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EDITORIAL

Tomorrow begins today

It may not have grabbed the headlines but the fate of long-term biodiversity conservation was also riding on the outcome of the climate talks in Copenhagen. As the authors of *Wildlife in a Warming World* explain overleaf, global warming will have a 'profound and global' impact on biodiversity.

Even 2°C of global warming will stress species and ecosystems, causing coral reefs in Australia, Southeast Asia and the Caribbean to bleach, for example. If we are to limit global warming to 2°C this century, we need to act quickly and decisively, yet delegations to Copenhagen have just decided to put off until tomorrow what could have been done today. Two weeks of tense talks concluded on 18 December with a vague agreement signed by a minority of countries that contains no internationally binding commitments to reducing carbon emissions, even if it mentions the target of limiting global warming to 2°C. The Copenhagen Accord also endorses the mechanism for Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD). We shall be examining the implications of this decision for biodiversity conservation in a subsequent issue of this journal.

The message of the International Year of Biodiversity is clear: act now to slow the alarming pace of biodiversity loss or regret it tomorrow. Climate change is not the only threat hanging over biodiversity, of course. Habitat loss, deforestation, overfishing and invasive species are just some of the other threats species face.

The Year gets under way at UNESCO headquarters in Paris on 21 January. The launch will be followed by a conference at which scientists will demonstrate how new knowledge can be used in biodiversity-related decision-making. Topics will include the new generation of taxonomy; biogeography and climate change; biodiversity priority-setting and planning; and the biodiversity science–policy interface. The conference proceedings and recommendations will be presented in October both to UNESCO's Executive Board and to the meeting of the Parties to the Convention on Biological Diversity (CBD) in Japan.

The importance of biodiversity for economic development will also be discussed at the scientific conference in January. Who would have thought, for example, that a simple natural dye could solve some of the Aral Sea Basin's most acute ecological and socio-economic problems, as we shall see in this issue?

Education will be a key objective of the Year. After eight days at UNESCO headquarters in Paris, a travelling exhibition will leave for a world tour on 30 January to convey the Year's main messages to policy- and decision-makers, students and the general public. A biodiversity learning kit for teachers and trainers will follow in October.

The Year will also underscore the ties between biological and cultural diversity. Together with the CBD and others, UNESCO is holding an international conference on biological and cultural diversity in June in Montreal (Canada). As we shall see in these pages, the Bushbuckridge traditional healers in South Africa personify this symbiosis between biological and cultural diversity. Now that they have discovered their rights, they intend to exercise them. The benefits will be both short and long term as, by protecting the medicinal plants that are their livelihood, they will also be protecting their communities' health.

W. Erdelen
Assistant Director-General for Natural Sciences

Wildlife in a warming world

'During the 2002–2003 Antarctic summer, several large icebergs broke off the Ross Ice Shelf. This forced the Adelie penguins in the Ross Sea region to navigate across large expanses of ice to forage. Most of the breeding birds failed to raise any chicks for lack of enough available food.' Emma Marks, prize–winner of UNESCO photo contest on The changing Face of the Earth

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.

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. Here, we 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 overleaf*).

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%).*

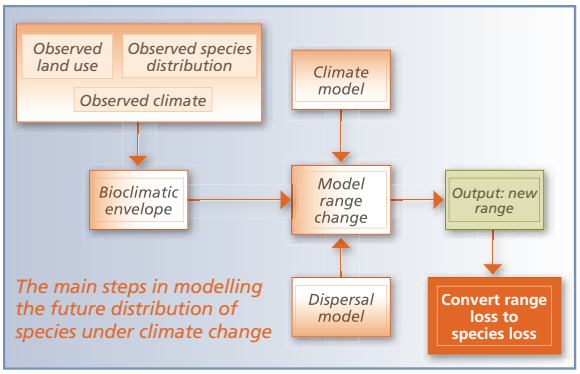
Secondly, climate change has become the dominating environmental agenda of the new century. Aligning biodiversity conservation with climate change is therefore far more likely to engage the interest of decision-makers and politicians than biodiversity conservation alone. This will also provide an effective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



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

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.

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') representing 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.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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.

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,

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 richness	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 on page 6 ...

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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Capucine monkeys in South America

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 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 page 8 *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.

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*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.*

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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
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

Source: Fischlin et al (2007) Ecosystems, their properties, goods, and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. *Contribution of Working Group II to the Fourth Assessment Report of IPCC.*

*By 2005, the average global temperature had risen by approximately 0.76°C since 1850.

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*

Examining footprints in the snow that seem to belong to the elusive Yeti, in a scene from Tintin in Tibet *by Belgian author Hergé*

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 to survey (see *box*). 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 3100 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

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.

Yellow Spotted Amazon River Turtles

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.

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 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 1 million records from collections or observations in Brazil, the most biodiverse country in the world.

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.

Anna Frangou[5], Richard J. Ladle[5], Ana C. M. Malhado[6] and Robert J. Whittaker[5]

Authorship order alphabetical

For details: robert.whittaker@ouce.ox.ac.uk; www.biogeography.org/

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.

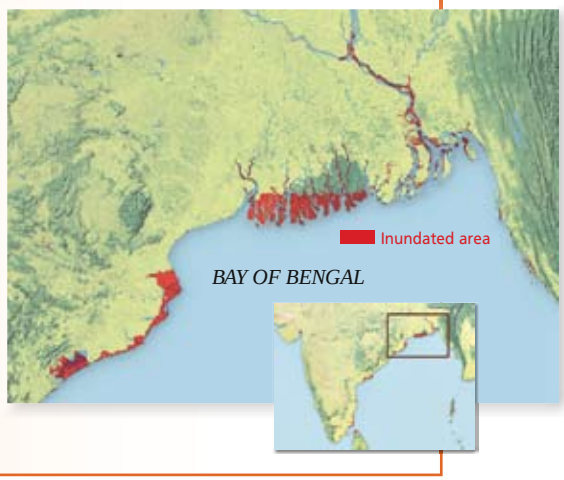
There is a continuous natural subsidence in the Sundarbans which causes sea level to rise by about 2.2 mm every year. Were sea level to rise by 45 cm worldwide, 75% of the Sundarbans mangroves could be destroyed. The IPCC predicts sea-level rise of up to 60 cm by the end of the century. However, this 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.

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



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/

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*
5. *Biodiversity Research Group, Oxford University, UK*
6. *Department of Agricultural and Environmental Engineering, Federal University of Viçosa, Brazil*

Science must be a priority, says new UNESCO head

Irina Bokova

On 15 October, the General Conference elected Irina Bokova Director-General of UNESCO for a four-year term. 'My belief is that science must be one of the priorities', she wrote on her website during the election campaign.[7] 'UNESCO should become the leader and mobilizer of governments, specialized agencies and the scientific community in the field of science, innovation and new technologies, including green technologies, under the slogan Science and Technology serving Humanity.'

'The greatest challenge is to lead the world into a new era of peace and humanism,' she believes, 'to create more inclusive, just and equitable societies through sustainable economic and social development, based on science, innovation and new technologies that will serve mankind and preserve the environment.'

For the new Director-General, 'climate change, biodiversity, mitigation of natural disasters, water resources management, energy and pandemics are the new key challenges in science which should be given priority in UNESCO's programmes, while incorporating the ethical dimension.' She also feels that 'UNESCO should complement national policies to better integrate science, research and science education.'

'In order to enhance the visibility of science as a priority,' she adds, 'I shall propose the establishment of a Scientific Advisory Committee of eminent personalities such as Nobel Prize laureates and winners of UNESCO prizes.'

'UNESCO's budget is clearly modest compared with our ambitions,' she observes. 'But we have to be realistic; in times of crisis, UNESCO should make a better and more efficient use of available resources, reduce administrative costs, modernize its structures and become a more reactive and performing organization. Programme implementation should clearly be given priority over administrative activity.'

Born in Sofia in 1952, Irina Bokova was the Ambassador of Bulgaria to France and Permanent Delegate to UNESCO until her election. A career diplomat and politician, she studied at the Moscow State Institute of International Relations then at the School of Public Affairs of the University of Maryland (USA). She served first as Deputy Minister of Foreign Affairs (1995–1997) then as Minister of Foreign Affairs (1997). In 1996, as candidate to the post of Vice-President of Bulgaria, she advocated her country's membership of the North Atlantic Treaty Organisation and European Union.

Irina Bokova was nominated on 22 September by the Executive Board, after obtaining 31 of the 58 ballots in the fifth round of voting, ahead of Hosni Farouk, Egyptian Minister of Culture. The Board selected her from among nine candidates interviewed on 15 September.

