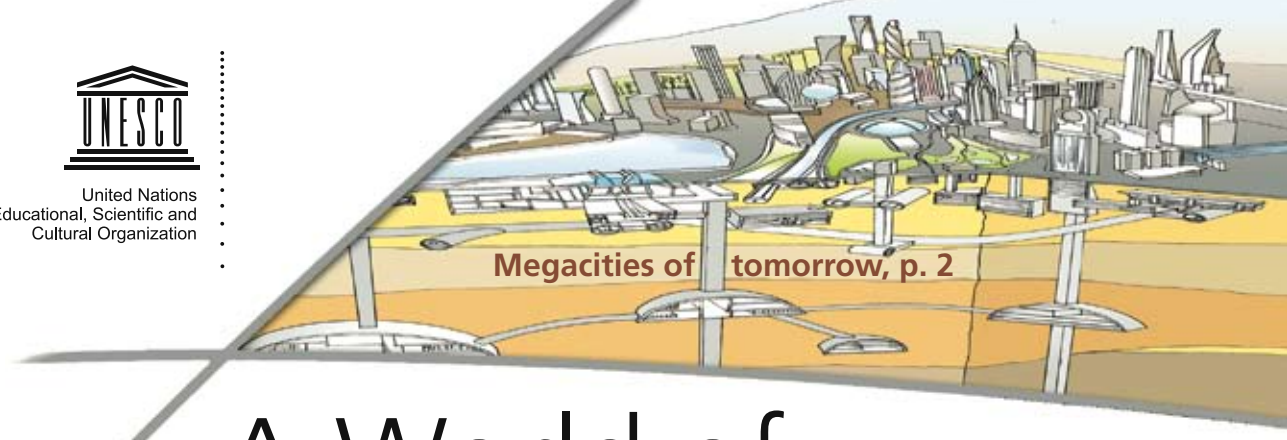
United Nations
Educational, Scientific and
Cultural Organization



A World of SCIENCE

Natural Sciences
Quarterly Newsletter

Vol. 6, No. 4
October–December 2008

IN THIS ISSUE

EDITORIAL

One size does not fit all

From 15 to 18 September, indigenous peoples occupied centre-stage at UNESCO. The Organization's Paris headquarters played host to both the first official visit of the UN Permanent Forum on Indigenous Issues and the annual meeting of the Inter-agency Support Group on Indigenous Peoples' Issues, attended by 20 UN agencies and programmes. One year after the historic adoption of the *Declaration on the Rights of Indigenous Peoples* by the UN General Assembly, the Inter-agency Support Group was in Paris to deliberate on the challenging goal of weaving culture and identity into development.

Challenging is the word, for the cultural dimension continues to take a back seat in development planning and implementation. The rush to attain the Millennium Development Goals (MDG) by 2015 reinforces the hand of those who advocate a 'one size fits all' approach, as the Mayangna communities of the Bosawas Biosphere Reserve in Nicaragua are painfully discovering.

Slash and burn agriculturalists, hunters and fishers, the Mayangna live in the heart of the Mesoamerican Biological Corridor. As we shall see in this issue, they are unequalled when it comes to knowing the ecology of their territories. They are also dauntless defenders of the rainforest they call home. But their success in bringing deforestation to a halt at the edge of their territories may yet be short-lived if current development efforts are pursued.

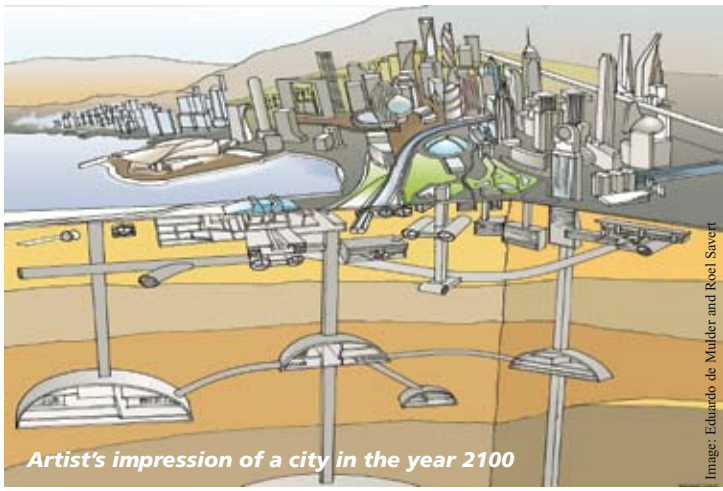
Called Zero Hunger, the national development programme has been designed to help mainstream rural Nicaraguans. Unfortunately, with the best of intentions, it is also sending cows, pigs and chickens deep into the Mayangna territories to develop 'model farms' there. Aside from the logistical headaches associated with transporting livestock by truck and boat to remote communities and the incompatibility of these farm animals with life in a tropical rainforest – many have not survived the experience –, the programme encourages tree-felling in the core zone of the biosphere reserve and heart of the Mesoamerican Corridor to provide pasture for these animals.

What an unfortunate paradox! In the name of food security, this development programme is encouraging deforestation and thereby compromising another MDG, environmental sustainability. It is also urging the Mayangna to give up a way of life that has sustained their culture and a fragile ecosystem for centuries.

Such ill-advised efforts are being repeated all over the world, wherever development continues to ignore the special needs of minority or indigenous groups. To help integrate culture and identity into development, the Inter-agency Support Group has elaborated the *UN Development Group Guidelines on Indigenous Peoples' Issues*, distributed to UN Country Teams in February 2008. Its message is clear: only through meaningful consultation with indigenous peoples will development be beneficial rather than detrimental to the very peoples it is supposed to serve, like the Mayangna.

W. Erdelen
Assistant Director-General for Natural Sciences

Megacities of tomorrow



Artist's impression of a city in the year 2100

Image: Eduardo de Mulder and Roel Savert

Half of humankind now lives in cities and, to nearly one in ten city-dwellers, a megacity is home. Thirty years ago, there were just three cities with a population of 10 million or more, the definition of a megacity: Mexico City, New York City and Tokyo. Today, a further 17 cities have joined their ranks and others hover just below the threshold.

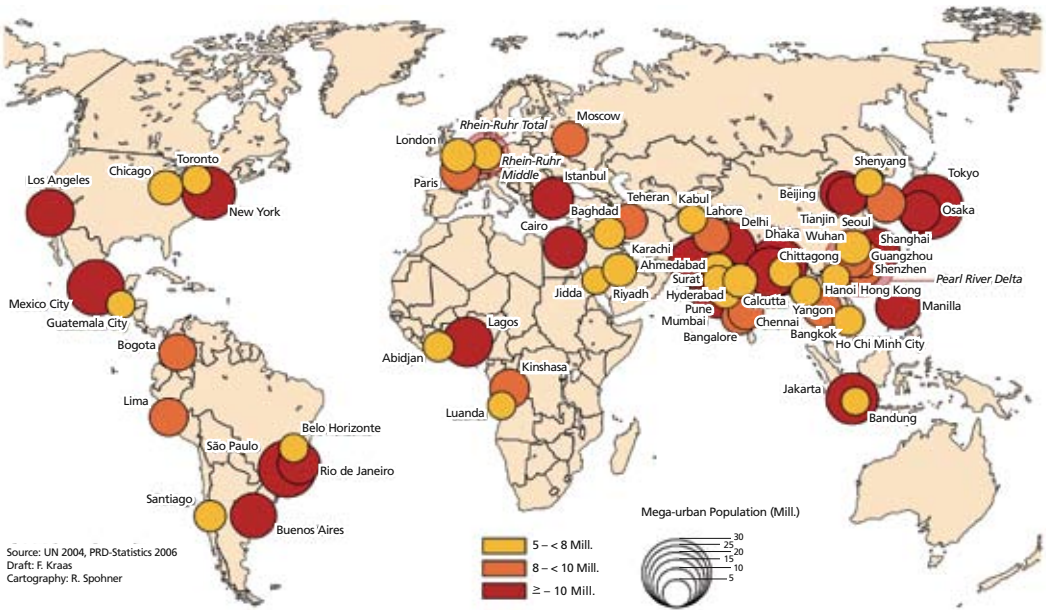
Megacities as far apart as Jakarta, Lagos, Manila, Mumbai, Bangkok, New York, Osaka-Kobe, Rio de Janeiro, São Paulo and Shanghai all have at least one thing in common: they are concentrated on narrow coastal strips. Other megacities are finding their plans for expansion constrained by natural obstacles like mountain ranges, volcanoes or earthquake fault lines, or by the development of necessary peri-urban agriculture and green belts.

Megacities are running out of space and the price of land is sky-high. They will have no choice in future but to make a more rational use of the space available to them. More and more, architects will wish to build not only high but also deep. This is more expensive in the short term but much more sustainable in the long term. Designing the megacity of the future – one of ten themes within the International Year of Planet Earth – will take a lot of planning and foresight. The expertise of geoscientists and geographers will be indispensable in ensuring that life in tomorrow's megacities is comfortable, sustainable and safe.

The United Nations predicts in its medium scenario that 9.2 billion people will live on our planet by 2050. From then onwards, the population is expected to remain more or less constant until at least 2300. Virtually all population growth between 2010 and 2030 will be concentrated in cities.

Even now, mega-urbanization is generating more competition for space, particularly in the sought-after central city where skyscrapers sprout. Extending outwards is not always easy, as urban sprawl is often restricted by physical boundaries like the sea or mountains. Cities can tunnel through mountains, of course, but this necessitates good engineering. They can extend their boundaries seaward through land reclamation but this may, in turn, modify marine current patterns, often resulting in coastal erosion elsewhere.

Moreover, not every site lends itself to construction, as the Japanese city of Kobe discovered to its cost. During the disastrous earthquake of January 1995, much of the damage occurred in the central city – built on soft rocks – and on reclaimed land in the port. Under the effect of the tremors, the land liquefied into a kind of sludge, causing buildings to topple. The epicentre of that earthquake was located just 20 km southwest of the city.



The biggest metropolises today. Between 2005 and 2030, the United Nations expects particularly rapid population growth averaging 2.2% annually in the urban areas of less developed regions. By 2030, Asia will rank first and Africa second in terms of the number of urban dwellers: almost seven out of every 10 urban residents in the world will be living in either Africa or Asia. Latin America is already very urbanized: 77% in 2005, with an expected rise to 84% by 2030. Cities expected to tip the 8 million mark by 2015 include Chennai (India), Tehran (Iran), Wuhan (China), Kinshasa (Dem. Rep. Congo), Lahore (Pakistan) and Lima (Peru). The fastest-growing of these cities between 2010 and 2015 will be Kinshasa (4.2% average annual growth), Lahore (2.8%) and Chennai (1.9%). The populations of London (8.5 million), Paris (9.8 million) and Seoul (9.5 million) should remain stable

Construction sites to be avoided thus include those lying on earthquake-prone fault lines. Other dangers to look out for are sites located in floodplains, on subsiding land or unstable slopes. Geoscientists are needed to assess a building site in the earliest stages of planning, preferably as early as the site selection phase. Geoscientists can also help identify suitable locations within a comprehensive urban land-use master plan.

