be extended to include those parts of the marine environment which are used by the colony for feeding, maintenance behaviours and social interactions. Such extensions are limited by the foraging range, depth and/or habitat preferences of the species concerned. The seaward boundary is, as far as possible, colony and/or species-specific, based on known or estimated foraging and maintenance behaviour.
2. Non-breeding (coastal) concentrations: these include sites, usually in coastal areas, which hold feeding and moulting concentrations of waterbirds, such as divers, grebes and benthos-feeding ducks. They could also refer to coastal feeding areas for auks, shearwaters, etc.
3. Migratory bottlenecks: these are sites whose geographic position means that seabirds fly over or around them in the course of regular migration. These sites are normally determined by topographic features, such as headlands and straits.
4. Areas for pelagic species: these sites comprise marine areas remote from land at which pelagic seabirds regularly gather in large numbers, whether to feed or for other purposes. These areas usually coincide with specific oceanographic features, such as shelf-breaks, eddies and upwellings, and their biological productivity is invariably high.

Methodologies for identifying and delimiting these sites have been developed and tested by a number of BirdLife Partners, and national marine IBA inventories have recently been published in Spain and Portugal (Ramirez et al., 2008, Arcos et al., 2009). Site delineation may draw on a wide range of relevant data for a number of species, including at-sea distribution records from satellite tracking and vessel-based and aerial surveys, foraging ranges and habitat modelling (for example, based on bathymetric measures and substrate classification). To support this work BirdLife has developed two extensive new databases. A foraging database includes published measures of foraging range, depth and trip duration, as well as key habitats, prey items and foraging associations. The 'Tracking Ocean Wanderers' database for Procellariiform birds (the petrels and albatrosses) brings together tracking data on 29 species, contributed by 57 scientists from 11 countries.

From identification to conservation

IBA inventories are a starting point for work to conserve and monitor these key sites in perpetuity. The inventories are crucial to inform national and international policy. Inventories help to highlight site networks and connections, set priorities for action and bring overlooked sites onto the conservation agenda. IBAs are a starting point for gap analysis and the building blocks for systematic conservation planning (Margules and Pressey, 2000). They inform development decisions, especially through project-specific, or strategic, Environmental Impact Assessment (BirdLife Asia, 2009). In practical terms, they have proved an effective focus for local community engagement (BirdLife International ,2007), and for participatory monitoring schemes (Bennun et al., 2005). IBAs form an excellent first cut of the larger Key Biodiversity Area network, and so are a good basis for planning, especially where (as is often the case) information on other taxonomic groups is not readily available (BirdLife International, 2004b).

Policy linkages

A number of characteristics combine to give IBA inventories strong linkages to policy mechanisms. These include the solid conceptual basis of IBAs in conservation science, clear and standardised criteria and thresholds, and use of accurate and relevant data derived from local knowledge. Some examples of these policy linkages are:

- IBAs provide an obvious starting point for implementing the CBD Programme of Work on Protected Areas, which enjoins Parties to set up "comprehensive, effectively managed, and ecologically representative national and regional systems of protected areas"
- The current set of indicators for the CBD Strategic Plan includes 'coverage of Protected Areas' (COP 7 Decision VII/30). The best available measure of this is the proportion of IBAs included in Protected Areas (Secretariat of the Convention on Biological Diversity 2010). This has also been adopted as an indicator for Millennium Development Goal 7 (United Nations 2010)
- The approaches under development for identifying marine IBAs on the high seas will contribute significantly to the CBD process for identifying Ecologically and Biologically Significant Areas outside national jurisdiction (Secretariat of the CBD, 2009)
- Criteria for the IBA category based on congregatory species are closely aligned (for waterbirds) with the criteria for designating wetlands of international importance under the Ramsar Convention. BirdLife has published 'shadow' directories of IBAs that are potential Ramsar sites, in support of Parties' efforts to ensure conservation and wise use of their wetlands
- The High Conservation Value (HCV) approach to identifying environmentally-sensitive areas is gaining increasing currency in the safeguard and certification approaches of industry organisations and others, for example the Round Table on Sustainable Biofuels and the Round Table for Sustainable Palm Oil (HCV Resource Network 2009). IBAs directly address the first HCV criterion, 'areas containing globally, regionally or nationally significant concentrations of biodiversity values'
- IBAs also directly inform the safeguard policies and processes of the major multilateral development banks (e.g. IFC, 2006)

To ensure that IBA information is as accessible and useful to policy-makers as possible, BirdLife has worked with a number of other organizations to share and integrate data, and make them available via innovative web mechanisms. These include the Critical Site Network tool[3], supporting the Africa-Eurasian Migratory Waterbird agreement, and the Integrated Biodiversity Assessment Tool (IBAT)[4].

IBAs and local engagement

IBAs focus on birds, one of the most accessible and popular groups of animals. They highlight internationally important biodiversity, often bringing significant sites on to the conservation agenda for the first time. For these reasons, IBAs have proved an excellent mechanism for engaging local communities in conservation. BirdLife Partners around the world are working with a diversity of local conservation groups (LCGs) to build local engagement and awareness of conservation, and to catalyse action for sustainable resource management (BirdLife International, 2007). There are currently LCGs working with BirdLife Partners at around 2,500 IBAs worldwide.

LCGs can play many important roles, from carrying out education and awareness programmes to supporting management planning and implementation. Many

3. http://wow.wetlands.org/INFORMATIONFLYWAY/CRITICALSITENETWORKTOOL/tabid/1349/language/en-US/Default.aspx
4. www.ibatforbusiness.org

groups are closely involved in site monitoring, alongside site management authorities, thus enabling a cost-effective and sustainable approach (Bennun et al., 2005; BirdLife International, 2006). By using a consistent framework, IBA monitoring allows conservation status, threats and actions to be tracked across a network of internationally important sites for biodiversity conservation (Adhola et al., 2008; Mwangi et al. in press).

IBAs and wider biodiversity

Birds are often used as indicators for the status of, and trends in, biodiversity as a whole. Birds are often good indicators for a number of reasons, not least the practical fact that we know far more about them than about most other taxa (BirdLife International 2004a). Because of this, there are many countries where IBAs have been identified, but other Key Biodiversity Areas based on additional taxa have not been.

IBAs are only a subset of KBAs, but so far, the evidence suggests that they are a large and useful subset that captures much other biodiversity, and most of the major sites. For example, surveys show that Uganda's IBA network captures at least 73% of the country's butterfly species (82% of narrow endemics), 73% of its woody plant species and 86% of its dragonflies, as well as 97% of its birds (Tushabe et al., 2006). This and other studies suggest that IBAs are an excellent first cut of the overall set of key biodiversity areas. However, some specific groups, such as freshwater fishes or narrowly endemic dryland plants, are unlikely to be well represented in IBAs and may require additional data-gathering as a priority.

Conclusions

IBAs, and KBAs more generally, are a powerful approach for practical conservation. They identify the most important sites for species conservation, using standard, objective criteria, through a process that is locally driven but maintains a global perspective. IBAs form a near-complete global set of KBAs for a major taxon, and an excellent first cut of the KBA network. Most importantly, the IBA inventory is ready to be put to use in enhancing conservation outcomes right now.

References

Adhola, T., Ng'weno, F., Matiku, P., Mulwa, R., Ngari, A., Barasa, F., Madindou, I., Wanyiri, M., Mwang'ombe, J., Musyoki, C., Ndonye, P., Ogoma, M., Machekele, J. and Musila, S. 2009. *Kenya's Important Bird Areas Status and Trends 2008*. Nairobi: Nature Kenya.

Arcos, J.M., Bécares, J., Rodríguez, B. and Ruiz, A. 2009. *Áreas Importantes para la Conservación de las Aves marinas en España*. LIFE04NAT/ES/000049. Madrid: Sociedad Española de Ornitología (SEO/BirdLife).

Bennun, L., Matiku, P., Mulwa, R., Mwangi, S. and Buckley, P. 2005. Monitoring Important Bird Areas in Africa: Towards a sustainable and scaleable system. *Biodiversity and Conservation* 14: 2575-2590.

BirdLife Asia. 2009. *Safeguarding Important Areas of Natural Habitat alongside Economic Development*. Mongolia Discussion Papers. Washington, D.C.: East Asia and Pacific Region Sustainable Development Department, World Bank.

BirdLife International, 2004a. *Important Bird Areas in Asia: Key sites for conservation*. Cambridge, UK: BirdLife International (BirdLife Conservation Series No. 13).

BirdLife International, 2004b. *State of the world's birds 2004: Indicators for our changing planet*. Cambridge, UK: BirdLife International.

BirdLife International 2004c. *A strategy for birds and people: Responding to our changing world*. Cambridge, U.K.: BirdLife International.

BirdLife International 2006. *Monitoring Important Bird Areas: A global framework*. Cambridge, UK. BirdLife International. Version 1.2.

BirdLife International 2007. *Conserving Biodiversity in Africa: Guidelines for applying the Site Support Group approach*. Nairobi, Kenya: BirdLife Africa Partnership Secretariat.

BirdLife International 2008. *Important Bird Areas in the Caribbean: Key sites for conservation*. Cambridge, UK: BirdLife International (BirdLife International Conservation Series No. 15).

BirdLife International and Conservation International 2005. *Áreas Importantes para la conservacíon de las aves en los Andes tropicales: sitios prioritarios para la conservacíon de la biodiversidad*. Quito, Ecuador: BirdLife International (BirdLife Conservation Series No. 14).

Devenish, C., Díaz Fernández, D.F., Clay, R.P., Davidson, I. and Yépez Zabala, I. (eds.) 2009. *Important Bird Areas Americas – Priority Sites for Biodiversity Conservation*. Quito, Ecuador: BirdLife International (BirdLife Conservation Series No. 16).

Eken, G., Bennun, L., Brooks, T.M., Darwall, W., Fishpool, L.D.C., Foster, M., Knox, D., Langhammer, P., Matiku, P., Radford, E., Salaman, P., Sechrest, W., Smith, M.L., Spector, S. and Tordoff, A. 2004. Key biodiversity areas as site conservation targets. *BioScience* 54: 1110-1118.

Evans, M.I. 1994. *Important Bird Areas in the Middle East*. Cambridge, UK: BirdLife International (BirdLife Conservation Series No. 2).

Fishpool, L.D.C. and Evans, M.I. (eds.) 2001. *Important Bird Areas in Africa and Associated Islands: Priority Sites for Conservation*. Cambridge UK: BirdLife International (BirdLife Conservation Series No. 11).

Grimmett, R.F.A. and Jones, T.A. 1989. *Important Bird Areas in Europe*. Cambridge, UK: International Council for Bird Preservation (Technical Publication 9).

Heath, M.F. and Evans, M.I. (eds.) 2000. *Important Bird Areas in Europe: Priority Sites for Conservation*. Cambridge UK: BirdLife International (BirdLife Conservation Series No. 8).

HCV Resource Network, 2009. *Mapping High Conservation Values at Large Scales for Effective Site-level Management*. Public consultation draft 1, May 2009. Oxford, UK: HCV Resource Network.

IFC, 2006. *International Finance Corporation's Performance Standards on Social and Environmental Sustainability*. Washington DC: International Finance Corporation.

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., Silva, N. de, Edgar, G.J., Eken, G., Fishpool, L.D.C., Fonseca, G.A.B. da, Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S.L., Salaman, P., Sechrest, W. and Tordoff, A.W. 2007. *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. Gland, Switzerland: IUCN.

Margules, C.R. and Pressey, R.L. 2000. Systematic conservation planning. *Nature* 405: 243–253.

Mwangi, M.A.K., Butchart, S.H.M., Munyekenye, F.B., Bennun, L.A., Evans, M.I., Fishpool, L.D.C., Kanyanya, E., Madindou, I., Machekele, J., Matiku, P., Mulwa, R., Ngari, A., Siele, J. and Stattersfield, A.J. (*in press*). *Tracking trends in key sites for biodiversity: A case study using Important Bird Areas in Kenya*. Bird Conservation International.

Osieck E.R. 2004. *Towards the Identification of Marine IBAs in the EU: An Exploration by the Birds and Habitat Directives Task Force*. Cambridge, UK: BirdLife International (unpublished report).

Ramírez, I., Geraldes, P., Meirinho, A., Amorim, P. and Paiva, V. 2008. *Áreas Importantes para as Aves Marinhas em Portugal – Important Areas for Seabirds in Portugal*. Projecto LIFE04 NAT/PT/000213. Lisboa: Sociedade Portuguesa Para o Estudo das Aves.

Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffmann, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S.L., Sechrest, W., Wallace, G.E., Berlin, K., Bielby, J., Burgess, N.D., Church, D.R., Cox, N., Knox, D., Loucks, C., Luck, G.W., Master, L.L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G.E., Shire, G., Strand, H., Wettengel, W. and Wikramanayake, W. 2005. Pinpointing and preventing imminent extinctions. *Proc. Nat. Acad. Sci. USA*. 51: 18497-18501.

Secretariat of the Convention on Biological Diversity, 2009. *Azores Scientific Criteria and Guidance for Identifying Ecologically or Biologically Significant Marine Areas and Designing Representative Networks of Marine Protected Areas in Open Ocean Waters and Deep Sea Habitats*. Montréal, Québec, Canada: Secretariat of the Convention on Biological Diversity.

Secretariat of the Convention on Biological Diversity, 2010. *Global Biodiversity Outlook 3*. Montréal, Québec, Canada: Secretariat of the Convention on Biological Diversity.

Stattersfield, A.J., Crosby, M.J., Long, A.J. and Wege, D.C. 1998. *Endemic Bird Areas of the World: Priorities for Biodiversity Conservation*. Cambridge UK: BirdLife International (BirdLife Conservation Series No.7).

United Nations 2010. *The Millennium Development Goals Report 2010*. New York: United Nations.

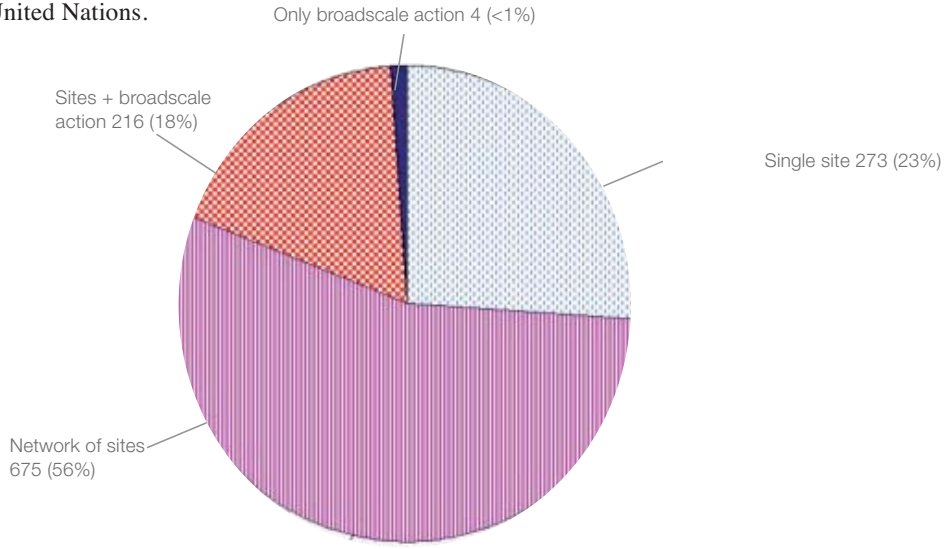

Fig1. Scale of action needed to conserve 1,203 globally threatened bird species.

Fig2. Global map of 10,431 Important Bird Areas identified and documented in the World Bird Database by January 2010.

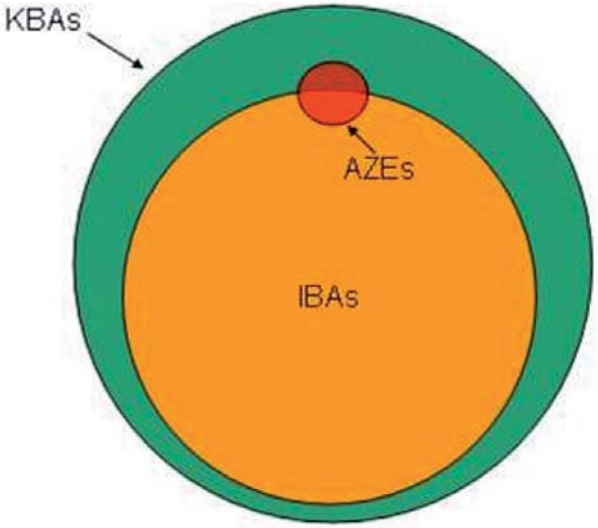

Fig3. The relationship between Important Bird Areas (IBAs), Key Biodiversity Areas (KBAs) and Alliance for Zero Extinction (AZE) sites (those holding the last population of an Endangered or Critically Endangered species: Ricketts et al. 2005).

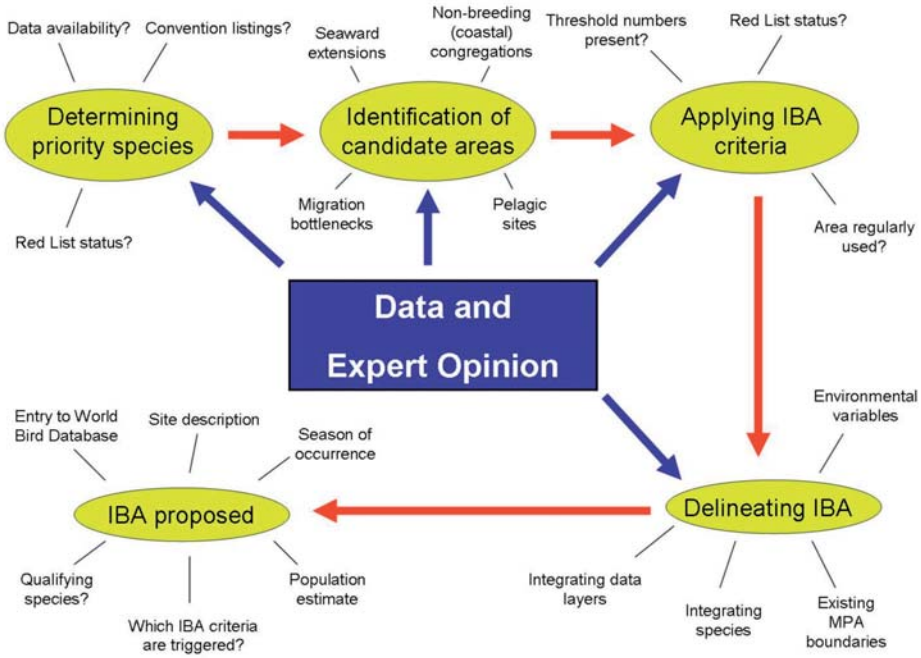

Fig4. Flow chart of the process for identifying marine Important Bird Areas.

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Important areas for freshwater biodiversity

While inland waters cover less than 1% of the world's surface (Gleick, 1996), they provide a home for 7% (126,000 species (Balian et al., 2008) of the estimated 1.8 million described species, including a quarter of the estimated 60,000 vertebrates. Inland water ecosystems not only provide habitat for the survival of their component species but also enable the storage and provision of clean water for human use. They also provide many important goods and services ranging from food and building materials, to water filtration, flood and erosion control, and are a critical resource for the livelihoods of many of the world's poorest communities (Millennium Ecosystem Assessment, 2005). For example, tropical rivers and inland fisheries have been valued globally at US$5.58 Bn per year (Neiland and Béné, 2008). The goods and services provided by the world's wetlands are valued at US$70 Bn per year (Schuyt and Brander 2004) – a figure equivalent to the GDP of some countries ranked in the top third of the world's economies (World Bank, 2008).

Despite the clear value of inland waters to people, both rich and poor, threats to these ecosystems and their component species are serious. Rapidly increasing human populations are putting ever-greater pressure on the goods and services supplied by freshwater ecosystems. The long-term survival of many wetland-dependant species is therefore becoming more precarious as wetlands are increasingly exploited for human use. In fact many authors rank freshwater ecosystems and the species they support as being the most threatened of all ecosystems worldwide.

Freshwater biodiversity is being threatened by a number of key impacts including overexploitation, water pollution, flow modification including water abstraction, destruction or degradation of habitat, and invasion by invasive alien species (Dudgeon et al., 2006; Millennium Ecosystem Assessment, 2005). Compounding these threats are the predicted global impacts of climate change leading to temperature changes and shifts in precipitation and runoff patterns (Dudgeon et al., 2006). Of these threats habitat loss and degradation is identified as one of the greatest impacts on freshwater species. It therefore follows that protection of these habitats through targeted site-based conservation efforts will be beneficial for many species. Historically, the bottleneck to this process has been the lack of readily available information on the conservation status and distributions of freshwater species at the site scale. Selection of important sites has therefore largely been based on the use of habitats as surrogates for freshwater species diversity. However, since 2005 IUCN has completed a number of comprehensive regional assessments of species in inland waters, where every described species from a taxonomic group, such as fishes, within a region has been assessed. This has enabled identification of those river or lake basins (the logical management units for freshwater systems) containing the highest levels of species richness, threatened species, restricted range species, migratory species and/or species important to the livelihoods of local communities. This information can now be used to help prioritize conservation efforts and to inform the development planning process so that impacts of development might be minimized or mitigated and development on critical sites for biodiversity may be avoided. A globally standardised approach was therefore required to identify those sites of most

importance for the conservation of global freshwater biodiversity at the site and landscape scales.

In response to this need, IUCN initiated a process in 2002 to develop the approach for identification of important sites for conservation of biodiversity in inland waters and convened a workshop to take the process forward. On the basis of a comprehensive review of those existing approaches already being implemented, the workshop output was the publication of a draft framework for the identification of important sites for conservation of freshwater biodiversity (Darwall and Vié, 2005). This framework is largely founded on the criteria employed to identify Important Bird Areas as developed by Birdlife International. A number of smaller workshops and data analyses were then conducted in an effort to refine the criteria towards use of quantitative thresholds. This paper outlines the progress made toward development of this approach for identification of what have now been termed freshwater KBAs.

The methodology, as described by Darwall and Vié (2005), can be broken down into seven steps (Table 1). Priority sites are selected primarily through assessments of species status and distributions, to reflect the focus and experience of IUCN's work on species assessments, but with full representation of habitats.

Table 1 – The seven step site prioritisation method

Step 1. Define the geographical boundaries within which to identify important sites.
Step 2. Define the wider ecological context of the designated assessment area.
Step 3. Identify and map the distribution of inland water habitat types.
Step 4. Catalogue the distribution and conservation status of priority aquatic taxa.
Step 5. Apply species-based selection criteria to identify sites.
Step 6. Ensure full representation of inland water habitats among those sites selected.
Step 7. Ensure inclusion of keystone species.

The species-based selection criteria used to identify important sites through Step 5 in Table 1 are based on the two principle measures of systematic conservation planning: *vulnerability* and '*irreplaceability*' (Langhammer et al., 2007) (Table 2). In the freshwater context we propose a KBA be defined as a river or lake sub-basin which could practically be managed as a single site. The size of these basins may range from small lakes to large river catchments. A sub-basin meets the vulnerability criterion for KBA status if it holds one or more globally-threatened species in any of the threat categories of Critically Endangered, Endangered, or Vulnerable, according to the IUCN Red List™. These species are considered as facing an extremely high, very high, or high risk of extinction in the wild, respectively. A site meets the 'irreplaceability' criterion for KBA status if it maintains a globally significant proportion of a species' total distribution range at some point in that species' lifecycle. This includes many species that have restricted ranges, highly clumped distributions within large ranges, congregate in large numbers, source populations on which significant proportions of the global population depend, or are restricted to particular biomes or bioregions. As data on freshwater species congregations are currently limited, in this study the 'irreplaceability' criterion is largely based on species of restricted range. A KBA can be identified under the vulnerability and the 'irreplaceability' criteria simultaneously; indeed many individual species trigger both the vulnerability and the 'irreplaceability' criteria. A KBA network defined according to the presence of species meeting the criteria would be expected to include all sites that play a crucial role in maintaining the global population of these species.

Table 2 – Summary of the site selection criteria

Criterion 1	A site is known or thought to hold a **significant number** of one or more globally threatened species or other species of conservation concern.
Criterion 2	A site is known or thought to hold **non-trivial numbers** of one or more species (or infraspecific taxa as appropriate) of restricted range.
Criterion 3	A site is known or thought to hold a significant component of the group of species that are confined to an appropriate **biogeographic unit**, or units.
Criterion 4	a) A site is known or thought to be critical for any life history stage of a species. b) A site is known or thought to hold more than a **threshold number** of individuals of a congregatory species.

Darwall and Vie (2005) concluded that, in order to apply these selection criteria, quantitative thresholds are needed for defining: a "restricted range" species, and the numbers and categories of threatened species required at a site to qualify it as important. A range of thresholds was applied to freshwater species datasets for Africa to evaluate the proportion of species captured and the land area which would be included. Preliminary results have indicated that suitable thresholds are sub-basins containing individuals of any threatened species and/or species with ranges of less than 1,000 km^2. For the trials conducted, these thresholds led to approximately 30% of all species and approximately 5% of the total land area within the assessment area being captured.

In 2009 IUCN and partners further defined the process for implementing the complete methodology. The implementation process is broken down into three distinct phases. Phase 1 involves the identification of those sub-basins which qualify as proposed KBAs according to the site selection criteria outlined above. Phase 2 requires a subsequent desktop study of the proposed KBAs to: conduct site boundary rationalisation in relation to the proximity to pre-existing protected or managed areas such as Important Bird Areas, national parks, Ramsar sites, or forest reserves, and to determine the relative suitability of site or landscape-based conservation. At this stage in the process it might be recommended that a KBA be proposed for site-based conservation actions in conjunction with catchment scale management actions to address more widespread threats operating at the catchment scale, such as invasive species or sedimentation. Finally, Phase 3 requires a stakeholder consultation leading to recommendations for an appropriate boundary delineation and management approach for the designated freshwater KBA. The freshwater KBA will then be taken forward to the relevant regional bodies for adoption at policy level and for aiding conservation advocacy for the site in question.

In conclusion, a process for the identification and validation of freshwater KBAs has been developed and trialled on species datasets newly available for all of continental Africa. The finalised species-based criteria and appropriate thresholds will be published shortly. The approach outlined in this paper provides an important addition to the toolbox for future conservation and management of biodiversity within inland waters.

References

Balian, E.V., Segers, H., Lévêque, C. and Martens, K. 2008. The freshwater animal diversity assessment: An overview of the results. *Hydrobiologia* 595: 627-637.

Darwall, W. and Vié, J.-C. 2005. Identifying important sites for conservation of freshwater biodiversity: Extending the species-based approach. *Fisheries Management and Ecology* 12: 287–293.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.-H., Soto, D., Stiassny, M.L.J. and Sullivan, C.A. 2006. Freshwater biodiversity: Importance, threats, status and conservation challenges. *Biological Review* 81: 163-182.

Gleick, P.H. 1996. Water resources. In: S.H. Schneider (ed.) *Encyclopaedia of Climate and Weather*, pp. 817-823. New York: Oxford University Press.

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., Silva, N. de., Edgar, G.J., Eken, G., Fishpool, L.D.C., Fonseca, G.A.B. da, Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A.. Salaman, P., Sechrest, W. and Tordoff, A.W. 2007. *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. Gland, Switzerland: IUCN.

Millennium Ecosystem Assessment 2005. *Ecosystems and Human Well-being: Wetlands and Water Synthesis*. Washington, D.C., USA: World Resources Institute.

Neiland, A.E. and Béné, C. (eds.) 2008. *Tropical River Fisheries Valuation: Background Papers to a Global Synthesis*. The WorldFish Center Studies and Reviews 1836, 290 pp. Penang, Malaysia: The WorldFish Center.

Schuyt, K. and Brander, L. 2004. *Living Waters Conserving the Source of Life – The economic value of the World's Wetlands*. Gland, Switzerland: WWF.

World Bank 2008. Gross domestic product 2007. *World Development Indicators database*. World Bank. Available at: http://siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf.

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The Brazilian Alliance for Zero Extinction: A frontline of defense against extinction by eliminating threats and restoring habitat to allow species populations to rebound

In order to improve the conservation status of species threatened with extinction in Brazil, the forum for the Brazilian Alliance for Zero Extinction (BAZE) was officially established by the Ministry of Environment, which announced the Federal Normative no. 182 of 22 May, 2006. BAZE is a Brazilian initiative composed of 40 governmental and non-governmental institutions, aimed at defining and implementing conservation strategies for species that are severely threatened with extinction. BAZE replicates at the national level the same goals as the global Alliance for Zero Extinction (AZE), which aims to identify the last remaining refuges of highly threatened species, and to suggest effective measures for sites protection.

Sites identified at the national level using the criteria established by the AZE, but using local datasets, can be extremely effective in identifying priority areas and opportunities when government agencies consider policy changes for the expansion of protected area systems. AZE criteria have been defined to be easily and consistently applied across all biogeographic regions and taxonomic groups. They are designed for application through a national, bottom-up, iterative process, led by national governments in collaboration with local stakeholders, to maximize the usefulness and the prospects for implementation of the resulting site priorities.

BAZE harmonizes rational global goals for reducing biodiversity loss, as endorsed by the heads of states and governments at the World Summit for Sustainable Development (WSSD) held in Johannesburg in 2002, and with the goal of protecting at least 10% of each eco-region up to 2010 as defined in the Global Strategy for Plant Conservation. Moreover, it will also provide for important contributions to the recommendations arising from the Fifth World Parks Congress (IUCN, Durban, South Africa, 2003). Additionally, the Potsdam Initiative 2010 states: “Focusing all our efforts on the achievement of the 2010 target of significantly reducing the loss of biodiversity in the coming years, we acknowledge the urgent need to halt human induced extinction of biodiversity as soon as possible.” Finally, it is hoped that the efforts of national alliances such as BAZE will be very useful in informing the development of the post-2010 targets of the Convention on Biological Diversity (CBD), and related indicators.

The Specific Goals of BAZE are to join technical, scientific, financial and political skills from governmental and non-governmental organizations, including international organizations; to conserve and recover the species listed in the Official List of Threatened Brazilian Fauna and Flora; and to align with the Brazilian Constitution, the CBD, the Millennium Development Goals and the Potsdam Initiative 2010.

BAZE opearates as follows. The Alliance’s public or private partners must align their programmes with the established goals, committing to incorporate them into their actions, which will allow the definition of clear targets, and efficient use of time and resources. Each partner will contribute according to their capacity and expertise to guide the programmes of national funding agencies. Research funding institutions which are already associated with BAZE should direct resources,

if only partially, to meet the goals proposed by BAZE. All BAZE member institutions are financially independent and it is expected that they will direct their projects to meet BAZE goals, as would all projects developed with resources raised by the Alliance. The Coordination Committee must make efforts to raise and direct funds to field research, land acquisition, construction of research infrastructure, surveillance and scientific publications. Additional resources may be directed to any partner, according to their technical and executive capacity, to work on the conservation of the focal area, species or product. BAZE member may pursue fundraising opportunities with private donors.

The Advantages of AZE Criteria and National Alliances include the participation of governments in national alliances which raises the chances of success for site conservation. Having numerous organizations working toward the same goal raises the chances of conserving these species. The general public understands the significance of extinction and that conservation of these sites is required in order to avoid extinction. This is a powerful message. National alliances receive support from the global AZE, which helps in attempting to seek funding for site conservation.

BAZE Sites

The starting point for BAZE implementation was to identify and map the highest priority sites for the conservation of threatened Brazilian species. Currently, there are 197 species of vertebrates threatened with extinction in Brazil, classified as "Critically Endangered" or "Endangered", according to IUCN criteria.

The identification and mapping of the sites integrated two broadly-accepted methodologies, using criteria adopted by AZE for site identification at the global scale (endangerment, irreplaceability, and discreteness) and the site delimitation criteria proposed in the Key Biodiversity Areas (Lanhammer et al., 2007).

The mapping work was based on the following sources:

- National Red Book of Threatened Fauna (Machado et al., 2008)
- Vegetation Cover of Brazilian Biomass (MMA 2006) to identify remaining vegetation, and land use categories
- Brazilian Geographical and Statistical Institute (IBGE, 2003) cartographic base maps to define municipal limits, infrastructure and topography
- National Water Agency (ANA, 2008) hydrographic base maps
- Federal and state protected area base maps (MMA, 2002).

The base maps were then compared to satellite images (MMA, 2002) in order to evaluate the human impact on vegetation and soil.

There were 36 trigger species identified, distributed in 32 sites. The Atlantic Forest and the Cerrado, both Brazilian hotspots, have the highest concentration of BAZE priority sites, with 16 sites in the Atlantic Forest and eight in the Cerrado, followed by four in the Caatinga, and two in the Amazon and Pampas, respectively. Of all BAZE priority sites, 19 have no protection, eight are partially protected and only five are protected by Integral Protection Conservation Units.

BAZE sites

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With mapping complete, the next steps for BAZE are the following:

- create conservation units for trigger species which are not yet represented in the current protected areas network
- implement improved management of existing protected areas and ecological relevant areas where trigger species occur
- elaborate management plans and conservation policies for BAZE sites
- support programmes and/or institutions designed to conserve and restore BAZE trigger species
- enhance the awareness of local communities regarding the importance of BAZE trigger species and their habitats
- consolidate support groups for the conservation and management of BAZE trigger species and habitats; and, ultimately
- improve the conservation status of BAZE trigger species.

BAZE urges other governments to establish similar national alliances for zero extinction with the intention to boldly take actions to halt biodiversity loss. Through effective collaboration between national conservation organizations and governments, national alliances can efficiently pinpoint and safeguard those sites and species in most imminent danger of extinction.