Concern over budget for science

At UNESCO's General Conference this year from 6 to 23 October, several delegates requested that the written report of the Natural Sciences Commission 'reflect their deep concern about the current budget situation' for science. Just US$59 million out of the Organization's total budget of US$653 million will go to the natural sciences in 2010–2011. A number of delegates questioned the balance between the allocations for administrative costs and programme activities.

Every two years, UNESCO's 193 member states congregate in Paris to adopt the programme and budget for the coming biennium. For 2010–2011, the new priorities are the use of science, technology and innovation policies to set countries on the path to sustainable development and greening of their economy, as well as attainment of the Millennium Development Goals. UNESCO's programmes in freshwater and the ecological sciences will be focusing on mitigation of, and adaptation to, climate change in least developed countries in particular.

The proposed Earth Science Education for Africa programme has been approved. An outcome of consultations across Africa within the International Year of Planet Earth, it will be building the capacity of African countries to manage and exploit their vast mineral resources effectively, while optimizing the benefit for African countries.

The Natural Sciences Commission also authorized the Director-General to seek funding for a study on the feasibility of establishing an International Engineering Science Programme at UNESCO.

The General Conference authorized the Director-General to sign agreements establishing nine international science centres (category 2) under the auspices of UNESCO. They are the International Centre on Space Technologies for Cultural and Natural Heritage (China); Centre for the Sustainable Management of Water Resources in the Caribbean Island States (Dominican Republic); International Training and Education Centre in Proteomics, Functional Genomics and Bioinformatics (Israel); International Centre on Water Resources and Global Change (Germany); International Centre on Coastal Ecohydrology (Portugal); International Centre for Education, Capacity building and Applied Research in Water (Brazil); International Centre for Integrated Water Resources Management (USA); Asia–Pacific Centre for Ecohydrology (Indonesia); and the Regional Centre for Science Park and Technology Incubator Development (Iran).

Colombia hosts **Year's largest space marathon**

Over three days, Barranquilla played host to 2000 teachers and 24 000 youngsters from 140 Colombian schools who had flocked to the coastal city to participate in Aventura Espacial (Space Adventure), the largest event worldwide of the International Year of Astronomy. Aventura Espacial was organized by Fundación Genius, in co-operation with UNESCO's Regional Bureau for Science in Latin America and the Caribbean in Montevideo (Uruguay), the UN Commitee on the Peaceful Uses of Outer Space (COPUOS), NASA, the Ministries of Education and Foreign Affairs of Colombia and the Maloka Science Centre of Colombia, among others.

©Guillermo Lemarchand

Students gathered in Barranquilla for their 'space adventure'

From 6 to 8 May, the 12–17 year-olds and their teachers attended 35 daily lectures given by prominent space scientists, the scientific content of which had been devised by experts from COPUOS, NASA and UNESCO.

The Vice-President of Colombia, Francisco Santos Calderón, who happens to be an amateur astronomer, received all the lecturers at the Presidential Palace before the event. He told them he was convinced that Colombia should develop 'a stronger space science programme, in co-operation with the National Commission for Space, COLCIENCIAS (the National Science and Technology Agency), universities and international organizations like UNESCO and COPUOS.'

During the three-day event, there were also science courses for teachers to attend, parachute simulators to try out, night-sky gazing with a telescope and an exhibition on space science. A number of contests were organized to test the youngsters' knowledge of space and astronomy, as well as an essay competition on the importance of science for society. Abraham Sánchez Elguedo and Sebastián Ujueta won a full scholarship to Georgia Tech University (USA). Five other pupils, Manuel Bermúdez Porto, María Fernanda Dávila, Valerie García, Luís Carlos González Castro and Ciro David Plata Barros, won a trip to the Kennedy Space Center (USA) to watch the Space Shuttle lift off for the International Space Station in February. Two other pupils, Paula Valderrama and Kevin Darío Alfonso Aldana, won a trip to the Republic of Korea to compete in a hydraulic rocket-launching competition.

As for science teacher Rodolfo González Novoa from Colegio San José, he won a trip to Montevideo to attend another event within the International Year of Astronomy, the Second Ibero-american Graduate School on Astrobiology taking place on 7–12 September. The theme of the school was From the Big Bang to Civilizations. Almost 80 graduates from 16 countries in the region attended the six-day event, which was organized by Guillermo Lemarchand, an astrophysicist from the University of Buenos Aires working as a consultant for UNESCO's office in Montevideo.

The intense classes and discussions among graduates and experts were combined with informal talks, public lectures, interviews with the media and a special science education workshop attended by 250 secondary school teachers from the region. The aim was to use public curiosity about the possibility of extraterrestrial life to walk students through the wide range of disciplines needed in the quest: astronomy, biology, physics, geosciences, atmospheric sciences, palaeontology, biochemistry, cognitive sciences, engineering and so on.

The graduate school was sponsored by the Organization of American States, Academy of Sciences for the Developing World (TWAS) and UNESCO's Abdus Salam International Centre for Theoretical Physics.

For details: glemarchand@unesco.org.uy; on the Space Shuttle mission in February: www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts130/l

Launch of **consortium for science in the South**

The ministers responsible for science and technology of the Group of 77 countries officially launched the Consortium of Science, Technology and Innovation in the South (COSTIS) on 4 November, during a ministerial roundtable at the start of the World Science Forum in Budapest (Hungary). The launch fulfills the promise of the Declaration adopted by ministers at the First Summit of the G77 and China in Havana (Cuba) in 2004.

The Academy of Sciences for the Developing World (TWAS) has spearheaded the development of COSTIS, in collaboration with UNESCO. COSTIS will provide the G77 countries with direct access to the developing world's best scientific minds.

'COSTIS represents a unique blend of political power and scientific and technical expertise,' says Mohamed Hassan, Executive Director of TWAS. 'The consortium will provide a platform for government agencies responsible for funding research and development to interact

with leaders in academia and industry.' COSTIS' main focus will be to promote science-based economic development and encourage international scientific cooperation through international exchange programmes and joint research projects. With many successful science-based economic development policies having been put in place in developing countries such as Brazil, China and India, COSTIS will enable developing countries to learn from one another.

COSTIS' flagship activity will be to convene periodic South–South forums on science, technology and innovation for development that address topics of critical concern, including the development of appropriate, affordable technologies for increasing access to safe drinking water, energy and information and communication technologies. In addition, COSTIS plans to support the creation of scientific centres of excellence.

'We will seek funding for our initiatives from a number of different sources,' says Hassan, 'including individual governments in the developing and developed worlds and international donors and foundations.'

Representatives of the G77, TWAS and UNESCO will serve on the steering committee. Their names will be announced in January.

COSTIS replaces the Third World Network of Scientific Organizations.

The World Science Forum was organized from 5 to 7 November by UNESCO, the International Council for Science and the Hungarian Academy of Science. The forum aspires to become to science what the Davos Forum is to economics.

For details: www.twas.org; www.sciforum.hu

Three science prizes awarded

In this, the International Year of Astronomy, it is only fitting that UNESCO's Kalinga Prize for the Popularization of Science should have gone to two astrophysicists: Professors Yash Pal from India and Trinh Xuan Thuan from Viet Nam. The prize was awarded at the World Science Forum in Budapest (Hungary) on 5 November, along with UNESCO's Great Man-Made River International Water Prize for Arid and Semi-Arid Zones and the Sultan Qaboos Prize for Environmental Preservation.

Professor Yash Pal has helped develop the concept of a number of television shows that popularize science, such as the *Science is Everywhere* series for rural children in India. He is also a familiar face on the widely watched scientific television magazine *Turning Point* for his role in answering viewers' questions. Professor Pal has also contributed to the development of several institutions in his country, including the Centre for Educational Communication in Ahmedabad.

Professor Trinh Xuan Thuan writes for the public in French but his books have been translated into at least 20 languages. Among his most famous are: *The Secret Melody*, a panorama of modern cosmology and its philosophical implications; *Birth of the Universe – the Big Bang and After*; *The Quantum and the Lotus*, a dialogue with the Buddhist monk Matthieu Ricard on the ways in which science and Buddhism converge and diverge in their descriptions of reality; and *The Ways of Light*, explaining the Universe through the signals it sends us in the form of light.