From a geological point of view, the best (and cheapest) places to build cities are where hard rock (bedrock) is exposed at the surface, as in Helsinki (Finland), Hong Kong (China), Madrid (Spain) and parts of Paris (France). The site should be at least 15 m above sea level and contain abundant fresh groundwater and sufficient recharge. Obviously, it should also be well beyond the reach of major earthquake zones and volcanoes.

Many of today's cities have of course 'inherited' their subsurface from history, growing slowly over the centuries to their current size. Where natural barriers have gradually put a stop to building out, they have had to build up, as in New York.

Going to ground

As the space available even for taller buildings becomes more limited, the urban population in developed countries in particular is going to be spending more of its time underground. In cities like Seoul (Republic of Korea) or Montreal (Canada), larger segments of the population already spend many hours per day in spacious, well-lit underground shopping malls and offices.

Cheaper, safer and faster underground excavation and drilling techniques, coupled with more comprehensive three-dimensional (3D) models of the subsurface, will further enhance development of the urban underground space. Before the second half of this century, the subsurface may well become an important direction for urban development. This does not mean that people will live in subterranean apartments but it is perfectly foreseeable that more than one in four citizens might work, travel and spend leisure time underground by the end of the century.

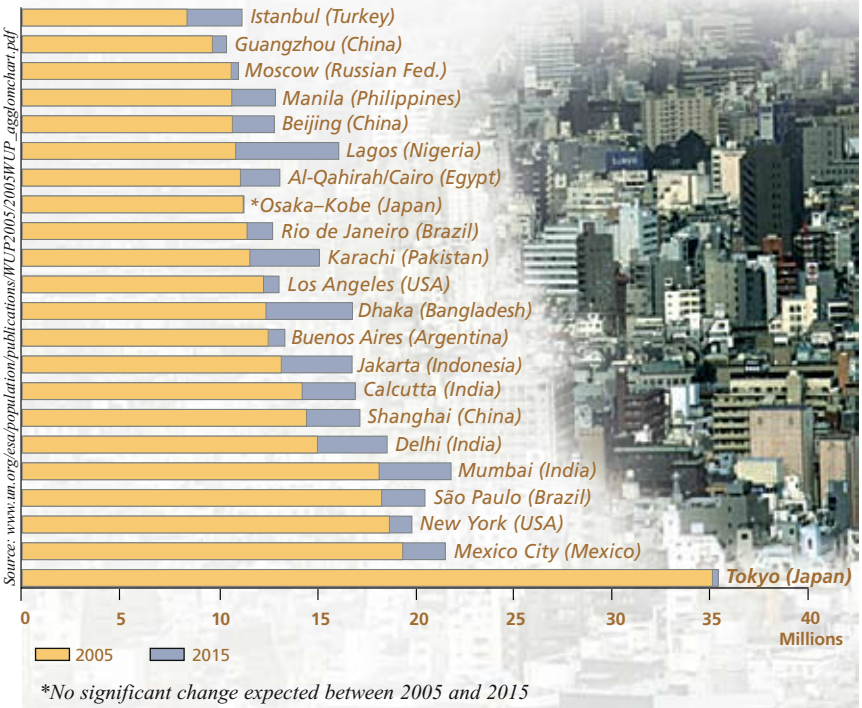
© F. Kraas

Construction of the Guangzhou underground railway system in China in March 2008

Underground construction is nothing new, in fact. In the Iraq of 14 centuries ago, early Arab settlers built houses below ground of up to three storeys to protect themselves from the heat but also to hide from hostile tribes.

In the second half of the 19th century, the construction of tunnels was vital to the rapid expansion of railway systems in mountainous areas. Meanwhile, lack of space caused cities like New York, Paris and London to develop underground public transport systems that other large cities have since emulated.

Population of megacities, 2005 and forecast to 2015



Source: www.un.org/esa/population/publications/WUP2005/2005WUP_agglomchart.pdf

*No significant change expected between 2005 and 2015

Underground cities

The decision to opt for an underground shopping mall as opposed to one above-ground is often driven by a combination of factors. One is the proximity of high-rise buildings and existing underground infrastructure like public transport systems. Another is the exorbitant price of land above-ground in the heart of a city.

The desire to escape cold winters or hot summers and to save energy can be another motivation. Concentrating services on several underground levels avoids the need to travel great distances. Underground public transport systems also reduce the use of private cars, limiting air pollution and the congestion of roads. Underground cities are also energy-efficient in other ways. The air temperature remains quite constant below ground, increasing only slightly with depth. Three metres beneath the surface, the temperature is a stable 10–15°C, requiring much less energy to

Tensions running high in Jakarta

The water and sanitation sector in Jakarta is one of the weakest in Asia, according to the World Bank. Just over half of the city's residents are connected to the network and even they are advised to boil their water.

With the blessing of international financial institutions, the Indonesian government has adopted a twinned strategy for improving the water supply sector: private sector participation and water law reform. This market-oriented reform includes the controversial new Water Law supported by the World Bank as a condition for refinancing. The new law establishes tradable water rights and redefines water as an economic good. NGOs and civil society groups have launched campaigns and court cases against the new Water Law, arguing that water is a human right.

In January 1998, a 25-year contract was signed with two international operators who promised to improve water quality and mobilize international finance for network expansion into poor areas. There was no public tendering process. The (British) Thames Water International and (French) Suez-Lyonnaise des Eaux put forward proposals directly to the government and were partnererd by two local private firms, members of two of the most important conglomerates in Indonesia: Salim Group, run by Bob Hassan, an associate of then-President Suharto, and Sigit Group, run by Sigit Harjojudanto, Suharto's eldest son. Thames PAM Jaya was given the exclusive right to operate and manage the existing water supply system in the eastern half of the city, supplying 2 million people out of a potential customer base of 5 million. Lyonnaise des Eaux's subsidiary Palyja was given a contract to supply the western half of the city, covering a slightly larger number of potential customers.

Flooding in Jakarta caused by burst water pipes

Indonesia descends into chaos

Months later, a combination of riots, the resignation of Suharto and the dramatic devaluation of the Indonesian rupiah threw the country into chaos. Confronted with public protest over rising prices of staple foods and gasoline, the municipality refused to raise water tariffs to compensate for the devaluation of the rupiah. Local managers cancelled the contracts with the two international firms only to see these reinstated by the federal government which had bowed to diplomatic and executive pressure. The private concessionaires resumed operations, having discreetly abandoned their Indonesian partners, now tainted by their association with ex-President Suharto.

The Governor of Jakarta was unwilling to implement the tariff increases agreed upon with the private concessionaires because of the popular unrest. Revenues in dollar terms plummeted from 1998 onwards. PAM Jaya, the municipal water utility, bore the risk for the shortfall in revenue and became increasingly indebted to the private companies. By September 2003, the cumulative deficit had reached Rp 990 billion (circa US$97 million). With negotiated annual tariff increases of less than 10% per year, it will take some time for PAM Jaya to repay the shortfall.

Meanwhile, the private concessionaires were causing resentment by hiring employees on higher salaries than those of PAM Jaya's employees. In turn, the private concessionaires complained of rigid labour laws and the weak sanctions available to them for poor employee performance. By mid-2000, labour relations had greatly deteriorated.

Targets are dramatically scaled back

In 1998, both international firms had committed to supplying potable water to the consumer by 2007 and to attaining universal coverage by 2023. These targets have since been dramatically scaled back. Service coverage has increased since 1998 but for both concession areas remains well below the original target. Over 80% of networked connections have gone to middle-income households or above which pay higher tariffs. The distribution of new connections has thus not been systematically pro-poor. This has led to growing consumer protest, including court challenges brought against the municipal water utility.

To some extent, this situation is a legacy of public sector management, attributable to unwillingness by the municipally-managed utility to extend the network into poor areas, due to fears of low cost recovery. It is also due to an implicitly 'anti-poor' tariff pricing policy, in which the water rate for public hydrants, used by poor households and water vendors, is higher per unit volume than water rates for individual households, implying a reduction in revenue for the city every time a poor household is connected to the network.

This legacy of public sector under-provision of individual household connections to poor customers has not been redressed by the private concessionaires, however. In the first five years of the concession, only 25% of new connections targeted the two lowest tariff bands, in a city where the majority of residents fall into the lower middle and low income categories. Today, poor users still have little incentive to connect to the network, which may prove more costly for them than alternative sources, such as groundwater or water bought from vendors.

Critics argue that private companies are unable to supply the poor on profitable terms. They cite cases of social revolt in many countries, at times resulting in the cancellation of contracts by governments, as in La Paz and Cochabamba in Bolivia, or in Manila in the Philippines. At times, the private sector has also withdrawn from contracts of its own volition, in the light of unacceptably high risk–return ratios. Indeed, Thames Water has now withdrawn from Jakarta. Proponents of privatization argue, however, that the long-term nature of water supply infrastructure and investment implies that many more years must pass before final judgment can be passed on private sector water supply concessions. Given continuing support from international financial institutions and strong civil society critique, this debate – and urban water conflicts over privatization – are set to continue.

This case study by Karen Bakker is taken from Urban Water Conflicts, *published by UNESCO's International Hydrological Programme in 2006. Other megacities analysed include Buenos Aires, Chennai, Delhi, Mexico and São Paulo: http://unesdoc.unesco.org/images/0014/001490E.pdf; For details, contact: a.tejada-guibert@unesco.org*

heat or cool than above ground where temperatures can be more extreme – as hot as 47°C in New Delhi (India) and as cold as 40°C below freezing in Québec (Canada) – and vary considerably at different times of the year.

Cost is another factor. When a building lies underground, there is no need to worry about appearances, as no-one will be admiring the façade. Thus, the exterior of underground constructions does not require regular maintenance. If longer, and more realistic, depreciation times were applied in calculating the deteriorating value of a given construction over time, underground constructions might turn out to be more economical than above-ground constructions.

©Susan Schneegans/UNESCO

For centuries, Les Halles in central Paris was the city's wholesale food market. In the early 1970s, the market was moved to the outskirts of Paris and a partially underground shopping mall sporting restaurants and cinemas was constructed on the site. The new Les Halles also became a point of convergence for underground train networks extending into the suburbs

Underground constructions in or close to the solid rock face may also be the best solution for coping with seismic risks. Thick layers of soft deposits may strongly accelerate seismic waves, thereby contributing to the destruction of constructions at the surface. For example, those parts of the city of Rome (Italy) which are built on solid rocks have survived several major earthquakes, unlike the lower parts of the city in the river valleys filled with soft sediments.

One problem underground cities may encounter is the presence of groundwater. Much of the aptly named Netherlands lies below sea level. In many Dutch cities, the groundwater table is quite close to the surface. That may seriously hamper construction of underground structures. In other cities, the groundwater table may be high only in places, as in London, situated on the River Thames.

In such cases, there are two main dangers to avoid when digging or boring tunnels in the central city. One is subsidence of the ground under often historic buildings. The tunnels may also float under the sheer upward force of groundwater. To prevent the first problem requires controlled, temporary pumping in construction pits and precise monitoring of the surrounding buildings. Floating tunnels can normally be countered by mechanically driving deep sheet piling into quite deep levels where layers of firm sediment or rock occur and by applying thick concrete floors that add weight to the construction.