References

ANA, 2008. *Biblioteca Virtual. Base de Dados de Georeferenciamento*. Agência Nacional de Águas. Ministério do Meio Ambiente. http://www.ana.gov.br/bibliotecavirtual/solicitacaoBasedeDados.asp. (Acessed on 15.02.2008).

IUCN ,2009. *IUCN Red List of Threatened Species*. http://www.iucnredlist.org.

IBGE, 2003. *Base Cartográfica Integrada do Brasil ao Milionésimo Digital – bCIMd. Versão 1.0*. Rio de Janeiro: Fundação Instituto Brasileiro de Geografia e Estatística. http://www2.ibge.gov.br/pub/Cartas_e_Mapas. (Acessed on 02.06.2007).

Langhammer, P. F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., Silva, N. de, Edgar, G.J., Eken, G., Fishpool, L.D.C., Fonseca, G.A.B. da, Foster, M.N., Knox D.H., Matiku P., Radford E.A., Rodrigues A.S.L., Salaman P., Sechrest W. and Tordoff, A.W. 2007. *Identification and Gap Analysis of KeyBiodiversity Areas: Targets for Comprehensive Protected Area Systems*. Gland, Switzerland: IUCN.

Machado, A.B.M, Drummond, G.M. and Paglia, A.P. 2008. *Livro Vermelho da Fauna Brasileira Ameaçada de Extinção* – 1.ed. Brasília, D.F.: MMA, Belo Horizonte: Fundação Biodiversitas.

MMA, 2002. *Imagens de Satélite*. Brasília, D.F.: Ministério do Meio Ambiente, . http:// mapas.mma.gov.br/mapas/mma/imagenssat/.

MMA, 2002b. *Biodiversidade Brasileira: Avaliação e Identificação de Áreas e Ações Prioritárias para Conservação, Utilização Sustentável e Repartição dos Benefícios da Biodiversidade nos Biomas Brasileiros*. Brasília, D.F.: Ministério do Meio Ambiente. (Série Biodiversidade, v. 5).

MMA, 2006. *Mapas de Cobertura Vegetal dos Biomas Brasileiros*. Brasília, D.F.: Ministério do Meio Ambiente. http:// mapas.mma.gov.br/ mapas/ aplic/probio/datadownload.

Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffmann, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S.L., Sechrest, W., Wallace, G.E., Berlin, K., Bielby, J., Burgess, N.D., Church, D.R., Cox, N., Knox, D., Loucks, C., Luck, G.W., Master, L.L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G.E., Shire, G., Strand, H., Wettengel, W. and Wikramanayake, E. 2005. Pinpointing and preventing imminent extinctions. *PNAS* 102 (51):18497-18501.

Silva, P.K.E. 2008. *Identificação e Mapeamento dos Sítios Prioritários para Conservação das Espécies de Vertebrados Ameaçados de Extinção no Âmbito da Aliança Brasileira Para Extinção Zero (BAZE)*. Unpublished Masters Thesis. Department of Ecology, Conservation and Wildlife Management. Federal University of Minas Gerais. Belo Horizonte, MG, Brasil.

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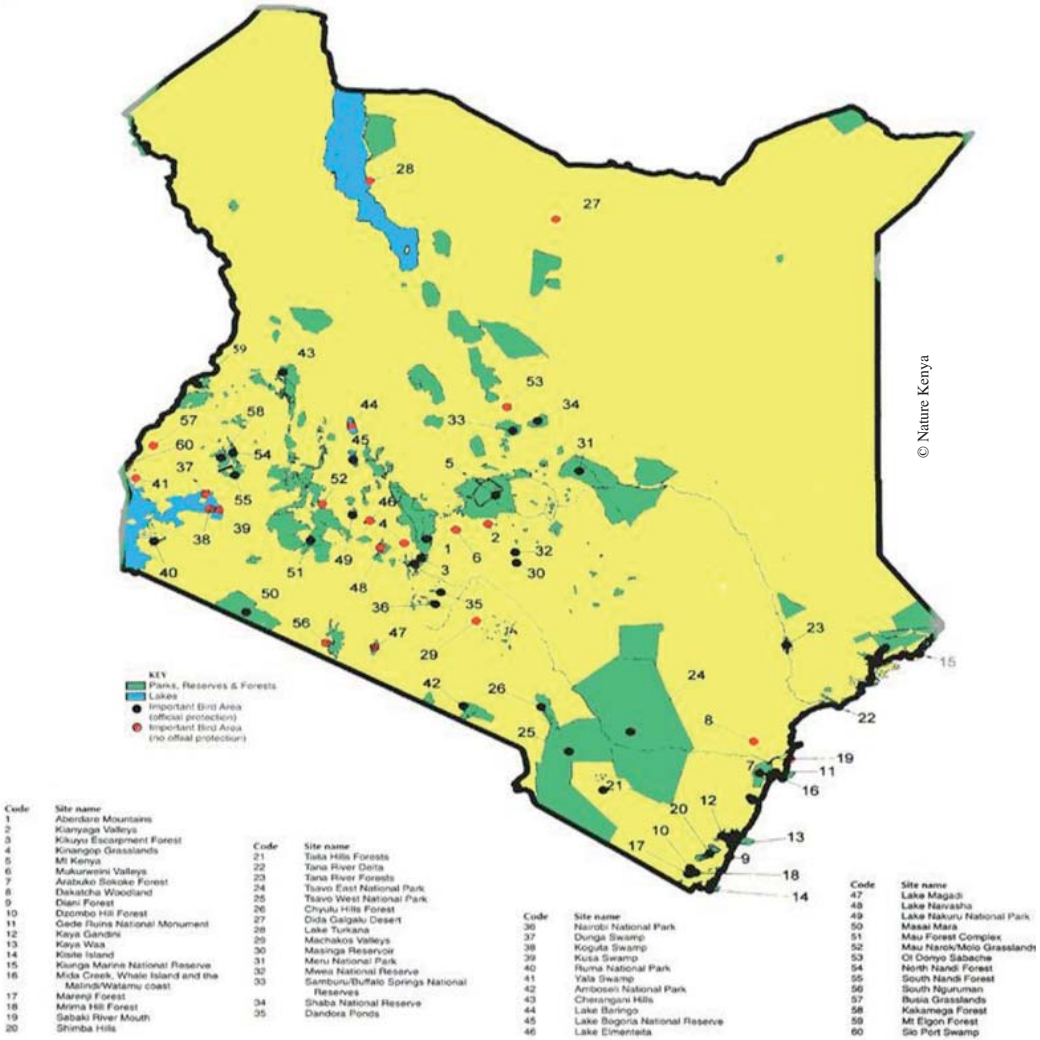
National action, advocacy and monitoring for Important Bird Areas in Kenya

Introduction

Important Bird Areas (IBAs) are sites of global importance for the conservation of birds and other biodiversity at global, regional and national level. IBAs are identified using internationally-agreed, objective, quantitative and scientifically-defensible criteria. Sites qualify as IBAs if they hold: 1) globally threatened bird species, 2) birds with restricted distribution, 3) birds characteristic of a particular biome, or 4) large numbers or congregations of bird species (Bennun and Njoroge 1999).

Additional research and analyses have shown that IBAs are also Key Biodiversity Areas (KBAs) (Eken et al. 2005). Outstanding examples include the Eastern Arc and Coastal Forests of Kenya and Tanzania where analyses show that out of the 160 sites critical for conserving the 333 globally threatened species, 23 out of the 25 most important sites are IBAs (see ecosystem profile on www.cepf.net).

The IBAs programme for Kenya, co-ordinated by Nature Kenya in collaboration with the National Museums of Kenya published the Important Bird Areas Directory in 1999. The Directory lists a total of 60 IBAs, and five potential sites as priorities for biodiversity action in Kenya. These IBAs represent 10% of the country's land area, covering almost all major ecosystems and take into account the full network of Kenya's protected areas (Bennun and Njoroge, 1999). The IBAs process adds value to the protected areas network by bringing on board new sites within private land as sites that are of critical importance for biodiversity conservation.



IBAs cover all the key habitats types for Kenya: 22 Forests (20 of them protected areas); 18 wetlands (only five are protected); 12 semi-arid and arid areas (seven are protected); six moist grasslands (three are protected); and two unprotected sites whose habitats cut-across the broad cross-sections of habitat categories. Of the 60 sites, 46 IBAs shelter globally threatened bird species, 29 are home to range-restricted birds, 32 contain biome-restricted bird species, and 13 hold congregations of birds (Bennun and Njoroge 1999).

Safeguarding IBAs in Kenya

There is more to the IBA process than compilation of information that led to identification of these sites. Immense threats and conservation barriers continue to jeopardize the existence of IBAs:

- Threatened biodiversity inside IBAs is still not protected: two out of 20 forest IBAs not protected; five out of 18 wetland IBAs not protected; five out of 12 semi-arid and arid areas IBAs not protected; three out of six moist grasslands not protected; and there are two unprotected sites whose habitats cut-across the broad cross-sections of habitat categories.
- Policy failures: in Kenya protection status for a site does not always mean that the biodiversity is effectively protected mainly due to policy and legislative implementation failures owing either to lack of capacity, resources or, sometimes, lack of political will.
- Local people and protected areas conflicts: like as elsewhere in Africa, Kenya's protected areas were established without wide consultations with indigenous local communities. As such, protected areas are perceived to be a violation of local community rights and a source of poverty as a result of problem animals or denied resources for local community economic development. The protected area costs are largely borne by neighbouring communities, whereas the benefits are universally shared, demonstrating unfairness and lack of equity in cost and benefit sharing.
- Serious habitat loss: the quest to feed people, satisfy energy needs, improve housing quality and standards, ensure good health and generally enhance economic development locally and nationally has put more pressure on protected areas leading to loss of wildlife habitats.
- Inadequate public participation: protected areas were largely established by colonial governments because they were good for photography or game hunting or because they contained valuable timber. The protected areas' services were not linked to the livelihoods of the local people and as such, protected areas were seen as government lands unfairly taken away from people. Wildlife protection was largely incidental but today it has become the core function of protected areas, yet the local people think wildlife protection is largely a duty of the government.
- Inadequate capacities: wildlife protection agencies have tried to protect biodiversity over the past century but clearly the continued loss of habitats is an indicator of protection failures. The key issues here are: inadequate government capacity; protected areas too large for government to ensure sufficient surveillance on their own; and lack of local institutions that sympathize with wildlife (where these exist they do not have adequate capacity to protect wildlife).
- Poverty: local communities continue to live on under one dollar per day, with the protected areas becoming the reservoir for supplementing income.
- Development is pulling in the opposite direction: the good development we all want is a major threat to protected areas or threatened species outside formal protected areas. The lack of visionary planning that safeguards and takes into account sustainable living is the main barrier.

Safeguarding IBAs and KBAs

To ensure IBA site conservation in perpetuity, Nature Kenya, the National Museums of Kenya and other key stakeholders and partners initiated a suite of actions:

1. Developed and implemented a biodiversity monitoring framework to understand changes and provide feedback to conservation and policy mechanisms (Bennun et al., 2005)
2. Mobilised government, non-government agencies and local communities to implement the national monitoring framework to collect, store, analyse and disseminate data and information to key stakeholders and decision-makers
3. Developed and implemented a suite of site-based conservation interventions and programmes by and for local communities for sustained action
4. Developed and implemented actions that integrate and mainstream monitoring and general site action into wider national environmental policy and legislation
5. Surveyed poorly known sites to promote better understanding and add new IBAs.

To elaborate further, Nature Kenya has mobilized resources and partnerships and implemented site specific activities in the following areas.

Empower local communities to take action: Nature Kenya has established local community structures called Site Support Groups (SSGs). SSGs are site champions, nuclei of community change, and are sustainable institutions as well as serving as educators, advocates, and monitors of biodiversity. To the extent that conservation actions are successful, SSGs provide ongoing local community capacity to continue working with government and the wider local community to protect IBAs for present and future generations. To ensure that SSGs are empowered to take action, Nature Kenya has systematically implemented site-based initiatives that aim to ensure that SSGs have the skills and tools to champion site conservation. Key SSG capacity-building areas include: building SSG institutional and technical capacity, making biodiversity relevant to SSGs, linking SSGs to government, initiating conservation incentives, and promoting SSG lessons sharing.

The work of SSGs does not end with their establishment and training. SSGs in Kenya are involved in tangible conservation initiatives as the caretakers of biodiversity in the IBAs they champion. Some specific actions include:

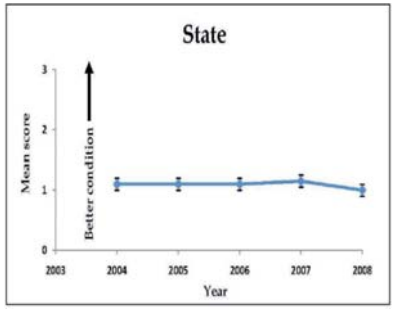
- promoting ownership and local partnerships with government and the wider community to move away from illegal activities to joint planning
- working with provincial administration to curb illegal activities and restore habitats
- lobbying government to recognize IBAs and make sound decisions for their protection
- raising public awareness and carrying out environmental education targeting school children and the general public
- monitoring IBAs and reporting to Nature Kenya and the National Museums of Kenya

Promote sustainable benefits and incentives: Local people around IBAs are generally poor, infrequently involved in the sharing of revenues accruing from IBAs and lack resources to sustain conservation actions. To ensure that SSGs and the rest of the local communities are enthused and that they also receive resources to sustain basic conservation actions, Nature Kenya develops a suite of income generating activities (IGAs). These include beekeeping, butterfly farming, mushroom farming, ecotourism; bird guide freelancing, aloe farming, tree seedlings for business and forest restoration, and energy-saving technologies (e.g. solar cookers and food warmers). After the businesses are set up, Nature Kenya builds the entrepreneurial capacity for the business owners by offering training in a variety of technical business areas including product value chain analysis, business planning, marketing and value adding. To ensure sustainable financing for SSGs' basic activities, especially education and monitoring, Nature Kenya facilitates the establishment of conservation-financing mechanisms managed by the SSGs. These mechanisms are based on a minimal levy, charged for the products produced and marketed and incomes earned to ensure that the IGAs help to finance conservation initiatives and SSGs are kept on track within their core conservation objectives. However, the conservation financing at the SSG level is largely a work in progress initiated over the past year and has potential for becoming a major source of finance for future conservation activities.

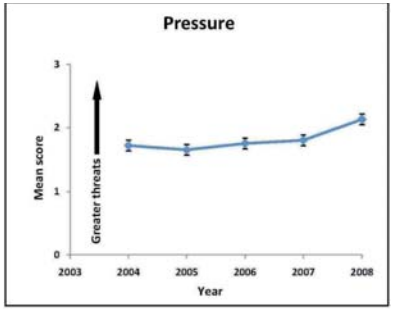
Advocate for KBAs protection: To ensure that the government is kept in check, Nature Kenya and SSGs are engaged in routine strategic advocacy work to mainstream IBAs into government planning and decision-making. The advocacy work includes: passage of appropriate policies and implementation; joint IBA/KBA management and national recognition; expansion of PA networks; sustainable development initiatives such as those for the Tana Delta and Lake Natron; sound climate change mitigation measures; NGO-government-local community partnerships; and adherence to international obligations and sustainable IBA monitoring.

Monitor and report state, pressure and responses: The focus here is on the IBAs conservation status based on routine monitoring coordinated by Nature Kenya and the National Museums of Kenya. To facilitate conceptual uniformity, Nature Kenya developed a monitoring framework owned by an established national liaison committee composed of 24 government and non-government agencies that work to ensure sustainable partnerships for IBA conservation,

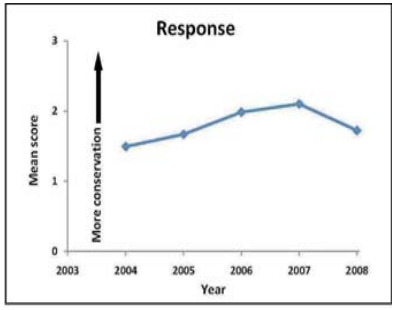
monitoring and reporting. The IBA monitoring aims to track state, pressure and response, assess the impact of conservation interventions, determine how IBAs continue to meet their conservation objectives, enable timely detection of threats and their impacts on biodiversity, and influence policy and management decisions. The monitoring data is collected at two levels: basic monitoring, mainly by government managers at each site, and detailed monitoring, mainly by trained SSGs at a subset of sites where baseline data for some well-studied species and habitats exist. The findings of the monitoring work are represented using the State-Pressure-Response approach on which the IBA monitoring framework is based, as summarized below.



State: A slight deterioration was observed in the state of the IBAs from a 1.13 mean score in 2007 down to 1.0 for the year 2008. Dispersal and migratory areas for wildlife have been encroached on, blocking free wildlife movement into/out of parks such as Aberdares National Park and Amboseli National Park. The percentage of moderate deterioration for all IBAs increased from 7% in 2007 to 33% in 2008. The percentage of small improvements for all IBAs reduced from 28% in 2007 to only 10% in 2008. A possible contributor to the decline in the state of habitat for 2008 could have been due to the wanton destruction of forests and farmlands during the post election upheavals (Adthola et al., 2009; Ng'weno et al., 2004).



Pressure: There was a net increase in the threats reported for 2008 in comparison to 2007. The highest threats recorded in all IBAs for 2008 include human settlement and urbanization, uncontrolled firewood collection, agricultural encroachment and illegal cultivation, illegal logging and vegetation destruction, overgrazing and illegal grazing which were threats to at least 66% of the IBAs. Pressure still continues to mount in the IBAs. Human population is high and increasing rapidly around most forest IBAs (e.g. Mau Complex, Cherangani Hills, Kikuyu Escarpment Forests); this continues to exert pressure on forest resources as the demand for fuel wood, building poles and other forest products increases (Adthola et al., 2009; Ng'weno et al., 2004).



Response: Conservation responses in IBAs also took a slight dip in 2008. This was understandable as upheavals in the political scene may have precluded many conservation efforts (Adthola et al., 2009; Ng'weno et al., 2004).

Communicating the monitoring results

IBA monitoring results are published in the form of a book and distributed to site managers, SSGs, national government offices, the media and relevant private sector agencies.

Enhanced recognition and protection: This state-of-the-art work by Nature Kenya, in partnership with other government and non-government agencies and SSGs, has generated some results within the policy and legislative arena in Kenya. There are visible NGO-government partnerships for sustainable IBA actions such as IBA monitoring; there is wider government recognition of IBAs such as Mau Forest complex in national development planning and decision-making; monitoring data are used to enhance the international recognition of IBAs and protection as in the case of Rift Valley Lakes listing under UNESCO's World Heritage conservation recognition and Tana Delta Ramsar listing; and the initiation of community conservation areas in some unprotected wetland IBAs.

Enhanced Management effectiveness: The Kenyan Government conservation agencies have led management planning processes for a variety of IBAs.

Stimulated policy and legislative reviews: The government has, over the last ten years, *inter alia*: agreed on the Environmental Management and Coordination Act and new Forest Act (2005); drafted a wetlands policy and an environment policy for Kenya; revised the Wildlife Act; developed an energy policy; and initiated development of a bio-energy policy for Kenya.

Enhanced joint actions: Over the past 15 years, the Kenyan Government has been very suspicious of NGO operations and collaboration between NGOs and the government has rarely produced lasting results. Today, the Kenyan Government has revised policies and legis-

lative frameworks, and NGOs are included in a number of government institutional boards of management, action groups and committees tasked to develop strategies or advise the government including the Mau Forest Taskforce. The IBA National Liaison Committee has continued to be operational with government support and SSGs are now fully recognized as conservation partners at the sites they operate. In 2009, Nature Kenya partnered with four government agencies and submitted a five million dollar programme to the GEF, which has since been approved for funding. No doubt, Nature Kenya will continue to use this project to strengthen NGO-government partnerships to ensure sustainable joint conservation actions for IBA conservation.

Lessons learned

Amongst the lessons learned from this IBA exercise we can enumerate the following:

- site prioritization is an invaluable tool for biodiversity protection
- joint NGO-government joint actions and partnerships are critical
- local community involvement is equal to the success of the conservation effort
- monitoring and reporting influences policy decisions and site management
- science always needs to be simplified for local people and site managers
- resource barriers must be offset if biodiversity is to have a chance
- ecosystem services are widely recognized but survival needs today reduces concern for the future
- poverty must be tackled alongside other actions or all biodiversity will be lost; and
- the problem is not lack of awareness but lack of resources

What remaining challenges do we face?

These include inadequate national and local capacity to implement policy; the scant technical capacity of local people; lack of political will as evident in budgetary allocations; climate change and inadequate capacity to maximize opportunities; the tension between development and conservation objectives; inadequate institutional frameworks and linkages; and poverty.

References

Adthola, T., Ng'weno, F., Matiku, P., Mulwa, R., Ngari, A., Barasa, F., Madindou, I., Wanyiri, M., Mwan'gombe, J., Musyoki, C., Ndonye, P., Ogoma, M., Mchekele, J., and Musila, S. 2009. *Kenya's Important Bird Areas: Status and Trends 2008*. Nairobi: Nature Kenya.

Bennun, L. and Njoroge, P. 1999. *Important Bird Areas in Kenya*. Nairobi: Nature Kenya.

Bennun, L., Matiku, P., Mulwa, R., Mwangi, S. and Buckley, P. 2005. Monitoring Important Bird Areas in Africa: Towards a sustainable and scaleable system. *Biodiversity and Conservation* 14: 2575-2590.

Eken, G., Bennun, L., Brooks, T.M., Darwall, W., Fishpool, L.D.C., Foster, M., Knox, D., Langhammer, P., Matiku, P., Radford, E., Salaman, P., Sechrest, W., Smith, M.L., Spector, S. and Tordoff, A. Key biodiversity areas as site conservation targets. *BioScience* 54: 1110-1118.

Ng'weno, F., Otieno, N. and Matiku P. (eds.) 2004. *Kenya's Important Bird Areas: Status and Trends 2004*. Nairobi: Nature Kenya.

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A biogeographical approach to protected areas in Europe: The Natura 2000 Network

With almost 26,000 sites, ranging from the ocean depths to the summit of the European Union's (EU) highest mountain and covering 18% of the EU's land area, Natura 2000 is probably the world's largest network of protected areas (Figure 1). The sites are designated following criteria given in the 1979 Directive on Wild Birds and the 1992 Directive on Flora, Fauna and Habitats. Both Directives also define the level of protection required.

The 1979 Directive on the conservation of wild birds protects all wild birds in the EU and was adopted at a time when the then European Economic Community had no formal competence for environmental issues but it was agreed unanimously by the then nine member states that the conservation of birds was a transfrontier responsibility requiring coordinated action (Jordan, 2005). The Directive requires the member states to designate sites, known as Special Protection Areas (SPA), for a list of species considered rare and/or threatened given in Annex I of the Directive (currently 192 species) together with sites which are important for migratory species.

Progress in designating sites was slow at first and many countries were subjected to legal proceedings for lack of progress in designating sites, but by the end of 2009 there were 5,242 sites, covering 574,819 km^2. As sites designated under the Ramsar Convention on Wetlands of International Importance also target sites which are important for migratory birds, it is no surprise that many SPAs are also Ramsar sites. The effectiveness of the SPA network in protecting targeted species has recently been shown (Donald et al., 2007), whilst unpublished work by the European Topic Centre on Biological Diversity (ETC-BD) suggests that changes in landuse in SPAs during the 1990s were less than in the wider countryside.

The 1992 Directive on the conservation of natural habitats and of wild fauna and flora, more usually known as the Habitats Directive, was envisaged as an EU level response to the Council of Europe's 1979 Bern Convention on the Conservation of European Wildlife and Natural Habitats (the EU is a signatory, as are all its member states). However, while the Bern Convention originally was focused on species protection, the Habitats Directive also protects selected habitats and requires the designation of protected areas known as Special Areas of Conservation (SAC). These must be designated for habitats which are considered rare, threatened or typical of a biogeographical region of Europe (see below) and for species considered endangered, vulnerable, rare or endemic and requiring particular attention. These habitats and species are listed in Annexes I and II of the Directive and these have been amended to include additional habitats and species each time the EU has been enlarged.

The habitats include both marine and terrestrial, and natural and semi-natural habitats. The later are particularly important in Europe as there are few areas unaffected by man and many habitats which are important for biodiversity are part of cultural landscapes which result from long periods of management, in some cases several centuries (Emanuelsson, 2009). This includes many of Europe's species-rich grasslands, together with other important habitats such as heaths. The majority of Annex I habitats correspond to plant communities, with almost two-thirds clearly referable

to a phytosociological taxon or plant assembly. However, there is a wide range of variability, with some habitats corresponding to a single plant association while others are defined at the level of a class. As well as plant communities there are some habitats which are landscape units, such as estuaries, or geophysical, such as glaciers and limestone pavements. There are relatively few marine habitats but they include very broad habitats such as 'reefs' which encompass as much variation as several terrestrial habitats combined. Although the 231 habitats are defined in a handbook published by the European Commission (European Commission, 2007) the definitions are usually quite short, only available in English and have to cover much variation, so many EU member states have published their own handbooks (e.g. Bensettiti, 2001-2005; Ssymank et al., 1998) or have published a correspondence with their own national habitat classifications (e.g. Chytry et al., 2001; Donita et al., 2005). The habitats, including problems with interpretation, are discussed by Evans (2006).

There are 811 taxa listed in Annex II, mostly species, but also some genera such as Eudontomyzon and Alosa (both fish) and sub-species which results in 911 species and sub-species. The species are mammals, fish, amphibians, reptiles, invertebrates and plants. Some species, although rare and/or threatened, are widespread and occur in many Member States whilst others, particularly plants, are endemics, including several which are only known from single sites such as the plant *Odontites granatensis* which is only found at one site in the Sierra de Nevada, Spain.

The 1992 Habitats Directive was the first EU legislation to introduce the concept of biogeographical regions. There are currently nine regions which are based on maps of potential natural vegetation (Bohn et al., 2004) but adjusted to fit political and administrative boundaries (Roekaerts, 2002) as shown in Figure 2. More recently, five marine regions have also been used, based on the European marine conventions, but these have no legal basis. Although the regions have been modified to make them easier to use administratively, they still form ecologically coherent units of similar environmental conditions as can be seen by comparing the biogeographical regions map with environmental classifications of Europe (e.g. Ozenda and Borel, 2000; Metzger et al., 2005).

The biogeographical regions have been used both for assessing the network of SACs during a series of seminars and for reporting on the conservation status of the habitats and species protected by the directive as required every six years (*see* http://biodiversity.eionet.europa.eu/article17 *for further information*).

The member state site proposals have been assessed at a series of regional seminars which involve the member states, NGOs and independent scientists together with the European Commission and the ETC-BD. As a result of these meetings all member states have been asked to propose additional sites, or extend existing sites, to better protect certain habitats and species. Possibly due to the slow implementation of the Birds Directive, the Habitats Directive includes a timetable for identifying and designating sites and although this has not been respected completely, progress in site designation has been much faster, and by the end of 2009 there were 22,419 sites covering 716,992 km^2. The terrestrial part of the SAC network, which covers 13% of the EU's land area, is considered to be close to completion (EEA, 2009) but the marine part of the network is far from complete, covering less than 3% of the EU's marine area, most of which is in inshore waters, with relatively few sites in offshore waters.

EU directives set targets and obligations, leaving the methods to the individual member states, which results in a range of approaches to the selection and management of sites. Thus some countries, such as Spain, tend to have few, large sites and others, for example Germany, favour very many small sites. Although Natura 2000 is a network of protected areas, both Directives also protect species in the wider countryside and the Habitats Directive refers to the need for landuse planning, with mention of ecological corridors and stepping stones.[5]

References

Bensettiti, F. (ed.) 2001-2005 *Cahiers d'habitats Natura 2000 – Connaissance et gestion des habitats et des espèces d'intérêt communautaire* (7 volumes). Paris: La documentation française.

Bohn, U., Gollub, G. and Hettwer, C. (2000) *Karte der natürlichen Vegetation Europas. Massstab 1:2.500.000 Karten und Legende*. Bonn: Bundesamt für Naturschutz.

5. For further information see http://biodiversity.eionet.europa.eu/activities/Natura_2000 and http://ec.europa.eu/environment/nature/index_en.htm.

Fig.1 – The Natura 2000 network in January 2010.

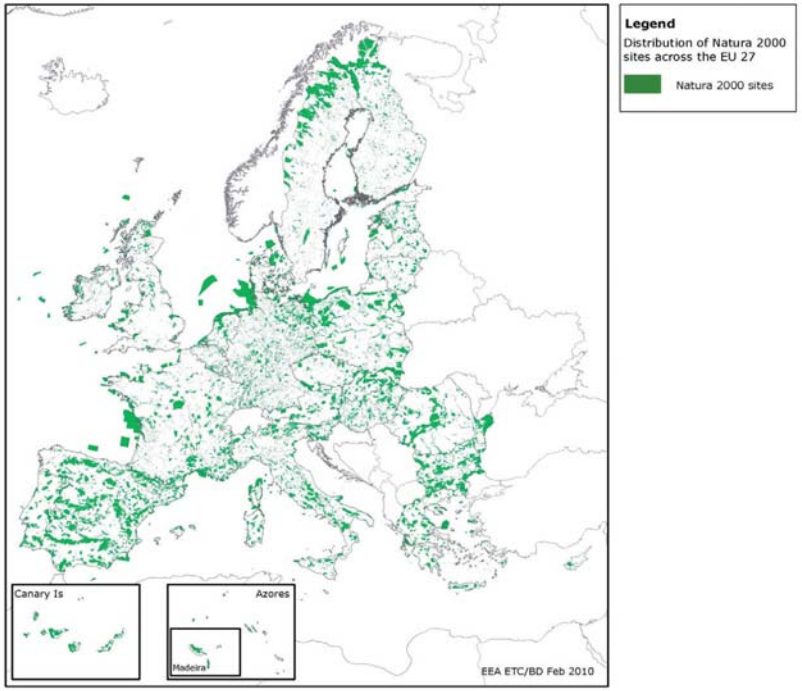
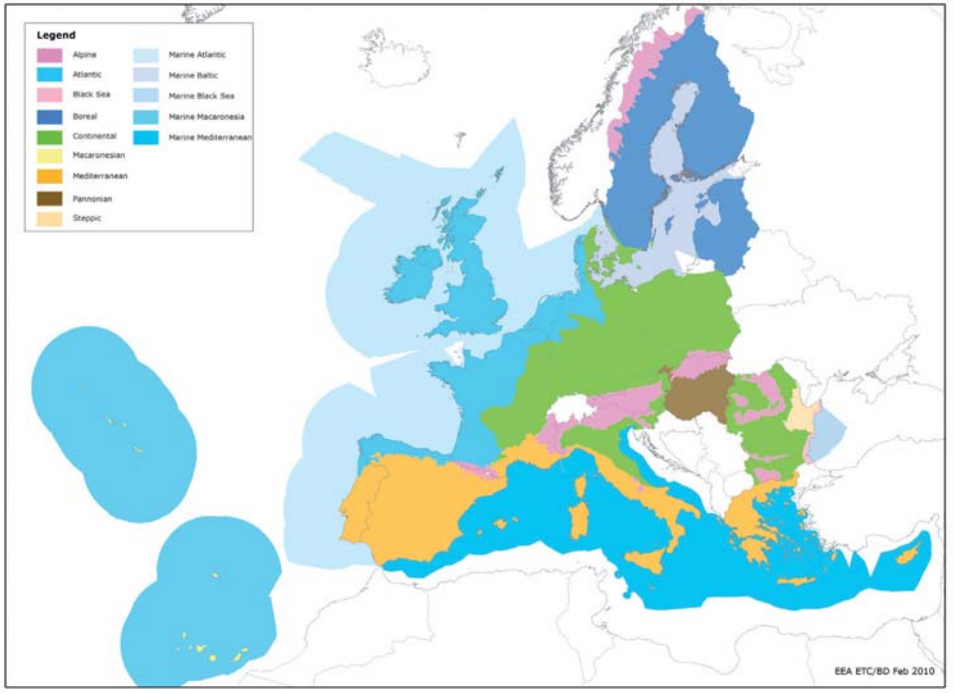


Fig.2 – The biogeographical and marine regions of the European Union.



Chytry, M., Kuãera, T. and Koãí M. (eds.) 2001. *Katalog biotopu Ceské republiky*. Prague: Agentura ochrany pfiírody a krajiny Czech.

Donald, P.F., Sanderson, F.J., Burfield, I.J., Bierman, S.M., Gregory, R.D. and Waliczky, Z. 2007. International conservation policy delivers benefits for birds in Europe. *Science* 317(5839): 810-3.

Donita, N., Popescu, A., Pauca-Comanescu, M., Mihailescu, S. and Biris, I.A. 2005. *Habitatele din România*. Bucharest: Editura Tehnica Silvica.

Emanuelsson, U. 2009. *The rural landscapes of Europe – How Man has Shaped European Nature*. Stockholm: Forskningsrådet Formas.

European Environment Agency. 2009. *Progress towards the European 2010 Biodiversity Target*. Copenhagen: EEA Report No. 4/2009.

European Commission, 2007. *Interpretation Manual of European Union Habitats – EUR 27*. Brussels: DG Environment – Nature and Biodiversity. http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/2007_07_im.pdf.

Evans, D. 2006 The Habitats of the European Union Habitats Directive. *Biology & Environment: Proceedings of the Royal Irish Academy* 106(3):167-173.

Evans, D. (*in press*). Interpreting the habitats of Annex I – Past, present and future. *Acta Botanica Gallica*.

Jordan, A. (ed.) 2005. *Environmental Policy in the European Union*. 2nd ed. London: Earthscan Ltd.