This year, the Great Man-Made River International Water Prize for Arid and Semi-Arid Zones goes to **Dr Bellachheb Chahbani** from the Institute of Arid Regions in Médenine (Tunisia) for improving the reliability of irrigated water while reducing the amount needed to irrigate crops. Dr Chahbani has developed a technology which limits run-off by storing water in buried stone pockets in deep soil terraces; this is combined with shallow water-diffusing systems and small earth dams for water collection and use. Dr Chahbani recruited both researchers and local farmers to test his technology, which is currently in use in both central and southern Tunisia and Algeria. Not only have operating costs been cut by about one-third but many crops have also been saved that would otherwise have perished from lack of water in times of drought.

UNESCO's Sultan Qaboos Prize for Environmental Preservation has been awarded to the **Autonomous Authority for National Parks (OAPN)**, which operates under the Spanish Ministry of Environment, Rural and Marine Areas. For the Bureau of the International Coordinating Council of UNESCO's Man and the Biosphere (MAB) Programme, which acted as jury, OAPN is a model for biosphere reserve management. It works to conserve Spain's natural heritage through efforts to save endangered species and their habitats, eliminate non-native species, restore degraded areas and monitor air and water quality, in addition to supporting environmental education and training.

OAPN has also helped countries in Ibero-America and the Caribbean, northwest Africa and southeast Asia to identify and fund subregional strategies for protecting biodiversity in biosphere reserves through South–South cooperation, technology transfer and training. The US$30,000 prize money will go towards setting up a biosphere school in the Bijagos Biosphere Reserve in Guinea Bissau *(see below)*.

A biosphere school for Guinea Bissau

The Spanish Autonomous Authority for National Parks (OAPN) has decided to devote the full prize-money of US$30,000 from the Sultan Qaboos Prize to setting up a school for the biosphere in Eticoga, a village in the Boloma Bijagos Biosphere Reserve of Guinea Bissau. The school will be the first to receive funding within

*The Boloma Bijagos Biosphere Reserve is an archipelago of 88 islands characterized by mangroves, forests, coastal savanna and sand banks. It is home to the Nile crocodile (*Crocodylus niloticus*) and the hippopotamus (*Hippopotamus amphibius*). People make a living from rice-growing, animal husbandry, exploiting wild palm trees, fishing and horticulture.*

Photo: OAPN

The future school for the biosphere in Eticoga

a new OAPN project on environmental education which is setting up five schools in regions of priority interest for Spanish co-operation in Africa and Latin America.

The school is attended by 80 children aged 5–10 years old, who start compulsory schooling when they are seven. The person in charge of the school, which also acts as a nursery, is called Second. He is a school teacher from Eticoga who manages the school on a voluntary basis. It was Second who came up with the idea for the project.

For the moment, the school is housed in a small room belonging to a public radio station which is no longer broadcasting. The school has no stationery, books or furniture.

The OAPN plans to remedy that. After rehabilitating infrastructure, it will equip the school with a blackboard, desks, chairs and other appropriate furniture and provide the children with school uniforms. Basic school stationery will be delivered, such as notebooks, pens, rulers and so on.

OAPN is also developing a book on environmental education for young children and their teachers which will be given to the school along with textbooks to help the children learn how to read, write and do arithmetic.

The project will stress the importance of sustainable development and biodiversity conservation in the biosphere reserve.

fjcantos@oapn.mma.es; m.clusener-godt@unesco.org

Healthier oceans vital for combating climate change

A 'blue carbon' fund for the maintenance and rehabilitation of key marine ecosystems which act as an effective carbon sink should be considered by governments keen to combat climate change, says a report launched by UNEP, FAO and UNESCO simultaneously in Cape Town (South Africa), Nairobi (Kenya) and Rome (Italy) on 14 October.

'Since the ocean has already absorbed 82% of the total additional energy accumulated in the planet due to global warming, it is fair to say that the ocean has already spared us from dangerous climate change,' says Patricio Bernal, Executive Secretary of UNESCO's Intergovernmental Oceanographic Commission (IOC). 'But each day, we are essentially dumping 25 million tons of carbon into the ocean. As a consequence, the ocean is turning more acidic,' posing a huge threat to organisms with calcareous structures. As waters warm up and the chemical composition of the ocean changes, the fragile equilibrium that sustains marine biodiversity is being disturbed with serious consequences for the marine ecology and the Earth's climate.

Blue Carbon: the Role of Healthy Oceans in Binding Carbon estimates that marine ecosystems such as seagrasses, mangroves and salt marshes capture and store about half the annual carbon emissions of the global transport sector. These habitats cover less than 1% of the sea bed, yet account for more than half of all carbon storage in ocean sediments.

The report warns that, far from maintaining and enhancing these natural carbon sinks, humanity is degrading them at an accelerating rate. It estimates that up to 7% of these blue carbon reservoirs are being lost annually, seven times the rate of loss 50 years ago. If more is not done to sustain these vital ecosystems, most may be lost within two decades, says the report.

Preventing further loss and catalysing their recovery could contribute to offsetting 3–7% of current fossil fuel emissions, or about 27 000 million tons of CO_2 in two decades. The effect would be equivalent to at least 10% of the reductions needed to keep concentrations of CO_2 in the atmosphere below 450 ppm and thereby global warming below 2°C.

Meanwhile, a study published in *Nature* on 19 November by Khatiwala et al. warns that the oceans are saturating and thus becoming a less effective carbon sink, as the more acidic they become, the less carbon they can absorb.

For details and to read the report, see page 24

Collapse of *karez* forces Iraqis to abandon homes

Over 100 000 people in northern Iraq have abandoned their homes since 2005 because of severe water shortages, a UNESCO study finds. Drought and excessive well-pumping have drawn down aquifer levels in the region, causing a dramatic decline in water flow in the ancient underground aqueducts (qanats) known as *karez* in Iraq.

The study is the first to document the effects of the ongoing drought on the *karez* systems. Designed especially for the arid climate, *karez* are renowned for their ability to remain productive even during dry spells. However, UNESCO's study confirms that, since the onset of drought four years ago, 70% of the active *karez* have dried up. The overexploitation of groundwater by modern pumped wells has also been a major factor. By August last year, only 116 out of 683 *karez* systems in northern Iraq were still supplying water to their beneficiaries.

Before the onset of drought, the greatest threats to the *karez* systems in Iraq were political turmoil, abandonment and neglect. Today, few people in Iraq know how to maintain or repair them. The village of Jafaron, one of the hardest-hit in the region, saw 44 of its 52 *karez* dry up in 2008, leaving its only source of food – 113 hectares of irrigated land – barren and prompting most of its population to emigrate.

Some 36 000 people are on the brink of abandoning their homes if conditions do not rapidly improve. Beyond the trickle of water that they receive from their *karez*, these people rely on water tanks, which must be refilled several times by trucks travelling long distances or by pumped wells, which often need to be dug deeper than before. For many, neither option is financially viable.

According to the study, swift action is needed to prevent further population displacement. UNESCO estimates that a single *karez* has the potential to provide enough household water for nearly 9000 individuals and irrigate over 200 hectares of farmland. In economic terms, that translates into 300 additional tons of grain per year or up to $160,000 of income generated at current market prices. The study identified 50 communities that will benefit from *karez* restoration works.

©Dale Lightfoot/Oklahoma State University

Young Iraqi girl filling a can with water piped from a karez opening

The UNESCO study provides the Government of Iraq with its first comprehensive inventory of *karez*. Before the study was undertaken, very little information on the number, location and condition of *karez* existed. Dr Dale Lightfoot, Head of the Department of Geography at Oklahoma State University (USA) and an internationally recognized expert on *karez*, conducted the survey on behalf of UNESCO.

UNESCO has been working with the government to rehabilitate *karez* systems since 2007 and plans to launch the new *Karez* Initiative for Community Revitalization this year to help rural communities rebuild their *karez* systems.

For details and to read the report, see page 24

Sustainable development needs cultural dimension

Cultural diversity has an important – if often underestimated – role to play in ensuring environmental sustainability and socio-economic development, says a report released by UNESCO on 20 October.

The *UNESCO World Report*: *Investing in Cultural Diversity and Intercultural Dialogue* observes that, while the international community has primarily sought scientific and technical responses to ecological challenges, there is growing awareness that cultural practices are intimately linked to environmental integrity. Just as cultural identity and social stability can be strongly influenced by environmental conditions, so too can cultural factors influence consumer behaviour and values related to environmental stewardship.

The emergence of a daunting nexus of environmental problems that threaten the stability, if not the very existence, of human societies has triggered widespread reflection on a holistic approach to development that would draw on a broad range of cultural experiences, intuitions and practices to ensure participatory approaches to adaptation and mitigation. If nothing is done, the impact of the large-scale environmental changes to come may include massive population displacements that will seriously threaten cultural continuity and diversity, particularly in rural areas and among place-dependent minority groups already under stress.