Since the turn of the century, underground construction has been expanding rapidly. This is particularly true in China, where underground space is increasing at an annual rate of 10% in Beijing, with comparable figures for Shanghai. Today, 30 km^2 of Beijing lies underground and this will expand to 90 km^2 by 2020. Beijing's underground city was originally built in 1969 as a labyrinth of potential air-raid shelters at the height of Sino-Soviet tensions. Although the shelters were never used for their original purpose, much of this network has today been converted into shopping and business centres, theatres and even a vast underground market.

In the city of Montreal, 40 km^2 of underground space connects three underground storeys. These storeys are interconnected by elevators, staircases and major open spaces offering broad access to daylight via special constructions in the roof.

Underground construction can only be done in a sustainable manner if we have access to as much knowledge and information regarding the subsurface as possible. It makes a big difference whether the subsurface is composed of bedrock or soft, water-saturated sediments. Moreover, fragmented hard rock in a brittle fault zone has construction properties which behave quite differently from a solid granite body in an earthquake.

Similarly, a geological study can reveal the presence of big boulders in sandy layers. These boulders will often have been deposited near the ice margins during an ice age and may destroy tunnel-boring machines attempting to access the subsurface.

Responsible underground city management entails designing escape routes in the case of fire, reliable air vents to ensure air quality is maintained and so on. Geoscientific input can contribute vital knowledge.

We are on our way to making the subsurface 'transparent'. Today's Geographic Information Systems (GIS), modelling techniques and geophysical methods give a much better insight into the properties and structure of the subsurface than before. Constructions below-ground demand far more of this vital knowledge than above-ground constructions and the same holds for their foundations.

Sinking cities

What do Amsterdam, Bangkok, Dhaka, Jakarta, Shanghai and Venice have in common? The answer is that all are built in deltas and all are sinking. Deltas are normally composed of relatively soft layers, such as clay, soft sands or peat. These soft layers cannot carry heavy buildings, making it necessary to dig foundations. Foundation piles have to be driven into sometimes deeply seated, firm sand, as in Amsterdam, Dubai and Bangkok.

Proper engineering can overcome poor natural foundations. It can also overcome land subsidence from the uneven spread of weight above ground, such as when high-rise buildings are of various heights. Engineering techniques can even allow us to build on water – but at a price..!

The heat-seekers

Some of the world's megacities are trapping so much heat in their concrete footpaths, asphalt roads and brick buildings that the streets remain warm long after sunset. Other influences, like hot air from air conditioning systems and refrigerators, or emissions from car engines, are also driving up temperatures. This phenomenon is known as the urban heat island and it is causing some of the world's cities to warm as much in a few decades as they have over an entire century.

Keeping cool

In recent years, NASA scientists have used satellites to monitor the heat island effect in Mexico City, New York City and other megacities (*on São Paulo, see page 8*). One secondary effect of warmer cities, they have observed, is the growing number of storms downwind from them.

In the summer of 2002, Stuart Gaffin* of Columbia University (USA) and his colleagues used satellite temperature data, city-wide land cover maps and weather data, along with a regional climate model, to identify the best strategies for cooling New York City. A comparison of satellite images showed that, where vegetation was dense, temperatures were cooler. Urban heat islands were thus worst where there was little or no vegetation. This is because evaporating moisture from soil and plants cools the air.

If you can't stand the heat, get a roof garden

Gaffin concluded from the study that light-coloured roofs were a less attractive option than plants for keeping cities cool. 'In reflecting the sunlight, [light-coloured roofs] may just bounce much of it off nearby buildings, heating up the immediate area. You haven't really gotten the light out of the city. And in the wintertime, light roofs may cool buildings unnecessarily, increasing heating demands.'

©UNESCO

Downtown New York (USA)

Although Gaffin's team concluded that plants were the best way of keeping a city cool, many megacities are growing so fast, and land is so valuable, that green belts like parks are being neglected by city-planners. Other options include tree-lined avenues and roof gardens. In Tokyo, where summers are becoming increasingly tropical,** demand for roof gardens has escalated in recent years.

Heat-seekers go to ground

When people think of global warming, they tend to imagine it as only happening above-ground. Yet, when combined with the heat island effect, global warming can penetrate more than 100 m below the surface. This makes global warming a groundwater issue, as the quality of groundwater can be altered geochemically and geomicrobially by higher subsurface temperatures. This risk has been identified by UNESCO's project on Groundwater Resources under the Pressures of Humanity and Climate Change (GRAPHIC).

In August last year, three Japanese scientists published a comparative study of the Combined Effects of Urbanization and Global Warming on the Subsurface Temperature of four Asian Cities: Tokyo and Osaka in Japan, Seoul in the Republic of Korea and Bangkok in Thailand. All four cities have in common that they 'urbanized rapidly during the last century, particularly after the Second World War.' All but Seoul lie on the coast and share similar geological features.

As their starting point, Makoto Taniguchi and Karen Jago-on from the Research Institute for Humanity and Nature in Kyoto and Takeshi Uemura from The Graduate University for Advanced Studies in Kanagawa perused studies which concluded that both air and surface temperatures had risen by approximately 0.5°C globally over the past century. This was well below the observed increase in surface warming in the four cities studied for the same 100-year period: Tokyo (2.8°C), Seoul (2.5°C), Osaka (2.2°C) and Bangkok (1.8°C).

The scientists analysed measurements done over the past 15 years of borehole temperatures below ground then averaged these temperatures within each of the four cities. As the logged boreholes had been drilled mostly before the 1980s, the water temperature in the boreholes represented the temperature of the groundwater surrounding them.

Digging down through time

By pinpointing the depth at which the borehole temperature deviated from the norm (the estimated linear temperature depth profile, or steady thermal gradient), the scientists were able to ascertain the point at which, in each city's history, urbanization had begun adding heat to the city. This is because heat is stored longer underground than at the surface. The deeper you dig, the farther back in time you are going. This depth was approximately 140 m for Tokyo, 80 m for Osaka and 50 m in both Seoul and Bangkok, indicating that Tokyo's urbanization had been affecting the temperature of the city for longer than in the three other smaller cities.

Studies on the effect of heat from urban areas on subsurface temperature are not common and subsurface temperature data have only rarely been used to time the onset of urbanization. This Asian study was the first attempt to evaluate these phenomena on a regional scale, although studies already exist for some individual European and Asian cities.

The Asian case study described here will appear next year in Groundwater and Climate Change, *published by the GRAPHIC project. For details of GRAPHIC, see pages 14 and 24.*

Read the study by Makoto Taniguchi et al.: www.vadosezonejournal.org (vol. 6, N°. 3, August 2007); contact the lead author: makoto@chikyu.ac.jp

* *See: www.nasa.gov/centers/goddard/news/topstory/2005/nyc_heatisland.html*

** *In the* New York Times *in August 2002, James Brooke cited Takehiro Mikami, a professor of climatology at Tokyo Metropolitan University, as saying that the number of tropical summer nights in Tokyo had risen in just a few years from close to zero to 30–40. He predicted that this number would climb to 50–60 tropical nights every summer by 2010. In parallel, medical entomologist Mutsuo Kobayashi observed that a mosquito vector of dengue fever had expanded its range to 100 km north of Tokyo*

Before beginning construction, the first step is always to measure the ground, take samples and collate what is known about the composition and structure of the subsurface. The outcome of these investigations then supplies the data for preparing a reliable subsurface model. This model should in turn be coupled to the design of the construction, resulting in a proper foundation plan.

Adding several storeys beneath a skyscraper normally adds to the stability of a construction. These underground constructions may be mutually connected for example via a train network and shopping galleries, together creating a wide concrete underground infrastructure. Such a concrete network may contribute to an overall greater underground stability of the city, spreading the load more evenly over a larger area. Piling remains crucial however, in particular in earthquake-prone areas and zones not built on a hard rock substratum.

In 2003, the *China Daily*[1] reported that the central government had begun construction of two surface subsidence monitoring networks, after a geological survey revealed that 46 cities in China were sinking due to the excessive pumping of groundwater. In some cases, high-rise buildings compounded the problem by bringing excess pressure to bear on the subsurface.

In Shanghai, for example, subsidence caused the city's N° 4 subway on the banks of the Huangpu River to cave in,

Approaching the inner-city in Shanghai

in July 2003, causing several nearby buildings to tilt. Yan Xuexin, deputy chief engineer of the Shanghai Geological Research Institute, told the *China Daily* that 'the varying heights and locations of skyscapers produce uneven pressure on the ground in Shanghai, which in turn creates uneven subsidence that may lead to safety risks'.

The Shanghai Geological Research Institute estimates that 'excessive groundwater pumping contributes to 70% of Shanghai's surface subsidence, with the remaining 30% created by the physical weight of skyscrapers.' More than 3000 buildings in Shanghai tower 18 storeys tall or more and a further 3000 were under construction in 2003, reported the *China Daily*. More than 100 existing buildings exceed 100 m in height.

To make matters worse, sinking cities facing the sea or a river, such as Bangkok, Mumbai or Dhaka, may also be prone to flooding. Currently, Synthetic Aperture Radar Interferometry (InSAR) techniques make it possible to measure land subsidence (and land heave) on millimeter scales from space. Using this methodology, a high-resolution and spatially differentiated picture of the particular areas prone to subsidence can be identified. This permits proper planning for infrastructure, such as dykes, skyscrapers, pumping stations and water pipelines, but also the elaboration of sophisticated plans for the evacuation of people from inundation-prone sites either in an emergency or permanently. The strongest subsiding areas are now quite well-known thanks to InSAR techniques. If these areas run the risk of frequent flooding, municipal authorities should turn them into wetlands or nature reserves, for example. If, on the other hand, the area is subject to only occasional flooding, an emergency evacuation plan may be more appropriate.

The world's first ghost city?

As we have seen above, excessive groundwater pumping in delta regions often causes land subsidence. This is because reduced pore water pressure will cause soft layers to shrink. Since we know the cause of such land subsidence, most cities have tackled the problem by avoiding excessive groundwater-pumping or by taking counter-measures like the infiltration of surface water to replenish groundwater stocks. If groundwater can no longer be pumped, freshwater for citizens may have to be obtained from purified surface water. Once water pumps were stopped in Shanghai, land subsidence almost ceased shortly afterwards. Nowadays, Shanghai has to transport alternative water resources through pipelines far from the city.

Shanghai is just one example of a widespread phenomenon. Between 1950 and 1995, average incomes rose by 218% in industrial nations and by 201% in the developing world. This was accompanied by a spectacular rise in life expectancy which saw the global population nearly double and the proportion of people living in poverty halve. These phenomena were accompanied by rapid urbanization. Today, a potent cocktail of steep population growth and a budding middle class, with its demand for home comforts like multiple bathrooms, green lawns and private swimming pools and for public leisure areas like parks and golf courses, has led to an excessive draw on groundwater in many large cities.

Some of the USA's biggest cities are depleting groundwater to a worrying extent, including Chicago on Lake Michigan near the Canadian border and Houston in the dry south.