Metzger, M.J., Bunce, R.G.H., Jongman, R.H.G,. Mücher, C.A and Watkins, J.W. 2005. A climatic stratification of the environment of Europe. *Global Ecology and Biogeography* 14 (6): 549–563.

Ozenda, P. and Borel, J-L. 2000. An ecological map of Europe: Why and how? *Comptes Rendus de l'Académie des Sciences, Series III – Sciences de la Vie* 323, no. 11: 983-994.

Roekaerts, M. 2002 *The Biogeographical Regions Map of Europe – Basic principles of its creation and overview of its development*. http://dataservice.eea.europa.eu/download.asp?id=5234&filetype=.pdf

Ssymank, A., Hauke, U., Ruckriem, C. and Schroder, E. 1998. *Das europaische Schutzgebietssystem Natura 2000. BfN-Handbuch zur Umsetzung der Fauna-Flora-Habitat-Richtlinie und der Vogelschutz-Richtlinie*. Bonn – Bad Godesberg: Schriftenreihe fur Landschaftspflege und Naturschutz, 53.

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Site-scale investment priorities: The example of the Caucasus

The Caucasus is among the planet's 34 most diverse and endangered hotspots identified by Conservation International (CI), and one of World Wide Fund for Nature's (WWF) Global 200 Ecoregions, identified as globally outstanding for biodiversity. More than 150 experts from six Caucasian countries identified key biodiversity areas (KBAs) and corridors for the Caucasus Hotspot (Ecosystem Profile, 2004). As a result, 205 KBAs were identified in the Caucasus, as well as 10 conservation corridors. The identified KBAs and corridors serve as the basis for setting site-scale targets and investment priorities in Armenia. The following site-scale targets and investment priorities were set up: awareness-raising among key stakeholders; development of alternative livelihoods for communities; enforcement of existing protected areas; enforcement of biodiversity protection in the corridors; and establishment of new protected areas in the KBAs.

Implementation of site-scale conservation, communication and alternative livelihood projects in partnership with the state agencies, communities, NGOs, and mass-media resulted in the enforcement of biodiversity protection in the southern corridor, strengthening of existing protected areas and the establishment of two new protected areas in the KBA in southern Armenia (Arevik National Park, 34,402 ha and Zangezur Sanctuary, 17,368 ha covering 1.7% of Armenia's territory).

Site-scale investment priorities: The example of the Caucasus

The Caucasus hotspot, historically interpreted as the isthmus between the Black and Caspian Seas, covers a total area of 580,000 km^2, including the nations of Armenia, Azerbaijan and Georgia, the North Caucasus portion of the Russian Federation, north-eastern Turkey and part of north-western Iran (Figure 1).

Major ecosystems of the Caucasus hotspot include forest, freshwater, marine, high mountain, dry mountain scrubland, steppe, semi-desert, and wetland (Ecosystem Profile: Caucasus Biodiversity Hotspot, 2003).

The ecosystem profile and five-year investment strategy for the Caucasus Region was developed based on stakeholder workshops and background reports coordinated by the WWF Caucasus Programme Office (WWF Caucasus). More than 130 experts from the six countries participated in the identification of Key Biodiversity Areas (KBAs) and corridors for the Caucasus Hotspot representing a variety of scientific, governmental and nongovernmental organizations. KBAs and corridors were defined in cooperation with scientists at CI's Center for Applied Biodiversity Science (CABS).

The identification followed these main steps

First important areas for each taxon were selected in the hotspot and the consolidated map was composed. Second, KBAs based on the analysis of overlay of important taxon areas were selected. Third, an analysis was conducted of the existing protected areas network to highlight important conservation gaps and address them adequately in ecosystem profiles. Lastly, important corridors were identified to ensure connectivity of the selected KBAs.

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Fig.1 – The Caucasus Hotspot. The Caucasus is among the planet's 34 most diverse and endangered hotspots, identified by Conservation International. The Caucasus is one of the World Wide Fund for Nature's (WWF) Global 200 Ecoregions, identified as globally outstanding for biodiversity. The Caucasus has also been named a large herbivore hotspot by WWF's Large Herbivore Initiative. More than 6,500 species of vascular plants are found in the Caucasus as well as at least 153 mammals, one-fifth of which are endemic to the region. Additionally, as many as 400 species of birds are found here, four of which are endemic to this hotspot. Similarly, 22 of the 77 reptiles and four of the 14 species of amphibians are endemic. More than 200 species of fish are found in the rivers and seas of the region, more than one-third of which are found nowhere else. Finally, 50 globally-threatened species of animals and one plant are identified in the hotspot.

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Fig.2 – KBAs and corridors.

As a result, WWF identified 205 KBAs in the Caucasus, covering 19% of the hotspots. These large KBAs were not delineated as blocks to be protected in their entirety, but indicate important areas where urgent conservation measures are required. Results of the GIS analysis were evaluated and important wildlife corridors identified to ensure connectivity of the selected KBAs. In total, ten conservation corridors were identified for the Caucasus hotspot as important for biodiversity conservation (Figure 2).

Major threats to biodiversity in the Caucasus include poaching and habitat loss due to infrastructure development (road construction, pipelines), illegal logging, mining etc. The root causes of these threats include socioeconomic, political and institutional factors. Socioeconomic factors include poverty, lack of public awareness and insufficient land-use planning. Political concerns include gaps and contradictions in legislation, military conflicts, and lack of transboundary cooperation. Institutional aspects are insufficient knowledge of conservation issues among key stakeholders, gaps in protected area networks and poor management.

To mitigate the main threats the following site-scale investment priorities were set up in Armenia as a part of the Caucasus Hotspot:

- awareness-raising among key stakeholders (regional administrations, communities, state agencies)
- development of alternative livelihoods for communities (involving communities in conservation and ecotourism)
- enforcement of existing protected areas
- enforcement of biodiversity protection outside of protected areas (in the corridors)
- establishment of new protected areas in the KBAs

Implementation of different site-scale projects in southern Armenia since 2002 has fostered a number of results. As a result of communication and community development projects the attitude of local people towards PAs has improved and they now support the buffer zone communities of existing Khosrov and Shikahogh reserves. Ten communities in support zones of PAs were able to develop alternative livelihoods and began generating additional income and now support existing, and the establishment of new, protected areas. Two new protected areas were established, namely Arevik National Park (34,402 ha) and Zangezur Sanctuary (17,368 ha) (Figure 3). The total area of the new PA, 51,770 ha, comprises more than 1.7% of Armenia's territory and covers around

80% of the KBAs in southern Armenia. Biodiversity protection significantly improved due to the involvement of local people in conservation and ecotourism, as well as strengthening of conservation inspections in the corridor of southern Armenia.

From this exercise we learned that the success of the site-scale conservation projects depends on the level of partnership with key stakeholders (state agencies, regional authorities, communities, scientific institutions, NGOs, donors, etc.). Site scale conservation targets should be supported by communication and community development projects as in this case study site scale investment priorities were based on the Regional Plans (Ecoregional Conservation Plan 2006) and the National Programmes (Strategy on Development of Protected Areas System in Armenia and National Action Plan, 2002), communities interests, actual land use and land tenure, and cultural and natural features of the site.

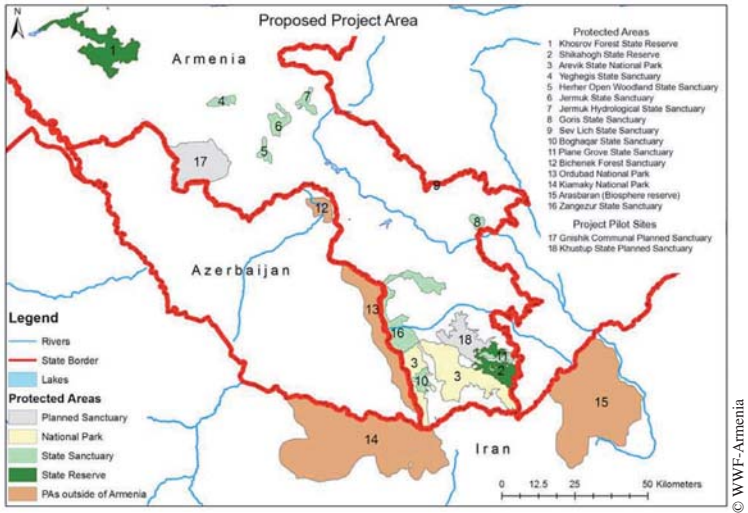

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Fig.3 – New protected areas in southern Armenia.

References

Ecosystem Profile: Caucasus Biodiversity Hotspot. Tbilisi, 2003.

Ecoregional Conservation Plan, Tbilisi, 2006.

Strategy on Development of Protected Areas System in Armenia and National Action Plan. Yerevan, 2002.

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The Integrated Biodiversity Assessment Tool: Site-scale information for better development decisions

Biodiversity is a potential material risk for most businesses. With business activities either relying directly or impacting on biodiversity, many companies are actively engaging in managing their dependences and impacts on biodiversity. The growing recognition of the importance of biodiversity by the business sector has resulted in a wide range of standards, principles and certification schemes, all of which require timely access to the best available data.

The Integrated Biodiversity Assessment Tool (IBAT), developed by the IBAT Alliance in partnership with leading institutions from the public and private sector, is a direct response to this need. IBAT provides decision-makers with access to critical information that supports planning and implementation of environmental safeguard policies and industry best practice standards. IBAT includes globally compiled spatial and tabular data drawn from established networks of national and regional sources on protected areas (World Database on Protected Areas), sites of global conservation importance (Key Biodiversity Areas, including Important Bird Areas and Alliance for Zero Extinction sites) and globally threatened species (The IUCN Red List of Threatened Species). These represent the majority of globally compiled biodiversity databases available at the scale of individual sites and species ranges.

The IBAT Alliance is currently formed by BirdLife International, Conservation International (CI), International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). The tool has been in development since 2005 and was finally launched in 2008 at the IUCN World Conservation Congress with a vision where decision-makers from the public and private sectors and the development community integrate biodiversity priorities in all development planning processes to ensure the conservation of critical habitats, and support the ongoing development and maintenance of key biodiversity datasets. A unique aspect of IBAT is the close partnership with users in order to present biodiversity data and guidance in ways that maximise understanding and practical implementation.

Since its launch, IBAT has attracted over 1,000 users, from companies, governments, multilateral organisations, consulting firms, and conservation organisations. The uptake of the tool by businesses from all sectors is due to its applications for planning new operations and assessing the risks associated with sourcing practices. Industry has a clear need for accurate and trusted biodiversity information at the finest scale possible to inform a range of management decisions. For example:

- Determining the location of a new development often has the greatest potential to significantly impact biodiversity. IBAT provides companies with the ability to scope particular regions and sites during the early stages of this decision-making process and thus integrate biodiversity risks within the full environmental impact analysis. This scoping process can prove beneficial in narrowing in on a site for the project and budgeting adequately for avoidance and mitigation measures that may be required as a result of biodiversity impacts.
- Effective supply chain management requires assessing suppliers and supply regions for potential biodiversity risks associated with the sourcing of raw materials, whether they are forest, agricultural, mineral or other products. Identifying potential issues associated with sources of raw materials can

inform strategies designed to effectively manage biodiversity risks within a company's supply chain. The biodiversity information provided within IBAT informs buyers of potential risks and can prompt further, in-depth discussions with suppliers on biodiversity conservation policies and management practices.

- Leading companies are increasingly committed to reporting publicly on their biodiversity performance, whether through the Global Reporting Initiative or annual corporate environmental reports. Preparing these reports requires the establishment of clear biodiversity indicators that can be aggregated at a corporate level and more easily verified. The biodiversity information provided within IBAT facilitates this process by ensuring uniformity of the data used to assess biodiversity issues across numerous operations and regions.

In terms of functionalities, some of the core features of IBAT are:

- easy access to credible, trusted key data sets:
  - threatened species
  - KBAs
  - protected areas
- simple mapping functions (including pan, zoom, query and measure tools)
- inclusion of spatial and tabular information
- links to more detailed information
- offers links to other tools and data sources, either directly or indirectly, including IUCN Red List of Threatened Species, the World Database on Protected Areas and Global Biodiversity Information Facility
- reports and outputs to support specific user needs (e.g. risk assessment and intersection analysis)
- print and download options
- information updated as new data becomes available
- link to national partners
- information presented in sector-specific context

By providing information on both protected and unprotected high priority sites for conservation, IBAT informs the practical implementation of environmental industry best practice standards. Access to this information at the earliest stages of project planning makes it easier to consider alternative projects, approaches or locations at a time when such changes are still economically viable. Beyond screening, IBAT can help inform and prioritise subsequent data collection, assessment and planning in the project cycle. IBAT supports a critical first step and is intended to inform – not replace – these subsequent processes.

The IBAT alliance is also working on different versions of IBATs, delivering tailored content and outputs, initially to three key sectors: research and conservation planning, business and development finance. During 2009, two additional versions of IBAT have been designed and implemented for internal use by project screening staff at the Inter-American Development Bank and another for the International Finance Corporation.

By providing reliable information to businesses, the IBAT alliance can not only help companies meet their compliance requirements and mitigate their footprint on biodiversity, but also help to fund further development of these key datasets benefiting policy-makers and the conservation community more broadly.

References

Brooks, T.M., Bakarr, M.I., Boucher, T.M., Fonseca, G.A.B. da, Hilton-Taylor, C., Hoekstra, J.M., Moritz, T., Olivieri, S., Parrish, J., Pressey, R.L., Rodrigues, A.S.L., Sechrest, W., Stattersfield, A., Strahm, W. 2004. Coverage provided by the global protected-area system: Is it enough? *Bioscience* 54: 1081-1091.

Devenish, C., Fernández, D. F. D., Clay, R. P., Davidson, I. J. and Zabala, I. Y. 2009. *Important Bird Areas Americas: Priority Sites for Biodiversity Conservation*. Quito: BirdLife International (BirdLife Conservation Series 16).

Jenkins, C.N. and Joppa, L. 2009. Expansion of the global terrestrial protected area system. *Biological Conservation* 142: 2166-2174.

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., Silva, N. de, Edgar, G.J., Eken, G., Fishpool, L.D.C., Fonseca, G.A.B. da, Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S.L., Salaman, P., Sechrest, W. and Tordoff, A.W. 2007. *Identification and Gap Analysis of Key Biodiversity Areas: Targets for Comprehensive Protected Area Systems*. Gland, Switzerland: IUCN.

Nagy, S. 2000. *European IBA Best Practice Guide*. Wageningen, The Netherlands: BirdLife International.

Rodrigues, A.S.L., Akcakaya, H.R., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Chanson, J.S., Fishpool, L.D.C., Fonseca, G.A.B. da, Gaston, K.J., Hoffmann, M., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J. and Yan, X. 2004a. Global gap analysis: Priority regions for expanding the global protected-area network. *Bioscience* 54: 1092-1100.

Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., Fonseca, G.A.B. da, Gaston, K.J., Hoffmann, M., Long, J.S., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J. and Yan, X. 2004b. Effectiveness of the global protected area network in representing species diversity. *Nature* 428: 640-643.

UNEP. 2010. *Are You a Green Leader? Business and Biodiversity: Making the Case for a Lasting Solution*. United Nations Environment Programme and UNEP-WCMC.

UNEP-WCMC. 2009. *Data structure of the World Database on Protected Areas (WDPA) Annual Release 2009*. New WDPA Schema. (Web-download Version – February 2009.)

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Taking social and cultural values into account in the process of managing biodiversity at the landscape scale: A few useful considerations

Landscape is a scale that is particularly appropriate for managing biodiversity, whether natural or anthropogenic (Otte, 2007). Such management is based on a thorough knowledge of the physical and biological constituents of landscape. However, more and more researchers, whether practitioners, government agencies or non-government organizations, have come to realize that taking social and cultural values into account is essential to successful biodiversity management (Hviding, 2006). Practices, perceptions and values play a role in the conservation or even the promotion of certain species and ecosystems or, on the contrary, increase the threats to which they are subjected (Katoh et al., 2009; Dagenais, 2008; Kasisi and Jacobs, 2001).

Many societies value biodiversity, directly or indirectly, and traditional knowledge and practices can be essential to maintaining that biodiversity, in both hunting and gathering or agricultural societies (Katoh et al., 2009; Berkes and Davidson-Hunt, 2006). The result of this human-nature interaction is often a rich and diversified landscape that is a valued living environment for the local populations and sometimes a prized destination for tourists.

If we ignore for the moment cultivated plants, domesticated animals, agricultural pests and diseases, some species have greatly benefited from human-induced changes to the environment. For example, pastures, fields and other open environments in an otherwise forested landscape are homes to birds, insects or plants that would not be so prevalent in an undisturbed environment (Rhéault and Domon, 2009; Katoh et al., 2009; Cooper, 2000). Urban derelict sites may harbor rare birds (Hinchcliff, 2008; Wilby and Perry, 2006). Cities allow for the evolution of new taxa (Zerbe et al., 2003).

However, practices cannot be frozen in time. Landscape planning must allow for change: change in the biophysical environment, such as climatic change (Lovejoy, 2008), or change in society, such as the advent of neorural populations (Paquette and Domon, 2003).

The best of landscape planning for biodiversity will fail without the support of all stakeholders, especially the local population (Côté and Gérardin, 2009). These stakeholders do not always share the same perspective (Natori et al., 2008; Benjamin et al., 2007).

Taking social and cultural values into account in the process of managing biodiversity at the landscape level should be thought of as a wonderful opportunity for a fertile human-nature partnership. However it does involve a number of challenges from research and policy perspectives. Some of these challenges are as follows:

1. The identification of
a. Natural as well as anthropogenic biodiversity components (Rhéault et Domon, 2009)
b. Practices, perceptions and values that are essential or detrimental to the conservation of biodiversity (Domon, 2009)

2. The development, adaptation or application of appropriate conservation concepts (e.g. biosphere reserves (Courcier and Domon, 2009), Category V Protected Landscapes/Seascapes of IUCN (Phillips, 2002); Humanized landscapes; Regional Natural Parks in France (Courcier and Domon, 2009))
a. To conserve or increase natural as well as anthropogenic biodiversity
b. To promote traditional biodiversity maintaining practices while allowing for the introduction of novel biodiversity enhancing practices
3. The use of legal and policy tools such as international conventions, particularly those related to culture, for the conservation of biodiversity maintenance practices (e.g. Convention on the Protection and Promotion of the Diversity of Cultural Expressions; Convention concerning the Protection of the World Cultural and Natural Heritage, and the Convention for the Safeguarding of the Intangible Cultural Heritage)
4. The development, adaptation and application of appropriate landscape planning tools and concepts to increase biodiversity in conservation and non-conservation areas (Courcier and Trépanier, 2009; Trépanier and Bryant, 2009). The objectives should be to diversify the range of habitats available within a multifunctional landscape and to ensure connectivity between those habitats for biodiversity protection now and in a future with climate change (Hannah and Hansen, 2005; Rhéault and Domon, 2009)
5. The conservation of valuable anthropogenic biodiversity while testing of new agricultural and horticultural species or cultivars and limiting or preventing the advent of invasive species in sensitive areas
6. The application of suitable biodiversity indicators to measure progress (Rhéault and Domon, 2009)
7. The adaptation of existing concepts to the urban environment (Dogsé, 2004)
8. The fostering of continuous support and involvement of all stakeholders towards biodiversity conservation goals in a context of multiple views on the subject (Côté and Girardin, 2009)

Meeting these challenges will ensure that taking social and cultural values into account in the management of biodiversity is not considered a parallel process but becomes part of a fully integrated socioecological biodiversity management system.

References

Benjamin, K., Bouchard, A. and Domon, G. 2007, Abandoned farmlands as components of rural landscapes: An analysis of perceptions and representations. *Landscape and Urban Planning* 83: 228-244.

Berkes, F. and Davidson-Hunt, I. J. 2006. Biodiversity, traditional management systems, and cultural landscapes: Examples from the boreal forest. *International Social Science Journal* 58 (187): 35-47.

Cooper, N. S. 2000. How natural is a nature reserve? An ideological study of British nature conservation landscapes. *Biodiversity and Conservation* 9: 1131-1152.

Côté, J.-C. and Gérardin, V. 2009. Le paysage humanisé au Québec comme projet d'une société menacée. In: Domon G. (ed.). *Le paysage humanisé au Québec, Nouveau statut, Nouveau paradigme*. Montréal: Les Presses de l'Université de Montréal. pp. 319-347.

Courcier, S. and Domon, G. 2009. Le statut de paysage humanisé au Québec. In: Domon G. (ed.). *Le paysage humanisé au Québec, Nouveau statut, Nouveau paradigme*. Montréal: Les presses de l'Université de Montréal. pp 21-55.

Courcier, S. and Trépanier, M.-O. 2009. Planification et moyens d'action. In: Domon, G. (ed.). *Le paysage humanisé au Québec, Nouveau Statut, Nouveau paradigme*. Montréal: Les Presses de l'Université de Montréal. pp. 237-314.

Dagenais, D. 2008. Designing with nature in landscape architecture. In: Brebbia, C. A. (ed.). *Design and Nature IV, WIT Transactions on Ecology and the Environment* 114: 213-223.

Dogsé, P. 2004. Toward Urban Biosphere Reserves. *Annals of the New York Academy of Sciences* 1023: 10-48.

Domon, G. 2009. Le diagnostic paysager. In: Domon, G. (ed.). *Le paysage humanisé au Québec, Nouveau statut, Nouveau paradigme*. Montréal: Les Presses de l'Université de Montréal. pp. 137-207.

Hannah, L. and Hansen, L. 2005. Designing landscapes and seascapes for change. In : Lovejoy, T.E. and Hannah, L. (eds). *Climate Change and Biodiversity*. New Haven, Connecticut: Yale University Press. pp. 329–341.

Hinchliffe S. 2008. Reconstituting nature conservation: Towards a careful political ecology. *Geoforum* 39 (1): 88-97.

Hviding, E. 2006. Knowing and managing biodiversity in the Pacific Islands: Challenges of environmentalism in Marovo Lagoon. *International Social Science Journal* 58 (187): 70-85.

Kasisi, R. and Jacobs, P. 2001. Strategies and action plans to conserve biological diversity: A cultural and scientific challenge. *Traditional Marine Resource Management and Knowledge*. *Bulletin* 13:14-23.

Katoh, K., Sakai, S. and Takahashi, T. 2009, Factors maintaining biodiversity in satoyama, a traditional agricultural landscape in Japan. *Biological Conserversation* 142: 1930-1936.

Lovejoy, T. E. 2008. Climate change and biodiversity. *Revue scientifique et technique de l'Office international des Epizooties* 27(2):331-338.

Natori, Y. and Chenoweth, R. 2008, Differences in rural landscape perceptions and preferences between farmers and naturalists. *Journal of Environmental Psychology* 28: 250-267.

Otte, A, Simmering, D. and Wolters, V. 2007. Biodiversity at the landscape level: Recent concepts and perspectives for multifunctional land use. *Landscape Ecology* 22:639-642.

Paquette, S. and Domon, G. 2003. Changing ruralities, changing landscapes: Exploring social recomposition using a multi-scale approach. *Journal of Rural Studies* 19: 425-444.

Phillips, A. 2002. *Management Guidelines for IUCN Category V Protected Areas: Protected Landscapes/Seascapes*. Gland, Switzerland and Cambridge, UK: IUCN.

Rheault, H. and Domon, G. 2009. La biodiversité des paysages humanisés. In: Domon, G. (ed.). *Le paysage humanisé au Québec, Nouveau Statut, Nouveau paradigme*. Montréal: Les Presses de l'Université de Montréal. pp. 59-91.

Trépanier, M.-O. and Bryant, C. 2009. Principe de gestion et d'organisation. In: Domon, G. (ed.). *Le paysage humanisé au Québec, Nouveau Statut, Nouveau paradigme*. Montréal: Les Presses de l'Université de Montréal. pp. 211-233.

Wilby, R. L. and Perry, G. L.W. 2006. Climate change, biodiversity and the urban environment: A critical review based on London, UK. *Progress in Physical Geogaphy* 30 (1): 73-98.

Zerbe, S., Maurer, U., Schmitz, S. and Sukopp, H. 2003. Biodiversity in Berlin and its potential for nature conservation. *Landscape and Urban Planning* 62: 139-148.

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Advancing socio-ecological production landscapes for the benefits of biodiversity and human well-being: The Satoyama Initiative

Background

In order to significantly slow down the rate of biodiversity loss at a global level, it is important to focus not only on wilderness areas, but also on human-influenced natural environments or biocultural landscapes, where human activities compatible with biodiversity conservation have been taking place, environments formed and maintained in many parts of the world through agriculture, forestry and fishing. In particular, by employing natural resource utilization methods which have been passed down for generations, areas derived from positive human-nature relationships are important not only to conserve biodiversity, but also to inspire ideas for the realization of societies in harmony with nature.

Satoyama landscapes are such areas in Japan. Satoyama refers to diverse land uses often consisting of secondary forests, agricultural lands, irrigation ponds etc., adjacent to rural settlements in Japan. This Japanese word is literally translated as yama (mountain/woodland/grassland) located in the vicinity of sato (village). Traditionally, Satoyama was managed for firewood and charcoal production, leaf litter collection for agricultural fertilizer, and hay collection for roofing materials. The compound landscape consisted of Satoyama, agricultural lands, human settlements and watershed areas in mosaic-like patterns of different types of land uses that were functionally interlinked. It is important to note that such Satoyama landscapes have provided various ecosystem services to people including useful natural resources and have imbued local communities with a sense of their roots and identity.

Such landscapes formed through harmonized human-nature relationships, including agroforestry and common lands, are widely found all over the world, although they differ from place to place according to the climatic, topological, cultural, and socioeconomic conditions. Each country or region has its own term for such landscapes – muyong, uma and payoh in the Philippines, mauel in Korea, chitemene in Malawi and Zambia, dehesa in Spain and terroirs in France. These are generally characterized by a wise use of biological resources in accordance with traditional cultural practices that are compatible with conservation and sustainable use.

However, these landscapes are threatened under modern socioeconomic conditions, and in many cases, have been lost. Increasing demand for fuel and food accompanied by population increase and economic growth, and deeply-rooted poverty, have caused inappropriate utilization of natural resources on the one hand, while on the other, expansive monocultures, ageing populations, and depopulation of rural areas have changed human-nature relationships in these areas markedly, resulting in the deterioration of biocultural landscapes. This situation hampers human enjoyment of the various benefits of nature (ecosystem services) in a sustainable manner and may also have deleterious effects on human well-being.

In order to improve the situation of biodiversity loss, new approaches different from conventional ones, like the establishment of protected areas, which prohibit human activities, are needed. In other words, it is important that the values of biodiversity conservation and biocultural landscapes, which contribute to human well-being, are recognized so that policies suited to the special features of each area might be adopted effectively, and the importance of promoting sustainable utilization and management of these landscapes shared globally.

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The Satoyama Initiative

The Satoyama Initiative aims to share such issues based on a common philosophy that values regional characteristics in order to maintain and rebuild positive human-nature relationships in certain biocultural landscapes for enhancing biodiversity conservation and human well-being. To this end, it would be beneficial to globally share and comparatively analyze methods of sustainable utilization and management of natural resources and associated knowledge in various parts of the world, recent problems and ways to overcome them. In addition, it would be useful to promote capacity building of affiliated parties and to strengthen the basis for activities by linking national and local governments, international organizations, the private sector, communities and NGOs, and to promote bilateral and multilateral international cooperation.

The United Nations University Institute of Advanced Studies (UNU-IAS) and the Government of Japan (Ministry of the Environment) have jointly initiated the Satoyama Initiative, which promotes sustainable utilization and management of natural resources, targeting various biocultural landscapes where particular emphasis is needed. The Satoyama Initiative has the potential to address food, water and fuel shortages, while respecting ethno-historical, cultural and ecological characteristics of the local area, by maintaining and rebuilding specific biocultural landscapes (including restoring deteriorated ecosystems through sustainable management) in ways that are well adapted to a number of global environmental problems, including prevailing socioeconomic issues and climate change. Thus, it may also contribute to the realization of policy goals linked to the advancement of humankind, such as the Millennium Development Goals, which will play a key role in human development and poverty alleviation. As global and national strategies are developed to achieve the level of food production needed for nine billion people, while reducing emissions from agriculture and land-clearing simultaneously, and mobilizing large-scale carbon sequestration through new methods of agriculture and forest land management, the Satoyama Initiative may offer a promising landscape framework for integrating sectoral initiatives.

Vision, approach and perspectives of the Satoyama Initiative

The vision of the Satoyama Initiative is 'realizing societies in harmony with nature', or societies built on positive human-nature relationships. In other words, these are societies where, through the maintenance and development of socioeconomic activities (including agriculture, forestry and fishing) in alignment with natural processes, and by managing and utilizing biological resources in a sustainable manner and thus maintaining biodiversity, people enjoy a stable supply of various natural benefits well into the future.

In order to pave the way towards the attainment of this vision, it is proposed that activities must be conducted in accordance with the following three-fold approach. Firstly, an understanding of the diverse ecosystem services essential to human well-being and the consolidation of wisdom in ensuring a stable supply of these services is indispensible. Secondly, the application of traditional knowledge to modern societies through the promotion of fruitful dialogue is critical for a stable supply of these ecosystem services and for coexistence in harmony with nature. Thirdly, social mechanisms, such as co-management systems for supporting and promoting such endeavors are also vital.

The maintenance and rebuilding of socio-ecological production landscapes in various areas in accordance with the approaches outlined above, in other words, putting the sustainable utilization and management of natural resources into practice, will entail the following ecological and socioeconomic perspectives:

- resource use within the carrying capacity and resilience of the environment
- cyclic use of natural resources
- recognition of the value and importance of local traditions and cultures
- natural resource management by various participating and cooperating entities
- contributions to local economies

The International Partnership for the Satoyama Initiative

The Japanese Government and UNU-IAS propose to establish the 'International Partnership for the Satoyama Initiative', which would aim to work towards the achievement of the long-term goal of 'realizing societies in harmony with nature' (IPSI), that is principally aimed at increasing the number of case studies where effective activities are implemented in accordance with the concept of this Initiative throughout the world. The International Partnership will be comprised of participating international agencies, national and local governments, civil societies, private companies, NPOs, NGOs, universities, research institutions and other organizations that will work together to maintain and revitalize socio-ecological production landscapes where human-nature relationships, with regards to land and natural resources use and management, are sustainable. Such a partnership has the potential to establish a unique and innovative dialogue and collaboration platform involving diverse stakeholders and paving

the way for an interdisciplinary, holistic and systems-based approach to knowledge production and sharing. Those who participate in the Initiative will be encouraged to provide practical information on related activities to be stored as case studies in the database. In addition, the Satoyama Initiative recognizes the importance of other ongoing initiatives dealing with socio-ecological production landscapes and seeks to provide a platform for cooperation and support.

The main activities promoted under the IPSI include:

I. Enhance understanding and raise awareness of the importance of socio-ecological production landscapes
   1) Knowledge Facilitation
      Collecting, analysing, synthesising and comparing case studies and distilling lessons learned for dissemination through a searchable online database and other means, and for use in capacity-building activities
      2) Policy Research – Undertaking research on ways to:
         i. Promote wisdom, knowledge and practice which enables a stable supply of diverse ecosystem services
         ii. Build bridges for inter-cultural communication between traditional ecological knowledge systems and modern sciences
         iii. Explore new forms of co-management systems while respecting traditional communal land tenure
         iv. Revitalise and innovate for socio-ecological production landscapes
         v. Integrate results in policy and decision-making processes
   3) Indicators Research
      Developing measurable indicators of resilience associated with linkages between human well-being and the socio-ecological production landscape, and applying these indicators

II. Activities to promote the maintaining and rebuilding of socio-ecological production landscapes
   4) Capacity Building
      Enhancing capacities for maintaining, rebuilding and revitalising socio-ecological production landscapes, including promoting education and regional capacity-building workshops
   5) On-the-Ground Activities
      Providing support for on-the-ground projects and activities to maintain, rebuild and revitalise socio-ecological production landscapes

As of April 2011, as many as 74 diverse organisations are members of the IPSI – increased from 51 at the time of the launch in October 2010 – consisting of national and local governments, NGOs, indigenous and community organisations, academic institutes, the private sector, and the UN and international organisations working together to maintain and rebuild socio-ecological production landscapes, and there are currently ten ongoing collaborative activities under the IPSI which are expected to expand further. The UNU-IAS serves as the Secretariat of the IPSI.[7]

References

Takeuchi, K., Brown, R.D., Washitani, I., Tsunekawa, A. and Yokohari, M. (eds.). 2002. *Satoyama: The Traditional Rural Landscape of Japan*. Tokyo: Springer-Verlag.

Satoyama Initiative Leaflet. Available at http://satoyama-initiative.org/en/wp-content/uploads/390/SI-Leaflet-EN-26042010.pdf. (printed in January 2010).