Local, rural or indigenous knowledge may offer solutions to contemporary environmental problems: from small-scale production processes with little surplus and low energy needs to a custodial approach to land and natural resources that avoids waste and resource depletion. For the report, it is urgent to 'operationalize' existing research on the cultural dimension of natural resources conservation and management.

The report cites some traditional mechanisms which have proven their worth over the centuries. In the Spanish towns of Murcia and Valencia, for instance, the Council of Wise Men

and the Water Court are two customary tribunals which hold jurisdiction in all matters pertaining to local irrigation.

Development policies must also be culturally relevant if they are to succeed. In Nigeria, the traditional monarchs exert a strong influence on their people. In a speech to UNESCO on behalf of the Council of Traditional Rulers of Nigeria in March 2007, the 50th Ooni (King) of Ife, Oba Okunade Sijuade, underscored the monarchs' commitment to promoting scientific development. 'Without doubt, science and technology are the basis for socio-economic development in any nation', he observed. 'However, technology must be culturally relevant and adapted to local situations and needs. Experience has shown that, in Nigeria, development strategies are designed and communicated in the English language, a language which is not accessible to a large percentage of the local people.'

The three monarchs of the Yoruba, Ibo and Hausa ethnic groups are tackling this problem via three initiatives: the teaching and communication of science and technology in the Yoruba, Ibo and Hausa languages, spoken by about 85% of Nigeria's 140 million inhabitants; the integration of traditional knowledge in building local innovation systems; and the building of bridges between the language communities in Nigeria and the diaspora. The monarchs are establishing a Yoruba Academy of Science, for example, to promote scientific cooperation among Yoruba-speaking communities worldwide. UNESCO has assisted with feasibility studies for the academy, which is due to be launched later this year.

For details and to read the report, see page 24

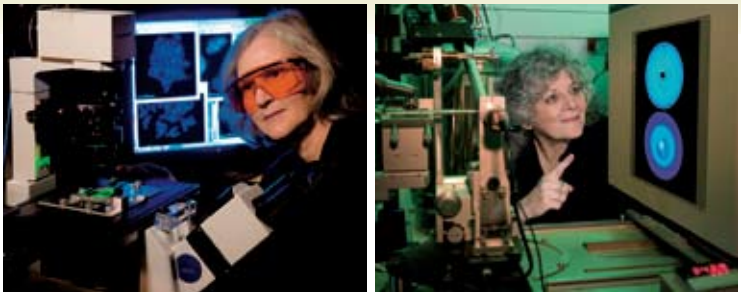
Two Nobel Prizes for L'ORÉAL–UNESCO laureates

Two days after Elizabeth Blackburn was awarded the Nobel Laureate in Physiology or Medicine on 5 October, a second L'OREAL√UNESCO laureate, Ada Yonath, learned she had received the Nobel Prize in Chemistry.

This year's Nobel Prize in Chemistry rewards research into one of life's core processes: the ribosome's translation of DNA information into cellular structures and activities necessary for life. Venkatraman Ramakrishnan, Thomas A. Steitz and Ada Yonath are honoured for having shown what the ribosome looks like and how this sub-cellular particle functions at the atomic level. All three have used X-ray crystallography to map the position of every one of the hundreds of thousands of atoms that make up the ribosome.

Ribosomes are a key target for antibiotics, as antibiotics are able to inhibit the ribosomal activity of harmful bacteria while leaving human ribosomes untouched. Prof. Yonath's research has shed light on the mechanisms underlying bacterial resistance to antibiotics.

This year's Nobel Prize in Physiology or Medicine is awarded to three scientists who have solved a major problem in biology: how the chromosomes can be copied in a complete way during cell divisions and how they are protected against the degradation which leads to disease. Affectionately dubbed 'the trio against ageing', Elizabeth Blackburn, Carol Greider and Jack Szostak have shown that the solution can be found in the ends of the chromosomes – the telomeres – and in an enzyme that forms them, telomerase.



©L'ORÉAL/Micheline Pelletier

Australian-born Elizabeth Blackburn (left) in her laboratory at the University of California (USA) and Ada Yonath in her laboratory at the Weizmann Institute for Science (Israel)

For details of the work of Professors Blackburn and Yonath, see also A World of Science, *April 2008*

18 countries test **tsunami system**

Eighteen countries[8] participated in an exercise on 14 October to test the effectiveness of the Indian Ocean Tsunami Warning and Mitigation System. The system was established by the UNESCO–IOC after the devastating tsunami of 26 December 2004. The exercise took place just days after an earthquake-generated tsunami killed more than 100 people in Samoa on 29 September.

Exercise Indian Ocean Wave 09 provided countries with an opportunity to test their operational lines of communications, review their tsunami warning and emergency response standard operating procedures and promote emergency preparedness.

The exercise scenario replicated the magnitude 9.2 earthquake off the northwest coast of Sumatra (Indonesia) in 2004 which generated a destructive tsunami affecting countries from as far away as Australia and South Africa. The simulated tsunami spread in real time across the entire Indian Ocean, taking approximately 12 hours to travel from Indonesia to the coast of South Africa. Bulletins were issued by the Japan Meteorogical Agency in Tokyo and the Pacific Tsunami Warning Center in Hawaii (USA), which have served as interim advisory services since 2005.

The recently established Regional Tsunami Watch Providers in Australia, India and Indonesia also participated in the exercise and shared experimental real time bulletins. These regional watch providers will soon replace the interim service currently provided from Hawaii and Tokyo.

For details: www.ioc-tsunami.org/

7. *see: www.bokova.eu*
8. *Australia, Bangladesh, India, Indonesia, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Myanmar, Oman, Pakistan, Seychelles, Singapore, Sri Lanka, Tanzania and Timor Leste*

Farouk El-Baz

Back to the Moon

China, India, Japan and the USA have all launched missions to the Moon in the past three years. China plans to follow up with the landing of a rover on our satellite in 2012. Japan has been capturing new images of the Moon's surface since 2007 via its Kagoya satellite. In September, India's Chandrayaan-1 mission announced it had found clear evidence of water at the poles, just weeks before NASA announced, on 13 November, the discovery of 95 litres of frozen water stored in part of a crater near the Moon's south pole, an area permanently shadowed from the warming rays of the Sun. NASA had detected the water by crashing one craft into the crater in October and having a second craft analyse the resulting debris.

What's more, the presence of water suggests that human life could be sustained on the Moon. Scientists hope that astronauts could one day not only drink this water but even extract oxygen from it for breathing and hydrogen for use as fuel. This would dramatically reduce the cost of colonizing the Moon: the cost of transporting 1 litre of water to the Moon has been estimated at US$50,000.

Egyptian-born geologist Farouk El-Baz assisted in the selection of landing sites for Apollo missions 11–17 from 1969 to 1972. Thirty-seven years after the last Moon walk, he 'returns to the Moon' to explain where the exploration of our satellite could take us next.

Can you describe your role in helping plan the first landing on the Moon in 1969?

I served as secretary of the NASA lunar landing site committee. Selected sites had to be flat to ensure a safe landing and scientifically rich to add to our knowledge of the Moon's history and composition. To pick a flat plain without being in possession of topographic data was a real challenge. We had to depend on sunlight shadows to 'estimate' surface tilts. Moreover, scientifically rich meant complex topography, which contradicted flatness.

In addition, there were the unexpected conditions we came across during the mission, such as the effect of excess gravitational pull on the spacecraft as it passed over the dense basaltic rocks of the maria. This pull caused the craft to land 7 km distant from the selected landing site of Apollo 11 and nearly endangered a safe landing. Corrections were made to the orbits of later missions to eliminate further mishaps.

What have the missions to the Moon taught us about conditions on Earth in desert environments?

The surface features of the Moon display the result of meteorite bombardments from the time the Solar System formed about 4.6 billion years ago. Its surface has no record of the erosive action of water and wind. In the desert, nearly all that we see results from active erosion and deposition by atmospheric agents, mostly wind. As the Moon does not have an atmosphere, it preserves the results of ancient events. Thus, we can see a multitude of preserved impact craters and lava flows that are over 3 billion years old. Such features on Earth have either been covered by younger sediments or succumbed to water and wind erosion long ago.

How did the Moon form and when?

Based on the composition and age of the returned lunar samples, the theory that fits the data best is that, early in the formation of the Solar System, a large body formed from the explosion of the initial Sun. When another planetary body collided with this proto-Earth, material was torn from it but continued circling the proto-Earth because of gravitational pull. The proto-Earth then solidified into the Earth and the torn matter formed the Moon.