Australian environmentalist Tim Flannery is said to have predicted that Perth in Western Australia could become the world's first ghost city. Perth's 2 million inhabitants use more water than any other city in Australia. The coastal city boasts sprawling green parks and well-watered gardens, despite sitting on the edge of a vast desert. Overconsumption is compounded by a steep decline in rainfall of 15–20% over the past 40 years, which has left water levels in the aquifer low[2].

Both victim and culprit

Megacities are thus both victims and producers of risk. They can cause subsidence by drawing too much groundwater but are also the first victims when land subsides or groundwater becomes scarce. They pollute the air and water they use, only to suffer the consequences of these self-inflicted ills.

Some ills are not immediately discernible. Cities with contaminated soils or polluted groundwater, for instance, may be sitting on a sanitary time bomb. The effect on human health of this contamination might only be felt in the longer term because the underground transport of contaminated materials is controlled by geological parameters which are normally relatively slow.

In the shorter term, health problems can arise from inadequate sanitation systems that are unable to keep up with population growth[3]. Or from deteriorated urban landscapes, such as 'wild' dumping sites, open waters in slum areas or urban heat islands (*see The heat-seekers*).

Small-scale waste recycling in Dhaka

How green is your green belt, São Paulo?

The hills surrounding São Paulo include important remnants of the Brazilian Atlantic Forest (*Mata Atlântica*). The ecosystem services provided by this 'green belt', such as water and food, biodiversity, climate regulation and recreational opportunities, are vital for the megacity. These services are coming under threat however from urban sprawl, population growth, mining, industrialization, forest fires, illegal logging and pollution. The long-term well-being of the megacity will depend on how well it relieves the growing pressure on ecosystem services.

It used to drizzle, now it pours

São Paulo is already feeling the effects of climate change. Since the 1950s, the average temperature in the city has risen by 1.5°C, observes Magda Lombardo from the University of São Paulo*. This rise has been accompanied by a curious phenomenon: the drizzle that was once a trademark of São Paulo has been replaced by heavy showers. Moreover, the heavier rainfall may be occurring at the expense of the wooded, peri-urban areas which seem to be experiencing less rainfall than before.

Tarik Rezende de Azevedo, also from the University of São Paulo, has demonstrated this phenomenon statistically. He found that there was greater rainfall on weekdays in the 1990s than on week-ends, due to the intensity of 'urban activities' during the week. This is because both air pollution and heat islands (see page 6) affect rainfall by changing wind patterns. The rise in air temperature over the city modifies air pressure, causing surface winds to converge over the source of heat, intensifying convective processes and thereby increasing the frequency and intensity of rain.

©Juarez Silva

*Two free-roaming residents of Mata Atlântica, a Bugio monkey (*Alouatta fusca*) and the elusive* Puma concolor, *classified as vulnerable. There are 20 000 plant species in Mata Atlântica, 8000 of which are endemic. Of the 1711 vertebrate species, 706 are endemic*
(Source: www.rbma.org.br)

Leaving a smaller ecological footprint

The São Paulo City Green Belt Biosphere Reserve was set up under UNESCO's Man and the Biosphere (MAB) Programme in 1994. Supported by a civil movement that generated 150 000 local signatures in favour of its establishment, the biosphere reserve seeks to reconcile urban development with nature conservation based on integrated management, local community schemes and sound science. São Paulo is the only biosphere reserve in the world that embraces a megacity.

Composed of representatives from governmental and municipal institutions, the private sector, NGOs, local communities and academia, the São Paulo City Green Belt Biosphere Reserve Management Council fixes the general policy and action plan for the biosphere reserve. It maintains ties to the São Paulo State Parliament and is ably served by a coordination office at the São Paulo Forest Institute.

Advocacy and public awareness-building about the importance and fragility of ecosystem services are among the biosphere reserve's core activities. Particular emphasis is put on eco-job creation and eco-business opportunities in such sectors as agro-forestry, organic agriculture, ecotourism, water management and waste recycling. Special centres have been established around the biosphere reserve to provide disadvantaged young people with 'eco-job' training.

'We have put public policies in place to support reforestation', explains Rodrigo Victor, the Biosphere Reserve Coordinator at the Forest Institute. 'Our most promising scheme is the voluntary carbon neutralization market, where companies pay for tree-planting to offset their emissions. In addition, land-owners are obliged to maintain at least 20% forest cover on their land, besides "permanent preservation areas" corresponding to river margins, water springs and hill tops.'

©Francisco Honda

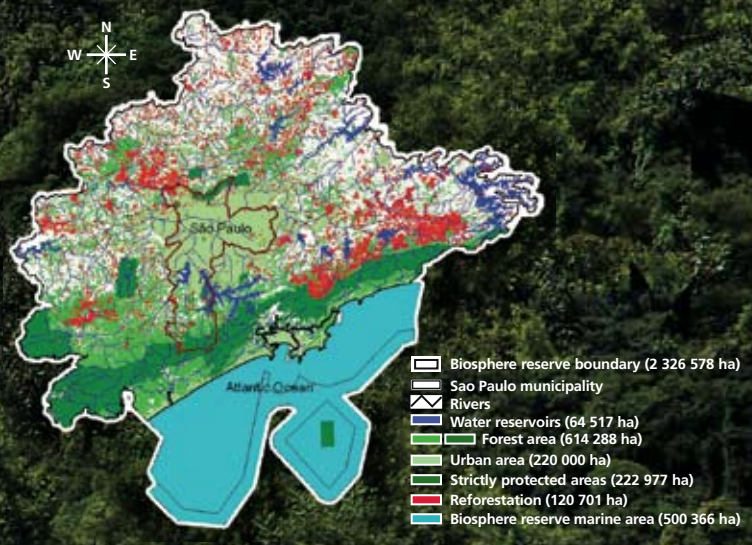
Tree-planting at the Embu Guaçu Eco-job Training Centre, as part of a scheme run by the biosphere reserve

'We are also fostering organic agriculture in some peri-urban areas', he says. 'Most of the vegetables supplying São Paulo used to come from the Green Belt. This protected the area from construction but often polluted the environment with pesticides and synthetic fertilizers. Then, as the city expanded, agricultural land became sought-after for construction, prices rose and the land was divided up and sold off. Now, "eating organic" is becoming fashionable and we are seeing a growing number of organic producers in the Green Belt.'

'Water is a big issue', stresses Victor. 'São Paulo is close to the supply limit, with per capita water availability in shorter supply than in the semi-arid ecosystems of the Northeast region. Sooner or later, the city may have to bring in water from distant places, putting a lot of pressure on other preserved landscapes. To avoid this, we need to make every effort to conserve and restore ecosystems in São Paulo's own Green Belt.'

For details: rbcv_sp@yahoo.com.br; p.dogse@unesco.org

**Source: Ferroni, Marcelo (2002) Artificial Desert.* ISTOÉ, *nº 1728, 14 November*



São Paulo City Green Belt Biosphere Reserve

Megacities also harbour poverty and social inequality. Arguably the most pressing need for the megacities of tomorrow in developing countries will be to find practical solutions for improving the plight of the poor, reducing social inequality and reversing environmental degradation. Here again, geoscientists and urban geographers can make a difference.


© F. Kraas
Disparities in Dhaka

The iniquity of inequity

When people migrate to the cities from rural areas, they are often driven by poverty. Unable to afford the prices in the central city, the poor become segregated from their more affluent neighbours in the outlying suburbs or in slums. This creates social inequalities, with urban services like electricity, piped water and sewerage systems not always reaching the outlying areas. This creates a sense of abandonment and fuels a mutual mistrust between the haves and the have-nots that can degenerate into conflict (*see Tensions running high in Jakarta on page 4*).

Poor people often live in the most hazardous urban areas, along river banks or on steep slopes vulnerable to natural disasters, such as floods or landslides caused by heavy rainfall. They often lack access to good quality drinking water, contributing to health risks, or they may live in slums close to, or even on, waste dumps.

Geographers and geoscientists can address urban equity problems by assisting in selecting more stable lands for housing the poor. In high-risk zones, they can devise solutions with poor families, such as securing unstable banks. They can also contribute upstream by engaging actively in the land-use planning process. This approach has proved its effectiveness in numerous projects driven by civil society in places like Rio de Janeiro, Manila or Mumbai.

They can identify good groundwater resources for human consumption and design better waste disposal sites using natural barriers to ensure long-term safety. Urbanization generates piles of waste from households, industry and the demolition of buildings and infrastructure. Knowing the composition of the urban subsurface helps greatly in selecting the best potential waste disposal sites. As all such sites leak with time, the safest sites for the long-term are those underlain by a natural barrier, such as a thick, impervious clay or shale bed.

A policy of slum eviction, often combined with forced resettlement schemes, is increasingly being replaced by slum upgrading and land-sharing projects. These new forms of public–private partnerships upgrade sites through investment coupled with compensational public housing whenever poor families need relodging.


© F. Kraas
Construction of a new home within a voluntary relocation project for poor families in Manila (Philippines)

In Mumbai for example, the administration, private sector and civil society are working together in parts of the vast slum of Dharavi to resettle families without recourse to eviction policies. Micro-credit schemes, new forms of public funding and new governance models have all contributed to solving the immediate problems of undersupply and congestion in slum areas while bolstering citizens' rights.

The rising cost of natural hazards

There are some risks which megacities can do little to avoid: geohazards. Over the past century, five of the world's 20 megacities have suffered a major earthquake (*see table overleaf*) and others are sitting on a time bomb, including Beijing, Calcutta, Delhi, Karachi, Manila and Mumbai.

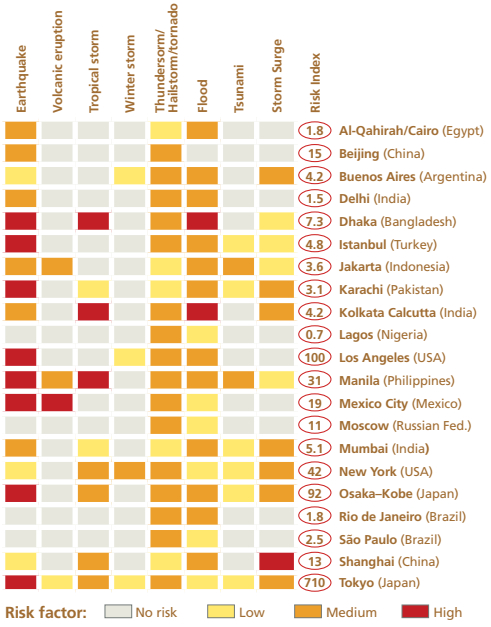
Major economic centres which concentrate masses of people and material assets, megacities are highly vulnerable environments in a crisis. When a natural disaster strikes, fire-fighting, restoring supply networks, communication lines and transportation, and caring for the wounded and homeless can be a logistical nightmare – one only needs to recall the chaotic evacuation of inhabitants from the flooded coastal city of New Orleans in the USA in 2005. It can take years for the economy to recover.

Knowing the types of risk a city faces can help it to prepare for a natural disaster (*see figure overleaf*). A city vulnerable to a volcanic eruption can design lava stream channels to drive potential main lava flows away from urbanized areas. Such channels have been constructed for example for Yogyakarta in Indonesia and Naples in Italy. You can also build safely in tsunami-prone zones but this demands knowledge of the width and composition of the coastal zone area.