United Nations University Institute of Advanced Studies. Discussion paper of the Global Workshop on the *Satoyama* Initiative, 29-30 January 2010, Paris. Available at http://satoyama-initiative.org/en/wp-content/uploads/390/DiscussionPaper.pdf

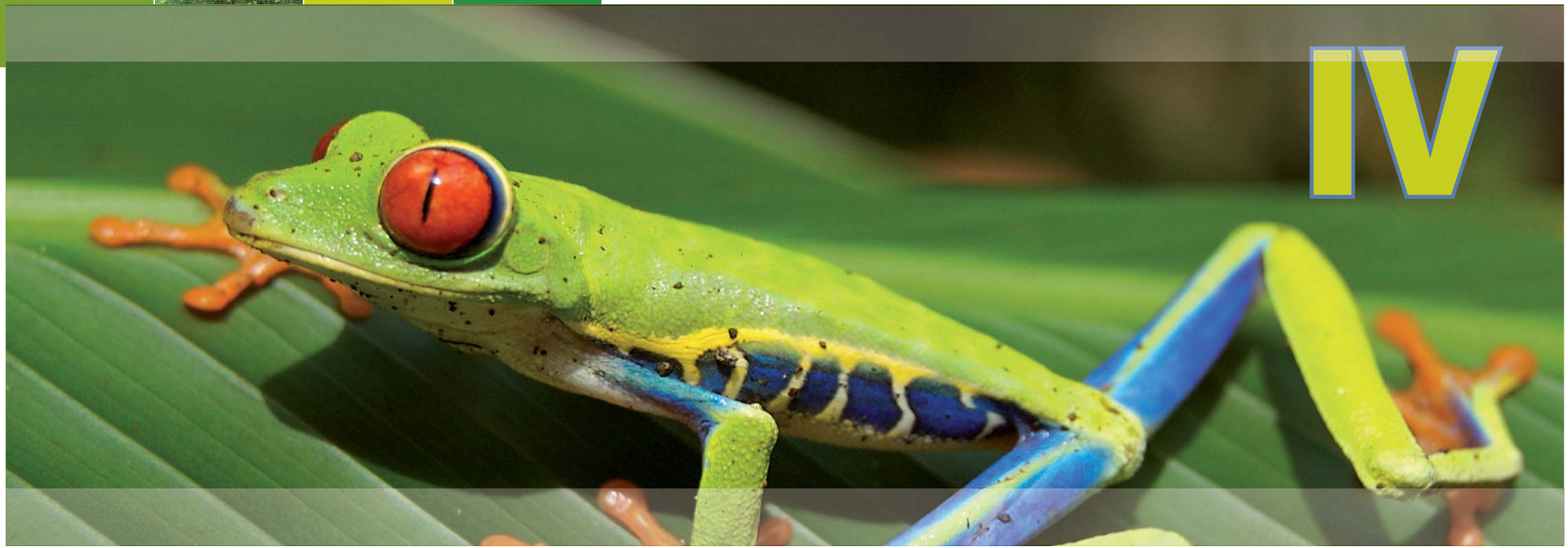
Satoyama landscape in Japan (K. Ichikawa).

Potato park in Peru (B.Y.L. Wong).

7. Note: The *Satoyama* Initiative has made tremendous progress since this paper was presented in January 2010. Above all, it should be highlighted that the Satoyama Initiative was recognized as a "useful tool to better understand and support human-influenced natural environments for the benefit of biodiversity and human well-being" at the Tenth Meeting of the Conference of the Parties (COP 10) to the Convention on Biological Diversity (CBD) which was held in Nagoya, Aichi, Japan in October 2010 (Decision X/32). The International Partnership for the Satoyama Initiative (IPSI) was also launched during the CBD COP 10 as a key mechanism for the implementation of the Initiative.

Le concept de conservation de la biodiversité est loin d'être partagé par tous les peuples de la planète, encore moins les formes et processus d'élaboration des plans de gestion des aires protégées issus du concept de conservation. La conservation ne pourra être pleinement efficace, que si elle tient compte de (…)la pluralité des intelligences de la nature. Il existe autant de perceptions du monde que de peuples sur la planète.

Robert Kasisi



IV

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BIODIVERSITY AT THE NEXUS OF SCIENCE WITH SOCIETY

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On linkages between linguistic diversity, traditional knowledge, and biodiversity, and UNESCO's recent work in this area

The strong positive correlation between the distribution of linguistic and biological diversity has been described in recent scientific literature, even though no compelling explanatory theory has emerged as yet (Berkes et al. 1999; UNESCO et al. 2003). Leaving the debate on causality to researchers, UNESCO has focused over the past few years on exploring the linkages among the following three areas in terms of their mutual effects and implications for policy: a) local and indigenous languages, b) traditional environmental knowledge that they convey and c) biodiversity conservation and sustainable management of resources.[8]

While much of the work has focused on the impact of biodiversity and environment management on indigenous languages, a project launched in 2008 with funding from the Global Environment Facility (GEF), began to look at the effect that language maintenance or loss may have on traditional knowledge and biodiversity.

It is estimated that at the current rate of endangerment about half of the world's languages are in danger of disappearing before the end of the century. For reference, according to the IUCN Red List assessment for 2008, 12% of bird species, 21% of mammal species and 30% of amphibian species are threatened with extinction (Vié et al., 2008).

If nothing is done, this trend will results in an attrition of traditional/indigenous knowledge about biodiversity, putting the latter at a greater risk of loss. As put by Gadgil, Berkes and Folke (1993), "Indigenous knowledge does indeed hold valuable information on the role that species play in ecologically sustainable systems. Such knowledge is of great value for an improved use of natural resources and ecological services, and could provide invaluable insights and clues for how to redirect the behaviour of the industrial world towards a path in synergy with the life-support environment on which it depends".

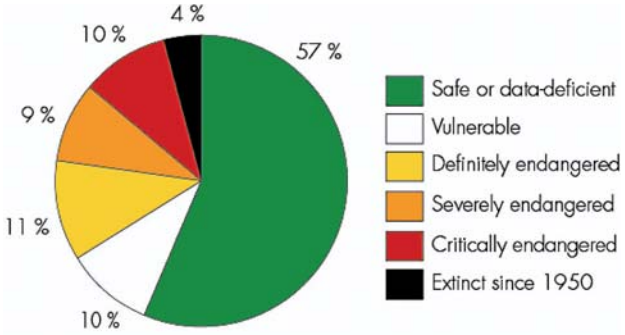

Fig.1 – Language vitality and endangerement status according to UNESCO's Atlas of the World's Languages in Danger (2010).

For instance, in Tofa (a Siberian language), each month is named after a hunting or gathering activity. The word for May means 'digging saranki root month' (*saranki* is a flower used year-round to treat common illnesses). Ebert (2005) reports: "The knowledge embedded in these words is lost when people begin

8. See www.unesco.org/science, www.unesco.org/culture, and *Biodiversity in UNESCO* booklet (UNESCO, 2007), online version available at http://unesdoc.unesco.org/images/0015/001514/151402e.pdf

using a more common language. Tofa children who now speak Russian no longer retain the monthly information, and many elders have also forgotten it".

It is from this perspective that Article 8 of the Convention on Biological Diversity (CBD) urges to "respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity". It is also from this standpoint that the CBD Conference of Parties decided in 2002 to use trends in linguistic diversity and numbers of speakers of indigenous languages as a proxy indicator for measuring progress towards the 2010 Biodiversity Target.[9]

After having initially focused on data collection and design of a custom-made database, we compiled a sample of 25 countries, representing a total of 246 indigenous/minority languages with trend data from governmental sources (mainly censuses and sometimes language surveys). We chose not to combine different sources in our sample, even if this would have increased dramatically the number of languages for which trends could be established. However, it should be borne in mind that different sources have collected their data based on a range of diverse assumptions, definitions and considerations. For example, the Mexican Institute of Statistics counts three speakers of Popoluca de Oluta in 1990, while the Ethnologue language index published by SIL (2005) counts 102 for the same year. Similarly, the Russian Federal State Statistics Service counts 456 speakers of Itelmen in 1989; another Russian source, the *Red Book of the Languages of Russia* (Neroznak, 2002), counts 2,481 for the same year, while the Ethnologue counts 100 speakers in 1991. Such examples abound and are rather the norm than exception.

To facilitate data analysis and interpretation, this set of 246 languages was broken down into three subsets of languages based on their size at the earliest datapoint ('Size Groups'):

- SG1: 1 to 9,999 speakers (57% of the sample)
- SG2: 10,000 to 99,999 speakers (23% of the sample)
- SG3: 100,000 and more speakers (20% of the sample)

This sample was then analyzed for trends in numbers of speakers indicating either language maintenance (number of speakers at the latest available data point superior to that at the earliest) or language attrition (number of speakers at the latest available data point inferior to that at the earliest).

To analyze the above sample, we used two approaches. The first consists in calculating trends in numbers of speakers of indigenous languages without comparing them to the population trends in the countries where they are spoken. We obtain thus a non-adjusted language maintenance index by calculating the ratio of languages with a positive trend to those with a negative trend.

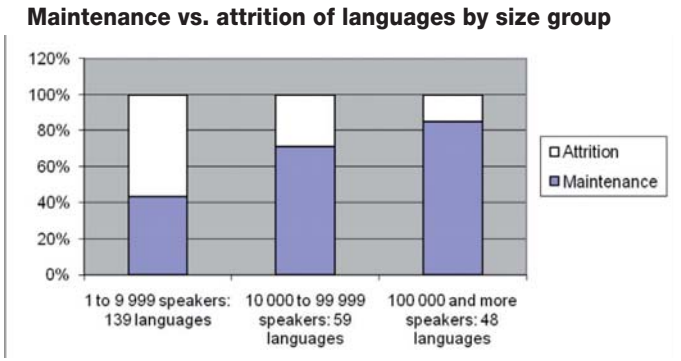

Fig.2 – Trends in indigenous languages without adjustment to population trends.

With this approach, 58% of the sample (143 languages) has a positive trend, and 42% (103 languages) have a negative trend. In terms of size groups, attrition is observed for 57% of the languages with fewer than 10,000 speakers, 29% of the languages between 10,000 and 99,999 speakers and 15% of the languages with more than 100,000 speakers.

The second approach consists in comparing trends in languages to the demographic trends over the same period in the country where they are spoken. If the language maintenance index is superior to the country's population growth index for the same period, we consider that the language trend is positive. If the language maintenance index is inferior to the population growth index, we consider that the language trend is negative. This approach results in the following distribution:

9. For an assessment of the state of biodiversity in 2010 and the failure of the international community to meet the 2010 Biodiversity Target, see Secretariat of the Convention on Biological Diversity (2010) Global Biodiversity Outlook 3, Montreal (available online at http://www.cbd.int/GBO3) and Butchart *et al.* 2010. Global biodiversity: Indicators of recent declines. Science 328: 1164-1168.

Maintenance vs. attrition of languages by size group, adjusted to total country population

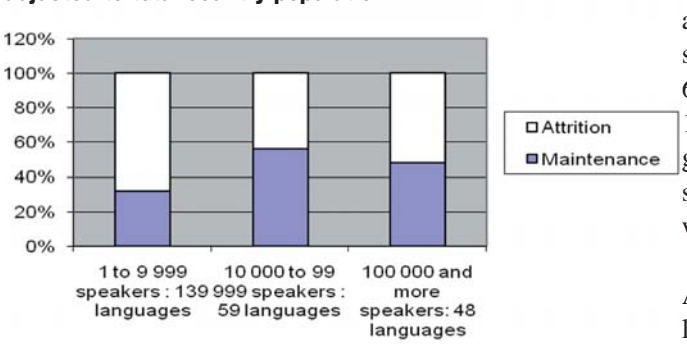

Fig.3 – Trends in indigenous languages, adjusted to country's population growth.

With this approach, only 41% of the sample (i.e., 100 languages) has a positive trend. Broken down by size groups, attrition is observed for 68% of the languages with under 10,000 speakers, 44% of the languages between 10,000 and 99,999 speakers and 52% of the languages with more than 100,000 speakers.

Adjusting language trends to population growth in a given country provides a valuable perspective, but also introduces certain biases (for instance, the 2.1% growth of Australian population in 2009 was due mainly to overseas migration (66%), according to the Australian Bureau of Statistics, and only to a smaller extent (34%) to natural growth). Therefore, adjusting to the trends in ethnic groups rather than the total population of the country seems to be a more interesting avenue worth exploring in the future.

To recapitulate, our data suggest a general trend toward attrition in indigenous languages with fewer than 10,000 speakers (approximately, 51% of the world's languages) and a maintenance trend for large indigenous languages over the past few decades. In other words, an analysis of official data collected by national governments corroborates the expert-generated estimate of loss of linguistic vitality and diversity, in particular, among small indigenous groups living in biodiversity-rich areas. This, in turn, suggests greater pressures on biodiversity and worsened conditions for its sustainable management and conservation.

The next step for this project consists in collecting more data in order to increase the sample and improve its representativeness in terms of languages, ethnic groups and countries. Following that, further analyses of the collected data is needed to account for ethnic group population trends, overall population trends, migration flows, linguistic policies at various levels, as well as changes in attitudes both among governments and the speakers of indigenous languages. Finally, it is essential to advocate for a harmonization and a certain degree of standardization of language data collection methodologies across the world in order to constitute usable datasets and distill trends on indigenous languages at national and global levels.

Based on these preliminary findings, it is already possible to recommend that efforts to preserve biodiversity, at policy and grassroots levels, should take into account the socio-cultural and linguistic situation. In other words, safeguarding traditional knowledge and the indigenous languages that carry it should be seen as an as yet underused but promising tool for biodiversity conservation.

References

Berkes, F., Harmon, D., Posey, D., Loh, J., Maffi, L., Mühlhäusler, P., Skutnabb-Kangas, T., Zent, S., Moore, J.L. 1999. *Cultural and Spiritual Values of Biodiversity*. United Nations Environment Programme.

Ebert, J. 2005. Tongue Tied. *Nature* 438: 148-149.

Gadgil, M., Berkes, F. and Folke, C. 1993. Indigenous Knowledge for Biodiversity Conservation. *Ambio* 22 (2/3).

Lewis, M.P. (ed.). 2005**.** *Ethnologue: Languages of the World***.** Dallas, Texas, USA: SIL International. Online version at http://www.ethnologue.com.

Moseley, C. (ed.). 2010. *Atlas of the World's Languages in Danger*. Paris: UNESCO Publishing. Online version at: http://www.unesco.org/culture/languages-atlas.

Neroznak, V.P. (ed.). 2002.*The Red Book of the Languages of Russia*. Moscow, Russia: Academia.

UNESCO, WWF and Terralingua. 2003. *Sharing a World of Difference: The Earth's Linguistic, Cultural and Biological Diversity*.

Vié, J.-C., Hilton-Taylor, C., Pollock, C., Ragle, J., Smart, J., Stuart, S.N. and Tong, R. 2008. The IUCN Red List: A key conservation tool. In: Vié, J.-C., Hilton-Taylor, C. and Stuart, S.N. (eds.). *The 2008 Review of The IUCN Red List of Threatened Species*. Gland, Switzerland: IUCN.

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The relationship between of cultural and biological diversity under the World Heritage Convention

How do biological and cultural diversity relate to each other under the umbrella of the World Heritage Convention? Because the World Heritage Convention was created to help identify and conserve the most outstanding places on earth, and not specifically to foster harmonious interplay of culture and nature, there is no straightforward way to respond. Some would even argue that the World Heritage Convention is the result of a "forced marriage" between two independent but parallel efforts at developing global heritage conservation instruments, one for nature and one for culture. Fortunately, the wedding was a resounding success, and if the number of offsprings is an indicator for that success, the 176 natural sites, the 689 cultural sites, and the 25 sites endowed with both natural and cultural world heritage values certainly point to a very fruitful marriage – not to mention the near universal ratification of the Convention.

Thus the relationship has no clean linear tale, although examples are plentiful of how the two diversities have interacted in some World Heritage sites, and how the Convention has been used in some cases to formally recognize the interplay between humans and the lands in which they live.

Of the 890 World Heritage sites currently listed, only 25 are simultaneously recognized under both natural and cultural criteria. This means that these sites have attributes of global importance under both the natural and cultural heritage criteria. This number represents less than 3% of all World Heritage sites. At first sight, this is not an impressive manifestation of conviviality between biological and cultural diversity under the World Heritage Convention! To make matters worse, by eliminating those mixed sites whose natural values are related to geological rather than biological attributes, we are left with only 13 sites (i.e., less than 1.5%) in which biological and cultural diversity are formally celebrated within the same area. By this simple yardstick, the World Heritage Convention has not been very effective in reconciling cultural and biological diversity within its mandate!

But the story does not end there. If you know how to look, you will actually find that biologically-founded celebration of humanity's cultural manifestations is common in the World Heritage List and you will find that cultural manifestations on the list also serve to protect biodiversity. I will try to highlight a few ways how this is demonstrated.

1. Some cultural sites that are founded on the relationship between people and the land: Humans have tended the land for centuries, maintaining equilibrium between the cultivated species and the economy. The agricultural species present may be rare varieties which contribute to agro-diversity concerns.

2. Cultural sites established to celebrate biodiversity: These are cultural sites recognized in part for the role they have played in the advancement of biodiversity knowledge. There is more potential for this kind of World Heritage site.

3. Cultural sites recognized in part for the aesthetic appeal of their gardens: Approximately 30 sites have the word “garden” or “park” (as in the “Palace and Park of Versailles”, and not in the national park sense) in their names.

4. Cultural sites telling us a story about biodiversity: Rock art sites enable us to learn more about the relationship between people and biodiversity from tens of thousands of years ago to the more recent past. These attest to past relationships and are valuable for biodiversity in terms of scientific information relating to historical ecosystems and planetary change.

5. Biodiversity sustaining people: Natural World Heritage sites in which people have carried out long-term, sustainable livelihoods demonstrate a long-lasting equilibrium between biodiversity and human welfare. The Solomon Islands, where land is managed under customary ownership, are an example.

6. Cultural sites sustaining biodiversity: These include cultural World Heritage sites located within biologically-diverse settings which are conserved by association. Many cultural sites play an inadvertent but important role in conserving biodiversity.

And finally, there are sacred sites.The World Heritage List contains several sites that embody the spiritual bond that exists between a community and a particular physical place.The material embodiment of the spiritual connection is usually expressed as sacred forests, sacred mountains and landscapes, often containing shrines, temples and other meditation infrastructure. There are several such sites on the World Heritage list.

In the end, it is these sacred sites which exemplify the highest plane of the relationship between cultural and biological diversity. These sites are not celebrating how we grow food and find medicine, or how we managed to overcome the physical challenges of a difficult terrain, or how we titillate our senses, nor even how we pursue scientific enquiry. These sites are celebrating a deep-rooted spiritual relationship with a place, one that has been transferred from generation to generation. Such sacred sites are found throughout the world and seem to be a universal attribute of human communities.

It is very empirical to carry out a removed, intellectual assessment of how the World Heritage Convention brings together cultural and biological diversity. But let us take it a step further. Could not a good anthropologist have predicted, once local communities eventually came together at the global scale, that this attribute of protecting sacred places would eventually manifest itself at the global level? It seems to me that the World Heritage Convention itself is but the logical extension of this process. The World Heritage Convention is only a modern-day manifestation of that deep-rooted human need to maintain a strong bond with special places – we are not disinterested observers in a laboratory situation here – we are still part of the cultural diversity ourselves. If we are interested in looking at how cultural and biological diversity interact at the highest levels, this legal instrument, adopted in 1972, is a good place to start.

MARTIN PRICE[10] AND ANA PERSIC[11]

The World Network of Biosphere Reserves: Bridging conservation and development

The Man and the Biosphere Programme and the World Network of Biosphere Reserves

UNESCO's Man and the Biosphere (MAB) Programme is an intergovernmental programme established in the 1970s with the objective of providing a scientific basis to improve people-environment relationships. One of the Programme's major contributions to the environmental and sustainable development debates and action from local to international levels has been the development of the biosphere reserve concept.

The concept originated as a tool for international cooperation and local action to address issues and problems at the interface between nature conservation, interdisciplinary research and monitoring, and educational prerogatives in the ecological and environmental sciences. The origin and the evolution of the concept has enjoyed an interactive relationship between MAB's interdisciplinary research, training and educational agenda and the nature conservation and related socioeconomic development interests of the global environmental and conservation communities (Ishwaran et al., 2008). Over time, the emphasis of the concept has moved from nature conservation and research, the focus in the early years of the MAB Programme, to the interaction between sustainable development and nature/biodiversity conservation, with research and education in supporting roles (Price, 1996).

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In 1995, at the International Conference on Biosphere Reserves in Seville, Spain, the aim of biosphere reserves – sites recognized under the MAB Programme within the World Network of Biosphere Reserves (WNBR) – was stated in the Statutory Framework for the WNBR: "biosphere reserves should strive to be sites of excellence to explore and demonstrate approaches to conservation and sustainable development at a regional scale" (UNESCO 1995). Biosphere reserves are under national sovereign jurisdiction, yet share their experience and ideas nationally, regionally and internationally within the WNBR. By 2010, this comprised 564 sites in 109 countries.

On the ground, biosphere reserves have three main functions: conservation of biological and cultural diversity; sustainable development at the regional scale; and research, monitoring and education. For the implementation of the three functions, biosphere reserves have a mandated zoning scheme, and specific organizational and governance arrangements which support dialogue between and the engagement of all the relevant stakeholders.

The zoning scheme, with core, buffer and transition areas, is closely associated with the idea of seeking to retain the protected core area as an integral part of the bio-regional landscape of which the biosphere reserve is part. At the same time, the management of biosphere reserves is seen as a 'pact' between the local community and society as a whole. Open, evolving and adaptive management strategies are promoted to ensure that biosphere reserves and their communities are better placed to respond to external political, economic and social pressures (UNESCO, 2002).

Biosphere Reserves and the Global Biodiversity Objectives

The Seville Strategy for Biosphere Reserves (UNESCO 1995), which also derived from the conference in 1995, specifically highlights the connections between biosphere reserves and the implementation of global biodiversity objectives, i.e. conservation, sustainable use and access to benefits from biodiversity, internationally agreed under the Convention on Biological Diversity (CBD).

At the international and national levels, the Strategy aims to "promote biosphere reserves as means of implementing the goals of the CBD" and to "integrate biosphere reserves in strategies for biodiversity conservation and sustainable use, in plans for protected areas and in the national biodiversity strategies and action plans provided for under Article 6 of the CBD".

Furthermore, many specific objectives of biosphere reserves directly relate to the three main goals of the CBD:

- preserving genetic resources, species, ecosystems and landscapes;
- identifying and promoting activities compatible with the goals of conservation and sustainable use; and
- ensuring that benefits derived from the use of natural resources are equitably shared among stakeholders through transfer of appropriate technologies, including traditional/indigenous knowledge.

New and emerging challenges

While all biosphere reserves include protected area at least in their core, the land (and sometimes water or sea) they encompass is more than a protected area. Thus, since its inception, the biosphere reserve concept has proved its value beyond protected areas and has been increasingly embraced by scientists, planners, policy makers and local communities to bring a variety of knowledge, scientific investigations and experiences to link biodiversity conservation and socioeconomic development for human well-being.

However, since the adoption of the Seville Strategy in 1995, global issues have emerged or intensified, making it imperative for the MAB Programme and the WNBR to adapt and change in order to effectively respond to these emerging challenges. In this context, the 3rd World Congress of Biosphere Reserves was held in Madrid, Spain in 2008. Its main objective was to gather together the communities involved with the MAB Programme and its biosphere reserves to jointly reflect on the future of the WNBR, the most important new and emerging challenges for the network, and the ways and means to collectively address them.

As a result of the Madrid discussions, the mission of the WNBR was defined as follows:

"To ensure environmental, economic, social (including cultural and spiritual) sustainability through:

- development and coordination of a worldwide network of places acting as demonstration areas and learning sites with the aim of maintaining and developing ecological and cultural diversity, and securing ecosystem services for human well-being;
- development and integration of knowledge including science for advancing our understanding of interactions between people and the rest of nature; and
- building global capacity for the management of complex socio-ecological systems, particularly through encouraging greater dialogue at the science-policy interface, environmental education and multi-media outreach to the wider community".

The major challenges identified as seriously exacerbating poverty and inequality in and around biosphere reserves and for other human populations include:

- accelerated climate change with consequences for societies and ecosystems;
- accelerated loss of biological and cultural diversity with unexpected consequences that impact the ability of ecosystems to continue to provide services critical for human well being; and
- rapid urbanization as a driver of environmental change.

To respond to these challenges, the Madrid Action Plan (MAP) for Biosphere Reserves for the period 2008-2013 (UNESCO 2008) was developed and adopted.

Priorities for the future

The MAP articulates actions, targets and success indicators, partnerships and other implementation strategies, and an evaluation framework for the WNBR. It builds on past experience in the Network and in individual biosphere reserves, and reaches out to all sectors of society to create new partnerships between environmental and development agendas. To this broad community, biosphere reserves should be seen both as a process and as an instrument to understand and adapt to change, as well as a catalyst of new ideas and territories to test innovative development approaches.

Along with enhanced cooperation, management and communication, improved zonation and extended partnerships, science and capacity enhancement was identified as a priority area for the future of the WNBR. In particular, the MAP highlights the need to improve the science-policy interface and dialogue, recommending:

- increased involvement of stakeholders in producing research agendas and in conducting problem-oriented applied research to ensure science-informed participatory and collaborative management;
- mobilisation of scientific and non-scientific actors, combining all knowledge systems; and
- training of biosphere reserve managers on science-policy-practice interactions and participatory management.

Contribution from MAB and biosphere reserve experiences to the 2010 International Year of Biodiversity

The 2010 International Year of Biodiversity (IYB) represents an excellent opportunity for the international community to revisit existing biodiversity targets and ways and means to achieve them for the benefit of society. In this context, the MAB Programme and the WNBR – as an internationally recognized network of learning sites for sustainable development – has great potential for developing and testing innovative approaches to achieving the objectives of the CBD in the context of sustainable development and for sharing knowledge and lessons learned at all levels.

References

Ishwaran, N., Persic, A. and Tri, N. H. 2008. Concept and practice: The case of UNESCO biosphere reserves. *International Journal of Environment and Sustainable Development* 7(2): 118-131.

Price, M.F. 1996. People in biosphere reserves: An evolving concept. *Society and Natural Resources* 9: 645-654.

UNESCO, 1995. *The Seville Strategy and the Statutory Framework of the World Network of Biosphere Reserves*. Paris: UNESCO.

UNESCO, 2002. *Biosphere Reserves: Special places for People and Nature*. Paris: UNESCO.

UNESCO, 2008. *Madrid Action Plan for Biosphere Reserves for 2008-2013*. Paris: UNESCO.

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Conservation de la biodiversité: la complexité de la participation des populations dans la gestion des aires protégées

Ambiguïté liée au concept de conservation de la biodiversité

Dès l'émergence du concept de conservation de la biodiversité, les praticiens se sont rapidement approprié le concept dans l'identification et l'exécution des activités de gestion des ressources naturelles, particulièrement dans les aires protégées. Mais l'interprétation de cette notion pervertira radicalement son sens premier, débouchant souvent sur des situations aux conséquences désastreuses non prévisibles pour la biodiversité elle-même. De nos jours, le vocable conservation est régulièrement associé à celui de protection (Kasisi et Jacobs, 2002). Chauvet et al. (1993) ont souligné une dualité de perceptions selon qu'on conçoit la gestion des ressources naturelles sur la base du modèle anglo-saxon ou latin, lorsqu'il s'agit de donner un sens aux vocables conservation, protection ou préservation. Par ailleurs, même dans les textes de la Convention sur la Diversité Biologique, l'article deux relatif à l'emploi des termes reste muet sur la définition du vocable conservation. Seuls les termes conservations *ex situ* et *in situ* y sont définis. Et de quelle manière? « La conservation c'est… la conservation des écosystèmes ». Aurait-il fallu, ici, expliciter la notion de conservation au lieu d'en donner l'explication par une tautologie? (Kasisi et Jacobs, 2002).

Plusieurs auteurs se sont inspirés du sens donné au concept de conservation dans la Stratégie Mondiale de la Conservation (SMC) (UICN, PNUE et WWF 1980) lorsqu'ils ont abordé les questions de gestion des ressources naturelles. A notre avis, la réponse appropriée devant permettre de pallier à cette ambiguïté sémantique serait d'adopter la définition de la conservation avancée par la SMC décrite comme : « la gestion de l'utilisation par l'homme de la biosphère de manière que les générations actuelles tirent le maximum d'avantages des ressources vivantes tout en assurant leur pérennité pour pouvoir satisfaire les aspirations et les besoins des générations futures ». Cette définition cadre parfaitement avec les grands principes du développement durable.

La participation dans le processus de planification des aires protégées

L'aménagement des aires protégées ou conservation *in situ* à travers l'élaboration des plans de gestion répond à l'impérative dictée par les stratégies et plans d'action de conservation et l'utilisation durable de la diversité biologique lesquels constituent des engagements de l'article six de la Convention sur la diversité biologique. Or, la plupart des exercices de planification de la stratégie et du plan d'action de la biodiversité ont été menés suivant la méthode de Planification des Projets par Objectifs (PPO). Le cycle de planification de ces stratégies et

plans d'actions devrait, en principe, s'inscrire dans une perspective participative, cyclique, adaptative et multisectorielle.

Le principe de processus participatif au cours des principales étapes de la planification de la stratégie et du plan d'actions de la biodiversité dans plusieurs pays d'Afrique francophone n'a été qu'un mythe. On comprend facilement pourquoi les paysans et même d'autres citoyens ont manifesté peu d'intérêt au processus, les premières ébauches de stratégie ayant été élaborées sur la base des données récoltées suivant les méthodes scientifiques classiques. Les savoirs traditionnels et locaux détenus par les paysans ont été ignorés dès le début de l'exercice, c'est à dire lors des études nationales. La raison fondamentale du mépris affiché face au savoir traditionnel et local par l'élite réside probablement au niveau de la perception que cette dernière se fait de ce concept même. Cette perception est basée sur le fait que ce qui vient de l'occident est toujours porteur d'objectivité. Pourtant, ces savoirs constituent, bien des fois, les meilleurs instruments porteurs de la réalité sur la situation de la biodiversité sur le terrain (Kasisi et Jacobs, 2002).

On ne peut pas, par ailleurs, parler de processus pleinement participatif lorsqu'on constate que, dans la plupart des ateliers de planification tenus dans les pays d'Afrique francophone ainsi que dans les différents comités de planification, la représentativité des femmes n'a jamais dépassé les 20% (Kasisi et Peter, 2002). On sait pourtant que les femmes occupent une place prépondérante dans le processus de gestion des ressources naturelles en Afrique. Enfin, il est à remarquer dans ces processus une faible prise en compte de la culture.

La culture comme élément fédérateur de la participation

Le concept de conservation de la biodiversité est loin d'être partagé par tous les peuples de la planète, encore moins les formes et processus d'élaboration des plans de gestion des aires protégées issus du concept de conservation. La conservation ne pourra être pleinement efficace, que si elle tient compte de ce que Descola (2008) appelle la pluralité des intelligences de la nature. Il existe autant de perceptions du monde que de peuples sur la planète.

Fig.1 – Localisation du Parc national de Kahuzi-Biega dans la région des Grands-Lacs d'Afrique (source : http://eligreenbaum.iss.utep.edu/Kahuzi-BiegaPark-copyrighted.jpg).

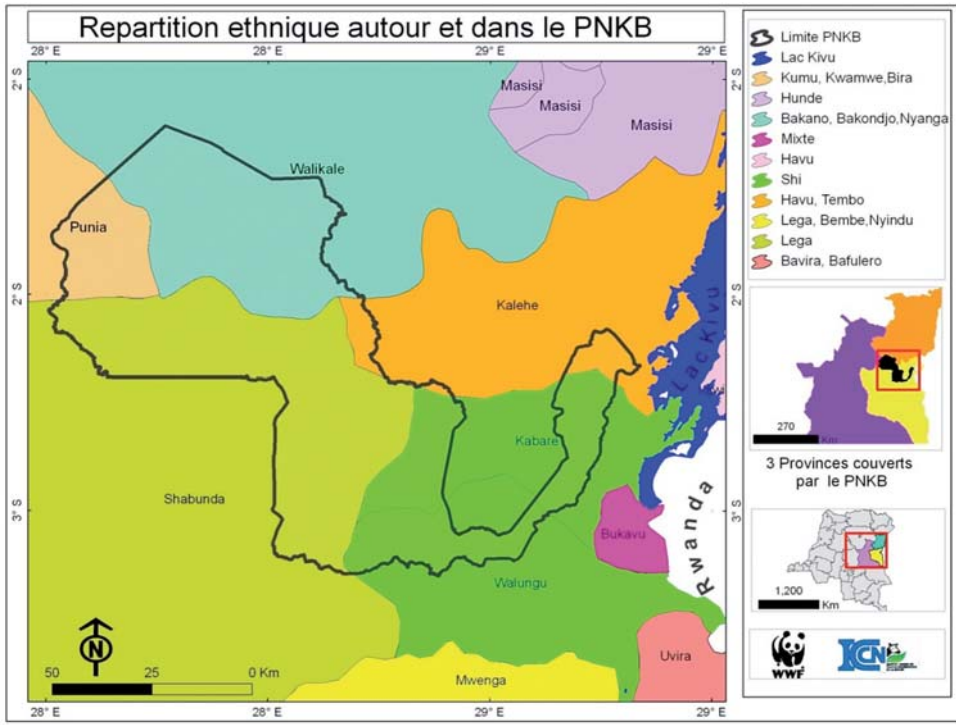

Fig.2 – L'ethnie Lega et sa localisation en rapport avec le Parc national de Kahuzi-Biega (source : Plan Général de Gestion du Parc national de Kahuzi-Biega. RDC (2010)).

Fig.3 – Kindi (initié) portant des signes distinctifs de son rang dans la société initiatique du Bwali chez les Lega de la RDC (source: Kasisi 1989).