What would happen if the Moon changed its orbit?

The Earth–Moon system is an integral part of the Sun's family. Breaking the bond between them would induce disorder. Removal of the gravitational pull of the Moon would stop the tides and affect the marine life that depends on them. The crustal plates would also have to respond to the loss by moving differently, which would cause numerous earthquakes and volcanic eruptions. The loss of the lunar mass would also affect the gravitational pull by other planets, adding to the pressures on crustal plates. If the Earth responded to that loss by rotating faster, then the wind speed would increase and the temperature of the atmosphere might rise sharply, causing snow to melt in the polar regions and a sharp rise in sea levels. Such a development would make our planet much less hospitable to life.

Where does the water on the Moon come from?

From the composition of lunar rocks, we know that basaltic volcanism was prevalent on the Moon until about 3 billion years ago. During such eruptions, many gases, including water vapour, would have been spewed from the hot lunar interior along with the lava. Most likely, these gases enveloped the Moon but this did not last long because of the weak lunar gravity,

Photo: NASA/Galileo spacecraft

The large, dark, basaltic plains you can see here are called maria (singular mare) because they were originally mistaken for seas. These plains were formed by ancient volcanic eruptions. It was the large round plains which increased the gravitational pull on the orbiting Apollo spacecraft in 1969.

just one-sixth that on Earth. Once some of the gases reached the polar regions, they froze in the permanently shadowed areas that are shielded from the warming rays of the Sun.

NASA is talking of colonizing the Moon in 2020. Do these plans include other space agencies?

There is already a lot of cooperation between NASA and both the Japanese and European space agencies with regard to lunar missions; NASA has supplied both of them with instruments for their missions. It is quite possible that further cooperation could lead to joint human missions to the Moon. This will depend on the viability of astronaut programmes in these countries. Today, the only countries other than the USA with experience in human space flight are Russia, which has a long history of it, and China, which started sending astronauts into orbit three years ago.

What are the chances of humans being able to settle on the Moon one day?

The ingenuity of human beings knows no limits. As long as we continue to think about our cosmos and our place in it, we will always find new ways of travelling across it. One real possibility is that of establishing a permanent presence in a space station at the point of equal gravity between the Earth and the Moon (known as L-5), where flights back and forth from a human base on the Moon would require minimal thrust. This would allow us to develop industrial use of the lunar soils for agriculture and for mining rare metals like titanium, which is used in aircraft construction, surgical instruments, etc.

After the Apollo astronauts returned lunar samples, scientists tested the soil for its ability to raise crops. The same seeds were placed in lunar and Earth soils, watered to the same extent and placed in the same environment. The plant in the Moon soil grew faster and became healthier because the lunar soil contains virgin chemicals that have never been utilized by plants.

However, before envisaging potential uses of this fertility, one must think of devising special soil-moving machinery to deal with the finely powdered lunar soil. Once processed on the Moon, the soil could be transported directly to Earth or via space stations in–between. Furthermore, oxygen could be extracted from the ice in the soil of the polar regions for breathing and making rocket fuel. Hydrogen could also be extracted from the ice for use in fuel cells.

The lunar soil samples contained helium-3. Why are countries interested in mining this gas on the Moon?

Helium-3 is a non-radioactive isotope that is lighter than hydrogen. It is very rare on Earth and much more common on the Moon, the reason being that it gets embedded in the lunar soil layer due to bombardment by the 'solar wind'. The deepest layers have been trapped from the time the Moon formed some 4.6 billion years ago and it continues to be lodged in the lunar soil today. Therefore, it is safe to assume that all lunar soil exposed to the Sun will contain helium-3, as solar wind bombardment is constant.

Helium-3 is amenable to nuclear fusion and could generate endless amounts of energy. Thus, this gas is not only being considered for energy generation at a Moon base but also on Earth.

But using helium-3 for energy production will have to wait until we master nuclear fusion?

Yes, fusion is only theoretically possible but there are experiments that show it is achievable and a pilot plant is being set up in France by an international consortium within the ITER project.[9]

Would one tonne of helium-3 really produce enough energy to satisfy 75% of the world's annual needs, equivalent to 130 million barrels of oil, making helium-3 worth about US$3 billion per tonne[10]?

I have not seen the data used to make this costing but in theory that sounds reasonable or at least in the ball park.

Is it true that no one country can own any part of the Moon?

Yes, the UN Outer Space Treaty signed by nearly all nations in 1967 prohibits ownership of the Moon. A decade later, developing countries started a campaign against mining but this was not successful because the major players refused to sign the second treaty: China, Europe, Japan, Russia and the USA. So, it is now possible for non-signatory countries to mine resources but not to own the lunar land.

It is thus the quest for energy that is at the heart of the emerging Moon race. Will the rest of the world also benefit from this 'miracle' energy source?

Some people make it sound like a sure thing but the technology is not yet proven; no-one can bank on it being feasible one day to produce energy from helium-3. In the event of success, naturally, the beneficiary would be the country or countries that take the initiative. Others would be left on their own, or would buy the energy they needed from multinational corporations, as if it were just another commodity!

Interview by Susan Schneegans

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9. *The project involves China, European Union, India, Japan, Korea (Rep.), Russia and the USA. The difficulty for the International Thermonuclear Experimental Reactor (ITER) will be to accelerate the nuclei to high enough speeds to overcome their electromagnetic repulsion (due to their positive charge) until the nuclei come close enough to achieve fusion.*

10. *Source of data: www.spacecentre.co.uk*

The **Bushbuckridge healers'** path to justice

The International Year of Biodiversity is likely to be a milestone in international environmental law. The ongoing negotiations under the auspices of the UN Convention on Biological Diversity will probably culminate in October in the adoption of a legally binding international regime on access and benefit-sharing. This instrument will regulate the way genetic resources and related traditional knowledge are accessed and how the benefits arising from their use are shared. The traditional healers living in the Kruger to Canyons Biosphere Region in South Africa will be among the many beneficiaries of this development.

Blyde River Canyon Nature Reserve, one of the core areas of the Kruger to Canyons Biosphere Region in South Africa

Kruger to Canyons Biosphere Region (K2C) is part of UNESCO's World Network of Biosphere Reserves. It bridges the Limpopo and Mpumalanga provinces in the northeast of the country. Spanning more than 4 million hectares, this vast area stretches over savanna woodlands, afromontane forests and grasslands. One of the largest biosphere reserves in the world, it encompasses some key biodiversity hotspots, including the well-known Kruger National Park and Blyde River Canyon Nature Reserve.

The biosphere reserve is not only extremely biodiverse but also culturally diverse. Its buffer and transition zones are home to about 1.6 million people from different ethnic backgrounds and language groups. Many of these communities are poor and live in rural areas.

When the K2C was officially designated a biosphere reserve by UNESCO's Man and the Biosphere (MAB) programme in 2001, many people saw this as an important step for the region's economic development. Communities joined forces with the local authorities to promote ecotourism and introduce educational programmes on the area's important biological and cultural diversity.

Traditional healers develop their own community protocol

Traditional healers provide primary healthcare for many people in the region. They also play an important cultural role by promoting traditional values and acting as the custodians of the complex knowledge of plants growing in the biosphere reserve. In their capacity as holders of traditional knowledge, they have acquired new rights under the South African Biodiversity Act (2004) and the Bioprospecting, Access and Benefit-Sharing Regulations (2008). In spite of this, they have only recently come together to discuss common concerns.

In March 2009, the Biosphere Committee began supporting a group of healers based at the Vukuzenzele Medicinal Plants Nursery in Bushbuckridge who wished to host a series of meetings with other groups of healers. Over the next five months, they held regular meetings to share views and learn more about South African law on the conservation of medicinal plants and the protection of traditional knowledge.

After a number of these meetings, more than 80 healers decided to form a governance structure under the name of Bushbuckridge Traditional Healers, with an Executive Committee to assist them in presenting their views to stakeholders. The Bushbuckridge Traditional Healers come from two separate language groups, the Sepedi and Tsonga, yet see themselves as a single group because of their specialist knowledge and reliance on the same medicinal plants.

They then worked with the Biosphere Committee and Natural Justice, an NGO of lawyers who advise communities on environmental issues, to develop their own protocol. This protocol was first presented to the local authorities, private game reserves and other stakeholders in the biosphere reserve in September 2009.

'We protect biodiversity'

In their seven-page protocol, the traditional healers outline the contribution they make to the health of their communities.