Although we cannot prevent an earthquake, it is becoming possible to predict them, if not yet in time to evacuate the population. In the meantime, there are seismic norms available for construction today which, if adhered to, will render structures resistant to earthquakes.

The future effects of climate change on coastal megacities will be multiple and complex. In addition to raising sea levels, climate change may reshape coastlines, forcing municipalities to rethink waterfront development. Saltwater intrusion may contaminate groundwater and heavier rainfall may cause landslides and flooding. Conversely, lesser rainfall may deplete groundwater, as in Perth, making some cities potentially uninhabitable.

Vulnerability of megacities to natural hazards



Source: Münchner Rückversicherungsgesellschaft (2004) Megacities – Megarisks*: www.munichre.com/publications/302-04271_en.pdf*

Megacities hit by natural disasters in the past century

City	Country	Year	Type of hazard	Human and structural cost (US$)	City GDP as share of national GDP (%)
Istanbul	Turkey	1999	Earthquake 7.6 magnitude	>17 000 killed, 500 000 left homeless, $3–6 billion damage in Istanbul, Kocaeli and Sakarya Provinces	25
Dhaka	Bangladesh	1998	Flood	1050 killed, $4.3 billion in damage	60
Kobe-Osaka	Japan	1995	Earthquake 6.9 magnitude	>6000 killed, >102 000 buildings destroyed, some by fire, 300 000 eva-cuated into shelters. Over $100 billion in damage	20 (with Kyoto)
Los Angeles	USA	1994	Earthquake 6.7 magnitude	60 killed, >5000 injured, >40 000 buildings damaged, fire damage. $44 billion in damage	<10
New York	USA	1992	Winter storm	20 killed, $3 billion in damage	<10
Mexico City	Mexico	1985	Earthquake 8.0 magnitude	>9500 killed	40
Manila	Philippines	1978	Typhoon Rita	340 killed, $115 million in economic losses	30
Karachi	Pakistan	1977	Flood	375 killed	20
Los Angeles	USA	1971	Earthquake	65 killed, fires broke out, $553 million in economic losses	<10
Rio de Janeiro/ São Paulo	Brazil	1967	Flood	>600 killed, $10 million in economic losses	40
Calcutta	India	1955	Flood	1700 killed, $65 million in economic losses	<10
New York	USA	1938	Hurricane	600 killed, $400 million in economic losses	<10
Tokyo	Japan	1923	Earthquake 7.9 magnitude	>140 000 killed (out of 4 million inhabitants). Caused 2 m of permanent uplift on the north shore of Sagami Bay (where a tsunami generated waves 12 m high) and horizontal displacements of 4.5 m on Boso Peninsula	40

Sources: Münchner Rückversicherungsgesellschaft (2004) Megacities – Megarisks; US Geological Survey

What is certain is that the cost of natural hazards is high and rising by the day. This is because urban expansion is occurring in more hazardous areas than before, the best and most stable sites having already been occupied. Earthquake-prone Mexico City, for example, continues to sprawl across the spongy sediment of a former lake!

Cities for two billion more

Science and technology have helped to make today's megacities what they are. Modern GIS, numeric modelling, space observation, scenario methods and new laboratory techniques have all greatly contributed to the current level of geoscientific knowledge and to a wide availability of data.

Science and technology can still do a lot more to improve life in megacities and make them more sustainable. Research in the geosciences is heading for instance towards the development of modern, GIS-based complex scenario models and decision-support systems. The development of highly complex theoretical concepts, such as on mega-urban growth patterns and sustainability performance, is under way.

©Benno Boer/UNESCO

Bahrain's World Trade Centre rises 240 m with twin towers 50 storeys high. Windmills fixed to the structure generate enough energy to light and air-condition the buildings

Innovative ideas include the development of locally-based resource cycles to make cities self-reliant in food, water and energy (*see How green is your greenbelt, São Paulo?*). This includes zero-energy buildings equipped with solar panels or windmills – some of which even produce more energy than they consume. In 2012, London Transport plans to introduce hybrid buses combining diesel engines with electric batteries; when the vehicle brakes, energy which would normally be wasted is recycled and used to charge the batteries[4]. The authorities claim that the hybrid buses will reduce nitrogen oxides by 89%, carbon monoxide by 83%, carbon dioxide by 38%, fuel use by 40% and noise levels by 30%.

Megacities are fertile ground for innovative ideas, perhaps because their sheer size magnifies any problem. Necessity is the mother of invention, the saying goes, and what greater motivation can there be than the knowledge that the world's cities will have to make room for 2 billion more residents in the next 40 years?

Eduardo F.J. de Mulder[5] and Frauke Kraas[6]

UNESCO is organizing thematic sessions during the Fourth World Urban Forum in November, see page 24 for details.

1. *Cities sinking due to excessive pumping of groundwater.* China Daily *(Hong Kong edition), 11 December 2003: www.chinadaily.com.cn/en/doc/2003-12/11/content_289290.htm*
2. *Agrye, Maggie (2007) Metropolis strives to meet its thirst. BBC News. 3 May.*
3. *For a case study of Accra, see* A World of Science*, July 2008*
4. *www.tfl.gov.uk/corporate/projectsandschemes/environment/2019.aspx*
5. *Executive Director, Secretariat, International Year of Planet Earth*
6. *Department of Geography, University of Cologne, Germany*

Benin first to host African Virtual Campus

Benin became the first country in sub-Saharan Africa to host the African Virtual Campus for Science and Technology on 7 July, with the official opening of an e-learning centre at the University of Abomey-Calavi in Cotonou, in the presence of Christine Ouinsavi and Vicentia Boco, respectively Minister of Primary Education and Minister of Higher Education and Research of Benin, as well as senior management from UNESCO.

Among the computers installed in the virtual campus is one equipped with a Braille Screen Terminal and sound system for visually impaired students.

Approved by UNESCO's General Conference in October last year, the African Virtual Campus is contributing to implementation of the *Science and Technology Consolidated Plan of Action* adopted by the African Union in January 2007. The UNESCO project is developing a network of fully operational e-learning national centres across Africa – one per country – by 2012, with initial financial support from the Government of Spain. This Internet-based network will be used for large-scale student and teacher training.

First-year student Germain Noudéhouénou Loko using a standard keyboard and Braille Screen Terminal at the launch of the e-learning centre at the University of Abomey-Calavi. 'Three days ago, we could never have imagined ourselves working on a Braille and sound computer,' he and Joseph Moussa told project coordinator Mohamed Miloudi from UNESCO. 'From now on, thanks to you, we shall be able to move forward with the world like our brothers and even, to a certain extent, without them.' Miloudi stayed on at the centre for a week to show the teaching staff how to use the new equipment

UNESCO Antenna in Cotonou

The African Virtual Campus will work closely with universities around the Mediterranean basin belonging to the first network founded by UNESCO and the European Commission in 2002, the Avicenna Virtual Campus. From day one, the participating university in each African country will be able to use the modules developed by the Avicenna network over the past five years. Ultimately, each African centre will produce modules of its own which will then be pooled among institutions participating in both the Avicenna and African Virtual Campuses.

UNESCO is launching a national Campus at the University of Abidjan in Côte d'Ivoire in October then a sub-regional network for 15 West African countries in Senegal in the first week of November.

For details: m.miloudi@unesco.org; on the Avicenna Virtual Campus, see A World of Science*, October 2006*

UNESCO nominated to AMCOST

UNESCO has been nominated to the Steering Committee of the African Ministerial Council on Science and Technology (AMCOST), the body which defines the African Union's agenda for science and technology within the framework of the *Science and Technology Consolidated Plan of Action* to 2010 (CPA). With this decision on 2 May, UNESCO becomes the only UN agency to be nominated to the AMCOST Steering Committee. The move comes in recognition of UNESCO's contribution over the past year to implementing the CPA.

Ten months after the African Union requested UNESCO's assistance in implementing the CPA, the General Conference of November 2007 endorsed UNESCO's plan of action comprising three flagship projects: Capacity-building in Science, Technology and Innovation (STI) Policy; Enhancing Science and Technology Education; and the African Virtual Campus.

In the past year, 17 African countries[7] have submitted requests for UNESCO assistance in reviewing their STI policy, including eight from the Southern African Development Community (SADC). UNESCO's Division of Science Policy is organizing a meeting in Gaborone (Botswana) from 22 to 26 September with the UNESCO Institute for Statistics to enable SADC countries that have already reviewed their STI policy – either with UNESCO or independently – to exchange ideas and best practices with those countries undergoing a review. The meeting will be run back to back with a training workshop on Statistics and Indicators in Science and Technology to stress the importance of these tools for any STI review.

Thanks to financial support from Spain and Japan, science policy formulation has commenced in Madagascar (May 2008), Burundi (June 2008), Central African Republic (July 2008) and Benin (July 2008).

On 1 July, UNESCO organized a ministerial breakfast at the High-level Segment of the UN Economic and Social Commission (ECOSOC) in New York. Chaired by Director-General Koïchiro Matsuura, the breakfast roundtable had as its theme STI policy: Key to Sustainable Development. The more than 50 Ambassadors present underscored the essential contribution STI policies make to meeting the Millennium Development Goals by providing a solid foundation for

7. *Benin, Botswana, Burundi, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Gabon, Gambia, Ghana, Madagascar, Malawi, Mauritania, Niger, Tanzania, Togo, Zambia and Zimbabwe*

economic growth and sustainable development. This was the first time UNESCO had organized a roundtable at an ECOSOC meeting and the first debate on STI policies in this forum.

UNESCO is the convener of the UN Science and Technology Cluster, an inter-agency group established in 2003 to coordinate the efforts of 13 UN agencies working in Africa. UNESCO convened the cluster's third meeting on 28 April this year at the African Union Commission in Addis Ababa on the theme of STI Policies.

More recently, UNESCO has been elected Rapporteur of the new African Cluster for Science and Technology. The cluster was launched on 18 July by the African Union, in order to improve pan-African coordination and thereby avoid duplication and wastage of resources in implementation of the CPA.

For details: www.unesco.org/science/psd; s.nair-bedouelle@unesco.org

Poland rewards **architect of molecular biology** centre

On 10 June, Maciej Nalecz was one of three scientists to be distinguished in this year's Honours list by the President of Poland for their role in the creation and development of the International Institute of Molecular and Cell Biology (IIMCB).

The distinction comes 13 years after the signing of an agreement between the Director-General of UNESCO and the Polish Deputy Prime Minister for the creation of the IIMCB under the auspices of UNESCO, in May 1995. Two years later, the institute would become a legal entity under the direct supervision of the President of the Polish Academy of Sciences, with the adoption of the Polish Parliamentary Bill.

This unprecedented Bill paved the way for a string of other international centres on Polish soil. All would be characterized by an Inter-national Advisory Board composed of world-class specialists who were responsible for overseeing the centre's work, a structure absent from earlier national legislation.

At the time, Maciej Nalecz was Director of the Marceli Nencki National Institute of Experimental Biology in Warsaw. It was thus on behalf of the Polish authorities that he set up the IIMCB and subsequently occupied the first Chair of its International Advisory Board.