La compréhension des différences de perceptions peut permettre d'accroître l'interprétation des bases rationnelles de ces différentes perceptions. C'est sur ces bases que les populations déterminent la manière dont elles vont gérer le milieu et les ressources. La prise en compte de ces perceptions commande au préalable qu'on y accède. Et cet accès passera par le symbolisme, la littérature (contes, proverbes, dictons, maximes, romans, etc.), les mythes, l'art, l'initiation etc. La connaissance et surtout l'ouverture à l'univers culturel peut contribuer à préciser et à comprendre le fonctionnement et l'articulation des mécanismes régissant toutes les sphères de la vie de la collectivité en vue d'y intégrer et d'y adapter les impératifs de la conservation et encore plus du développement. En Afrique, la vision (représentation) du monde qui est le reflet de cet univers culturel est accessible entre autres par la voie de l'initiation (Kasisi, 1989).

Sur l'importance de l'initiation en tant qu'instrument d'accès à la découverte et de respect des différences de perception, les extraits ci-dessous démontrant des réactions virulentes et quelque peu sarcastiques à l'article « Le Bwali, rite initiatique de la tribu Lega, en RD Congo » publié par Kilosho Barthélemy sur son site Internet le 8 septembre 2006 permettent de tirer quelques enseignements en rapport avec le choc des cultures. Ceci a, sans nul doute, des conséquences sur les stratégies de gestion des ressources et milieux naturels.

L'article en question, très sommaire, soulevait la menace que représentait la présence des groupes armés sur l'avenir du rite initiatique du Bwali chez le peuple Lega vivant en périphérie et dans une partie du Parc national de Kahuzi-Biega en République démocratique du Congo (Figures 1 et 2).

« Quand on voit ce genre de rite 'initiatique' on est en droit de se demander si nous vivons tous sur la même échelle du temps. Ce qui est à peu près certain c'est que ce n'est pas un des méfaits de la colonisation tant décriés par ceux qui, 'grâce' à elle, peuvent... la décrier. Que faudra-t-il pour que les comportements primitifs et sanguinaires de certains humains cessent ? Il est dommage que l'auteur de cet article se soit senti obligé de masquer certains aspects dérangeants, sans doute le voile pudique d'un reste de civilisation.» Par Paul M. 9 septembre 2006.

Décidément, le clash de différence des perceptions entre des individus provenant d'univers différents (occidentaux envers les autres cultures et vice versa) a la vie dure et restera donc longtemps d'actualité.

Étalée sur une durée de trente jours, l'initiation par le Bwali comme voie de connaissance témoigne, par son essence, que la majorité de ses rites marquent les grands moments, les principales articulations de la vie de l'individu et, par conséquent celle de la société. Issues du savoir initiatique, tout en créant une cohésion sociale dans la population Lega, elles conditionnent le comportement de l'homme au cours de son existence et fixent les normes d'éthique de la société orientant ainsi son comportement face à l'utilisation des ressources et du milieu naturels à partir de règles très strictes dans le respect de l'équilibre de la nature. N'est-il donc pas opportun, aujourd'hui d'envisager la réhabilitation de ces normes d'éthique environnementale traditionnelle?

La pratique initiatique du Bwali qui constitue un véritable patrimoine culturel immatériel devrait être inscrite sur la liste représentative du patrimoine culturel immatériel de l'humanité de l'UNESCO, à l'instar de la mascarade Makishi de Zambie qui a pu bénéficier de ce statut en 2008. L'adaptation de certaines pratiques du Bwali pourrait ainsi contribuer au programme de protection et d'utilisation durable des ressources du Parc national de Kahuzi-Biega.

Le Bwali supervisé par les initiés (Figure 3) offre un avantage certain car il permet de minimiser les contrecoups inhérents à une acculturation brutale qui impliquerait à la fois déculturation (perte de certains traits culturels) et enculturation exogène (participation à une nouvelle culture notamment celle imposée par la présence des milices rwandaises). Elle permet en outre une forme de ré-culturation qui implique une certaine réappropriation de la culture originelle.

Prétendre que l'intervention du religieux comme élément culturel dans la gestion de l'espace est une affaire purement extra-occidentale, comme le font les internautes ayant réagi au texte de Kilosho, relève d'une ignorance déconcertante.

Il suffit de rappeler qu'en Europe les zones humides ont été délaissées et souvent marquées par un moindre développement durant des siècles. Ce qui a empêché la mise en valeur des zones humides européennes, c'est une vision héritée de Descartes mais aussi présente chez les Physiocrates et dans tous les milieux catholiques de l'époque qui fait de « l'organique » le véhicule des turpitudes, des comportements amoraux et des pratiques démoniaques, une vision qui fait du contrôle de la nature par l'homme une marque du dessein de Dieu (Sajaloli, 2007).

Le respect de la diversité biologique implique le respect de la diversité humaine. L'un et l'autre sont des éléments fondamentaux de stabilité et de paix sur la terre. Créer des formes de développement durable, en harmonie avec les besoins et les aspirations de chaque culture, exige d'abandonner des modèles qui s'attaquent fondamentalement aux vies et aux perspectives de ces cultures. La tolérance et le respect réciproque de la singularité culturelle sont les conditions indispensables d'une compréhension mutuelle accrue entre les peuples et d'une reconnaissance de notre commune humanité (UNESCO et PNUE, 2003).

Bibliographie

Chauvet, M. et Olivier L. 1993. *La biodiversité, enjeu planétaire*. Sang de la terre, Paris.

Descola, P. 2008. A qui appartient la nature ? laviedesidees.fr. p. 11.

ICCN. (2010. Plan Général de Gestion du Parc national de Kahuzi-Biega (RDC) http://eligreenbaum.iss.utep.edu/Kahuzi-BiegaPark-copyrighted.jpg.

Kasisi, R. 1989. La planification et l'application d'un développement durable comme principale stratégie de conservation des ressources dans la région du Parc National de Kahuzi-Biega (Zaïre). Université de Montréal. Thèse de Doctorat.

Kasisi, R. and Jacobs, P. 2001. Strategies and action plans to conserve biological diversity: A cultural and scientific challenge. *Traditional Marine Resource Management and Knowledge* 13: 14-23.

Kilosho, B. 2006. www.agoravox.fr/auteur/kilosho-barthelemy.

Sajaloli, B. 2007. Nature et religion : une sacrée géographie ! *Cafés Géographiques* 1175: p. 6.

UICN, PNUE et WWF. 1980. Stratégie Mondiale pour la Conservation : la conservation des ressources vivantes au service du développement.

UNESCO et PNUE. 2003. Diversité culturelle et biodiversité pour un développement durable. Table-ronde. Sommet mondial pour le développement durable en 2002.

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Les sciences citoyennes et la conservation de la biodiversité

Comment suivre le devenir de la biodiversité?

Répondre à cette question est devenu un enjeu important pour les citoyens, les scientifiques, les gestionnaires et les décideurs politiques. On ne peut y répondre qu'à la condition qu'un obstacle majeur soit surmonté : celui de la mesure de la répartition et de la dynamique de la biodiversité sur de larges échelles de temps et d'espace. En effet, face aux changements globaux, les habitats et la distribution des espèces changent de façon complexe. Comment mesurer ces changements ? A quelle vitesse les espèces répondent-elles au réchauffement climatique ? Les aires protégées sont-elles vraiment efficaces ? Quelles sont les espèces gagnantes et les espèces perdantes ? Peut-on synthétiser le devenir de la biodiversité sous la forme d'indicateurs tout à la fois utilisables par les décideurs, compris par le citoyen et scientifiquement pertinents ?

Les scientifiques ne peuvent répondre seuls à ces questions. Fondés sur la rencontre entre l'expérience, la compétence et la bonne volonté de participants volontaires et l'approche scientifique, les programmes de sciences-citoyennes sont dès lors devenus un outil incontournable des stratégies de conservation à large échelle (Devictor et al., 2010).

Les sciences citoyennes : l'élaboration d'une boite à outils au service de la compréhension et de la conservation de la biodiversité

Dans un programme de science citoyenne, il s'agit de fédérer et de rassembler la récolte de données sur la biodiversité qui intéressent les citoyens et les scientifiques. Une telle collaboration permet aux scientifiques et aux participants de décider, ensemble, d'un nombre de paramètres clefs à relever, des espèces à suivre, et de la façon de récolter les données. Autrement dit, il s'agit de structurer un protocole qui garantira que les données reflètent bien les phénomènes que l'on cherche à mesurer. C'est une étape cruciale dans la récolte des données scientifiques. Ainsi, si les données récoltées par les citoyens révèlent qu'une espèce est en déclin, les scientifiques pourront s'assurer qu'il s'agit bien d'un déclin réel et pas d'un changement dans la méthode utilisée. Un bon protocole doit être simple, rigoureux, mais aussi ludique et facile à reproduire. Pour cela, il doit être pensé et discuté entre les scientifiques et les participants.

Une collaboration de ce type a toujours accompagné la science mais elle s'est considérablement développée grâce aux moyens modernes de communication et de gestion d'exploitation des données (Silvertown 2009). Les programmes de sciences-citoyennes qui se sont ainsi développés dans de nombreux pays concernent de nombreux groupes taxonomiques (plantes, papillons, oiseaux, poissons, mammifères, insectes…) et permettent d'aborder des questions variées sur la biodiversité (impact de la fragmentation des paysages, changement dans la phénologie des espèces en réponse au réchauffement climatique, qualité des écosystèmes, évaluation des aires protégées, impact de la fréquentation touristique…).

Les données récoltées par les programmes de sciences-citoyennes sont, comme toutes données scientifiques, ni « bonnes » ni « mauvaises ». En revanche, leur utilisation est plus ou moins pertinente pour répondre à une question posée. Mais quel que soit l'objectif ou la question posée, un intérêt scientifique majeur

de ces données réside dans leur grande quantité. En effet, la puissance d'une relation statistique étant fonction de la taille de l'échantillon, les programmes de sciences permettent de détecter des mécanismes et des tendances qu'il serait impossible ou très coûteux de détecter autrement (Schmeller et al., 2009).

Grâce à ce type de collaboration entre scientifiques et amateurs volontaires, la recherche sur la biodiversité a fait des progrès considérables et le nombre de résultats scientifiques publiés à l'aide de ces données ne cesse d'augmenter. Les sciences-citoyennes fournissent en outre des indicateurs sur la biodiversité officiellement utilisés par les gouvernements. Par exemple, l'indicateur de « bien-être humain » en Angleterre ou de « développement durable » en France est basé sur la tendance des oiseaux communs, dénombrés chaque année par des ornithologues bénévoles.

Vers une écologie citoyenne de la reconnexion

Dans un monde essentiellement urbanisé, les sciences-citoyennes peuvent favoriser la reconnexion du public avec la nature (Miller 2005). En effet, ces programmes s'appuient généralement sur les suivis d'espèces communes, dans des habitats ordinaires. Ces espèces, faciles à identifier, participent à l'émerveillement des citoyens pour la nature de tous les jours. Les sciences-citoyennes permettent aux participants de pouvoir compter sur les scientifiques pour valoriser, publier et utiliser leurs données pour mieux faire connaître aux décideurs et au public le devenir et le fonctionnement de cette nature familière. Mais cette reconnexion est double : les scientifiques qui participent à ces programmes doivent à leur tour justifier auprès des citoyens le sens de leur démarche, les étapes d'un raisonnement scientifique et l'impact de leurs travaux pour la communauté.

Ainsi, la réussite d'un programme de science-citoyenne ne se limite pas aux données récoltées. C'est aussi une opportunité originale pour que les scientifiques se rapprochent des réseaux d'amateurs, pour fédérer un groupe de personnes autour d'un enjeu et de valeurs communes. Cette reconnexion des scientifiques-citoyens et des citoyens-scientifiques s'exprime pleinement dans les nombreux outils pédagogiques associés à ces programmes. Les sites Internet des programmes de science-citoyennes proposent très souvent gratuitement des plaquettes téléchargeables destinées aux enseignants, aux enfants ou aux parents concernant le déroulement du programme ou approfondissant certains aspects (les critères d'identification et l'écologie des espèces suivies, comment mener à bien la réalisation d'une expérience…).

Quelques facteurs clefs de la réussite des programmes de science-citoyennes

Ces programmes sont depuis peu admis par la communauté scientifique comme un moyen nécessaire pour créer un véritable observatoire de la biodiversité. Si ces projets s'appuient sur une large participation bénévole, leur coordination, leur animation et leur maintien reposent bien souvent sur les cinq points clefs suivants (Devictor et al., 2010):

a) *Simplicité*. L'objectif et les méthodes doivent être très simples à expliquer et à comprendre. Le site Internet associé au programme doit être clair, notamment en ce qui concerne la transmission des données.
b) *Protocole*. Un protocole bien pensé et standardisé est nécessaire. Les scientifiques doivent s'assurer que le protocole est compatible avec ce que les gens peuvent et ont envie de faire. Le protocole doit permettre l'analyse et l'interprétation rigoureuses des données. La propriété des données et les règles d'accès doivent être clairement établies.
c) *Echange*. Les participants doivent être informés régulièrement de ce qui est fait avec leurs données et pourquoi. Les résultats, cartes et graphiques élaborés grâce aux données récoltées doivent être rapidement disponibles et régulièrement mis à jour.
d) *Communication*. Une stratégie de communication est cruciale pour favoriser la participation de nouveaux bénévoles et fidéliser les personnes qui adhèrent au programme. Cela suppose des communiqués de presse, l'activation des réseaux de naturalistes, un site Internet attractif, des publications à la fois scientifiques et de vulgarisation.
e) *Durabilité*. La continuité des projets de sciences-citoyennes doit être garantie. Une équipe permanente doit assurer le fonctionnement général et l'exploitation des données, et l'implication des scientifiques depuis la validation du protocole jusqu'à l'analyse et la publication des résultats.

Conclusion

Le positivisme scientifique et le développement technologique ont contribué à l'instauration d'une méfiance et d'une fascination pour la démarche scientifique. Bien que nécessaires, les groupes internationaux d'experts qui décident de la connaissance scientifique sur le changement climatique (GIEC) ou sur la biodiversité (IPBES), témoignent du caractère élitiste d'une science d'un monde en crise, que les citoyens ne peuvent que « croire ». Les sciences-citoyennes font un pas de côté par rapport à cette vision très hiérarchique de la connaissance et de la gouvernance et viennent la compléter. Il s'agit de restaurer une relation de confiance entre citoyens et scientifiques en impliquant les participants dans la recherche scientifique sur la biodiversité. Les citoyens ne sont pas « objets » mais « sujets » de la science produite, ajoutant une légitimité démocratique à la légitimité scientifique des résultats issus de leurs données.

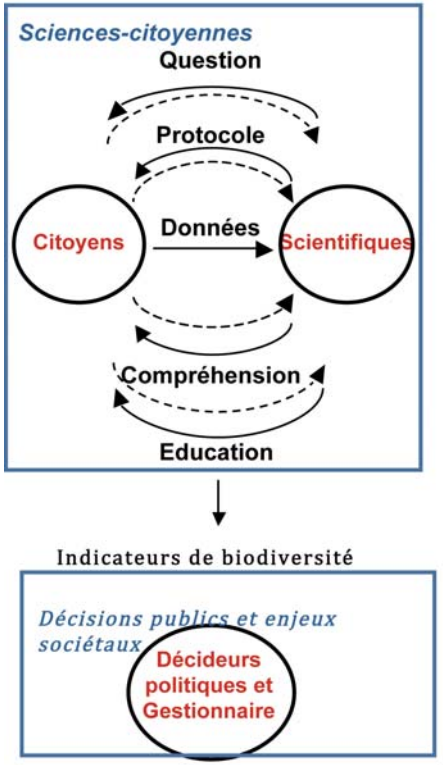
Bibliographie

Devictor, V., Whittaker, R.J. and Beltrame, C. 2010. Beyond scarcity: Citizen science programmes as useful tools for conservation biogeography. *Diversity and Distributions* 16: 354-362.

Miller, J.R. 2005. Biodiversity conservation and the extinction of experience. *Trends in Ecology and Evolution* 20:430-434.

Schmeller, D.S., Henry, P.Y., Julliard, R., Gruber, B., Clobert, J., Dziock, F., Lengyel, S., Nowicki, P., Déri, E., Budrys, E., Kull, T., Tali, K., Bauch, B., Settel, J., Van Swaay, C., Kobler, A., Babij, V., Papastergiadou, E. and Henle, K. 2009, Advantages of volunteer-based biodiversity monitoring in Europe. *Conservation Biology* 23: 307-316.

Silvertown, J. 2009. A new dawn for citizen science. *Trends in Ecology and Evolution* 24: 467-471.



Les programmes de sciences-citoyennes résultent d'une collaboration étroite entre citoyens et scientifiques. Il s'agit d'un échange permettant la mise en place d'un protocole pour répondre à des questions, la récolte et la valorisation de données pertinentes, ainsi que des outils d'éducation à la science et à la nature. Au-delà de cet échange, les données récoltées peuvent servir à la construction d'indicateurs de biodiversité utilisés par les décideurs politiques et les gestionnaires.

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UNESCO's efforts in the area of gender equality

UNESCO is commitment to gender equality in all its domains: designation of gender equality as a global priority in the UNESCO Medium Term Srategy for 2008-2013; the UNESCO Gender Equality Action Plan (GEAP) for 2008-2013; and commitment to gender parity in decision-making levels by 2015.

UNESCO and its Member States strongly believe that there is a need to raise awareness of the gender-differentiated practices and knowledge related to biological resources and sustainable development. This is why we are working towards a better recognition of the role of women in biodiversity management and the decision-making process.

In this regard, UNESCO's GEAP states that:

- Gender-responsive approaches to biodiversity conservation and sustainable development will be fostered through the promotion of effective participation of women in decision-making processes;
- The value of indigenous and local knowledge held by women will be highlighted and showcased, with particular reference to natural disaster preparedness and response, biodiversity conservation and climate change.

Likewise, UNESCO's Member States strongly support the Organization's commitment towards gender equality in biodiversity. H.E. Dr Davidson L. Hepburn, President of UNESCO's General Conference, reiterated this firm commitment in his address on the occasion of the UNESCO High-level event for the launch of the International Year of Biodiversity on 21 January 2010.

He said that in the fall of 2009, when UNESCO's Member States debated UNESCO's contribution in support of the implementation of the International Year of Biodiversity, "several Member States emphasized that UNESCO also provides a framework to stress the role of women in relation to biodiversity conservation and its sustainable use and, therefore, the equal participation of women, including scientists, should be incorporated in the planned activities".

Today, in light of this pledge, we will discuss why the pivotal role of gender in addressing biodiversity challenges merits special consideration in the formulation of conservation policies, strategies, and projects at all levels.

As you know, 2010 is the International Year of Biodiversity. Our side-event is timely, as this year, we also celebrate the 15th anniversary of the Beijing Platform for Action, which was adopted in 1995 at the Fourth World Conference on Women.

Fifteen years ago, the Beijing Platform for Action, in its Strategic objective K.1, called for an increased active involvement of women in environmental decision-making at all levels. More specifically, it:

- Encouraged the "effective protection and use of the knowledge, innovations and practices of women of indigenous and local communities, including practices relating to traditional medicines, biodiversity and indigenous technologies";
- Encouraged to "safeguard the existing intellectual property rights of these women as protected under national and international law";
- Encouraged "fair and equitable sharing of benefits arising from the utilization of such knowledge, innovation and practices".

Where are we now, fifteen years later? What have we been doing? What still needs to be done?

Expert work in the area of gender equality has helped and will further assist better understand the gender dimensions of biodiversity and will help us identify the rights and wrongs of the international community's actions in this regard. This includes issues such as why gender makes a difference in biodiversity and how this speaks to the Gender Plan of Action of the Convention on Biological Diversity and its implementation; the role of gender in agrobiodiversity and food security; and the work carried out by civil society.

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Le Réseau d'appui à la citoyenneté des Femmes Rurals d'Afrique de l'Ouest du Tchad (RESACIFROAT) et l'Union des Femmes Rurales Ouest Africaines et du Tchad (L'UFROAT)

Introduction

A l'occasion du lancement de l'année internationale de la biodiversité, le RESACIFROAT a eu l'honneur d'être invité à présenter son expérience d'appui aux associations de femmes rurales de la sous région ouest-africaine. C'est dans ce cadre que cette présentation a été élaborée avec l'espoir qu'elle permettra de voir et de donner toute l'importance et la valeur aux efforts que les femmes rurales dans un contexte environnemental de plus en plus difficile, ne cessent de concéder.

En effet, les piliers de l'agriculture que sont le, la paysan(ne), la terre, l'eau et la biodiversité sont de plus en plus mis à mal par les changements climatiques dont les effets sont perceptibles sur les terrains d'Afrique.

La biodiversité est le capital de vie et de survie de l'homme. Elle sous-tend les valeurs sociales, les religions et les croyances de chaque aire culturelle. En tant que capital de survie, elle est une ressource de refuge à chaque fois que les activités planifiées échouent, elle offre donc des solutions aux situations inattendues.

Un des acteurs de la conservation et de la promotion de la biodiversité demeure les femmes rurales à travers les types de culture qu'elles entretiennent et utilisent, cultures dites mineures et négligées dans les échanges commerciaux et la recherche scientifique. Ces cultures sont très rustiques et largement utilisées dans l'alimentation pendant les périodes de soudure quand les greniers sont vides et qu'il faut nourrir la famille jusqu'aux prochaines récoltes.

L'occasion que nous procure la préparation de cette communication nous conforte dans notre conviction que la femme rurale à travers sa place et le rôle qu'elle joue dans l'agriculture paysanne familiale en tant que système de production doit être valorisée et participer encore mieux aux prises de décisions concernant l'avenir de l'agriculture africaine.

C'est avec cette volonté que le Réseau d'Appui à la Citoyenneté des Femmes Rurales d'Afrique de l'Ouest et du Tchad (RESACIFROAT) œuvre avec les femmes rurales organisées en un réseau ouest africain (UFROAT) depuis plusieurs années.

Création de l'UFROAT

Sous l'égide d'une institution sous régionale de formation, les femmes rurales représentant les structures paysannes locales de huit pays d'Afrique de l'Ouest (Bénin, Burkina Faso, Côte d'Ivoire, Guinée Conakry, Mali, Niger, Tchad et Togo), après plusieurs rencontres d'échanges qui ont confirmé la similitude des situations de la femme dans les différents pays et leur volonté de s'unir pour faire face ensemble aux défis à relever, ont décidé de mettre en place une structure fédérative de leurs forces, c'est ainsi qu'est née en mars 2000, l'Union des Femmes Rurales d'Afrique de l'Ouest et du Tchad (UFROAT).

Aujourd'hui, ce sont huit pays qui sont organisés au niveau national et qui continuent de se rencontrer au niveau régional pour faire avancer leurs réflexions et leur combat.

En tant que cadre fédérateur issu de la volonté des femmes rurales de se faire entendre et de participer au développement de leurs communautés, l'UFROAT se donne les objectifs suivants :

- Briser les barrières de l'isolement par la promotion des échanges entre les femmes rurales au niveau local, national et sous régional ;
- Renforcer les capacités de structuration et les capacités institutionnelles ;
- Renforcer les capacités individuelles des membres ;
- Défendre les droits des femmes rurales et contribuer à les faire exercer ;
- Promouvoir la participation et la représentation des femmes rurales dans les instances de décision ;
- Devenir un outil de dialogue, de négociation et de propositions pour les femmes rurales de la zone ouest-africaine.

L'UFROAT représente aujourd'hui un rassemblement de plus de mille cinq cent femmes rurales dans chacun des huit pays qui ont mis en place une structure nationale, soit au total plus de douze mille femmes rurales poursuivant les mêmes objectifs.

Espace d'échanges et de construction de la personnalité, les femmes rurales pensent que :

- C'est dans les échanges que naissent les nouvelles idées ;
- C'est des échanges qu'on apprend des autres ce que l'on n'oubliera pas ;
- C'est en échangeant que l'on prend confiance en soi, et qu'on se stimule mutuellement.

Le RESACIFROAT

Face à cette volonté d'un groupe social classé parmi les plus pauvres et défavorisées par leur faible scolarisation et certaines considérations sociales et culturelles, de s'impliquer pour promouvoir des changements dans leurs communautés, des femmes et des hommes disposant d'une expertise et d'une grande expérience dans le domaine du développement, se sont organisés en réseau pour apporter en solidarité leur soutien aux efforts des femmes rurales.

Une vingtaine de femmes (15) et d'hommes (4) de plusieurs pays d'Afrique (Bénin, Burkina Faso, Guinée Conakry, Mali, Niger, Sénégal, Tchad et Togo) et d'Europe (Belgique) sociologues, ingénieurs d'agriculture, professeurs d'université, animatrices de terrain etc. ont crée ensemble un réseau au sein duquel chacun(e) apporte ses compétences, son expertise pour répondre aux besoins d'appui des organisations de femmes rurales au sein de l'UFROAT.

Les premières rencontres qui ont réuni les déléguées des femmes rurales et le RESACIFROAT avaient pour objectif de donner la parole aux femmes rurales, afin qu'elles s'expriment, qu'elles analysent ensemble leur situation, leur contexte et qu'elles prennent des décisions concernant leur avenir. Ces échanges ont mis en exergue les potentialités des femmes rurales et les préoccupations auxquelles elles souhaitaient en premier lieu s'attaquer ensemble et avec l'appui du RESACIFROAT.

C'est ainsi que la question des ressources naturelles a été retenue parmi toutes les préoccupations comme prioritaire. Pour répondre à ce souci, un plan de travail a été élaboré qui a abouti à un plan d'actions régional dont voici les étapes du processus:

1. Organisation d'ateliers nationaux d'analyse de situation :

Pour impliquer les femmes rurales dans l'analyse de situation, des ateliers ont été organisés par pays, où les femmes ont analysé elles mêmes la situation de leurs ressources naturelles, ainsi que la place qu'elles jouent dans la gestion de ces ressources. Six ateliers au Bénin, Burkina Faso, Mali, Niger, Togo et Tchad en langue du milieu ont été réalisés et ont permis de faire la synthèse suivante, indiquant de façon globale la situation dans les pays. Du fait de la division du travail et la féminisation de certaines tâches, les femmes rurales jouent un grand rôle dans la gestion des ressources naturelles (GRN). Elles sont impliquées dans différents secteurs de la GRN à travers leurs activités de production agricole (agriculture et élevage), les activités de cueillette, l'approvisionnement des ménages en bois de chauffe et en eau. En outre en tant qu'éducatrice, la femme peut influencer le comportement des jeunes enfants qui constituent la génération future. Les femmes interviennent dans la cueillette, la transformation et la commercialisation des produits forestiers. Ces produits de cueillette en particulier le karité, le néré, constituent une source importante de revenus pour les femmes au Burkina Faso et au Mali. La valeur marchande de plus en plus grande de ces produits de cueillette fait que les femmes se comportent souvent en agents destructeurs. On observe ainsi la cueillette par les femmes des fruits avant maturation, empêchant la régénération naturelle et entraînant la faible qualité des fruits et des produits dérivés.

Différentes parties des plantes (feuilles, écorces, racine) sont utilisées dans la pharmacopée. Les femmes sont impliquées dans la cueillette de ces plantes médicinale pour les soins de la famille. L'exclusivité de la cueillette pour les soins des enfants est par exemple assurée par la femme. La forte demande urbaine des produits de la pharmacopée entraîne une forte pression sur les plantes médicinales, ce qui peut compromettre leur régénération.

L'utilisation des ressources naturelles a longtemps été perçue surtout dans l'optique d'une exploitation souvent incontrôlée par les populations jusqu'au moment où la dégradation s'est exacerbée et a atteint un seuil où la nécessité de leur gestion s'impose comme un enjeu de développement durable. Les femmes rurales ayant un rôle central visant à assurer la subsistance de la famille se sont retrouvées au cœur des actions de GRN alors qu'elles ne disposent que d'un faible pouvoir de décision et de contrôle des RN et qu'elles n'ont par ailleurs pas été impliquées dans la formulation des politiques et stratégies. D'une façon générale pour l'essentiel des conventions de GRN, les femmes ne sont concernées qu'en tant qu'utilisatrices. Leur non implication dans la formulation des politiques en matière de gestion des RN est un facteur limitant dans l'impact de ces politiques sur l'environnement. L'exemple de certaines conventions au Mali où, elles ont été réellement impliquées et responsabilisées montrent qu'elles peuvent mieux négocier les règle et leur rôle dans la GRN.

2. Organisation d'un atelier régional de validation:

Les résultats des sept ateliers ont permis de concevoir et d'élaborer un plan d'actions en communication qui visait comme principal objectif de rendre capables de jouer un rôle de premier plan dans la formulation des politiques nationales et régionales ainsi que dans la mise en œuvre des programmes de gestion des ressources naturelles.

Pour poursuivre la méthode participative, un atelier régional réunissant environ 80 femmes rurales de sept pays a été organisé pour valider le plan d'actions ainsi élaboré afin que toutes les femmes rurales s'approprient le programme.

3. Organisation de plusieurs ateliers nationaux d'échanges et de renforcement des capacités :

En attendant d'obtenir le financement du plan régional, le RESACIFROAT, avec l'appui de certains partenaires techniques et financiers comme le CTA, a organisé dans les pays concernés des ateliers d'échanges notamment sur comment mettre en œuvre les stratégies d'implication des femmes dans la protection de l'environnement ; d'autres ateliers ont été organisés pour renforcer leurs capacités de production, tout en préservant l'environnement. Environ trois cent soixante femmes rurales ont pris part à ces rencontres et formations.

4. Organisation de voyages d'études :

Les voyages d'études sont un des moyens privilégiés de formation des femmes rurales; en effet, ils permettent de découvrir des initiatives porteuses de protection de l'environnement réalisées par d'autres femmes dans des contextes souvent similaires et qui permettent des duplications. C'est ainsi que des visites d'études ont été préparées sur le plan pédagogique pour obtenir les meilleurs résultats, dans les domaines de la mise en œuvre de conventions collectives de gestion des terroirs au sud du Mali et de la récupération des sols à Maradi au Niger.

5. Elaboration et mise en œuvre d'un programme régional de promotion de la communication à travers les TIC:

Pour faciliter les échanges entre les femmes rurales des sept pays, le CTA a apporté son appui technique et financier dans l'élaboration et la mise en œuvre d'un programme d'équipement des UFROAT de sept pays et de deux structures régionales en ordinateurs et connexion à l'Internet, ainsi que la formation et le recyclage de trois personnes de chacun des pays et des deux structures régionales. Vingt six personnes ont été formées et recyclées et environ 75 ont été formées sur place.

Résultats atteints

Les résultats atteints à ce jour sont très encourageants et peuvent se décliner comme suit :

- Les femmes rurales sont organisées au niveau de la sous région et peuvent constituer un acteur de dialogue; pour elles, l'union n'est pas un simple mot
- Il existe une plus grande prise de conscience de l'état de la dégradation des ressources naturelles et la biodiversité et de la nécessité des changements de

comportements à introduire pour préserver l'avenir; aujourd'hui, toutes les femmes rurales membres de l'UFROAT ont introduit dans leurs actions, le reboisement, des attitudes de protection des arbres, des semences, etc.

- Elles ont développé des capacités de prise de parole, d'analyse des réalités contextuelles de niveau régional et de recherche de solutions
- Des relations de solidarité se sont développées et se renforcent aujourd'hui à travers le programme de technologies de l'information; en effet, des blogs ont été crées, des plateformes d'échanges, qui leur permettent d'échanger et de se présenter (cf. les adresses suivantes : resacifroat@ning.com, ou femmesrurales@dgroups.org).

Difficultés / opportunités

- Les femmes rurales ont besoin de se rencontrer de façon régulière pour se soutenir et se stimuler mutuellement, mais les rencontres coûtent cher et ne trouvent pas souvent de partenaires prêts à s'engager
- Le plan de communication élaboré avec toutes les femmes rurales dans une démarche innovante n'a pas trouvé de financement et plusieurs des actions ne sont pas mises en œuvre, ce qui peut constituer des blocages pour la réussite du plan
- Plusieurs des femmes rurales leaders capables d'induire des changements dans leur milieu sont totalement démunies (par exemple, Rebecca, au nord du Bénin, est enclavée derrière les montagnes et n'a pas de moyens de communication; Mariama, femme élue conseillère municipale à Maradi au Niger et capable de mobiliser de nombreuses femmes rurales, ne dispose elle non plus de moyens; et Féréma, à l'ouest du Burkina, qui se bat pour apprendre aux femmes à lire et écrire dans leur langue et à construire des foyers améliorés pour combattre la désertification, doit marcher des kilomètres à pieds pour rejoindre les autres femmes)
- Malgré toutes ces difficultés, les femmes rurales sont ouvertes au changement et prêtes à s'engager dans le combat pour préserver la biodiversité et garantir de meilleures conditions de vie à leurs communautés.

Perspectives

En termes de perspectives, le RESACIFROAT va continuer à appuyer les femmes rurales dans leur combat contre la sous-information, l'insuffisance de ressources, l'analphabétisme qui les frappent et qui risquent d'accentuer leur exclusion et leur marginalisation sur les ressources naturelles. Le RESACIFROAT veut aussi continuer à chercher des partenaires convaincus et prêts à s'engager dans le projet de communication pour la prise en charge de la dimension genre dans la gestion des ressources naturelles et la biodiversité. Il est important de développer la solidarité féminine et la collaboration entre femmes pour soutenir les efforts des femmes rurales dans la protection des ressources naturelles et de la biodiversité.

Bibliographie

Film illustrant un travail que nous avons réalisé avec les femmes rurales sous les numéros 134 et 135 (http://vimeo.com/10610049).

Founè, Samaké A. 2009. Biodiversité et femmes en Afrique.

Founè, Samaké A. 2009. Biodiversité et agro-carburant: Les piliers de l'agriculture. Le paysan, la terre, l'eau et la biodiversité.

Granié, A.M. et Guétal-Bernard, H. 2006. Empreintes et inventivités des femmes dans le développement rural. Toulouse, France: Presses Universitaires du Mirail et Institut de Recherche pour le Développement (IRD).