They explain that, although they share common knowledge of the main types of illnesses in the community, each has a specific way of treating those illnesses. As they specialize in different ailments, they also refer patients to one another. As their patients are poor, the healers often provide healthcare regardless of whether the patient can pay. 'Our ancestors prohibit us from pressuring people for money,' they explain, 'so we rely on goodwill and reciprocity.'

In the protocol, the healers explain their communities' affinity with the surrounding biodiversity. 'We believe that only harvested leaves or bark that are taken in ways that ensure the survival of the plant or tree will heal the patient', they say. 'This means that we take only strips of bark, selected leaves or stems of plants and always cover the roots of trees or plants after we have collected what we require. Also, we have rules linked to the seasons in which we can collect various plants, with severe consequences such as jeopardizing rains if they are transgressed. Because we harvest for immediate use, we never collect large-scale amounts of any particular resource We protect biodiversity in other ways, such as guarding against veld fires and discouraging poaching of plants by *muti* hunters' (hunters of traditional medicines).

Concern about overharvesting and lack of access

The healers describe the threats posed to their livelihood by limited access to, or loss of, local biodiversity. 'The numbers of plants are falling due to overharvesting by herbalists or *muti* hunters who collect large quantities using unsustainable methods' they state. 'The Mariepskop conservation area is important to us because of the great diversity of plants it sustains but difficult for us to access because we have, until recently, been unsure of the regulations relating to collecting medicinal plants and face logistical and cost-related barriers to travelling to those areas. We are excluded from the Bushbuckridge Nature Reserve, which is closer to us than Mariepskop but remains totally inaccessible.' They add that 'private land is off-bounds to us.'

'We want our consent to be sought'

'We have been visited by scores of researchers', observe the healers, 'who generally provide us with few details of who they are working for and what our knowledge will be used for. We have not yet entered into any benefit-sharing agreements regarding our knowledge or material transfer agreements for the plants they have accessed. This has made us jaded about sharing information with researchers, whom we now distrust. We want our consent to be sought before our knowledge or plants are taken and to be acknowledged as the holders of the knowledge and benefit from any commercialization.'

The healers turned to Natural Justice to learn about their legal rights. Based on their understanding of the law, the healers then decided that the conditions they posed for transferring their traditional knowledge would depend largely on the user. This means that students wishing to become healers will be expected to make arrangements with the local healers to set up a mentorship and can expect to pay a fee. Healers from other areas and academic researchers will be directed to the Executive Committee formed by the healers for due consideration of their proposal. 'We know our rights', the healers affirm and 'will require to see the letter from the Department of Water and Environmental Affairs stating that [researchers] can conduct the research.' Commercial bioprospectors will also be expected to apply to the Executive Committee, as the first step in negotiations with the company towards a benefit-sharing agreement, monetary or otherwise.

The healers propose a partnership

In the protocol, the healers propose working with traditional authorities to regulate access to communal lands by *muti* hunters to tackle the problem of overharvesting. They also ask for better access to conservation areas. 'Now we are clear about the procedures for accessing plants from Mariepskop,' they say, 'we want to be recognized by the

Meeting of the Bushbuckridge Traditional Healers in mid-2009 to devise their own community protocol

Department of Agriculture, Forest and Fisheries (DAFF) as both contributing to, and benefiting from, the region's biodiversity.' They also propose working with DAFF to establish a system that facilitates their access to the resources under its management. They call on the department to 'explore the establishment of a medicinal plants conservation and development area on Mariepskop to increase the *in situ* cultivation of the most important medicinal plants.'

Concluding their protocol, the healers appeal to the Biosphere Committee for assistance in evaluating how they could replicate successful community-run medicinal plant nurseries in the area. They also ask the Mpumalanga Tourism and Parks Agency to set aside some land for the purpose. Similarly, the Department of Health and Social Development is invited 'to speed up' its registration process for healers so that they can carry cards certifying them as traditional health practitioners.

Looking ahead

The process of developing a protocol has helped the healers to define themselves as a group with shared values and knowledge that transcends language barriers. Now, the protocol is enabling them to clarify their key concerns and to work together to tackle common challenges. The community protocol not only articulates their views; it also sends the message to researchers and bioprospectors planning to use their indigenous resources or traditional knowledge that they know their rights and intend to exercise them. This also affords potential users greater legal certainty in the event that permission is granted.

© Johanna von Braun

Vukuzenzele Medicinal Plant Nursery, run by women who belong to the Bushbuckridge Traditional Healers

As a result of the protocol, the community has met with the Department of Science and Technology to look into how they can contribute to the Farma to Pharma Grand Challenge, which aims to connect local communities to conservation schemes and bioprospecting opportunities.

Inspired by the initial success of the Bushbuckridge Biocultural Community Protocol, UNESCO's Man and the Biosphere (MAB) programme plans to help interested communities living in biosphere reserves elsewhere in the world to develop their own community protocols. In this endeavour, MAB will be pursuing its collaboration with the German Development Agency, Natural Justice and UNEP.

Ana Persic[11] and Harry Jonas[12]

For details: www.kruger2canyons.com; www.unesco.org/mab ; www.unep.org/communityprotocols/index.asp

11. *Assistant Programme Specialist in UNESCO's Division of Ecological and Earth Sciences*
12. *Co-Director of Natural Justice*

Towards an international regime on access and benefit-sharing

At the World Summit for Sustainable Development in Johannesburg (South Africa) in 2002, governments called for the negotiation of an international regime to promote the fair and equitable sharing of benefits arising from the utilization of plant and animal species (genetic resources).

This call was taken up by the Conference of the Parties to the Convention on Biological Diversity, which, in 2004, mandated the standing working group on access and benefit-sharing to elaborate and negotiate an international regime on access to genetic resources and benefit-sharing (IRABS). Provisions already existed in the Convention for Access to Genetic Resources (Article 15) and Traditional Knowledge (Article 8j) but an effective implementation mechanism was lacking. The aim of the new regime would be to adopt one or more instruments for implementing the provisions in Articles 8j and 15, within the overarching objectives of the Convention: conservation; sustainable use and access; and benefit-sharing.

In 2008, the Conference of the Parties extended the working group's mandate. The group was instructed to negotiate a text for the operational side of IRABS and to identify clearly those components of the regime which would be addressed through either legally binding measures, non-legally binding measures or a mix of the two. The text resulting from these negotiations will be submitted for adoption to the next meeting of the Conference of the Parties in October 2010.

IRABS is expected to make a major contribution to achieving the Convention's third objective, the 'fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies.'

There is no doubt that IRABS will also have a big impact on the lives of indigenous peoples and local communities. The desired environmental and social benefits of this instrument will only be possible, however, if implementation at the local level ensures there is adequate respect for the communities' cultural values and ways of life that contribute to the conservation and sustainable use of biodiversity.*

For details: www.cbd.int/abs/ir/regime.shtml

* *Kabir Bavikatte and Harry Jonas (eds) (2009)* Biocultural Community Protocols: a Community Approach to ensuring the Integrity of Environmental Law and Policy. *UNEP.*

Can a **blue dye** help save the Aral Sea?

Indigo. The word may sound exotic but this herb permeates our daily lives. You may even be wearing it. Many of us had our first encounter with indigo long ago, the day we bought our first pair of blue jeans. Indigo is the most ancient natural dye in the world. Four thousand years ago, the leaves of *Indigofera tinctoria* were already being used to dye cloth blue. Today, natural methods of producing indigo dye have given way to chemical manufacturing processes in all but southeast India.

If a UNESCO project in Uzbekistan goes ahead as planned, however, natural indigo may soon also be produced in one of the most ecologically ravaged regions in the world, the Aral Sea Basin.

Photo courtesy of Rasul Mirzaakhmedov

A model wearing an outfit by internationally renowned designer Oscar de la Renta at the International Fair of Natural Dyes in the USA in 2005. The skirt has been dyed using natural Uzbek indigo.