Even after being appointed Director of the Division of Basic Sciences and Engineering at UNESCO in October 2001, Professor Nalecz continued to serve on the International Advisory Board of the IIMCB but this time in his capacity as Representative of the Director-General of UNESCO, as envisaged by the Parliamentary Bill.

©Polish Academy of Sciences

Maciej Nalecz receiving the Officer Cross of the Order of Polonia Restitut from the hands of the President of the Polish Academy of Sciences, Prof. Michal Kleiber, during a special ceremony in Warsaw on 10 June. Professors Jacek Kuznicki and Maciej Zylicz, Director and Head of the Molecular Biology Department at the IIMCB respectively, were awarded the same distinction

In just 10 years, the IIMCB has accumulated a series of firsts: it was the first scientific centre in Eastern Europe to host a research group of the Max-Planck Society, the Laboratory of Structural Biology headed by Dr Mathias Bohtler; the first to share a PhD programme with Utrecht University; and the first to accumulate research grants from the British Wellcome Trust and the American Howard Hughes Foundation.

In 2003, it was nominated Centre of Excellence in Molecular Bio-Medicine by the European Commission. Four years later, the Polish Ministry of Higher Education and Research nominated it Top Research Institution in the Life Sciences in Poland.

The institute currently employs over 80 researchers grouped in nine departments and operates on an annual budget of about €20 million.

For details: www.iimcb.gov.pl

UNCLOS gives countries **breathing space**

In a historical decision, the States Parties to the United Nations Convention on the Law of the Sea (UNCLOS) have come up with a solution for countries struggling to demonstrate the limits of their continental shelf before the deadline of 13 May 2009.

Up until now, States Parties to UNCLOS were obliged to provide geoscientific proof that their continental shelf extended beyond 200 nautical miles to the Commission on the Limits of the Continental Shelf by 13 May 2009. Many Member States were not in a position to submit all the scientific and technical data in time, however, effectively barring them from making their rightful claims.

The decision adopted at the UNCLOS meeting in New York from 13 to 20 June states that the deadline will be satisfied 'by submitting to the Secretary-General [of the United Nations] preliminary information indicative of the outer limits of the continental shelf beyond 200 nautical miles and a description of the status of preparation and intended date of making a submission in accordance with the requirements of Article 76 of the Convention (…)'.

'This means that a country to which the deadline applies still needs to submit the required preliminary information to the Secretary-General on time,' explains Aurora Mateos of UNESCO's Intergovernmental Oceanographic Commission, 'but is entitled to indicate at the time of making the preliminary submission a date most favourable to the State for completing the submission.'

For details, see A World of Science*, July 2008; e.desa@unesco.org; a.mateos@unesco.org*

Kanawinka joins global geopark network

Kanawinka Geopark in Australia became the 57th member of UNESCO's Global Network of National Geoparks on 22 June, at the start of the 3rd International Geoparks Conference in Osnabrueck (Germany). Kanawinka is also the first Australian geopark to join the global network.

Geoparks aspiring to join the network from Brazil, Canada, Croatia, Finland, Hungary, India, Japan, Korea, Malaysia, Norway, Slovenia, South Africa, Sweden and Oman all made presentations in Osnabrueck on their geological charms – for geoparks must be exceptional to join the global network. Six of Germany's 11 national geoparks have already been admitted, including the geopark hosting the June meeting, TERRA.Vita.

Over four days, more than 350 earth scientists discussed ways of sharing their passion for geology with the general public, via a geopark experience spiced with geotourism, education and art.

During the conference, the TERRA.Vita Geopark ran a youth camp for more than 40 youngsters aged 12–15 years from 10 geoparks across Europe, with the slogan Meet your Geopark. The teens learned how to approach the Earth artistically via workshops on photographing nature, the taxidermy of fossils and experimental archaeology.

©K. Zöttl

Art mimics geology in this scene from the Nördlinger Ries, a national geopark in Germany which is the site of a meteorite impact crater. The scene was painted by Klaus Zöttl using minerals found at the site, including suevite and Bunte Breccia, a colourful mix consisting of Triassic clay and sandstones and dark Jurassic clays About 15 million years ago, a meteorite almost 1 km in diameter impacted the Alb Plateau at a speed of about 70 000 km hour, penetrating 1 km into the Earth's crust and creating a transient crater 12 km in diameter which destroyed all life within a radius of 100 km. The impact formed a totally new rock type called suevite, a mixture of molten rock and shattered crystalline basement rock which was deposited in and around the impact crater, today 25 km in diameter

©City of Mount Gambier

When November comes around each year, Mount Gambier's Blue Lake in Kanawinka Geopark mysteriously starts changing from the steel blue colour of winter to a brilliant turquoise then back to the sombre steel blue again from March. No other lake in the world changes colour so dramatically with the seasons. The process begins when water flowing over rocks into the lake collects limestone; dead algae and land vegetation (humic substances) are then chemically attracted to the calcite and are still clinging to it as it falls to the lake floor when the lake warms; with the removal of these humic substances from the upper reaches, the lake's natural blue colour becomes more evident

The success of the youth camp convinced TERRA.vita Geopark to create a regular youth exchange programme among European geoparks. 'If we want to talk about sustainability,' observed Timo Kluttig, one of the conference organizers, 'we should start by talking to youth.'

Langkawi Geopark in Malaysia (*see page 20*) will be hosting UNESCO's next international conference on geoparks in 2010.

For details: m.patzak@unesco.org; www.mountgambiertourism.com.au

Launch of European Ocean Acidification Project

UNESCO's Intergovernmental Oceanographic Commission (IOC) has joined a consortium of over 100 scientists from 27 organizations in nine countries in a research project of the European Union addressing ocean acidification.

The European Project on Ocean Acidification (EPOCA) was launched on 10 June. With a budget of €16.5 million over four years, EPOCA's goal will be to document ocean acidification, investigate its impact on biological processes, predict its consequences for the next 100 years and advise policy-makers on potential thresholds or tipping points that should not be exceeded.

Through its International Ocean Carbon Coordination Project, the UNESCO-IOC will be working with EPOCA to ensure that activities are coordinated with non-EU partners. It will also develop a working group to establish international standards and best practices for ocean acidification experiments.

From 6 to 9 October, the UNESCO-IOC is organizing a second scientific conference on The Oceans in a High CO_2 World. Some 300 scientists will gather to review what is known about the impact of ocean acidification on the marine ecosystem and develop internationally agreed research priorities and strategies.

For details: http://epoca-project.eu; www.ioccp.org; m.hood@unesco.org; on the UNESCO-IOC's Ocean Acidification Network: www.ocean-acidification.net; see also p. 24

GRAPHIC Africa kicks off

Little is known of the impact of climate variability and change on groundwater in Africa. To fill this knowledge gap, groundwater and climate experts meeting in Kampala (Uganda) on 24–28 June have launched the African component of UNESCO's project on Groundwater Resources under the Pressures of Humanity and Climate Change (GRAPHIC).

Groundwater is the primary source of freshwater in many countries, especially in Africa. While much is known about the reaction of surface flows to global change, the impact of climate change and human activities on groundwater around the world remains poorly understood, largely due to the invisibility of the resource and the difficulties in assessing it.

To remedy this, the GRAPHIC project has established regional networks of experts in Latin America and the Caribbean, Asia and the Pacific, Europe and North America. GRAPHIC connects researchers all over the world, enabling them to share their findings and experiences. Although each case is different, common phenomena have been observed, such as a correlation in the rise in temperature above and below ground (*see page 6*).

With the Intergovernmental Panel on Climate Change having confirmed last year that Africa is the continent most vulnerable to climate change, it has become urgent to establish baseline data and monitoring networks so that trends can be studied over the medium to long term and forecasts made. These forecasts will in turn serve as the basis for policy decisions.

Among the conference attendees in Kampala were water and climate scientists, managers and policy-makers from 23 African countries. The active participation of a dozen parliamentarians and several ministers from Uganda, Ethiopia and the Government of Southern Sudan was particularly meaningful, as this dialogue between politicians and scientists is crucial: the sustainable management of groundwater in Africa will be reliant on strong national institutions and legal frameworks. Some 60 experts from 16 African countries attended the GRAPHIC Africa launch at the conference.

GRAPHIC Africa will be drawing upon the complementary body of knowledge accumulated within other UNESCO projects, such as that for Internationally Shared Aquifer Resource Management (ISARM) which has mapped 39 of Africa's transboundary aquifers so far.[8]

In September, UNESCO issued a call for proposals for the preparation of national case studies within GRAPHIC Africa. Ideally, each case study should trace the history of groundwater in a specific part of the country. This will provide the basis for forecasts of how the resource might react to future climate variations. The deadline for submitting proposals is 31 December.

For details: h.treidel@unesco.org; makoto@chikyu.ac.jp; see also the new GRAPHIC framework document, page 24

8. *See* A World of Science, *July 2007*

Geological gems join World Heritage

Among the 27 sites inscribed on UNESCO's World Heritage List on 6–10 July feature several of exceptional geological interest. These include Joggins Fossil Cliffs in Canada, Mount Sanqingshan National Park in China with its 48 granite peaks, the volcanic island of Surtsey in Iceland, the Swiss Tectonic Arena Sardona and the French Lagoons of New Caledonia containing both living and ancient fossil reefs.

The other three natural sites inscribed on the World Heritage List are Saryarka – Steppe and Lakes of Northern Kazakhstan (Kazakhstan), the Monarch Butterfly Biosphere Reserve (Mexico) and the Socotra Archipelago (Yemen).

A total of 19 cultural sites were also added to the List, including Al-Hijr (Madâin Sâlih) in Saudi Arabia, which harbours 111 monumental tombs and water wells testifying to the architectural accomplishment and hydraulic expertise of the Nabataean civilization 2000 years ago.

The World Heritage Committee inscribed the new sites in Quebec City (Canada), itself a World Heritage site since 1985 and currently celebrating its 400th anniversary.

UNESCO's World Heritage List now numbers 878 sites in 145 countries: 679 cultural, 174 natural and 25 mixed sites.

For details and more photos: www.unesco.org/en/whc/

Surtsey Island was formed by volcanic eruptions between 1963 and 1967. Free from human interference, this pristine natural laboratory of 141 ha situated 32 km south of Iceland has been producing unique information on the colonization process of new land by plant and animal life. Since they began studying the island in 1964, scientists have observed the arrival of seeds carried by ocean currents, the appearance of moulds, bacteria and fungi, followed in 1965 by the first vascular plant, of which there were 10 species by the end of the first decade. By 2004, these numbered 60, together with 75 bryophytes, 71 lichens and 24 fungi. Eighty-nine bird species have been recorded on Surtsey and 335 invertebrate species

Patricia M. Glibert

Scientists take a stand against ocean fertilization with urea

With atmospheric emissions of CO_2 growing at an alarming rate, there is no shortage of geo-engineering schemes to limit the effects of climate change. One of the most extravagant proposes installing a giant parasol in orbit to cool the planet! More down to Earth are schemes to inject CO_2 into the ground or ocean or to 'fertilize' the ocean. The ocean is a tempting target because it absorbs about one-third of atmospheric CO_2. In recent decades, several controversial experiments have 'fertilized' parts of the ocean with iron in an attempt to stimulate plankton growth at the surface. Now, attention is turning to doing the same with urea. Plankton absorb carbon through photosynthesis, so accelerating plankton growth would remove massive amounts of carbon from the Earth's atmosphere, the theory goes. When these microscopic plants died, they would conveniently carry the carbon to the ocean floor, storing it there for eons. Many marine biologists and climate scientists shudder at the thought: we simply do not know yet whether fertilizing the ocean might trigger runaway algal blooms which could deprive vast expanses of ocean of oxygen. This uncertainty has not deterred companies from proposing to dump large quantities of urea into the sea.