Potentiel des objectifs du Millénaire pour le développement (OMD) pour la réduction de la vulnérabilité aux changements climatiques en Afrique de l'Ouest. Cahier des changements climatiques de l'institut d'applications et de vulgarisation en sciences N° 14, 2009.

Rabbinge, R. 2009. Agriculture et changements climatiques: Processus de négociation conclu à Copenhague. Note d'orientation IFPRI. http:// knowledge.cta

RESACIFROAT. 2005. Projet de communication participative pour le développement en vue de l'implication des femmes rurales ouest africaines et tchadiennes dans la gestion des ressources naturelles.

RESACIFROAT. 2009a. Rapport de l'assemblée générale.

RESACIFROAT. 2009b. Rapport final des journées de réflexion sur la citoyenneté des femmes rurales en Afrique de l'Ouest et au Tchad.

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Benefit sharing by research, education and knowledge transfer: A success story of biodiversity research in southern Ecuador

Introduction

The Andes of Ecuador are one of the "hottest" hotspots of biodiversity worldwide; however, they are severely endangered by the drivers of global change, in particular by deforestation. For 13 years, an interdisciplinary consortium of Ecuadorian and German researchers has been investigating biodiversity, ecosystem functioning and services, environmental and land-use change effects, and the socioeconomic conditions in the valley of the Rio San Francisco. This river breaches through the eastern range of the South Ecuadorian Andes between the provincial capitals Loja and Zamora (for further information refer to Beck et al., 2008, Bendix and Beck, 2009). The main goal of the research unit, "Biodiversity and Sustainable Management of a Megadiverse Mountain Ecosystem in South Ecuador", sponsored by the German Research Foundation (DFG), is to develop science-directed recommendations for a sustainable land use portfolio of this biodiversity hotspot, a portfolio that simultaneously preserves biodiversity, ecosystem processes and services in the natural system, and restores impoverished biological diversity and lost ecosystems services on the deforested mountain slopes, thus striving for a better livelihood of the local people.

With this, the main goal of the German research programme is in full agreement with the intentions of the Convention on Biological Diversity (CBD). By articles seven (Identification and Monitoring of species, functions, and use) and 12 (Research and Training), joint biodiversity research of scientists from abroad and local researchers is encouraged (UN 1993). Article 12 of the CBD clearly points to the specific needs of developing countries in scientific and technical education of scientific staff in local universities, where special emphasis of Article 15 is placed on the access to genetic resources of all partners. Modern technologies of inventorying, e.g. molecular "bar-coding" or high resolution spectral remote sensing of vegetation, are brought in and may encourage the host countries to strive to establish on their own the required facilities, with the assistance and funding of guest researchers (Article 16 of the convention). In the scope of an ecosystem study that term is ambiguous, because water and soil samples could contain useful biological material, however, climatological data could hardly be considered as genetic material. Nevertheless, such data may be shared under the umbrella of the CBD, following mutual understanding and acknowledgement of a real partnership. This precondition for successful research in developing countries is summarized under the term Access and Benefit Sharing (ABS) of the CBD.

Effective implementation of the intentions of the CBD, however, requires research as a major component of the mission of universities in the cooperating country. To date, the situation of most Latin American universities is not suitable for basic biodiversity research. Some of the main reasons for the currently poor situation of these universities, which particularly holds for the structure of Ecuadorian universities, have been identified by Arocenam and Sutz (2001), Thorn and Soo (2006), University of Cuenca (2006) and Romero (2009) as follows:

- Most universities in Latin America are predominantly teaching universities and are not equipped for academic research. Thus, they do not produce (enough) Ph.Ds for tertiary institutions including university staff development
- Only a low proportion of professors hold a Ph.D. degree which implies that they teach mostly undergraduate courses. This academic structure means that

the universities do not produce a sufficient number of highly ranked scientific papers, thus compromising their international visibility and competitiveness
- Even at the few research universities with an appreciable sector for research, new basic knowledge can rarely be generated, partly due to a lack of access to cutting-edge research technologies and insufficient infrastructure
- Lack of opportunities (permanent position, adequate pay, possibility to gain higher degrees, etc.) discourages aspiring young researchers from staying with their local university leading to brain drain, mainly to the US or Europe (but also to national industry).

Beyond the pure research issues, the CBD underlines in Article 13 (Public Education and Awareness), the importance of the involvement of national actors regarding the conservation and sustainable use of biological diversity. Particularly, exchange of information with the public gained from technical, scientific and socioeconomic research, the transfer of knowledge from basic science to applications and public environmental education and training shall foster public awareness and guarantee the embeddedness of basic biodiversity research activities. To advance acceptance by the public, indigenous and traditional knowledge should be considered in the research programmes.

The DFG 816 approach

In accordance with the goals of the CBD, the research activities of the German Research Unit (DFG No 816) are focused on four pillars:

- conducting and promoting joint multidisciplinary biodiversity research to investigate biodiversity, ecosystem functioning and ecosystem services under environmental change in the hot spot area of the south-eastern Ecuadorian Andes;
- supporting academic education, academic staff development and the establishment of relevant research technologies at the Ecuadorian partner universities regarding all interdisciplinary issues of biodiversity research;
- developing science-directed recommendations for sustainable management of extraordinary biodiversity, including complete protection and conservation by appropriate use, and supporting respective administrative structures, together with the national authorities and NGOs;
- facilitating transfer of the compiled knowledge to the public to boost awareness at the site for the needs and benefits of biodiversity research to safeguard ecosystem services and human well-being, and in turn, to attain acceptance of the local population.

The operation of the German Research Unit in South Ecuador has become an internationally-appreciated success story. This success benefited from a well-developed network of focal actors. At first, researchers from Ecuadorian and German universities, but also from other countries (Belgium, Brazil, Peru, USA) collaborated in a multidisciplinary research approach. The main cooperation partners of the German research group are the two universities in Loja (the Technical UTPL and the National University UNL), but further co-operation in the country is also well-established (e.g. with the University of Azuay in Cuenca, the Pontífica Catholic University of Quito (PUCE) and the Ecuadorian Weather Service (INAMHI). The scientific advisory board of the research unit cooperates with the German (DFG) and Ecuadorian funding agencies (SENACYT, AGECI) to warrant funding for the research programmes. Also, the development of the science landscape in southern Ecuador towards a national focal region for biodiversity and biotechnology research and education is the result of discussion between the German-Ecuadorian research consortium of the Research Unit, the funding agencies, the national planning authority SENPLADES and the NGO Nature and Culture International (NCI). Last but not least, the Ministry of Environment (MAE) is supporting the research activities, and, at the same time, benefits from the results with special regard to biodiversity protection and other environmental issues.

Scientific education and capacity building

Capacity building, one of the major aims of ABS, is supported in Ecuador by the Research Unit by including Ecuadorian scientists at all scientific qualification levels in the research programme, and by supporting the autonomous development of scientific staff at the local universities.
The programme's research projects are jointly developed by the Ecuadorian and the German principal investigators while funding of staff (e.g. Ecuadorian and German Ph.D. positions) and instrumentation is mainly provided by the German Research Foundation. Figure 1(a) clearly reveals the very successful capacity

building effect achieved after 13 years of collaborative research. A reasonable number of the researchers, particularly at the diploma/tesistas and Ph.D levels, are Ecuadorian collaborators. It should also be stressed that students from other Latin American countries, such as Brazil and Peru have been, and still are, attracted by the research programme. The development of the share of the Ecuadorian researchers over 13 years of research (Fig. 1b) reveals that the absolute number, but also the academic level, of the contributing Ecuadorian scientists has been significantly increased.

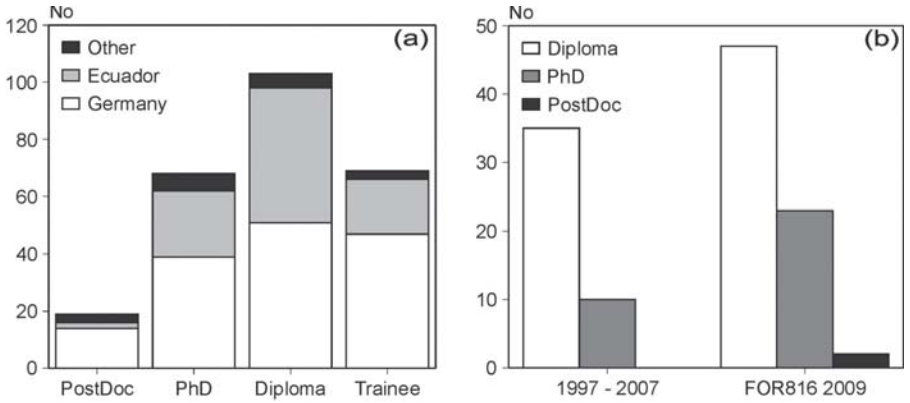

Fig.1 – (a) Researchers at different qualification levels working in the research unit and (b) Number of Ecuadorian researchers since the beginning of the research activities in southern Ecuador (Source: RU816 Data Warehouse, December 2009 – www.TropicalMountainForest.org).

This underpins the contribution of the research group to the careers of Ecuadorian scientific staff from Ph.D students to leadership positions in universities and NGOs. One excellent example is that of Dr. Juan Pablo Suárez who enrolled at UTPL as a first year student for biology. He did his Ph.D studies in a project (see, e.g., Suárez et al., 2006) of a mycorrhiza research group of the university of Tübingen (Germany), but at the same time was instrumental in establishing a Micropropagation and Molecular Biology Lab at his home university. He now holds the position of the Director of Research at UTPL, where he started building up a research group for genetics, acquiring research funds for it and establishing collaboration beyond the German research group. Another successful Ecuadorian Ph.D student has been appointed Director of an Ecuadorian National Park. Based on three consecutive memoranda of understanding since 1997, which emphasize capacity building, many students at all levels received training within the scope of the research programme (including, eight current Ph.D students). Activities were not only focused on fieldwork, but also on technical skills though internships in German universities. One recent achievement is the launch of two Ecuadorian-German research projects which were designed by colleagues of the UNL and submitted to the Ecuadorian funding agency SENACYT.

The success in staff promotion has led to greater international visibility of the research activities of the collaborating Ecuadorian universities (especially UNL and UTPL). This is mainly due to the increase of contributions in international peer-reviewed journals (Figure 2), where the relative contributions by Ecuadorian scientist as co-authors and first authors have steadily increased over the years.

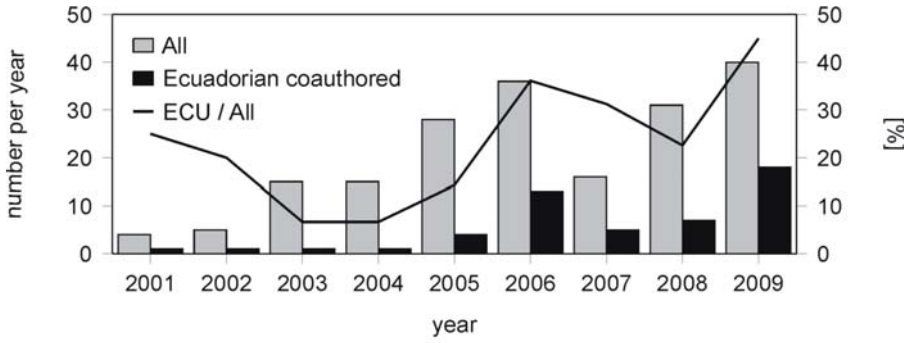

Fig.2 – Articles in international peer-reviewed journals (Source: RU816 Data Warehouse, December 2009).

The second area, which promotes local university staff, as noted by the World Bank (Thorn and Soo, 2006) was started in 2009 with a particular cooperation programme between the DFG and South Ecuadorian universities. Here, the project design is prepared by Ecuadorian principal indicators adapting the

objective to the programme of the German research group to warrant a synergetic use of available resources. The Ecuadorian Ph.D students and their living costs are provided by the Ecuadorian side whereas the DFG supports grants for visiting the home institutes of the German co-advising project partners. In addition to scientific staff promotion, technical staff at the Ecuadorian university is trained by the German scientists to properly operate jointly-established research infrastructure (e.g. sophisticated biochemical and genetic laboratory facilities, field instrumentation etc.).

Shared access to research facilities, technology and information

The importance of the research programme for the development of the universities in southern Ecuador is obvious. At the beginning of the research in 1997, UTPL was a pure teaching university without a biology department. After 13 years of joint research, the situation has dramatically changed. UTPL now possesses biological research personnel and infrastructure as well as teaching staff. Through the collaboration with the German programme, laboratories for molecular biology, soil analysis (including the analysis of trace gas fluxes) and geographical information systems have been established. Improving their facilities in this way, the cooperating Ecuadorian university was able to increase its international attractiveness far beyond the cooperation with the German research group: UTPL hosts more than 600 visiting professors per year and supports more than 300 research visits of its own scientists abroad. Funding for science development from national agencies amounted to US$ 4M in 2009.

At the UNL, the joint research programme similarly led to the establishment and extension of important research infrastructure for use by all partners: (i) improvement of the soil analysis lab, (ii) enrichment of the UNL Herbarium "Reinaldo Espinosa" by 3,500 new specimens, (iii) improved UNL laboratories for dendrochronology and (iv) plant physiology, and (v) a tree nursery which is indispensable for the long-term reforestation experiments of the research group. Very important for multidisciplinary biodiversity research in a foreign country is the availability of, and guaranteed unlimited access to, a research platform which includes a research station and well-managed experimental and monitoring sites. First of all, the research programme benefits from the close cooperation with the local foundation NCI, which provides the well-equipped research station Estación Científica San Francisco (ECSF). This station offers accommodation and board, provides basic research infrastructure such as laboratories for soil and water analysis and IT labs, and runs a herbarium and a lecture hall. Furthermore, many parts of the research area are owned by the foundation, e.g. the protected natural mountain forest of the Reserva Biologíca San Francisco (RBSF). Similarly, wide areas where the natural forest has been converted into pastures or exotic tree plantations are also available for research. The access to research areas of the cooperating universities is also an option.

The research group's gained knowledge on biodiversity and underlying ecosystem processes/services is compiled in a central data warehouse (Nauß et al. 2007), which is open to all contributing scientist and cooperating organizations at different scientific levels. To date, the data warehouse not only keeps more than 19 Mio stored data, but also offers access to the digital publications, which is normally hardly possible at Ecuadorian universities.

Potentials of a transfer of basic research to application

The overarching objectives of the research programme (sustainable, science-directed development) imply that relevant results from basic research should be developed into applications to serve communities concerning biodiversity protection, and the restoration of biological diversity and ecosystem services including on fallow lands. Two land use options are intensively investigated. The mountain forest in Ecuador is threatened by slash-and-burn for pasture land. Unfortunately, many of these pastures are soon overgrown by aggressive weeds like bracken fern, becoming abandoned after only a few years of use which increases the pressure on the remaining, extremely biodiverse, mountain forest (refer to Hartig and Beck, 2003). To safeguard usability of the pastures, and thus the livelihood of the local farmers, sustainable pasture management strategies are under experimental investigation. Even active pastures are poor in biological diversity (e.g., Nöske et al., 2008) as compared to the natural forest, and with the loss of biodiversity, ecosystem services are degraded too (e.g. climate regulation function – see Fries et al., 2009). One intensively studied land use option is reforestation with native tree species. This is expected to yield a close to natural mountain forest (Weber et al., 2008), restoring biodiversity and ecosystem ser-

vices and, at the same, time improving revenue for the land owners (Knoke et al., 2009). To that end, the research programme also investigates the potential of indigenous forms of land use for inclusion in a sustainable land use portfolio (Pohle and Gerique, 2008).

The DFG is currently discussing a new funding instrument ("Transfer Project") which would promote the development of knowledge from basic research into applications. In many cases this means research into ways by which to scale-up technologies or lessons. The idea is to co-finance such transfer projects, i.e. the Ecuadorian partner would also contribute part of the financial or material resources which are necessary for that kind of research.

In that respect, the foundation NCI plays a focal role as mediator between the Ecuadorian-German research consortium, the national and local administration and the public. Several applied programmes are conducted by NCI where information from the research programme is used to: (i) support local communities in sustainable land use management; (ii) create a regional conservation system; (iii) organize a regional public water fund (FORAGUA); (iv) improve watershed management and promote hydro-power; and (v) advance environmental education. One milestone of successful cooperation was the approval of the UNESCO Biosphere Reserve Podocarpus–El Condor in 2007. The results of the research programme were the scientific basis for the preparation of the proposal and the research unit acts as a long-term model project for biodiversity protection and sustainable development for the implementation of the biosphere reserve concept.

Public education and awareness

The results of the research programme are mostly published in English in scientific journals or books, which make their appreciation and use by the local people difficult. Thus, it is absolutely necessary to translate the results into local languages in order to raise awareness and foster the feeling of responsibility by the public for biodiversity and related ecosystem services. In addition, environmental information on a more popular scientific level is necessary for stakeholders and interested people. Such activities are regularly organized jointly. One example is the publication of a booklet by NCI and the research programme (Kiss and Bräuning, 2008) summarizing and translating the scientific results into Spanish for a wider readership. Additionally, annual symposia with keynote talks in Spanish and monthly research meetings, both open to the public, were and still are organized in Loja. The lecture hall of the research station is used to conduct classes and field courses on biodiversity and the environment, but also specific courses for the local administration.

DFG and the ABS process

As the previous sections show, the research programme successfully addresses all claims of the CBD. That is also a precondition to apply for funds related to biodiversity research at the DFG (2008). Since 2008, DFG has had guidelines to fulfill CBD principles and also to ensure that DFG-funded projects will be conducted in accordance with the CBD principles. They are part of the approval of an applicant's grant by the DFG, and are also referred to in the general information for draft grants proposals. It is fair to say that DFG CBD Guidelines have two kinds of effects. At the beginning when the researcher is drafting the application for a grant, the guidelines assist him or her in preparing the proposal in compliance with the CBD principles. Secondly, if the researcher accepts a grant from the DFG, he/she also accepts the regulations of the guidelines.

To keep abreast of developments in the CBD-ABS process, DFG has made various efforts over the years: it has established an ABS working group which observes ABS activities at an international level; employs an ABS programme officer; participates in the Conference of the Parties to the CBD and in ABS working group meetings; co-hosts workshops and co-organizes side-events at workshops and conferences; and has developed a network to improve the information level and awareness of researchers for CBD issues, especially of ABS measures.

Ecuador is part of the Andean Community (CAN). In 1996, CAN countries (Venezuela, Colombia, Ecuador, Peru and Bolivia) signed the Andean ABS Decision 391 (http://www.cbd.int/abs/measures/group.shtml?code=am-and) but, to date, only Bolivia and Peru haved brought the regulations into effect. In Ecuador, granting of research permission is an administrative decision of the environmental authorities.

The German research group regularly applies for research permission to the Ministry of Environment and fulfils all underlying laws and regulations. One additional benefit, besides the issues mentioned in the previous sections, is the contribution of the research programme to the national specimen repositories which, at the same time, is a precondition for getting research permission.

References

Arocenam, R. and Sutz, J. 2001. Changing knowledge production and Latin American universities. *Research Policy* 30: 1221–1234.

Beck, E., Bendix, J., Kottke, I., Makeschin, F. and Mosandl, R. (eds.). 2008. Gradients in a tropical mountain ecosystem of Ecuador. *Ecological Studies* 198.

Bendix, J. and Beck, E. 2009. Spatial aspects of ecosystem research in a biodiversity hot spot of southern Ecuador – an introduction. *Erdkunde* 63: 305-308.

DFG, 2008. Guidelines for funding proposals concerning research projects within the scope of the Convention on Biological Diversity. Bonn, Germany: CBD.

Fries, A., Rollenbeck, R., Göttlicher, D., Nauß, T., Homeier, J., Peters, T. and Bendix, J. 2009. Thermal structure of a megadiverse Andean mountain ecosystem in southern Ecuador and its regionalization. *Erdkunde* 63: 321-33.

Hartig, K. and Beck, E. 2003. The bracken fern (*Pteridium aquilinum*) dilemma in the Andes of South Ecuador. *Ecotropica* 9: 3-13.

Kiss, K. and Bräuning, A. 2008: El bosque húmedo de montaña – Investigaciones sobre la diversidad de un ecosistema de montaña en el sur del Ecuador. Loja – Ecuador: Unidad de investigación FOR402. DFG, TMF y Naturaleza y Cultura Internacional. (also available in English)

Knoke, T., Calvas, B., Aguirre, N., Roman-Cuesta, R.M., Günter, S., Stimm, B., Weber, M. and Mosandl, R. 2009. Can tropical farmers reconcile subsistence demands with forest conservation? *Frontiers in Ecology and the Environment*. 7:10. pp. 548-554.

Nauß, T., Göttlicher, D., Dobbermann, M. and Bendix, J. 2007. Central data services in multidisciplinary environmental research projects. *E-Journal of Informatics in Agriculture* 2: 1-13.

Nöske, N.M., Hilt, N., Werner, F.A., Brehm, G., Fiedler, K., Sipman, H. and Gradstein, S.R. 2008. Disturbance effects on diversity of epiphytes and moths in a montane forest in Ecuador. *Basic and Applied Ecology* 9: 4-12.

Pohle, P. and Gerique, A. 2008. Sustainable and non sustainable use of natural resources by indigenous and local communities. In: Bendix, J., Kottke, I., Makeschin, F. and Mosandl, R. (eds.). Gradients in a Tropical Mountain Ecosystem of Ecuador. *Ecological Studies* 198: 347-362.

Romero, L.M. 2009. Scientific capacity building across borders in Latin America: A case study on inclusion. In: Fegan, J. and Field, M.H. (eds.). *Education Across Borders*: 61-75. Springer.

Suárez, J.P., Weiß, M., Abele, A., Garnica, S., Oberwinkler, F. and Kottke, I. 2006. Diverse tulasnelloid fungi form mycorrhizas with epiphytic orchids in an Andean cloud forest. *Mycological Research* 110: 1257-1270.

Thorn, K. and Soo, M. 2006. *Latin American Universities and the third mission – Trends, challenges and policy options*. World Bank Policy Research Working Paper 4002.

United Nations, 1993. Mutilateral Convention on Biological Diversity (with annexes). Vol. 1760 I-30619. www.cbd.int/convention/convention.shtml (last access 16 Feb 2010).

University of Cuenca (eds.). 2006. *Institutional change to strengthen research and education*. Cuenca, Ecuador.

Weber, M., Günter, S., Aguirre, N., Stimm, B. and Mosandl, R. 2008. Reforestation of abandoned pastures: Silvicultural means to accelerate forest recovery and biodiversity. In: Beck, E., Bendix, J., Kottke, I., Makeschin, F. and Mosandl, R. (eds.). Gradients in a Tropical Mountain Ecosystem of Ecuador. *Ecological Studies* 198: 447-458.

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Valuing biodiversity from an economic perspective

Biodiversity as natural capital

Human activities have increased species extinction rates by as much as 1,000 times relative to background rates which were typical over Earth's history. Furthermore, 10–50% of well-studied higher taxonomic groups (mammals, birds, amphibians, conifers, and cycads) currently face extinction (Millennium Ecosystem Assessment 2005), while 20–30% of species assessed are likely to be threatened with extinction from climate-change impacts – possibly within this century – as the increase in global average temperature above pre-industrial levels exceeds 2°–3°C (Intergovernmental Panel for Climate Change, 2007).

Biodiversity as measured by an appropriate metric, such as species richness, Shannon or Simpson index, is reduced by these increased extinction rates. Biodiversity can be regarded as a stock of natural capital, which, combined with other such stocks, generate a number of services to humans. These services, which are classified by the Millennium Ecosystem Assessment as supporting (nutrient cycling, soil formation, primary production), provisioning (food, fresh water, wood and fiber, fuel), regulating (climate, flood, disease regulation, water purification), and cultural (aesthetic, spiritual, educational, recreational), directly affect human well-being.

Biodiversity is essential for the proper functioning of an ecosystem so that it retains its ability to provide a flow of supporting, provisioning, regulating and cultural services. Thus biodiversity loss is expected to have a negative impact on these services, which will consequently result in reductions in human well-being.

Given the above links between biodiversity and human well-being, it seems reasonable to base the valuation of biodiversity on the value of ecosystems services lost due to reduction in biodiversity, measured in some appropriate metric. To obtain this valuation a number of steps should be taken, with the purpose of obtaining an approximate quantification of the impact of biodiversity loss on ecosystem services.

Biodiversity and ecosystem characteristics

The first step is to identify the impact of biodiversity on a number of important ecosystem characteristics, which include:

- Productivity: More diverse plant systems are more productive than less diverse ones. Empirical studies relating the number of species in ecosystems to plant productivity found that functional diversity is a principal factor explaining plant productivity.
- Resilience: Diverse systems are more resilient to exogenous disturbances. Diversity promotes stability; monocultures tend to make ecosystems unstable.
- Insurance: Insurance is associated with the possibility of finding genes in non-commercially used species that can be used to build resistance against lethal diseases affecting other species. Thus genetic diversity can be used as insurance against catastrophic events or infections.
- Knowledge: Biodiversity can be used as a source of knowledge with which to develop new products in the biotechnology or pharmaceuticals industry.

The economic dimension of biodiversity can be understood in the following context:

- biodiversity loss implies changes in ecosystems characteristics and loss in ecosystem services;
- loss in ecosystem services has a negative impact on human well-being;
- to value changes in biodiversity we need to value the impact on human well-being; and
- to value the impact on human well-being, we need to value changes in ecosystem services resulting from changes in biodiversity.

Therefore, ecosystem valuation implies biodiversity valuation.

Valuation of ecosystem services

The value of an ecosystem is the value of the services it produces and can be defined formally as the discounted sum of the flow of the values of all services provided by this ecosystem, or: $\text{value} = \sum_{t=0}^{\infty} \frac{VS_t}{(1+r)^t}$, where VS_t is the value of ecosystem services at time t, and r is the discount rate.

The economic values associated with ecosystems services include direct use values (e.g. production or consumption of provisioning services); indirect use values (the value of resilience); option values that reflect potential future values; and non-use values, which reflect the intrinsic value of nature. If there are markets for ecosystems services, then the valuation of these services is relatively simple since it entails the use of market prices, with some possible adjustments to take into account market distortions. Markets are however missing or fail to produce socially-optimal outcomes because of well-known market failures associated with ecosystem services, such as lack of well-defined property rights and open access, or incomplete future markets and obstacles in intergenerational negotiations. Under market failures, valuation requires the use of specific non-market valuation methods, which include mainly travel cost methods; methods of hedonic pricing; production function; averting behavior; expected damage; and stated preference methods. These valuation methods have been extensively used to estimate direct and indirect use values, option values and non-use values generated by the provision of ecosystem services.

Valuing a stock of natural capital

Valuation of ecosystem services as described above can be used to value the stocks of natural capital existing in ecosystems, including the valuation of biodiversity. If approximately efficient markets for the ecosystem services generated by the natural stock exist, then the market price is a good proxy, especially for provisioning services and direct use values. In this case the value of a unit of a stock of natural capital is the present value of the future flow of the value of provisioning services provided by this unit of the stock (e.g. timber or commercial fishery) valued at market prices. If the services generated by the natural capital generate externalities, positive or negative, these externalities will not be captured by market prices, unless appropriate regulation is in place, and should be valued accordingly. This argument suggests that when the natural capital generates services for which markets are missing, then the value of a unit of the stock is the present value of the future flow of the provisioning services plus the present value of the future flow of the value of services associated with values such as indirect use, option, or non-use values. Indirect use or non-use values are obtained by an appropriate application of the nonmarket valuation methods mentioned above. Obtaining the value of a unit of capital stock using this approach implies that an accounting or shadow price for the natural capital stock is obtained. An accounting or shadow price for a natural stock is defined as the change in the total value of ecosystem services caused by a marginal change in the stock associated with the specific service.

Formally, let

$$V = \int_0^{\infty} e^{-rt} U\left(\mathbf{s}(t), \mathbf{c}(t), t\right) \qquad (1)$$

$$\frac{d\mathbf{s}(t)}{dt} = \mathbf{f}\left(\mathbf{s}(t), \mathbf{c}(t), t\right), \ \mathbf{s}(0) = \mathbf{s}_0$$

where V is the total value of an ecosystem; $\mathbf{s}(t) = \left(s_1(t), \ldots s_n(t)\right)$ is a vector of n stocks of natural capital existing in this system at time t; $\mathbf{s}(t) = \left(s_1(t), \ldots s_n(t)\right)$ is a vector of m provisioning services generated by these stocks of natural capital at time t; $\mathbf{s}(t) = \left(s_1(t), \ldots s_n(t)\right)$ is the flow of benefits generated at time t by the

ecosystem through the provision of ecosystem services, and $\mathbf{f}(\mathbf{s}(t),\mathbf{c}(t),t)$ is an n-dimensional dynamical system describing the evolution of the $i=1,....,n$ stocks of natural capital in the ecosystem. Then, the accounting price for a specific stock, s_i, is defined as $p_i = \frac{\partial V}{\partial s_i}$. If the time paths of provisioning services are chosen optimally, then the optimized value of the ecosystem is defined, for a time stationary problem, by the dynamic programming equation:

$$V = \frac{1}{r}\max_{\mathbf{c}(t)}\left[U(\mathbf{s},\mathbf{c}) + \sum_{i=1}^{n}\frac{\partial V}{\partial s_i} f_i(\mathbf{s},\mathbf{c})\right] \quad (2)$$

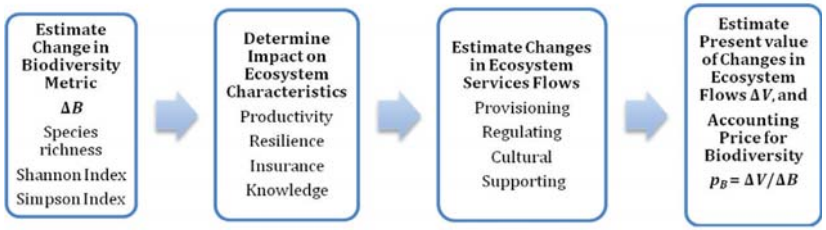
In this case the accounting prices $p_i = \frac{\partial V}{\partial s_i}$ are derived as solutions of the optimization problem, and can be regarded as efficient prices that could be used to obtain optimal resource allocation.

Valuing changes in biodiversity

The formal framework described above, although complicated for practical applications, provides a consistent framework for valuing changes in biodiversity. Let for example V_1 be the expected present value of timber harvest from a forest when species richness is B_1, and let V_2 be the expected present value of timber harvest from a forest when species richness is B_2. Then the accounting price of biodiversity in terms of timber value can be defined as $p_B = \frac{V_2 - V_1}{B_2 - B_1} = \frac{\Delta V}{\Delta B}$

It is clear that this accounting price for small changes in the biodiversity metric converges to the accounting price for a specific stock defined above. If the value of the forest can be defined in terms of more services (e.g. water regulation, potential development of pharmaceuticals, aesthetic or recreational services), and changes in these services can be associated with changes in the biodiversity metric, then a more efficient accounting price for biodiversity will be obtained.

A framework for valuing changes in biodiversity based on the value of ecosystem services can be described as follows:



This method allows the valuation of the impact of changes in biodiversity due to factors such as development and changes in land use and ecosystem destruction, general environmental degradation, or climate change.

Furthermore, it allows for the provision of operational and meaningful benefit-cost rules for policies which change biodiversity. Suppose that a conservation project increases the biodiversity metric by ΔB, while the cost associated with this project is C. Then a cost benefit rule for accepting the project would be $p_B \Delta B - C > 0$. Similar cost benefit rules can be used for projects that protect ecosystems from climate change.

As an example, consider that climate change is expected to cause the loss of N species in a coastal ecosystem which means that the biodiversity metric species richness will change by $\Delta B = N$. Assume that this change will have the following effects on ecosystems services:

- reduction in watershed protection services by y hectares, equivalent to value V_y
- reduction in provisioning services by V_p

Then the accounting price of biodiversity is $p_B = \frac{V_y + V_p}{N}$.

A project that will prevent this loss at a cost C, could be assessed on the benefit-cost test $(V_y+V_p)-C$. Of course this has to be understood as only an approximate rule providing a lower bound for the benefit/cost ratio, since it is most likely that the value of ecosystems services lost due to biodiversity loss is underestimated because of the well-known market failures associated with environmental resources.

References

Intergovernmental Panel for Climate Change, 2007. *Fourth Assessment Report: Climate Change 2007*.

Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being, Biodiversity Synthesis Report*. Washington, DC: World Resources Institute.

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Valuing marine protected areas: A case study application within The Economics of Ecosystems and Biodiversity (TEEB)

Introduction

The Economics of Ecosystems and Biodiversity (TEEB) was conceived at the meeting of the G8 countries and the five major newly-industrialising countries environment ministers that took place in Potsdam in March 2007 to evaluate the costs of policy inaction and the benefits of policy action concerning conservation.[5] TEEB's objectives are to influence and inspire the conservation of ecosystems and biodiversity by documenting economic methodologies and case study applications that allow decision-makers at all levels to determine the full value that ecosystems provide, therein linking with the Millennium Ecosystem Assessment (MA 2003). Human well-being is dependent upon these ecosystem services (ESS). Provisioning services are often tangible and have a market value (e.g. timber production) but others that are also fundamental to human well-being (e.g. resilience) are outside the market. This results in decision-making at all levels often under-valuing these services and thus under-valuing conservation.

Economic valuation methodologies have been developed and applied to address this issue, but these have primarily focused on terrestrial ecosystems, and many examples of such applications are presented in the TEEB reports. This paper focuses on marine ecosystems. The intermediate section presents a case study, and in the final section the wider implications of the analysis are drawn out.