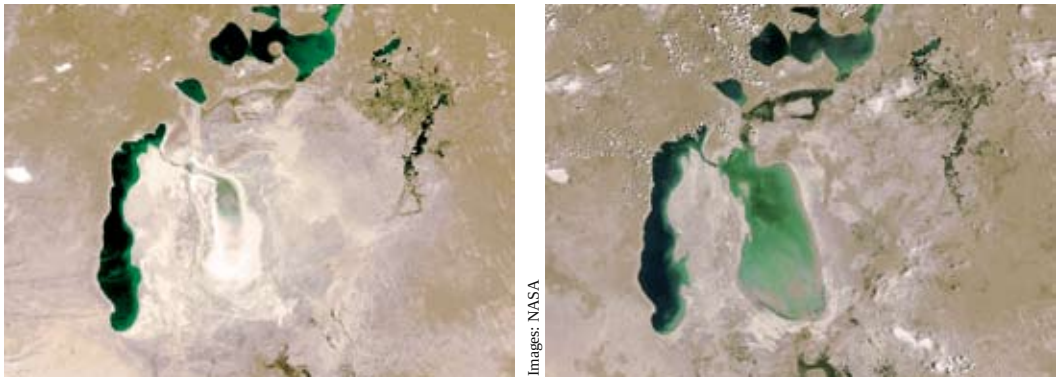
Not long ago, people would have laughed at the idea of growing *I. tinctoria* in the Aral Sea Basin. After all, why choose a region where the climate has become hostile not only to herbs like indigo but also to humans? Intensive irrigation and the drainage of lands for agriculture over the past 40 years has turned what was once the fourth-biggest lake in the world into a salty, toxic desert where little will grow. The little freshwater that remains is polluted by cotton fertilizers and pesticides, as well as domestic and industrial waste.

It would be no exaggeration to say that the water situation in Uzbekistan has become critical. According to new satellite imagery provided by the European Space Agency, the Uzbek part of the Aral Sea has shrunk by 80% in just three years (*see satellite images*). At this rate, 'by 2020, the entire southern part of the sea will have dried up completely,' reported ScienceDaily.com on 12 July 2009. The same report observed that efforts were under way to plant saline-loving shrubs and trees in the area to prevent an environmentally catastrophic dust bowl. 'Each year, violent sandstorms pick up at least 150 000 tons of salt and sand from the Aral [basin] and transport it across hundreds of kilometres,' the journal wrote, 'causing severe health problems for the local population and making the winters colder and the summers hotter.'

An excellent crazy idea

There is no trace throughout history of indigo ever having been grown in Central Asia (*see box overleaf*). Not, that is, until the team at UNESCO's Tashkent Office launched the UzIndigo project in 2005. The economy of the Karakalpakstan and Khorezm Provinces is based on agriculture. Farmers depend upon cotton for their livelihood, even though such a thirsty crop is obviously ill-adapted to the region's ecosystem. What farmers needed, the UNESCO team reasoned, was an alternative source of income that would not exacerbate the basin's ecological problems.

I. tinctoria seemed to fit the bill. Growing indigo would not only boost the local economy but also rehabilitate the salt-ridden soils, the team reasoned. For *I. tinctoria* is a herb of many talents. Once the natural dye has been extracted, the plant's leaves, hollow stem (culm) and roots can be used as a nitrogen-rich 'green fertilizer' for vegetables, vineyards or fruit trees. Unfortunately, many of the secrets of growing



Images: NASA

These satellite images of the Aral Sea were taken in 2009 (left) and 2006 by the European Space Agency. They show the alarming rate at which the Aral Sea is shrinking. Although the northern tip of the sea will be preserved, thanks to a dam funded by the World Bank, the rest is expected to vanish within a decade.

and extracting indigo have been lost to all but a handful of master growers in India, China and Japan. Considerable research would thus be necessary before indigo could be grown in Central Asia.

Adapting indigo to salty, low-yield soils

The UzIndigo team first analysed the different options for growing *I. tinctoria* in the salty soils of the Aral Sea Basin. A team of scientists headed by Professor Abdukodir Ergashev, Science Advisor at UNESCO's Tashkent Office, set about studying agricultural methods for growing indigo and extracting the paint base from the plant. The scientists were assisted by a UNESCO project involving the University of Bonn in Germany and Urgench State University in Uzbekistan. Funded by Germany, this project is blending applied scientific research and management techniques to develop informed, consistent agricultural policies for the region to improve land and water management. The project has introduced laser-levelling of land, for instance, to limit run-off and thereby ensure that rainwater penetrates the soil.

©UNESCO/Abdukodir Ergashev

A professor from the National University of Uzbekistan measuring the height of I. tinctoria *with a post-graduate student on the university's experimental plot. The scientists concluded that these plants were ready for harvesting.*

A brief history of the king of dyes

Indigo has been called the 'king of dyes.' The word 'indigo' comes from the Latin word *indicum* and the Greek *indikos*, both meaning 'Indian'. Latin and Greek being Indo-European languages, it is thus hardly surprising that the origin of indigo can be traced back to the Asian tropics. Even today, Indians consider that the dye is the colour of Krishna, a Hindu god. They are not the only ones to associate indigo with a deity, however; the Turks associate it with the colour of their god Tangri.

Adapted from Balfour-Paul Jenny (1998) *Indigo*. British Museum Press

Countries with a history of growing indigo

Indigo has also been grown since ancient times by Touaregs in the Sahel and nomadic populations in West Africa. Even the tunic in which Egyptian Pharaon Tutankhamen (1341–1323 BC) was buried was painted with indigo.

Indigofera tinctoria was first brought to Europe by Arabian merchants in the 8th century AD. Fearful of the competition, European dyers rose up against it. At the time, they worked with a dark blue dye extracted from a plant called woad (*Isatis tinctoria*), a well-known source of natural indigo that has been used for thousands of years in Europe and the Middle East to paint fabrics. Despite the protestations of local dyers, the 'king of dyes' did not take long to find its niche in Europe.

After a lull, indigo once again became fashionable in Europe in the late 18th century. It would take German chemist Adolf von Baeyer until 1882, however, to establish the structure of indigo and succeed in producing it artificially, after 15 years of research.

In the past 20 years, natural indigo dye has been in great demand in the textile and pottery industries because of its innocuousness for health.

Professor Ergashev's team devised a number of experiments to determine how indigo would react to saline and low-yield soils. These experiments were conducted on the experimental farm of Urgench State University in 2006. Indigo was planted once the winter wheat crop had been harvested. This research led to the development of a new cultivar of indigo especially adapted to the harsh local conditions, Feruz-1. It is able to grow in exceedingly saline soils thanks to a combination of highly developed bacteria in the plant's roots.

In 2008, additional field experiments were carried out in collaboration with an association of farmers in Bagat District to identify the effect of various dosages of fertilizers on the size of indigo plants. Although the indigo plant fixes nitrogen in the soil, it was discovered that the plant would grow considerably taller if mineral fertilizers were added. This is important, as one aim of the project is to maximize yield per hectare.

©UNESCO/Michael Barry Lane

Young women from the Aral Sea Basin weaving carpets with natural dyes for export

The local market is no less promising. By developing alternative cash crops to cotton, such as natural dyes, medicinal plants, vegetables and fruit, growers will be able to supply not only the local population but also hotels and restaurants. In addition, the project will promote water-saving technologies of benefit not only to agriculture but also to the domestic and industrial sectors.

The project thus holds the key to solving some of the most acute social, economic and ecological problems in the ravaged Aral Sea Basin. Last year, it was able to move into second gear, thanks to a US$55,000 outlay from the Small Grants Programme of the UNDP, World Bank and UNEP's Global Environmental Facility. This grant has enabled UNESCO to run training workshops for farmers on how to grow indigo under the particular conditions of the Aral Sea basin.

Marketing indigo: do or dye

From the outset, it was decided to target both the local and international markets for indigo dye from the region. The European Bank for Reconstruction and Development helped to identify reliable markets in Europe. Up to 35 tons of *I. tinctoria* can be harvested from each hectare of soil in Karakalpakstan and Khorezm Provinces, despite the soil's low fertility. From this, more than 100 kg of natural indigo dye paste can be extracted. On the European market, 1 kg of indigo dye is worth €80–240. Indigo dye is thus a highly effective economic lever.

©UNESCO/Abdukodir Ergashev

Seeds donated by UNESCO about to be distributed to farmers at the workshop in May 2009

The first workshop was organized in the province of Urgench in Uzbekistan's Khorezm region on 26–27 May last year. Most of the 30 participants were farmers but the workshop also attracted teachers and scientists eager to learn about the biotechnology of natural dyes and how to improve soil ecology. UNESCO's Tashkent Office used this opportunity to provide farmers with seeds of Feruz-1 to enable them to conduct field tests on their own properties.

The main obstacle to widespread cultivation of *I. tinctoria* is the absence of seeds in Uzbekistan. One option would be to establish the country's first farm specialized in seed production then to share this technology with Uzbek farmers.