In what some are calling a *de facto* moratorium, delegates from 191 countries attending the 9th Conference of the Parties to the Convention on Biological Diversity (CBD) adopted a document on 30 May requesting that countries prohibit ocean fertilization until there is an adequate scientific basis. The delegates agreed that the CBD should look to the London Convention for guidance on regulating fertilization. Here, Patricia Glibert from the University of Maryland Center for Environmental Science in the USA takes us behind the scenes of this burning issue.

Why are people turning from iron to urea fertilization?

More than a dozen large-scale iron enrichment experiments have been conducted in the ocean in the past two decades. Most have involved adding iron to the equatorial North Pacific, the subarctic Pacific and the Southern Ocean, known to have ample amounts of nitrogen and phosphorus but limited quantities of iron and thus little phytoplankton.

The iron enrichment experiments have consistently demonstrated that a phytoplankton bloom can be 'manufactured'. However, they have been less successful in demonstrating that the carbon biomass produced (the algae) could be exported to the deep sea for even short periods of time, let alone long enough to have an effect on climate. Meanwhile, the carbon-offset market has been expanding rapidly and attracting new enterprises. If phytoplankton blooms can lock away carbon by sinking it to the seabed, the market for these carbon-offset markets could be huge, particularly if an international quota system for carbon trading is agreed upon.

In regions where it is the lack of nitrogen, rather than the lack of iron, that is limiting plankton growth, nitrogen is being proposed to stimulate new blooms. New 'prime the pump' schemes in recent years thus propose fertilizing the oceans with one form of nitrogen, urea. Urea is the major nitrogen fertilizer used in agricultural applications; it is thus thought that its effect on plant growth can be mimicked in the sea. Proponents of this plan not only suggest that carbon will be drawn down from the atmosphere; they claim that fish production will be enhanced as well.

Although urea is excreted naturally by many animals as urine, it is produced commercially by getting CO_2 and anhydrous ammonia to react under high pressure and temperature. The molten mixture is then processed into a useable liquid or granular form. For urea enrichment at sea, the idea is to pump urea through a pipe from a urea-generating plant on shore. Urea production is energy-intensive and the energy used is most commonly derived from natural gas. There is thus a touch of irony in the idea of using fossil fuels to create biomass to sequester carbon from the atmosphere that was derived from fossil fuel burning!

Several commercial enterprises hope to benefit from ocean fertilization. One such company is the Ocean Nourishment Corporation based in Australia; it recently proposed to enrich the Sulu Sea off the Philippines, home to the UNESCO World Heritage Tubbataha Reef Marine Park, with 1000 tonnes of urea. They have also targeted the Arabian Gulf recently as another potential site for such an experiment.

Why did scientists feel this plan was unwise?

Urea enrichment inspires many of the same concerns that have been expressed for iron fertilization. If large-scale blooms do occur and, if they settle and decompose, the area could be starved of oxygen (hypoxia). Oxygen 'dead zones'

are not only unlikely to enhance fish production but may also generate other greenhouse gases: both methane (CH_4) and nitrous oxide (N_2O) may be produced by the microbial degradation of organic matter under low oxygen conditions. These gases would counteract any potential benefits of trapping carbon from the atmosphere.

All of the schemes for ocean enrichment and fertilization share concerns over verification. Quantifying the flux of carbon to the deep sea – or the potential enhancement of fisheries from increased algal production – is not easy. Much of the carbon is recycled before it sinks through microbial food webs; some may be transported via ocean currents, with the effects felt far from the initial site of fertilization. Satellite imagery, proposed by the Ocean Nourishment Corporation, is not sufficient, as it may only verify that a near-surface bloom has occurred, not its composition, nor its rate of sinking.

One risk that may be greater under urea enrichment than under iron enrichment is the potential for an increase of toxin-producing microalgae called dinoflagellates. In many coastal regions of the world where urea dominates the agricultural use of nitrogen fertilizer and where such nutrient runoff enriches the nearshore waters, the frequency and duration of toxin-producing dinoflagellates have increased.

In the Philippines, the site of the recent proposal for urea fertilization, known toxic dinoflagellates include *Pyrodinium bahamense* and *Gymnodinium catenatum*, both of which cause paralytic shellfish poisoning, as well as *Cochlodinium sp*. which causes fish kills. Numerous deaths have been recorded in the Philippines from people eating shellfish containing paralytic shellfish toxins. There is thus a real concern that seafood contamination could increase. Moreover, there is some evidence that, for at least some species, the toxin content of dinoflagellates increases under urea enrichment. Many dinoflagellates also produce resting stages during their life cycle when the cells are capable of blooming again if conditions are right, leading to the potential for new blooms even after the initial urea enrichment has come to an end.

Laboratory studies show that cyanobacteria, or blue-green algae, are likely to respond to urea enrichment, as they have high rates of urea uptake relative to many other groups of phytoplankton. Interestingly, many species from this group do not have a tendency to sink. One of these, *Trichodesmium*, can form extensive surface scums visible from space, but that nonetheless do not sequester carbon to the deep sea!

How did the scientific community stop the experiment in the Philippines?

In the specific case of the plan to fertilize the Philippines with urea, a group of 57 scientists from 18 countries[9] combined their expertise on urea metabolism, algal physiology, harmful algal blooms, eutrophication, hypoxia and local regional oceanography, as well as the economics of carbon cap-and-trade programmes, in a scientific paper expressing their concerns published in June[10]. The scientific reasons outlined in the paper – the same as those I summarized earlier – were also presented by local scientists to the Philippine officials.

The World Wildlife Fund for Nature and other bodies also raised concerns. These were heard and the Philippine government subsequently declined permission for the Ocean Nourishment Corporation to proceed with its plan.

Is the scientific community unified on this question?

There is a great deal of unity regarding concern about ocean fertilization. Concerns over iron enrichment experiments have been expressed for many years, in scientific journals and by individuals to their governments. Moreover, several scientific bodies have urged caution in ocean enrichment experiments and called for independent verification of the outcome of such experiments. Among them are the Scientific Committee on Ocean Research (SCOR) and the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), an independent international advisory body of the United Nations, as well as two international programmes, the Surface Ocean Lower Atmosphere Study (SOLAS) and the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB), which is supported by the UNESCO-IOC and SCOR.

Several conventions have followed suit. The London Convention, under the auspices of the International Maritime Organization, is examining the scientific and regulatory aspects of large-scale open-ocean fertilization experiments through a scientific working group. This May, the UNESCO-IOC was invited to participate in discussions within this working group; the group issued a consensus statement based on a series of scientific and technical questions posed by the London Convention Scientific Group, underscoring the same concerns. Later the same month, the Convention on Biological Diversity held that, given the uncertainties as to the outcome of ocean fertilization, large-scale efforts to fertilize the oceans were simply not justified.

Although there is much that we still do not understand about how the oceans may respond to large-scale enrichments with urea, iron or other elements, the environmental impact may be considerable, especially in areas where marine biodiversity is high and marine life is important for the local economy. There are major concerns over urea fertilization and the potential for development of harmful algae and hypoxia. Promises of enhanced fish production or the selling of carbon credits based on expected long-term sequestration are premature at best.

Interview by Henrik Enevoldsen[11]

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On the growing impact of harmful algal blooms on fisheries and human health, see The red tide, in A World of Science*, July 2006*

9. *from Australia, P.R. China, Denmark, France, Germany, Indonesia, Ireland, Japan, Rep of Korea, Kuwait, Malaysia, Oman, Philippines, Sweden, South Africa, UK, USA and Vietnam*
10. *Glibert, P.M et al. (2008) Ocean urea fertilization for carbon credits poses high ecological risks.* Marine Pollution Bulletin *56 : 1043–1236*
11. *GEOHAB programme: h.enevoldsen@unesco.org*

Mayangna knowledge deep in the heart of **Mesoamerica**

One of the last extensive areas of Central American tropical rainforest lies along the border of Nicaragua with Honduras. This transboundary area, which includes the Bosawas Biosphere Reserve in Nicaragua and the Rio Plátano Biosphere Reserve on the Honduran side, has come to be known as the Heart of the Mesoamerican Biological Corridor. The second-largest rainforest in the Americas after the Amazon, it is of utmost importance for the conservation of Central American biodiversity. The area is also home to the indigenous Mayangna and Miskito peoples who have occupied these lands for centuries.

Unfortunately, the sweeping advance of the agricultural frontier, illegal logging and the organized illegal trade in plant and animal species are threatening the area's biological and cultural diversity. The Mayangna and Miskito communities in the Bosawas Biosphere Reserve refuse to be passive bystanders.

In their struggle to defend their homeland, they first embarked on a landmark claims process that culminated in May 2005 in the Nicaraguan government's recognition of land titles for 86 Mayangna and Miskito communities. This land settlement provides the communities with full rights over lands used for agriculture, hunting and gathering, as well as co-dominion with the State over remote conservation areas located in the highlands of the Isabelia Mountain Range. Together, the indigenous territories and the co-management areas cover the greater part of the Bosawas core zone.

Recent studies reveal that the Mayangna and Miskito have succeeded in containing the deforestation of the Bosawas Biosphere Reserve by marking and peacefully patrolling the boundaries of their territories. This outcome, documented using satellite imagery, is all the more remarkable in that the agricultural frontier has swept across vast areas and penetrated unhindered into the core zone of the reserve, only to be halted by the vigilance and determination of the indigenous communities.[12]

We are a people both humble and proud

Who better to introduce the Mayangna than themselves:

> *We are an indigenous group that lives along the banks of the small rivers that constitute the headwaters of the Prinzapolka, Coco and Wawa rivers. We are a humble people yet, at the same time, very proud. … Our culture is very different from that of other indigenous groups and that of the* mestizos. *We conserve nature and continue to live surrounded by living beings, both plants and animals.*

In Nicaragua, the Mayangna population is estimated at 20 000, one-third of whom live in the indigenous territories of the Bosawas Biosphere Reserve. Agriculture centred primarily on the production of rice, beans, bananas and yucca is the mainstay of the contemporary Mayangna way of life but the original pursuits of hunting, fishing and gathering are still of great importance. Indeed, for many Mayangna communities, fishing remains the primary source of protein.