The UK Marine and Coastal Access Bill

Costanza et al. (1997) suggest that marine ecosystems may constitute around 60% of the value of the biosphere, and fish productivity is but a small fraction of this. Halpern et al. (2008) paint a sombre picture of anthropogenic damage occurring in temperate waters. Thus not only are marine ecosystems valuable in terms of ESS delivery but this provisioning is also threatened.

Like many other nations, the UK's marine legislation has traditionally operated under a complex system of national, regional and international codes that address the control and operation of activities within the marine environment (Boyes et al. 2003). The UK Marine and Coastal Access Bill (2009)[6] attempts to apply the ecosystem approach to management accounting for the full range of ESS, i.e., not treating provisioning ESS (e.g. fisheries) in isolation. A cornerstone of the Bill was the introduction of a network of marine protected areas, termed Marine Conservation Zones (MCZs). An evidence base was required to justify this legislation and thus an assessment of costs and of benefits was carried out.

The details of the benefit estimation are set out in Hussain et al. (2010). Two sets of management regimes, with varying degrees of exclusion and thus reduced anthropogenic impact, were assessed in the context of three network scenarios describing the proposed location of MCZ sites. The benefit estimate relied on benefits transfer (BT) wherein estimates derived from other primary studies are transferred to the policy site. The main methodological challenges were the paucity of appropriate primary valuation studies and the way that estimates were framed in these studies, viz. in aggregate terms.

5. http://ec.europa.eu/environment/nature/biodiversity/economics/
6. http://www.publications.parliament.uk/pa/jt200708/jtselect/jtmarine/159/15902.htm

An appraisal of economic efficiency requires the application of with-minus-without conditions such that only the incremental costs and benefits associated with the policy instrument are valued. Since the application of MCZs was not an all-or-nothing and the only ESS provisioning estimates found for BT were expressed in aggregate terms, a novel methodology to assess incremental impacts was developed (Hussain et al. 2010). The table below sets out the ESS that pertain to terrestrial marine ecosystems and for which a value was found[12], with the final column showing the annual aggregate values used.

Ecosystem Service	Definition	Value used (£ 2007)
Food provision	Plants and animals taken from the marine environment for human consumption	£ 885 million
Raw materials	The extraction of marine organisms for all purposes, except human consumption	£ 117 million
Nutrient cycling	The storage, cycling and maintenance of availability of nutrients mediated by living marine organism	£ 1.3 billion
Gas and climate regulation	The balance and maintenance of the chemical composition of the atmosphere and oceans by marine living organisms	£ 8.2 billion
Disturbance prevention and alleviation	The dampening of environmental disturbances by biogenic structures	£ 440 million
Cognitive values	Cognitive development, including education and research, resulting from marine organisms	£ 453 million
Leisure and recreation	The refreshment and stimulation of the human body and mind through the perusal and engagement with living marine organisms in their natural environment	£ 1.4-£3.4 billion

Marine Ecosystem Services – categories, definitions and annual aggregate values (after Hussain et al., 2010).

12. Values were not found for four ESS: resistance and resilience; biologically-mediated habitat; bioremediation of waste; and cultural heritage and identity.

The valuation literature was extensively searched and then screened for the quality of the data source (valuation method used, integrity of application, transferability to the MCZ study etc.). All value used was expressed in the aggregate (for the UK overall and across all marine landscapes). In all but one case (leisure and recreation) only one estimate was available as opposed to a range of alternatives; the sensitivity analysis thus was constrained in this regard.

The methodology developed had to account for varying the impact of MCZ designation across the different ESS; and within any single ESS, the impacts would vary across different landscape types. The methodology thus scored the impact of designation for each individual ESS or landscape. This scoring was relative to the benchmark, i.e. how much provisioning of the particular ESS/landscape combination would occur were MCZs not to be designated.

Since the only estimates (where available) were for 2007-equivalent provisioning, this had to be used as the benchmark. Thus the scores were all relative to this 2007 provisioning. Two elements were scored: the extent to which MCZs would impact on provisioning, measured as a percentage change; and when this change in provisioning would likely occur – the impact trajectory. The latter is important because of the standard economic application of discounting (in this case at the UK government-defined rate at the time of the study, i.e. 3.5%). What discounting implies is that a 30% increase in provisioning for a particular ESS creates a greater welfare change (benefit) to society if it occurs from year 1 onwards as compared to such a benefit starting at year 10. The study also applied an impact trajectory, i.e. will the change in provisioning likely follow a linear, logarithmic or exponential pathway?

As well as assigning this score for each ESS landscape, the methodology had to account for how important one hectare of a particular landscape is relative to other landscapes for that ESS. Marine ecologists determined four categories for the ESS with regard to this question:

- For four ESS categories ('nutrient cycling'; 'gas and climate regulation'; 'food provision'; and 'raw materials'), each landscape was scored for per hectare provision ('high'/3; 'medium'/2; 'low'/1); these scores were sum-

med, and benefits for each landscape apportioned based on both this score and total area.

- Apportioning for 'disturbance prevention and alleviation' was also area-based but one habitat type (Zostera beds) was given a higher weighting owing to proximity to the shore.
- Finally, the two remaining ESS categories ('leisure and recreation' and 'cognitive values') could not be differentiated based on any biological or geographical reasoning. Thus each landscape/TDH (Threatened and Declining Habitats) was arbitrarily apportioned the same share of the total ESS benefit category value, i.e. $1/35^{th}$.

Once this methodology had been applied, the aggregate benefit estimates for each of the three propose MCZ networks/two management regimes was estimated. The present value (using the 3.5% discount rate) ranged from around £11.0-£23.5 billion. Applying sensitivity analysis reduced this range from around £6.4 to £15.1 billion. 'Gas and climate regulation' accounted for the bulk of this expected benefit (around 70%) with 'nutrient cycling' and 'leisure and recreation' around 10% each.

The assessment of the costs of the MCZ networks was assessed by ABPMer (2007). Secondary data and literature were assessed and interviews carried out with affected industries (fisheries, telecommunications, oil and gas extraction etc.); the cost estimate ranged from £0.4-£1.2 billion, implying a worst-case benefit-cost ratio of five.

Wider implications of the study

The marine study is perhaps useful as an example within TEEB for several reasons. First, it arguably inspired conservation. As is often the case, the constituency of the beneficiaries of conservation are widely spread (i.e. society at large) whereas affected industries are highly organised and potentially vocal. Thus a strong evidence base was required to propagate the conservation policy. The analysis of costs and benefits was thus carried out on like-for-like basis. Secondly, this benefit-cost ratio is likely to be an under-estimate: the study only found values for seven of the 11 ESS categories; no network spill-over benefits were accounted for; non-use values were not included and a study carried out by Moran and McVittie (2008) estimates non-use values for the Bill to range between £487 million and £1.170 million per year.

The values used in this study have been entered into an Access database which is to be made publicly available (in a user-friendly searchable format) at the TEEB website . Although this database of values is incomplete (values do not exist for all ESS/all biomes) the marine study demonstrates that a case for conservation can still be made even if there is a paucity of valuation data. Further, TEEB provides guidance on not only rigorous mathematical analyses but also qualitative non-mathematic analyses.

References

ABPMer, 2007. *Cost Impact of Marine Biodiversity Policies on Business – The Marine Bill*. London: Final Report to Defra.

Boyes, S., Warren, L. and Elliott, M. 2003. *Summary of Current Legislation Relevant to Nature Conservation in the Marine Environment in the United Kingdom*. London: Report to Joint Nature Conservation Committee.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R. G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R. 2008. A Global map of human impact on marine ecosystems. *Science* 319: 948-952.

Hussain, S.S., Winrow-Giffin, A., Moran, D., Robinson, L.A., Fofana, O., Paramor, O.A.L., Frid, C.L.J. 2010. An *ex ante* ecological economic assessment of the benefits arising from marine protected areas designation in the UK. *Ecological Economics* 69: 828-838.

Millenium Ecosystem Assessment, 2003. *Ecosystems and Human Well-being: A Framework for Assessment. Chapter 2: Ecosystems and Their Services*. http://www.millenniumassessment.org/.

Moran, D. and McVittie, A. 2008. *Determining Monetary Values for Use and Non-use Goods and Services: Marine Biodiversity – Primary Valuation*. London: Final Report to Defra.

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Outcomes of IAP's International Conference on Biodiversity

The InterAcademy Panel on International Issues (IAP), established in 1994, is a global network of merit-based science academies. Its current membership, which stands at 104, includes virtually every merit-based science academy in the world (the total number of merit-based academies is 107). However, it is important to keep in mind that there are some 191 countries in the world today. That means roughly half of the countries do not have merit-based science academies.

The secretariat of IAP is located in Trieste, Italy. It receives its core funding from the Italian government. IAP itself is part of a network of international organizations, all headquartered in Trieste. This network, which is sometimes referred to as the Trieste System, shares a common interest in building scientific capacity in the developing world. Other members of the network, representing IAP's closest partners, include TWAS, the Academy of Sciences for the Developing World; TWOWS, the Third World Organization for Women in Science; IAMP, the Inter-Academy Medical Panel; and COSTIS, the Consortium on Science, Technology and Innovation for the South. The oldest member of the network is the Abdus Salam International Centre for Theoretical Physics (ICTP), which was created in 1964.

IAP's primary mission is to build the capacity of science academies so that they can become stronger voices for science and science-based development both within their own nations and in regional and international settings. More specifically, IAP is interested in having science academies serve in an advisory capacity for decision-makers on policy issues that have a strong science component. In addition, IAP seeks to develop programmes designed to engage the public in science and science policy issues. It is also interested in helping to create merit-based academies in countries where they do not presently exist.

IAP sponsors a number of programmes that are intended to advance its goals. For example, member academies have worked together on initiatives to improve science education (this effort is led by the Chilean Academy of Sciences); investigate the role that science can play in natural disaster mitigation (led by the Chinese Academy of Sciences); explore science-based strategies for improving access to safe drinking water (led by the Mexican Academy of Sciences); and build the capacity of small academies (led by TWAS).

IAP also issues statements. The statements seek to raise awareness about critical science-related issues both among the public and policy makers. Statements have focused, for example, on the teaching of evolution, tropical rain forest management and ocean acidification. Upcoming statements will examine the impact of the global financial crisis on investments in research and development and food security.

Another major focus of IAP is to support young scientists. For example, it sponsors an annual Young Scientist Conference that takes place at the World Economic Forum (WEF) of New Champions in Tianjin, China, and which is sometimes called the "Summer Davos". IAP also was a major sponsor of the inaugural meeting of the Global Young Scientists' Academy in Berlin, Germany, in February.

On 13 and 14 January 2010, IAP held an international workshop on biodiversity in conjunction with its general assembly. The event was sponsored by the UK's Royal Society and took place in London. The theme was "integrating ecosystem services into biodiversity management". The goals were similar to those of the UNESCO International Year of Biodiversity (IYB) Science-Policy Conference.

These were to:

- Examine the role science can play in issues related to biodiversity;
- Pay particular attention to the interface between science and policy;
- Advance the goals of biodiversity conservation and sustainable use; and
- Present science-based strategies to help ensure that the full range of ecological services provided by biodiversity are recognized and distributed in an equitable manner.

Presentations at the IAP conference, which were given by some of the most eminent researchers and scholars in their fields, covered a broad range of topics, including:

- Green accounting and shadow pricing;
- Ecologically sound job creation based on sustainable land use practices;
- Ecological models that analyze trade-offs in pursuing strategies for biodiversity conservation and sustainable use;
- The role of international organizations in resource management, especially in areas not under national jurisdiction (for example, the oceans and polar regions);
- Lessons learned and that could be applied from climate change negotiations and policies in the international discussions that will take place during the IYB;
- The impact of climate change on biodiversity; and
- The impact of habitat change and resource use on climate.

A good portion of the discussions at the IAP conference examined the scientific community's current state of knowledge concerning biodiversity and ecosystem services. The complexity of the issue led most of the participants to conclude that a great deal more research needs to be done, especially in the basic sciences. Nevertheless, in terms of policies, the participants agreed that we have sufficient knowledge for introducing effective measures to improve biodiversity conservation and sustainable use. Among the key areas of consensus examined during the conference were: the level of biodiversity within an ecosystem largely determines its ability to deliver a broad range of ecosystem services; recent research indicates that the rate of biodiversity loss is more severe than previous studies indicated; and not all ecosystem sciences can be maximized at the same time. As a result, there is an urgent need to increase our knowledge and understanding of synergies and tradeoffs. The latter is an area where science can play a critical role in assisting the policy-making community.

Other points of consensus that surfaced during the conference are that it is important to establish economic values for biodiversity and ecosystem services, and that biodiversity is most often managed at the local level, even though how it is managed has global implications. The gap between site-specific decision-making and global impacts poses special challenges for both policy makers and the scientific community. It also highlights the importance of science education and public involvement in efforts to promote biodiversity conservation and sustainable use.

The outcome of the IAP conference included a number of insights that were also raised at the UNESCO conference held the following week. This reiteration of major points suggests that there is a broad consensus within the scientific community on the urgent need to establish effective policies for protecting biodiversity and that the IYB provides an unparalled opportunity to make progress on this front.

At the conceptual level, participants at the IAP conference concurred that:

- Global resources and ecosystem services are bountiful but are by no means limitless. The ongoing depreciation of our resources and biodiversity carries significant costs to society, but these costs have yet to be fully appreciated or incorporated into economic development policies. The need to do so is becoming more acute because, as many participants at the conference noted, we may now be entering an era of resource shortages.
- Science is a key player in promoting sustainable biodiversity use. Research, for example, is critical for gauging trends, examining tradeoffs and laying out options for wise and effective action. Yet, there was also broad recognition that science is only one of many players when it comes to biodiversity. Economics, sociology, culture and aesthetics also play a critical role in shaping attitudes and policies toward biodiversity.
- As mentioned earlier, participants also acknowledged that we need to know more about biodiversity. Yet, at the same time, it is important to recognize

that we already know a lot. Consequently, applications of existing knowledge may prove to be as important as the discovery of new knowledge. This factor, many speakers at the conference noted, makes close interaction between the scientific and policy communities essential.

- And, finally, participants emphasized the importance of developing sophisticated models that incorporate ecological and economic data, and that present tradeoffs and realistic scenarios for policy makers. Yet, at the same time, there is a need to continue to develop case studies, especially of successful experiences of applications of science to address critical biodiversity challenges. In short, we must continue to build the theoretical and empirical knowledge base.

At the tactical level, participants at the conference concurred that:

- There is a need to train the next generation of researchers to engage in investigations of biodiversity and to devise effective strategies for biodiversity conservation and sustainable use
- There is a need to draw the natural and social sciences closer together both at the policy and programmatic levels
- There is a need for IAP members to collaborate more closely on issues related to biodiversity and also for IAP to work more closely with other institutions, including the international organizations, research centres and universities
- And, finally, there is a need to engage the public both in broadbased discussions on the risks that current development trends pose for biodiversity and possible solutions to help ensure the conservation and sustainable use of nature's bounty for current and future generations. Progress, many participants maintained, will depend not only on the science-policy interface but also on the science-public interface.

The conference concluded with a communiqué, unanimously agreed to by all participants, that contains specific recommendations for policy and decision-makers as well as the scientific community.[13]

Over the past several decades, a great deal of work has been done at both the local and regional levels in assessing the state of biodiversity and managing the health of ecosystems. Yet, much of this work has yet to reach a scale that makes it truly global in reach and impact. That will be one of the challenges facing researchers who study biodiversity and those involved in the UN International Year of Biodiversity. How can the scope of biodiversity and ecosystem studies be broadened in ways that address the issue on a global scale without compromising the site-specific investigations that supply the details and insights necessary to shed light on these issues? And, more generally, how can the science and economics that have helped us understand this compelling, yet endlessly complex issue, be communicated to a larger public in ways that move the discussion from science conferences and workshops to government offices and communities across the globe?

Successfully addressing such challenges may well determine whether the science that informs our understanding of biodiversity creates a durable foundation of knowledge that allows policy makers and the public to appreciate the scope of the challenges – and that ultimately leads to resource practices that do not place the well-being of future generations and, ultimately, our planet at risk.

13. For the complete text of the communiqué, see www.interacademies.net/cms/10233.aspx

In a changing world, we need to adapt. We need to inspire action, through connection with nature and its stories at all levels.

From the Conference Recommendations

V

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STATEMENT AND RECOMMENDATIONS BY CONFERENCE PARTICIPANTS

Statement and Recommendations from the UNESCO International Year of Biodiversity Science Policy Conference

Taxonomy, Conservation Biogeography, The role of indigenous and local knowledge in biodiversity conservation, Biodiversity and gender, Priority-setting in conservation: strengthening site-scale approaches, Managing Biodiversity at the Landscape Scale, Biodiversity and development, Communication, education and public awareness

Déclaration et recommandations de la Conférence de l'Année internationale de la biodiversité de l'UNESCO : Sciences et politiques de la biodiversité

La taxonomie, Biogéographie de la conservation, Le rôle des connaissances autochtones et locales dans la conservation de la biodiversité, Biodiversité et égalité entre les sexes, Établissement des priorités en matière de conservation : renforcement des approches à l'échelle des sites, Gestion de la biodiversité à l'échelle des paysages, Biodiversité et développement, Communication, éducation et sensibilisation du public

Statement and Recommendations from theUNESCO International Year of Biodiversity Science Policy Conference
(UNESCO Headquarters, Paris, 25-29 January 2010)

The Context

In the framework of the United Nations' International Year of Biodiversity (IYB), the UNESCO IYB Biodiversity Science Policy Conference (UNESCO Headquarters, Paris, France, 25 to 29 January 2010) brought together more than 250 participants from all continents to present new scientific findings on biodiversity relating to several key thematic and crosscutting issues, and to assess implications for policy-making. The Conference followed the UNESCO high-level launch of IYB in Paris on 21 and 22 January 2010. It took place five years after the International Conference on Biodiversity Science and Governance, also held at UNESCO Headquarters in Paris in January 2005.

While taking into account the priorities expressed by the Parties to the Convention on Biological Diversity (CBD), the Conference gave special attention to the voice of the scientific community so as to highlight new knowledge that could be used in the context of biodiversity-related decisions. As such, the statement and recommendations from the Conference will be presented to a number of relevant meetings in the course of 2010, including: the Trondheim Conference on the post-2010 Biodiversity Target to be held in February; the special session on biodiversity of the United Nations General Assembly to be held in New York on 25 September; the 185th session of the Executive Board of UNESCO to be held in Paris in the fall; and the meeting of the Conference of the Parties to the CBD to be held in Nagoya, Japan, in October. The outcomes of the Conference will also be disseminated widely and presented at other relevant fora.

The Global Biodiversity Challenge

Biodiversity, the variety of life on Earth, provides us all with the critical goods and services on which our lives depend. Provision of food, fibers, energy and medicines, purification of air and water, moderation of floods and droughts, stabilization of climate – these are just some of the vital services provided by biodiversity. The goods and services supplied by biodiversity constitute the basis upon which the economy, including trade, is built. As such, biodiversity has acted as a unique ingredient of sustainable development and is essential for achieving the Millennium Development Goals.

Biodiversity's contribution to human life and well-being is not just practical, physical and utilitarian, but also cultural and spiritual. The diversity of the natural world has been a constant source of inspiration throughout human history, influencing traditions and the way our society has evolved. Yet, in recent decades, biodiversity has been lost at an unprecedented rate, mostly due to unsustainable human activities, and the 2010 Biodiversity Target that was agreed upon at the World Summit on Sustainable Development and later by the Parties to the CBD in 2002 has not been achieved. Given the importance of biodiversity to human development and well-being, the reversal of biodiversity loss has become one of the major challenges that society faces today.

The Vision

Despite widespread scientific and other evidence for the current global biodiversity crisis, and the inadequate response to earlier calls to halt it, participants in the Conference were united in their resolve to effect positive change. Recognizing the importance of all different scales to ecosystem function, we need to broaden our vision and our spheres of action. A technological revolution is underway, changing the way that we exchange and process information. We are living in an increasingly interconnected world, biologically, culturally and scientifically. This is having major impacts on the ways in which we can work and communicate. It offers an opportunity to rise to the challenge of addressing an issue that needs to be tackled on multiple scales simultaneously. We must embrace these new technologies and develop efficient mechanisms for structuring and using them, while better acknowledging the valuable contributions that indigenous and local knowledge can provide. Biodiversity itself can provide the inspiration for survival. In a changing world, we need to adapt. We need to inspire action, through connection with nature and its stories at all levels. Biodiversity is dynamic, and flexible on multiple spatial and temporal scales, responding to the biotic and abiotic environment in which it finds itself. Therefore, we too must be dynamic and flexible in our response, balancing local and global, current and future needs.

We recognize the crucial importance of local diversity, both biological and cultural, in maintaining global stability. More substantive research on the links between biological and cultural diversity should be supported in order to better understand the impacts of biodiversity loss on human life and well-being, as well as the impacts of cultural transformation on status and trends of biodiversity. In this regard, interdisciplinary approaches to biodiversity research and collaboration between natural and social sciences have to be enhanced. Participatory approaches to biodiversity research (as opposed to top-down approaches) need to be favored, while respecting social organization, natural worldviews and land/sea tenure systems. This will provide for better integration of the 'human component' in the study of ecological processes, closely linked to socioeconomic and cultural processes and vice-versa.

Priorities for and Modalities of Action

The following section reflects major sessions and related topics of the Conference. It does not attempt to provide a list of all the most urgent issues related to biodiversity. Rather, it reflects the presentations and discussions at the Conference with regard to the themes dealt with and the priority actions identified and recommended.

Taxonomy

Taxonomy, the discovery, naming, distinguishing and classification of natural organisms by scientists and people everywhere provides the foundation of the biodiversity knowledge base and underpins all efforts in biodiversity research, conservation, and management.

Taxonomic science is at the start of a 21st century renaissance. Even though resources are not yet widely available, there are projects and initiatives serving as examples of a new taxonomy and the impact it will have.

For scaling-up taxonomy, business as usual is not an option in the face of the grand challenges, with the great majority of species remaining undiscovered, most countries and areas lacking comprehensive biodiversity inventories, and a critical lack of relevant expertise and capacities in most biodiversity rich countries.

A key component will be to strengthen and give increased support to natural history museums and in situ and ex situ biological collections as an essential infrastructure for biodiversity knowledge generation, as well as for education and outreach, and to respond to the need to establish and maintain such infrastructures in all regions. The regular addition and upgrading of biological specimens and samples in these collections is essential for their efficient functioning for research and education, and possible regulations for international access of biological materials must not unnecessarily impede the regular transfer and exchange of such materials for non-commercial purposes.

Scaling-up and sustaining taxonomy may best be achieved through:

Supporting indigenous and local communities in capturing and preserving their taxonomic knowledge;
Applying cybertaxonomy, molecular and other innovative approaches to accelerate the taxonomic work flow of discovery and description;

Using digital and molecular infrastructure tools to integrate taxonomic data with other types of life science information, thus also broadening the products available to support identification and other services;

Prioritization of taxonomic efforts according to scientific knowledge gaps and user needs;

Making communication and outreach standard practice, and using Internet media platforms to reach the public and others;

Training a new generation of taxonomists, able to work flexibly and collaboratively, and taking stock of new and emerging technologies and tools;

Appreciating the valuable contributions of taxonomy and recognizing it as a branch of cutting-edge science.

Conservation Biogeography

Conservation biogeography is the study of the spatial distributions of patterns and processes of life through time, in relation to threats and impacts at multiple and interlinked scales. Drawing from historical and present-day ecological information, it can inform mitigation and proactive strategies for biodiversity conservation, as well as help predict potential future impacts. As a tool for citizen science, it can help connect people with their environment and further their understanding, while generating cost-effective global datasets that can inform biodiversity monitoring and conservation planning. It is especially useful in informing policy-makers on scales, dynamics, and uncertainty surrounding biodiversity impacts from climate change and other anthropogenic forces in marine and terrestrial ecosystems.

So that conservation biogeography can most effectively inform biodiversity policy-making, the Conference recommends:

Use biogeographical data and tools at all scales, from local to global models, explicitly in conjunction with economic, social and cultural data, to aid in planning for a sustainable future and mitigating the impacts of environmental change;

Use biogeographic knowledge, increase efforts to strengthen protected areas networks in light of environmental change, and to encourage biodiversity-friendly landscapes outside of protected areas;

Seize opportunities to create and restore ecosystem function in degraded landscapes, possibly by judiciously applying proactive approaches such as rewilding and assisted migration;

Increase the biogeographical knowledge-base in terrestrial, freshwater, and particularly marine ecosystems, as a basis for producing biogeographical tools for policy guidance;

Increase explicit communication networks and interaction between policy-makers, scientists, educators, practitioners and local stakeholders in order to facilitate and stimulate useful scientific knowledge for mitigating impacts on biodiversity and guiding proactive conservation strategies.

The role of indigenous and local knowledge in biodiversity conservation

Indigenous peoples, who often live in diverse and fragile ecosystems, have developed ancestral indigenous knowledge, innovations, practices, values, language, culture and spirituality through their special relationship with biodiversity and their natural surroundings. In turn, this knowledge and practice guides the sustainable use and management of landscapes and ecological dynamics, while also providing a special contribution to the science of biodiversity conservation. Recognition of this important contribution and the dynamic exchange of knowledge under a fair and equitable framework and protocol will support biodiversity conservation and healthy ecosystem services.

Anthropological research, management experience and local voices teach us that many indigenous and local communities shape, create and manage biodiversity through their actions and social organization. Traditional agriculture, fishing, pastoralism and other occupations have created unique milieus through their actions, and through selection on plants and animals. Research has begun to elucidate this role through historical ecology, and is nowadays taken into account by national parks that had previously failed to manage anthropogenic ecosystems through the exclusion of human populations. Tenure and stewardship organization, combined with knowledge and know-how, worldview and ethics, have a very important role conserving a mosaic of ecosystems created through co-evolution between human beings and other forms of life. Biodiversity cannot be separated from cultural diversity. Therefore they must be understood and studied together through interdisciplinary research, including social sciences in cooperation with traditional local and indigenous knowledge holders.
Recommended actions include:

Enhance the linkages between scientific and traditional local and indigenous knowledge related to biodiversity, for the benefit of local knowledge holders, scientists and decision-makers;

Promote transmission of local and indigenous knowledge on biodiversity, particularly within and through intercultural education, so as to ensure the continuity of local and indigenous taxonomy, knowledge and know-how.

Biodiversity and gender

The gendered division of labour has resulted in women and men in many societies having distinct forms of traditional knowledge related to biodiversity. Women are increasingly seen as embodying specific biodiversity knowledge, and there are many examples of the sustainable manner in which women use biodiversity. Nevertheless, their role in biodiversity management and decision-making process is often ignored.

To ensure the equal participation of women and women's organizations in decision-making processes related to biodiversity, the Conference recommends that: Special consideration is given to the pivotal role of gender in addressing biodiversity challenges, notably in the formulation of conservation policies, strategies, and projects at all levels;

The Gender Plan of Action of the CBD is fully implemented;

Appropriate measures are taken to ensure that gender equality is mainstreamed in the actions, activities and initiatives conducted under the CBD;

National capacities are developed to facilitate the understanding of the importance of including gender issues in biodiversity initiatives;

Appropriate measures are taken to guarantee that the benefits derived from access to and use of biodiversity resources are equitably distributed between women and men.

Priority-setting in conservation: strengthening site-scale approaches

Sites are areas, large or small, that can potentially be delimited and conserved as a unit. Safeguarding sites is a well-established and effective conservation approach that is appropriate for many species. While sites must be viewed as part of landscapes (thus connected and buffered where appropriate and treated in the context of an ecosystem approach), protection of individual sites is an important starting point.

Where are the most important sites for conservation? Studies show that most Protected Area networks have serious gaps. While there have been numerous efforts to set priorities at a broad scale, these do not identify the actual sites to conserve. However, site-scale priority setting exercises, for example the key biodiversity areas (KBAs) approach, directly address this need.

KBAs are identified using internationally consistent criteria based on vulnerability and irreplaceability, but through a nationally-led process involving a range of stakeholders and drawing extensively on local knowledge. KBAs make use of the best available data, while at the same time anticipating improved datasets in the future and thus the need to refine KBA inventories over time. Recent advances, led by a range of organizations, have improved KBA documentation and extended the approach to further taxa and to the marine and freshwater realms. Sites holding the only populations of highly threatened species form an important subset of KBAs. These have been identified by the Alliance for Zero Extinctions for several taxonomic groups that are fully assessed on the IUCN Red List.

The KBA process identifies key sites, but does not prescribe how these should be conserved (for example, through a formal protected area or community-based conservation) nor which particular KBAs are priorities for action. KBAs must be used alongside and complementing other approaches, but they are nevertheless a powerful tool for conservation. They directly inform policy, including commitments under international agreements, and form the building blocks for systematic conservation planning. Because of its participatory nature, the KBA process has demonstrated effectiveness as a means of building scientific and institutional capacity, fostering effective government-civil society partnerships, and as a focus for engaging local communities in conservation and monitoring.

The Conference recommends that:

The post-2010 CBD targets should recognize the need to conserve the most important sites for biodiversity, not just a percentage area of land and sea;

One effective way to halt further extinctions, and to conserve important centres of endemism, is to protect sites that hold the only populations of highly threatened species. These should be a top priority for conservation attention;

National, sub-national and regional Protected Area planning exercises should incorporate the most important biodiversity sites (such as KBAs) as fundamental building blocks;

Site-scale conservation priorities should be brought to the attention of, and taken account of by, voluntary standard and certification schemes that aim to safeguard biodiversity;

There should be further co-ordination and consolidation of existing KBA approaches, including the provision of KBA information.

Managing Biodiversity at the Landscape Scale

Socio-ecological production landscapes have an important role in biodiversity conservation, and can help to optimize ecosystem services and improve human well-being in a sustainable manner. Management that relates biodiversity to other landscape functions valued by society – ecosystem services –is central to this issue.

Recommendations on managing biodiversity at the landscape level include the following:
Identify socio-ecological production landscapes for optimizing ecosystem services and human well-being in a sustainable manner, for example through the Satoyama Initiative;

Recognize the role of indigenous and local communities in conserving biodiversity, and find ways to record and transfer their knowledge so that it can be used by newcomers, who can also bring knowledge, skills and investments important for adaptive management;

In changing biophysical or social environments, find ways to maintain landscape characteristics that are beneficial to biodiversity, either by conserving traditional practices or through novel approaches;

Recognize the practices, perceptions and values of different groups in the population regarding biodiversity and other landscape functions in managing and valorizing biodiversity at the landscape level;

The biodiversity of the urban environment, where more than 50% of humans now live, should be inventoried, conserved and enhanced in a way that allows the rich human-nature interaction that is so essential for well-being.

Biodiversity and development

Access to biodiversity is vital for the basic needs of many of the world's poorest people. It is critical as a form of insurance, as well as being the foundation for local, regional and global economies. However, when discussing trade-offs in conservation versus extractive resource use, we often do not fully account, in economic terms, for all the goods and particularly the non-market ecosystem services that biodiversity provides. This commonly results in policies that, although intended to improve human livelihoods, actually do the opposite. While the rich can often afford to replace ecosystem services, the poor cannot. Economic models, appropriate evaluation metrics, and transparent accounting methods for tangible and intangible biodiversity benefits, can contribute to redressing this imbalance. It is important, however, to recognize that economic approaches also have their limitations and cannot capture all the values of biodiversity.

Recommendations arising from the Conference include the need to:
Incorporate explicit economic accounting of non-market value goods and services when developing plans for a sustainable future;

Promote and apply, where appropriate, methodological tools (e.g. as outlined in The Economics of Ecosystems and Biodiversity Report) that can facilitate full economic accounting of alternative scenarios for biodiversity use;

Mainstream biodiversity into all development, agriculture, fisheries, industry, business and policy decisions;

Establish rewarding partnerships at all economic levels, from micro to global, and be creative in raising and using funds.

Communication, education and public awareness

Both scientists and educators facilitate a process that leads actors to discover the world around them, to further explore it, gain insights and take action, the results of which are to be shared around the world.

Given this common interest, all those actively involved in biodiversity communication, education and public awareness should:
Engage in dialogues to better understand how they can inform and support each others' work;

Mobilize inspirational personalities and biodiversity symbols to communicate biodiversity issues to the general public;

Take advantage of the opportunities offered by information and communications technologies, including the Internet, radio and television, to foster explicit communication networks and interaction between policy-makers, stakeholders and scientists;

Partner with others, including intergovernmental organizations, governments, education and research institutions, civil society organizations, indigenous and local communities and the private sector;

Identify demonstration projects, illustrating good practices, suitable for scaling-up and increase explicit mechanisms for scale-matched, and cross-scale information sharing;

Work with existing frameworks including inter alia the United Nations Decade of Education for Sustainable Development (2005-2014);

Recognize citizen science as an important, but often underfunded, tool for implementing biodiversity communication, education and public awareness.

The Way Forward

It is necessary to highlight for the benefit of decision-makers and stakeholders the full value of biodiversity, not least its role in ecosystem functioning and maintenance of ecosystem services, thus helping society adapt to climate change, underpinning food and health security and adding value to the global economy.

The integration of biodiversity concerns into political strategies, action plans and implementation measures requires mechanisms to ensure the delivery of sound, reliable and targeted information in support to these policies.

Recommendations from biodiversity science need to be developed in close consultation with other stakeholders and policy experts to ensure that the public and the decision-makers understand the range of possible options, their likely outcomes, and what specific interventions can achieve them.

There is a need for a more systematic use of existing tools that can convey biodiversity knowledge in forms understandable and usable by decision-mak-

ers, such as indicators, models, scenarios, economic valuation techniques and maps, as well as to increase literacy among decision-makers as to the usefulness and limitations of such tools.