The UNESCO team is optimistic. 'Whereas it once seemed almost impossible to grow *I. tinctoria* in Uzbekistan, now there is a way,' enthuses Professor Ergashev. 'Thanks to the introduction of indigo-growing, degraded lands will recover fertility in a few years' time. We are pleased to have solved this difficult scientific dilemma.'

Alexandr Osipov[13]

With thanks to Prof. Abdukodir Ergashev, who designed the indigo project, for providing many research materials and illustrations for this article.

On the state of the Aral Sea, see also *the interview of Prof. Seversky, head of the Laboratory of Glaciology at Kazakhstan's Institute of Geography, in* A World of Science, *April 2007*

13. Science Officer, UNESCO Tashkent office: a.osipov@unesco.org

2010 International Year of Biodiversity

Diary

9–10 January
Astronomy beyond 2009
Closing ceremony for Intl Year of Astronomy. Will summarize Year's achievements and look ahead. Held in *Aula Magna* of the university where Galileo Galilei taught. Padua (Italy): *www.beyond2009.org*

10–14 January
The contribution of space science to astronomy
Symposium UNESCO–COSPAR (Committee on Space Research), one of events winding up Intl Year of Astronomy. UNESCO Paris. *r.missotten@unesco.org www.iap.fr/cospar-iya/index_en.html*

11–13 January
Gulf Eco
Conf. planned with UNESCO assistance. Golden Tulip Hotel. Muscat (Oman): *www.oite.com/; b.boer@unesco.org*

19–22 January
Ocean Observations Panel for Climate
GOOS–GCOS–WCRP expert group. Miami (USA): *a.fischer@unesco.org*

20–22 January
Ocean Data and Information Network for Africa
14th meeting of steering committee. Project groups 40 marine institutions in 25 African countries. UNESCO-IOC IODE office, Oostende (Belgium): *s.mazzilli@unesco.org* (in Nairobi)

21–22 January
Launch of Intl Year of Biodiversity
High-level event with presentations and discussions by influential decision- and policy-makers, experts and opinion-makers to raise awareness of the challenge. UNESCO, Paris. Programme: *www.unesco.org/en/biodiversity*

21–29 January
Biodiversity is life. Biodiversity is our life.
Exhibition. Themes include: Why are we losing biodiversity and what can we do about it? Why is biodiversity important for the economy and development? UNESCO Paris: *www.unesco.org/en/biodiversity*

25–29 January
Biodiversity science and policy
UNESCO conf. for Intl Year of Biodiversity. See editorial. Includes side event on gender and biodiversity on 27 January: *www.unesco.org/en/biodiversity*

27–29 January
Advisory Committee for Biosphere Reserves
Meeting to evaluate proposals for new biosphere reserves. UNESCO Paris: *www.unesco.org/mab*

1–2 February
Framework for education and training on water
UNESCO implementing agency for Flemish funds-in-trust project to build capacity in South Africa's water sector. Limpopo (South Africa): *www.fetwater.co.za*

12–28 February
Sustainable Development Summit
10th annual summit. High-level panel on biodiversity for development and policy dialogue. Delhi (India): *s.arico@unesco.org*

23–25 February
Managing transboundary aquifers in Eastern Africa
With Intergovernmental Authority on Development. Addis Ababa (Ethiopia): *a.makarigakis@unesco.org*

3–4 March
L'OREAL–UNESCO award ceremony
Award of 15 fellowships in the life sciences (3 March) and five prizes to outstanding women scientists (4 March) in presence of Director-General. UNESCO Paris (France): *r.clair@unesco.org; www.forwomeninscience.com*

22 March
World Water Day
On communicating water quality challenges and opportunities. Coordinated by UNEP: *www.worldwaterday.org/*

9–15 April
Geoparks
4th intl conf. Langkawi Geopark (Malaysia): *m.patzak@unesco.org*

New **Releases**

Climate Change and Arctic Sustainable Development

Produced by UNESCO LINKS programme. Foreword by HSH Prince Albert II of Monaco and UNESCO Director-General, UNESCO Publishing, €22.00, ISBN: 978-92-3-104139-6. English only, 376 pp.
Brings together the knowledge, concerns and visions of leading Arctic scientists, prominent Chukchi, Even, Inuit and Saami leaders from across the circumpolar North and international experts in education, health and ethics. They highlight the urgent need for a sustained interdisciplinary and multi-actor approach to monitoring, managing and responding to climate change in the Arctic and explore avenues for achieving this. Presented at UN global climate conference in Copenhagen in December 2009.

Survey of Infiltration *Karez* in Northern Iraq
History and Current Status of Underground Aqueducts

Dale Lightfoot. Report commissioned by UNESCO Iraq office. Exists in English; Arabic and Kurdish editions coming soon, 56 pp (see page 14).
For details: *c.walther@unesco.org; www.unesco.org/en/iraq-office/*
Read the report: *http://unesdoc.unesco.org/images/0018/001850/185057E.pdf*

Aqua-LAC

Periodical. Víctor Pochat (ed. in Chief). Published twice a year by UNESCO-IHP, Regional Bureau for Science in Latin America (Montevideo, Uruguay), ISSN: 1688-2881, Spanish with abstracts also in English, 100 pp.
Complies articles on scientific, policy-related, legislative, educational and social topics related to water sciences and water resources. Targets the scientific community, water resources managers, decision-makers and the general public. Manuscripts submitted for publication must be originals that have not been submitted elsewhere. They will undergo a review process. Manuscripts are accepted in English or Spanish.
For details or to request an e-subscription: *aqualac@unesco.org.uy;*
download the second issue: *www.unesco.org.uy/phi/infocus/AquaLAC2-Sep2009-web.pdf*

Investing in Cultural Diversity and Intercultural Dialogue
UNESCO World Report 2

UNESCO Reference Works series. UNESCO Publishing, €30,00, ISBN: 978-92-3-104077-1. Exists in English, French and Spanish, 416 pp.
For details, see page 14 or write to: *worldreport2@unesco.org;*
read the report: *www.unesco.org/en/world-reports/cultural-diversity*

Tsunami Risk Assessment and Mitigation for the Ocean
Knowing your tsunami risk and what to do about it

Produced by UNESCO-IOC, Manuals and Guides Series 52, English only, 84 pp.
Download: *http://unesdoc.unesco.org/images/0018/001847/184777e.pdf*

Blue Carbon
The Role of Healthy Oceans in Binding Carbon

Nellemann et al (eds) Produced by UNEP, FAO and UNESCO. ISBN: 978-827701-060-1,English only, 72 pp (see page 13).
Read the report: *www.grida.no/;* for details, contact one of the editors: *l.fonseca@unesco.org*

World Network of Biosphere Reserves

Map produced by UNESCO-MAB of the 553 biosphere reserves located in 107 countries in 2009, including nine transboundary or transcontinental biosphere reserves. Download (light version): *http://unesdoc.unesco.org/images/0018/001848/184853M.pdf*
(printable version, 2 Mo) : *www.unesco.org/science/doc/Carte_RB_2009.pdf*

The Right to Water

Produced by UNESCO's Sectors of Social and Human Sciences and Natural Sciences, and by UNESCO-Extea (UNESCO Centre Basque Country), English only, 16 pp.
Outcome of international experts' meting on 7–8 July 2009. The human right to water is indispensable for leading a life of dignity. Preventable diseases caused by unsafe water and poor sanitation kill almost 5000 children under the age of five every day. Each year, 443 million school days are lost due to sickness caused by poor water and sanitation. Millions of women and young girls collect water for their families every day, a practice that prevents girls from attending school.
Download: *http://unesdoc.unesco.org/images/0018/001854/185432e.pdf*

Internationally Shared Aquifers in the Balkan Region
Preliminary Assessment

Brochure and CD produced by UNESCO Chair at Aristotle University of Thessaloniki in Greece, at completion of project phase I. UNESCO-IHP, English only, 4 pp.
Includes a CD with the inventory of the region's 65 transboundary aquifers of the region. For details: *ihp@unesco.org.*
Download: *www.unesco.org/water/news/pdf/inventory_see.pdf*

Water Education for Sustainable Development

Brochure produced by UNESCO programmes and centres related to fresh water, English only, 8 pp.
Describes UNESCO's work in: education and professional development of water scientists, engineers, managers, decision-makers and water technicians; water education in schools; community and stakeholder education; and water education for mass media professionals. Download: *http://unesdoc.unesco.org/images/0018/001853/185302e.pdf*

Global Ocean Observing System
A summary for policy-makers

Brochure produced by UNESCO-IOC, English only, 14 pp.
Download: *http://unesdoc.unesco.org/images/0018/001856/185696e.pdf*

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