In this regard, there was general support expressed for an effective mechanism to link biodiversity science and policy, such as that being discussed in the context of an intergovernmental and multi-stakeholder process on an Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES).

Improved and expanded mechanisms for funding are of central importance, including funding for biodiversity research, conservation and citizen science. Funding should take into account issues related to scale. Funding mechanisms need a clearly defined relationship with, and appropriate involvement in, a future IPBES.

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Déclaration et recommandations de la Conférence de l'Année internationale de la biodiversité de l'UNESCO: Sciences et politiques de la biodiversité

(Siège de l'UNESCO, Paris, 25-29 janvier 2010)

Contexte

Dans le cadre de l'Année internationale de la biodiversité des Nations Unies, la Conférence de l'Année internationale de la biodiversité de l'UNESCO: Sciences et politiques de la biodiversité (Siège de l'UNESCO, Paris, 25-29 janvier 2010) a rassemblé plus de 250 participants venus de tous les continents pour présenter les nouvelles découvertes scientifiques sur la biodiversité concernant plusieurs questions thématiques et transversales importantes, ainsi que pour en évaluer l'incidence sur l'élaboration des politiques. La Conférence a eu lieu suite au lancement de haut niveau de l'Année internationale à Paris les 21 et 22 janvier 2010. Elle est intervenue cinq ans après la Conférence internationale « Biodiversité: science et gouvernance », qui s'est également tenue au Siège de l'UNESCO à Paris, en janvier 2005.

Tout en tenant compte des priorités exprimées par les Parties à la Convention sur la diversité biologique (CDB), la Conférence a accordé une attention particulière à l'opinion de la communauté scientifique afin de mettre en valeur les nouvelles connaissances qui pourraient être prises en compte dans le cadre de décisions concernant la biodiversité. En conséquence, la déclaration et les recommandations de la Conférence seront présentées au cours d'un certain nombre de réunions pertinentes en 2010, notamment: la Conférence de Trondheim sur l'Objectif post-2010 relatif à la diversité biologique, qui sera organisée en février; la session extraordinaire de l'Assemblée générale des Nations Unies consacrée à la biodiversité, qui se tiendra à New York le 25 septembre; la 185ème session du Conseil exécutif de l'UNESCO, qui aura lieu à Paris en automne; et la réunion de la Conférence des Parties à la CDB, qui se tiendra à Nagoya (Japon) en octobre. Les résultats de la Conférence seront également largement diffusés et présentés dans le cadre d'autres instances pertinentes.

Le défi mondial de la biodiversité

La biodiversité, la variété des espèces présentes sur Terre, est la source de tous les biens et services essentiels dont dépend notre existence. Nourriture, fibres, énergie, médicaments, purification de l'air et de l'eau, atténuation des inondations et des sécheresses, stabilisation du climat ne sont que quelques-uns des services essentiels rendus par la biodiversité. Les biens et services fournis par celle-ci constituent la base sur laquelle repose l'économie, y compris les échanges. En conséquence, la biodiversité est un ingrédient unique du développement durable et elle est indispensable pour atteindre les Objectifs du Millénaire pour le développement.

La contribution de la biodiversité à la vie et au bien-être des êtres humains n'est pas seulement d'ordre pratique, physique et utilitaire, mais aussi culturel et spirituel. La diversité du monde naturel a été une source d'inspiration constante tout au long de l'histoire de l'humanité, influençant les traditions et l'évolution de notre société. Pourtant, au cours des dernières décennies, la biodiversité a décliné à un rythme sans précédent, principalement à cause d'activités humaines non viables; de plus, l'Objectif biodiversité 2010 adopté au Sommet mondial pour le développement durable, puis par les Parties à la CDB en 2002, n'a pas été atteint. Étant donné l'importance de la biodiversité pour le développement et le bien-être des êtres humains, l'inversion de la tendance à la perte de biodiversité est devenue l'un des principaux défis auquel notre société doit faire face aujourd'hui.

La vision

Malgré l'abondance des preuves scientifiques et autres de la crise mondiale actuelle de la biodiversité et l'insuffisance des actions en réponse aux appels pas-

sés pour y mettre un terme, les participants à la Conférence étaient unanimement déterminés à susciter un changement positif. Conscients de l'importance des différentes échelles dans les fonctions des écosystèmes, nous devons élargir notre vision et nos champs d'action. La révolution technologique en cours modifie notre manière d'échanger et de traiter l'information. Nous vivons dans un monde toujours plus interconnecté sur les plans biologique, culturel et scientifique, ce qui a des conséquences majeures sur la manière dont nous pouvons travailler et communiquer. C'est l'occasion de relever le défi et de résoudre une question qui doit être abordée simultanément à différentes échelles. Il nous faut adopter ces nouvelles technologies et mettre en œuvre des mécanismes efficaces pour les structurer et les utiliser, tout en reconnaissant mieux les précieuses contributions que peuvent apporter les connaissances autochtones et locales. La biodiversité elle-même peut être une source d'inspiration pour notre survie. Dans un monde en évolution, nous devons nous adapter. Il faut susciter l'action en relation avec la nature et ses histoires à tous les niveaux. La biodiversité, qui est dynamique et flexible à des échelles spatiales et temporelles multiples, répond à l'environnement biotique ou abiotique dans lequel elle se trouve. À notre tour, nous devons avoir une réaction dynamique et flexible, en établissant un équilibre entre les niveaux local et mondial et les besoins présents et futurs.

Nous reconnaissons l'importance vitale de la diversité locale, tant biologique que culturelle, pour le maintien de la stabilité mondiale. Il faudrait encourager davantage les recherches approfondies sur les liens entre la diversité biologique et culturelle afin de mieux comprendre les effets de la perte de biodiversité sur la vie et le bien-être des êtres humains, ainsi que les effets des transformations culturelles sur le statut et les tendances de la biodiversité. De ce point de vue, les approches pluridisciplinaires de la recherche sur la biodiversité et la collaboration entre les sciences exactes et naturelles et les sciences sociales doivent être encouragées. Il convient de favoriser les approches participatives (plutôt que directives) de la recherche sur la biodiversité, tout en respectant l'organisation sociale, les visions naturelles du monde et les régimes foncier ou maritime. Cela permettra une meilleure prise en compte du « facteur humain » dans l'étude des processus écologiques, ceux-ci étant étroitement liés aux processus socioéconomiques et culturels et inversement.

Priorités et modalités d'action

Cette section rend compte des principales sessions de la Conférence et des sujets s'y rapportant. Il ne s'agit pas d'essayer de dresser une liste de toutes les questions les plus urgentes concernant la biodiversité, mais de présenter les thèmes abordés et les actions prioritaires identifiées et recommandées durant les exposés et les discussions tenus lors de la Conférence.

La taxonomie

La taxonomie la découverte, la dénomination, l'identification et le classement des organismes naturels par les scientifiques ou toute autre personne où qu'ils se trouvent constitue la base des connaissances sur la biodiversité et sous-tend tous les efforts de recherche, de conservation et de gestion de la biodiversité.

Cette science entame une renaissance à l'aube du XXI^{ème} siècle. Même si les ressources ne sont pas encore largement disponibles, certains projets et initiatives offrent déjà des exemples d'une nouvelle taxonomie et de l'impact qu'elle aura.

Pour développer le recours à la taxonomie, le maintien du statu quo n'est pas envisageable face aux grands défis: la grande majorité des espèces n'a pas encore été découverte, la plupart des pays et des zones ne possèdent pas d'inventaire complet de leur biodiversité, et la plupart des pays riches en biodiversité souffrent d'un cruel manque d'experts et de ressources pertinentes.

Il faut impérativement renforcer et soutenir davantage les musées d'histoire naturelle et les collections biologiques in situ et ex situ, en tant qu'infrastructures essentielles pour la production de connaissances sur la biodiversité, ainsi que pour l'éducation et la sensibilisation du public, et aussi pour répondre au besoin d'établir et d'entretenir ce type d'infrastructures dans toutes les régions. L'ajout et le renouvellement réguliers des spécimens biologiques et des échantillons dans ces collections sont indispensables pour leur utilisation efficace dans la recherche et l'éducation ; en outre, la réglementation possible de l'accès aux substances biologiques à l'échelle internationale ne doit pas entraver inutilement le transfert et l'échange réguliers de ces substances dans le cadre d'activités non commerciales.

Les meilleurs moyens de développer et de soutenir la taxonomie sont les suivants:

Aider les communautés autochtones et locales à acquérir et préserver leurs connaissances taxonomiques;

Mettre en œuvre une cybertaxonomie, ainsi que des approches moléculaires et autres approches innovantes pour accélérer les flux de travail, de découverte et de description taxonomiques;

Utiliser des outils d'infrastructure numérique et moléculaire pour intégrer les données taxonomiques à d'autres types d'informations sur les sciences de la vie, et élargir ainsi les produits disponibles pour soutenir l'identification et autres services;

Hiérarchiser les efforts déployés en taxonomie en fonction des lacunes dans les connaissances scientifiques et des besoins des utilisateurs;

Faire de la communication et de la sensibilisation des pratiques habituelles et utiliser les médias de l'Internet pour sensibiliser le public et les autres acteurs;

Former une nouvelle génération de taxonomistes capables de travailler de manière flexible et collaborative, et faire le point sur les technologies et outils nouveaux ou émergeants;

Reconnaître les précieuses contributions de la taxonomie et l'accepter comme une science d'avant-garde.

Biogéographie de la conservation

La biogéographie de la conservation est l'étude de la répartition spatiale des schémas et des processus de la vie dans le temps, par rapport aux menaces et à leurs conséquences à de multiples niveaux interdépendants. En s'appuyant sur des données écologiques historiques et actuelles, elle permet de guider les stratégies proactives d'atténuation pour la conservation de la biodiversité, et de prévoir les conséquences possibles à venir. En tant qu'outil d'une science citoyenne, elle peut aider les gens à se rapprocher de leur environnement et à mieux le connaître, tout en générant des bases de données mondiales rentables pour orienter la surveillance de la biodiversité et la planification de la conservation. Elle est particulièrement utile pour guider les décideurs s'agissant des différentes échelles, des dynamiques et de l'incertitude concernant les effets du changement climatique et d'autres forces anthropiques sur la biodiversité dans les écosystèmes marins et terrestres.

Afin que la biogéographie de la conservation puisse orienter le plus efficacement possible la prise de décision concernant la biodiversité, la Conférence recommande ce qui suit:

Utiliser des données et outils biogéographiques à toutes les échelles, depuis les modèles locaux jusqu'aux modèles mondiaux, expressément et conjointement avec des données économiques, sociales et culturelles, pour contribuer à la planification d'un avenir durable et à l'atténuation des effets des changements environnementaux;

Utiliser les connaissances biogéographiques, accentuer les efforts pour renforcer les réseaux de zones protégées face aux changements environnementaux, et favoriser les paysages respectant la biodiversité en dehors des zones protégées;

Saisir les occasions de créer et de restaurer les fonctions des écosystèmes dans les paysages dégradés, par exemple en mettant judicieusement en œuvre des approches proactives telles que la réintroduction d'espèces extirpées et l'aide à la migration;

Accroître la base des connaissances biogéographiques sur les écosystèmes terrestres, d'eau douce et surtout marins, afin de générer des outils biogéographiques d'assistance à la prise de décision;

Accroître les réseaux explicites de communication et les interactions entre décideurs, scientifiques, éducateurs, spécialistes et parties prenantes locales, afin de faciliter et de stimuler les connaissances scientifiques utiles pour l'atténuation des effets sur la biodiversité et l'orientation des stratégies proactives de conservation.

Le rôle des connaissances autochtones et locales dans la conservation de la biodiversité

Les peuples autochtones, qui vivent souvent au sein d'écosystèmes fragiles et variés, ont développé des connaissances, des innovations, des pratiques, des valeurs, un langage, une culture et une spiritualité autochtones et ancestraux grâce à leur relation spéciale avec la biodiversité et leur environnement naturel. À leur tour, ces connaissances et pratiques orientent l'utilisation et la gestion durables des paysages et des dynamiques écologiques, tout en offrant une contribution particulière à la science de conservation de la biodiversité. La reconnaissance de cette contribution importante et l'échange actif de connaissances dans le cadre d'un protocole juste et équitable contribueront à la conservation de la biodiversité et à des services écosystémiques sains.

La recherche anthropologique, l'expérience de la gestion et les acteurs locaux nous apprennent que de nombreuses communautés autochtones et locales modèlent, créent et gèrent la biodiversité par leurs actions et leur organisation sociale. Ces actions et la sélection de plantes et d'animaux dans le cadre de l'agriculture traditionnelle, de la pêche, du pastoralisme ou d'autres activités ont engendré des milieux uniques. La recherche a commencé à clarifier ce rôle grâce à l'écologie historique, et il en est aujourd'hui tenu compte par les parcs nationaux qui avaient jusque-là échoué dans une gestion des écosystèmes anthropiques qui ne prenait pas en compte les populations humaines. L'organisation de la propriété et de la gestion, mais aussi le savoir, le savoir-faire, la vision du monde et l'éthique, jouent un rôle très important dans la conservation d'une mosaïque d'écosystèmes créés grâce à l'évolution parallèle des humains et des autres formes de vie. La biodiversité ne peut être séparée de la diversité culturelle. Elles doivent donc être comprises et étudiées ensemble dans le cadre de recherches pluridisciplinaires, y compris en sciences sociales, en coopération avec les détenteurs de savoirs locaux et autochtones.

Il est recommandé d'entreprendre notamment les actions suivantes:
Renforcer les liens entre les connaissances scientifiques et les connaissances locales et autochtones traditionnelles relatives à la biodiversité, dans l'intérêt des détenteurs de savoirs locaux, des scientifiques et des décideurs;

Favoriser la transmission des connaissances locales et autochtones sur la biodiversité, particulièrement par le biais de l'éducation interculturelle, afin de garantir la continuité de la taxonomie, des savoirs et des savoir-faire locaux et autochtones.

Biodiversité et égalité entre les sexes

En raison de la répartition du travail en fonction des sexes, les hommes et les femmes, dans nombre de sociétés, possèdent des formes distinctes de connaissances sur la biodiversité. On reconnaît de plus en plus que les femmes détiennent des connaissances spécifiques sur la biodiversité et il existe de nombreux exemples de son utilisation durable par les femmes. Malgré cela, le rôle de celles-ci dans la gestion de la biodiversité et la prise de décision n'est souvent pas pris en compte.

Pour garantir la participation égale des femmes et des organisations féminines dans les processus de prise de décision liés à la biodiversité, la Conférence recommande:

Qu'une attention particulière soit accordée au rôle essentiel joué par les femmes dans les réponses aux défis de la biodiversité, notamment dans la formulation de politiques, stratégies et projets de conservation à tous les niveaux;

Que le Plan d'action concernant l'égalité entre les sexes de la CDB soit mis en œuvre dans sa totalité;

Que des mesures appropriées soient adoptées pour garantir l'intégration de l'égalité des sexes dans les actions, activités et initiatives menées dans le cadre de la CDB;

Que les capacités nationales soient développées pour mieux faire comprendre l'importance d'inclure les questions d'égalité entre les sexes dans les initiatives sur la biodiversité;
Que des mesures appropriées soient prises pour garantir que les bienfaits tirés de l'accès aux ressources de la biodiversité ainsi que de son utilisation soient distribués équitablement entre les femmes et les hommes.

Établissement des priorités en matière de conservation : renforcement des approches à l'échelle des sites

Un site est une zone, grande ou petite, qui peut être délimitée et préservée comme une unité. La sauvegarde de sites est une approche de conservation établie, efficace et adaptée à de nombreuses espèces. Bien que les sites doivent être considérés comme faisant partie des paysages (et donc connectés avec une zone tampon si nécessaire, et envisagés dans le cadre d'une approche écosystémique), la protection de sites spécifiques est un point de départ important.

Où se trouvent les sites de conservation les plus importants ? Les études montrent que la plupart des réseaux de zones protégées comportent de sérieuses failles. Même si de nombreux efforts ont été déployés pour établir les priorités à une grande échelle, celles-ci ne spécifient pas quels sites doivent être effectivement protégés. Cependant, les exercices d'établissement des priorités à l'échelle des sites, comme les zones clés de la biodiversité (ZCB), répondent directement à ce besoin.

Les ZCB sont désignées selon des critères cohérents, à l'échelle internationale, de vulnérabilité et d'irremplaçabilité, mais aussi selon un processus national faisant appel à diverses parties prenantes et s'appuyant fortement sur les savoirs locaux. Les ZCB exploitent les meilleures données disponibles, tout en anticipant l'amélioration future des bases de données et donc la nécessité d'affiner régulièrement les inventaires des ZCB. Des avancées récentes, réalisées par un ensemble d'organisations, ont amélioré la documentation sur les ZCB et élargi l'approche à davantage de taxons, ainsi qu'aux domaines marins et d'eau douce. Les sites abritant les dernières populations d'espèces fortement menacées constituent un sous-ensemble important des ZCB. Ceux-ci ont été identifiés par l'Alliance zéro extinction s'agissant de plusieurs groupes taxonomiques entièrement recensés sur la liste rouge de l'UICN.

Le processus des ZCB désigne les sites clés, mais ne spécifie pas la manière dont ils doivent être conservés (au moyen d'une zone protégée officielle ou d'une conservation fondée sur la communauté, par exemple), ni quelles ZCB en particulier sont considérées comme prioritaires. Les ZCB doivent être utilisées en parallèle et en complément d'autres approches, mais elles sont néanmoins un outil de conservation efficace. Elles guident directement l'élaboration des politiques, notamment les engagements dans le cadre d'accords internationaux, et sont les éléments fondateurs d'une planification systématique de la conservation. En raison de sa nature participative, le processus ZCB a prouvé son efficacité comme moyen de développer la capacité scientifique et institutionnelle et de promouvoir des partenariats efficaces entre les pouvoirs publics et la société civile, ainsi que comme base pour inciter les communautés locales à s'engager dans la conservation et la surveillance.

La Conférence recommande ce qui suit:

Les objectifs de la CDB pour l'après-2010 devraient reconnaître la nécessité de préserver les sites les plus importants de la biodiversité, et non se contenter de fixer un pourcentage de surfaces terrestres et marines à protéger;

Un moyen efficace de prévenir l'extinction de nouvelles espèces et de conserver les centres importants d'endémisme est de protéger les sites qui abritent les dernières populations d'espèces très menacées. Ceux-ci doivent être prioritaires dans les efforts de conservation;

Les exercices de planification de zones protégées au plan national, sous-national et régional devraient englober les sites de biodiversité les plus importants (tels que les ZCB) en tant qu'éléments fondateurs essentiels;

Les priorités de conservation à l'échelle des sites devraient être portées à la connaissance des mécanismes volontaires de normalisation et de certification visant à sauvegarder la biodiversité, et prises en compte par ces derniers;

Il faudrait développer la coordination et le regroupement des approches ZCB existantes, notamment la fourniture d'informations sur les ZCB.

Gestion de la biodiversité à l'échelle des paysages

Les paysages socioécologiques de production jouent un rôle important dans la conservation de la biodiversité et peuvent contribuer à optimiser les services écosystémiques et à améliorer le bien-être des êtres humains de manière durable. Une gestion associant la biodiversité à d'autres fonctions du paysage auxquelles la société accorde de l'importance les services écosystémiques est essentielle sur cette question.

Les recommandations sur la gestion de la biodiversité à l'échelle des paysages comprennent les actions suivantes:

Identifier les paysages socioécologiques de production pour optimiser les services écosystémiques et améliorer le bien-être des êtres humains de manière durable, par exemple dans le cadre de l'Initiative de Satoyama;

Reconnaître le rôle des communautés autochtones et locales dans la conservation de la biodiversité et trouver des moyens de consigner et transmettre leurs connaissances pour qu'elles puissent être utilisées par les nouveaux venus, qui peuvent apporter à leur tour des connaissances, des compétences et des investissements importants pour une gestion adaptative;

Dans des environnements biophysiques et sociaux en évolution, trouver des moyens de préserver les caractéristiques des paysages qui sont bénéfiques pour la biodiversité, soit en préservant les pratiques traditionnelles, soit par le biais de nouvelles approches;

Reconnaître les pratiques, perceptions et valeurs de différents groupes de la population en ce qui concerne la biodiversité et d'autres fonctions des paysages dans la gestion et la valorisation de la biodiversité au niveau des paysages;

Inventorier, préserver et mettre en valeur la biodiversité de l'environnement urbain, où réside aujourd'hui plus de 50 % de la population mondiale, de manière à favoriser l'enrichissante interaction entre l'homme et la nature si essentielle à son bien-être.

Biodiversité et développement

L'accès à la biodiversité est indispensable pour répondre aux besoins de base d'une grande partie des personnes les plus pauvres de la planète. C'est une forme d'assurance essentielle, ainsi que la fondation des économies locales, régionales et mondiales. Cependant, en comparant les avantages respectifs de la conservation et de l'extraction des ressources, on ne rend souvent que partiellement compte, en termes économiques, de tous les bienfaits, particulièrement les services écosystémiques non marchands, découlant de la biodiversité. Cela donne fréquemment lieu à des politiques qui, bien que visant à améliorer le quotidien des gens, ont en fait le résultat inverse. Si les riches peuvent souvent trouver des substituts aux services écosystémiques, les pauvres n'en ont souvent pas les moyens. Il est possible de remédier à ce déséquilibre par des modèles économiques, des mesures d'évaluation adaptées et des méthodes comptables transparentes qui calculent les avantages matériels et immatériels offerts par la biodiversité. Il est cependant important de reconnaître que les approches économiques ont aussi des limites et ne peuvent rendre compte de tous les avantages que procure la biodiversité.

Les recommandations de la Conférence soulignent notamment la nécessité:

D'établir une comptabilité économique explicite de la valeur non marchande des biens et services afin de la prendre en compte dans les plans de développement durable;

De promouvoir et de mettre en œuvre, le cas échéant, des outils méthodologiques (comme ceux décrits dans le rapport L'économie des écosystèmes et de la biodiversité) qui peuvent faciliter une comptabilité économique complète d'autres scénarios d'utilisation de la biodiversité;

D'intégrer la biodiversité dans toutes les décisions concernant le développement, l'agriculture, la pêche, l'industrie, les affaires et les politiques à suivre;

De mettre en œuvre des partenariats bénéfiques à tous les niveaux économiques, du niveau microéconomique au niveau mondial, et d'être inventif dans la récolte et l'utilisation des fonds.

Communication, éducation et sensibilisation du public

Les scientifiques et les éducateurs contribuent tous à amener les divers acteurs à découvrir le monde qui les entoure, à l'explorer davantage, à se faire une opinion et à agir, pour obtenir des résultats qui seront partagés dans le monde entier.

Étant donné cet intérêt commun, tous les acteurs du domaine de la biodiversité impliqués dans la communication, l'éducation et la sensibilisation du public devraient:

Dialoguer pour mieux comprendre comment ils pourraient soutenir leurs travaux respectifs et y contribuer;

Mobiliser des personnalités influentes et des symboles de la biodiversité pour faire passer des messages sur la biodiversité au grand public;

Profiter des possibilités offertes par les technologies de l'information et de la communication, notamment l'Internet, la radio et la télévision, pour promouvoir des réseaux explicites de communication et une interaction entre décideurs, parties prenantes et scientifiques;

Créer des partenariats avec d'autres acteurs, notamment des organisations intergouvernementales, des gouvernements, des établissements d'enseignement et de recherche, des organisations de la société civile, des communautés autochtones et locales et le secteur privé;

Repérer des projets de démonstration illustrant les bonnes pratiques et adaptés pour renforcer et développer à plus grande échelle des mécanismes explicites de partage de l'information à des échelles comparables ou entre des échelles différentes;

Travailler dans le cadre de structures existantes, notamment la Décennie des Nations Unies pour l'éducation au service du développement durable (2005-2014);

Reconnaître la science citoyenne comme un outil important, mais souvent insuffisamment financé, de communication, d'éducation et de sensibilisation du public dans le domaine de la biodiversité.

Perspectives futures

Il est nécessaire de souligner à l'attention des décideurs et des parties prenantes toute l'importance de la biodiversité, particulièrement le rôle qu'elle joue dans le fonctionnement des écosystèmes et l'entretien des services écosystémiques, en permettant à la société de s'adapter au changement climatique, en soutenant la sécurité alimentaire et la santé et en ajoutant de la valeur à l'économie mondiale.

L'intégration des préoccupations relatives à la biodiversité dans les stratégies politiques, les plans d'action et les mesures de mise en œuvre requiert des mécanismes assurant la diffusion d'informations exactes, fiables et ciblées à l'appui de ces politiques.

Les recommandations en matière de science de la biodiversité doivent être élaborées en étroite collaboration avec les autres parties prenantes et les experts en politique pour que le public et les décideurs aient conscience de la diversité des options possibles, de leurs résultats probables et des interventions spécifiques permettant de les concrétiser.

Il est nécessaire d'utiliser de manière plus systématique les outils existants permettant de transmettre les connaissances relatives à la biodiversité sous des formes accessibles et utilisables par les décideurs, comme les indicateurs, les modèles, les scénarios, les techniques d'évaluation économique et les cartes, ainsi que de sensibiliser les décideurs à l'utilité et aux limites de ces outils.

À ce propos, l'ensemble des participants a exprimé son soutien à un mécanisme efficace liant la science de la biodiversité et les politiques, comme celui envisagé dans le cadre du processus intergouvernemental et multipartite concernant une Plate-forme intergouvernementale scientifique et politique sur la biodiversité et les services écosystémiques (IPBES).

Des mécanismes de financement améliorés et élargis sont essentiels, notamment pour le financement de la recherche sur la biodiversité, de la conservation et de la science citoyenne. Le financement devrait prendre en compte les questions liées à l'échelle. Les mécanismes de financement doivent avoir une relation clairement définie avec une IPBES à venir et y participer de manière adaptée.

VI

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CORAT, SANYE GÜLSER is currently the Director of UNESCO's Division for Gender Equality. Before joining UNESCO, she pursued a dual career in academia and in international development. Her academic work included research and teaching in the field of political economy at Carleton University and the University of Ottawa in Canada. As an international development practitioner, she was a senior development advisor for various bilateral development agencies (Canadian International Development Agency and the International Development Research Center), for multi-lateral lending institutions (the World Bank and the Asian Development Bank), UN agencies (UNDP and UNCTAD) and for civil society organizations, especially in Asia and Africa. She also has private sector experience as the Chief Executive Officer of an international consulting company (ECI Consulting, Inc.) in Canada. Ms. Corat holds a B.A. Honours degree from Boğaziçi University (Istanbul, Turkey). She has M.A. degrees from the College of Europe (Bruges, Belgium) and the Norman Paterson School of International Affairs, Carleton University (Ottawa, Canada). She pursued her doctoral studies in the Political Science Department of Carleton University.

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DARWALL, WILLIAM has over 20 years' experience working on and leading collaborative research projects on the ecology and conservation of aquatic ecosystems in developing countries. He is currently Manager of the IUCN Freshwater Biodiversity Unit in Cambridge, UK. The main focus of his work includes implementation of large-scale biodiversity assessments of freshwater systems, including assessment of threatened species status for the IUCN Red List. Darwall currently manages a large project to assess freshwater biodiversity throughout continental Africa, and a number of other related projects in Europe and Asia, with a focus on livelihood values of freshwater species. He holds a Ph.D. in Biological Sciences from the University of Hull (2004) as well as an M.Sc. in Ecology and Evolution from the University of Utah and a B.Sc. in Zoology from the University of St Andrews, Scotland.

DEVICTOR, VINCENT est chargé de recherche au CNRS à Montpellier Il cherche à développer une interface entre la recherche fondamentale en macroécologie et des outils pratiques de biologie de la conservation. Ses thématiques de recherches s'organisent autour de l'écologie de la conservation à larges échelles et s'appuient largement sur l'utilisation des données de sciences-citoyennes, en particulier sur les oiseaux. Son projet de recherche vise à aborder les questions nouvelles qui s'imposent en biogéographie (impact du réchauffement climatique sur la distribution des espèces, distribution de la diversité phylogénétique, relation diversité/fonction à large échelle) en utilisant les apports récents de l'écologie des communautés, de l'écologie évolutive et de l'écologie fonctionnelle.

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FRANGOU, ANNA is currently a D.Phil. student at the University of Oxford, studying statistical genetics, and co-supervised by Professor Gil McVean and Dr Simon Myers. She completed an M.Sc. in Biodiversity, Conservation and Management in 2009 with Professor Robert Whittaker at the same institution. Despite the move to studying genetics and human evolution, she maintains a strong interest and involvement in conservation, and plans to apply the skills obtained during her D.Phil. to questions of conservation once she completes her degree.
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KASISI, ROBERT est le professeur à la faculté de l'aménagement de l'Université de Montréal depuis 1997. Spécialiste en environnement et en gestion des ressources naturelles, il a travaillé pour le WWF International en Suisse et en Afrique. En tant que consultant, il a dirigé l'élaboration de la stratégie nationale de biodiversité et le plan d'action de plusieurs pays africains. Il travaille sur plusieurs projets de gestion des ressources naturelles notamment les aires protégées en Afrique et dans les Caraïbes. Il a dirigé des études d'impacts environnementaux et sociaux de certains projets en Afrique. Ses publications sont orientées sur les questions relatives à l'environnement ainsi que sur la relation entre l'environnement et la culture. Membre de la Commission scientifique de Gestion des Écosystèmes de l'UICN. Conseiller scientifique au Centre de Développement de la Recherche Internationale en Environnement (CEDRIE) affilié au CERIUM de l'Université de Montréal.

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LOVEJOY, THOMAS EUGENE III is chief biodiversity adviser to the president of the World Bank, senior adviser to the president of the United Nations Foundation, and president of the Heinz Center for Science, Economics, and the Environment. He is also a University Professor of Environmental Science and Policy at George Mason University. Dr. Lovejoy introduced the term biological diversity to the scientific community in 1980. Lovejoy, a tropical biologist and conservation biologist, has worked in the Amazon of Brazil since 1965. He

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MANVELYAN, KAREN is Director of the Armenian Branch of WWF. He graduated from Yerevan Zoo-veterinary institute and holds a Ph.D. in animal physiology. Prior to joining WWF he worked as Head of Department of Biodiversity Conservation of the Institute of Botany as well as Scientific Director of the Yerevan Zoo. He holds a Diploma in Endangered Species Management from the University of Kent. He completed training courses on Endangered Species Management at the Gerald Durrell Wildlife Conservation Trust as well as on Wetlands Management. He specialized in conservation of endangered species of plants and animals and protected areas management.

MATIKU, PAUL holds a M. Phil. in Biological Sciences of Moi University; and is currently writing his thesis for a Ph.D. in Environmental Planning and Management of Kenyatta University. He has served as Executive Director for Nature Kenya since 2000; represents Africa in Birdlife International's Global Council; serves on the Birdlife Africa Regional Committee; and represents Africa in the UNEP-WCMC 2010 Biodiversity Indicators Project.

MINASYAN, ANAHIT holds a graduate degree in linguistics from Yerevan State University and another one in social sciences from the Central European University (Budapest). Prior to joining UNESCO, she worked in academia, as a research fellow and lecturer, and collaborated with NGOs. She is at present a UNESCO Programme Specialist in the field of Culture, in charge of UNESCO's Endangered Languages Programme, whose flagship publication is the *Atlas of the World's Languages in Danger*.

NATORI, YOSHIHIRO joined the Environment Agency (EA) of the Japanese Government as a National Park Ranger in 1975. Subsequently he has worked at the Nature Conservation Bureau and the Global Environment Department of EA, the Embassy of Japan in Kenya, and in the Regional Office for Asia and the Pacific of UNEP, based in Thailand, as the Deputy Regional Director. Since then he has worked as the Director of the Wildlife Division of the Ministry of the Environment, was dispatched to the United Nations University Institute of Advanced Studies (UNU-IAS) in July 2006 and was responsible for the Education for Sustainable Development Programme and International Satoyama Initiative as a Senior Fellow. Since September 2010, he has been working at the Nagao Natural Environment Foundation, a non-profit organisation based in Japan.

OUOBA, ROSALIE est la Présidente du Réseau d'appui à la citoyenneté des Femmes Rurales d'Afrique de l'Ouest et du Tchad. (RESACIFROAT). Elle est titulaire d'un diplôme d'études supérieures spécialisées (DESS) en santé publique et nutrition dans le processus du développement de l'université de Paris I. Elle est spécialiste en développement rural avec une grande connaissance du monde associatif rural notamment ouest africain et plus spécialement celui des femmes. Rosalie était la Directrice générale du centre d'études économiques et sociales pour l'Afrique de l'Ouest (CESAO), institution régionale en Afrique de l'Ouest, chargé de développer les compétences dans le domaine du développement. Depuis cinq ans elle a mis ces compétences au service du renforcement des capacités des associations de femmes rurales de l'Afrique de l'Ouest et du Tchad au sein d'un réseau ouest africain, le RESACIFROAT. Parallèlement à ces activités, Rosalie est active dans le domaine associatif, elle est vice présidente de la Commission Nationale des Droits Humains du Burkina (CNDH) et présidente de l'association des femmes et associations professionnelles du Burkina depuis 2005.

PATRY, MARC spent several years in the field, working on sustainable forestry and nature conservation challenges in Mexico's Yucatan peninsula, and in the Galapagos Islands of Ecuador, before taking on his job with UNESCO's World Heritage Centre. He obtained a bachelor`s degree in biology, and another in education and taught high school science for a few years before completing a master`s degree in rural planning and development, after which he worked for a few years in agricultural land use planning for the province of Ontario, Canada.

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