Following meetings in late 2003 with assemblies of Mayangna leaders and members of the Amak, Arangdak and Santo Tomas de Umra communities, UNESCO's Local and Indigenous Knowledge Systems (LINKS) programme launched a project to record the collective knowledge and worldviews of the Mayangna people. The following year, a close-knit team of Mayangna led by Nacilio Miguel of Arangdak began fieldwork in the community of Arangdak

A Mayangna woman shares her knowledge about the fish she has caught, a mupih, *the common snook (*Centropomus undecimalis*)*

© Paule Gros

on the Lakus River, under the scientific direction of conservation biologist Paule Gros and the guidance of ethnobiologist Douglas Nakashima, the authors of the present article.

The project focused on the communities of Lakus River, in order to ensure an in-depth understanding of Mayangna knowledge at one particular location. However, since 2005, numerous consultations have been held with representatives from all other Mayangna communities, to guarantee that the work and resulting publication would belong to all the Mayangna of Bosawas, as the indigenous leaders themselves had requested.

For the Mayangna, this book, *Conocimientos del pueblo Mayangna sobre la convivencia del hombre y la naturaleza: peces y tortugas,*[13] has a dual purpose. On the one hand, it responds to the desire expressed by the Mayangna peoples to safeguard their intangible heritage, notably their knowledge of nature and the Universe, and to this end to create a pedagogical resource for schools in Mayangna and Spanish. The volume also serves to demonstrate to the scientific community the depth and breadth of local knowledge of the natural milieu and, as a result, the key role that the Mayangna must play in the sustainable use and management of the extensive territories from which they derive their livelihood, which include the Bosawas Biosphere Reserve.

This drawing by Cristobal Thamy depicts the Mayangna legend of the slider and black turtle and their successful associations with the crocodile and water tiger respectively

A tale of two turtles

One legend that the Mayangna continue to share with their children concerns two turtles that, in their language, are named *kuah* and *ahsa*: the Mesoamerican slider (*Trachemys venusta venusta*) and the black wood turtle (*Rhinoclemmys funerea*) respectively. In earlier times, so the story goes, the slider and black turtle lived together in the depths of a large river pool. However, *yapu*, the American crocodile (*Crocodylus acutus*), devoured many turtles, showing a marked preference for black turtles, as it seems it was a friend of the slider. The black turtle reluctantly decided that it would have to flee to survive. It escaped to the headwaters of the river where no crocodiles resided. This is why, today, the slider lives in the lower reaches of the river alongside the crocodile, whereas the black turtle frequents the streams of the headwaters, where it has befriended *was nawahni*, the water tiger, with whom it shares caves along the banks of the streams.

The story of *kuah* and *ahsa* weaves Mayangna ecological understandings, with their unique cosmovision of the world in which they live. On the one hand, it spells out differences in the distribution and preferred habitats of the two turtle species, as well as their ecological relationship with key predators or 'partners' with whom they co-exist: the crocodile and the water tiger. The latter creature, on the other hand, is a mysterious being, unknown to science, which may in fact trace its roots to cosmologies shared widely among Amerindian cultures, in which the terrestrial world is mirrored by a watery underworld populated by water beings.

The story of the slider and the black turtle is but one of the innumerable gems that the Mayangna are recording and preparing to publish next year in *Conocimientos del pueblo Mayangna sobre la convivencia del hombre y la naturaleza.* This richly-illustrated volume focuses on *was dini balna*, living things of the aquatic milieu, particularly fishes and turtles.

Piercing the secrets of the fish and turtles of Bosawas

While some scientific research has been done, no systematic survey of the fishes and turtles of the Bosawas Biosphere Reserve has ever been completed. As a result, scientific understanding remains approximate and is primarily based upon extrapolations from research done elsewhere in Central America or even farther afield. Mayangna knowledge therefore offers information and interpretations that complement current scientific data and which can fill this knowledge gap, at least in part.

The information provided by the Mayangna within this LINKS project attests to their extensive, detailed knowledge of the fish and turtle species of Bosawas. They describe river habitats far inland for *angh angh*, the burro grunt (*Pomadasys crocro*), a species that scientists generally associate with coastal environments.

Mayangna descriptions of *mulalah*, the guapote (*Parachromis dovii*), reveal that the females of local populations are often yellow in colour. While commonplace in Bosawas, this colouration is of rare occurrence elsewhere. In addition, the Mayangna describe massive upstream migrations in winter of *susum*, the Guatemalan chulín (*Rhamdia guatemalensis*). At certain well-known places along this migration route, *susum* can be captured easily and in large quantities. No record of such a phenomenon appears in the scientific literature.

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A man bow-fishing from a canoe with his dog

The kikilwi *(migration) of* susum *happens only in a few specific places. It takes place only in winter. When it is on migration, it is easy to capture in large quantities, as the fish are very docile. You can catch up to 30 pounds (14 kg) in one go.*

In another vein, certain species serve as indicators of the change of season or of exceptional events. For example, when *musiwa*, a snook fish (*Centropomus spp*.), is seen jumping out of the water, this is a sure sign of winter. *Ahsa*, the black wood turtle, is another important indicator but of a very different phenomenon. The Mayangna know that the black turtle is not strong enough to resist a strong current. When they see black turtles adrift, one after another, this forewarns them of a coming flood.

When I see that the river carries ahsa *adrift and this is seen a second time, it is certain that there will be a major flood.*

A final example of the breadth of Mayangna knowledge, as well as its application in resource management, is their knowledge of the introduction of fish species. For example, *pahwa*, the blackbelt cichlid (*Vieja maculicauda*), is not native to the Waspuk River. Some generations ago, the large quantities of this important food fish were intentionally transported by the Mayangna from the Wawa River to the Waspuk River. The introduction was a success and today the abundant *pahwa* are fished in large numbers. The etymology of the current fish's name in Mayngna, *pahwa*, relates to this event, as it derives from the term *pah Wawa* meaning 'from Wawa'.

But the Mayangna also have knowledge of another more recent introduction that is a source of much concern. This is the invasive species for which the Mayangna have not yet coined a name, the tilapia (*Oreochromis spp*). They refer to it by the Miskito name of *krahna*. *Krahna* is said to have escaped from fish farms located either in the Apanas reservoir or along the upper course of the Coco River. It invaded the Coco River system during floods caused by Hurricane Juana in 1988. Year after year, the Mayangna have stood by helplessly as this species has invaded one river basin after another along the Coco River. They have documented this phenomenon, which has been accompanied by declines in native fish species due to competition from, and predation, by *krahna*.

Intertwining biological, cultural and linguistic diversity

Mayangna knowledge is more than simply a collection of empirical observations, as useful as these may be for complementing scientific knowledge and building State–indigenous co-management. As illustrated by the legend of the Mesoamerican slider and the black wood turtle, Mayangna knowledge is a complex tapestry that interweaves the empirical and the symbolic, nature and culture into a unified and unique indigenous vision of the world.

The LINKS project documents a full range of information about the 30 fish and six turtles known to the Mayangna communities of Bosawas. This encompasses both new and old techniques employed to locate, entice and capture these animals, as well as the manner in which they are prepared for human consumption and other purposes.

© Menuka Scerbon-Didi

A woman line-fishing for pahwa, the blackbelt cichlid

This project also considers the worldview in which Mayangna knowledge and know-how of the aquatic world is anchored. This includes important prescriptions and proscriptions concerning *liwa*, the master spirit of the aquatic world, with whom certain fish and turtles are closely affiliated. They must be treated with particular respect or the transgressor may suffer illness and hardship as a result. Respect includes taking only as many fish as one can use.

In this, the United Nations International Year of Languages, the significance of this project cannot be overestimated. *Conocimientos del pueblo Mayangna sobre la convivencia del hombre y la naturaleza* will provide the Mayangna communities with a unique, valuable reference work in their mother tongue and Spanish. The volume will also contribute to quality education within the United Nations Decade of Education for Sustainable Development, which recognizes the values of both indigenous language and indigenous knowledge.

By Paule Gros[14] and Douglas Nakashima[15]

For details: www.unesco.org/links

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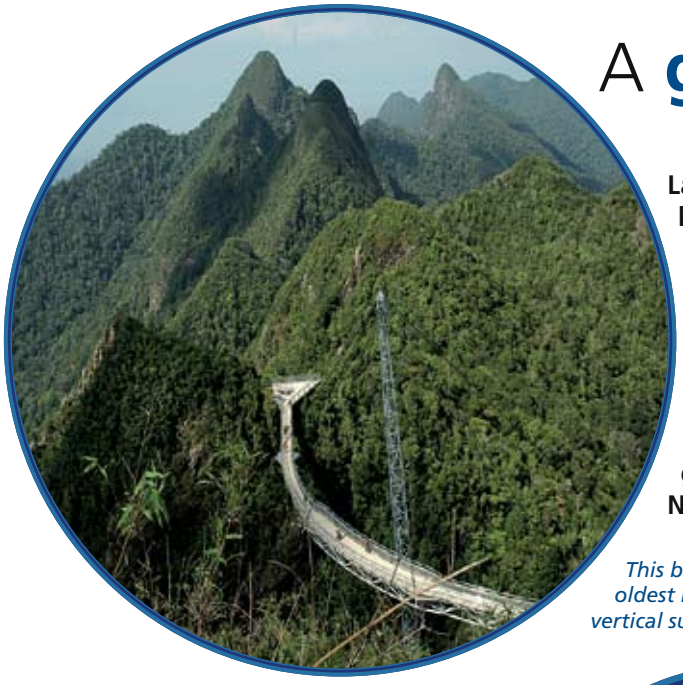
12. Stocks, A., McMahan, B and P. Taber (2007) Indigenous, colonist and government impacts on Nicaragua's Bosawas Reserve. Conservation Biology *21:1495-1505*

13. Mayangna Knowledge on the Co-existence of People and Nature: Fish and Turtles

14. Prior to joining UNESCO as a consultant, Dr Gros worked with the Mayangna of Bosawas from 2000 to 2003, as Field Director of the Biodiversity project of the Saint Louis Zoo (USA)

15. Chief of UNESCO's Section for Science and Society and head of the LINKS programme



A geotropical paradise

Langkawi is the first geopark in Malaysia and the first of its kind in the Tropics. Among its outstanding features, a jagged landscape of karst islands sculpted over millions of years and the most complete Palaeozoic[16] sedimentary rock sequence in the region, a veritable archive of the evolution of Malaysia's climate and biota over the past 500 million years. Thanks to its breathtaking scenery, tropical climate and rich geological past – not to mention vast stretches of sandy beach – Langkawi is a budding tourist destination. A year ago, it became the first geopark in Southeast Asia to join UNESCO's Global Network of National Geoparks.

This beautiful mountain range in Machinchang Cambrian Geoforest Park is the oldest rock formation in Malaysia, dating back more than 500 Ma. Visible is the vertical support system of the hanging bridge

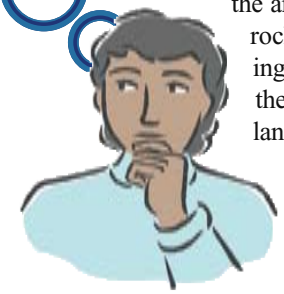
Langkawi is the birthplace of the oldest rock in Malaysia. The archipelago is built on layers (strata) of different kinds of sedimentary rock which trace the history of the islands in much the same way the rings on a tree trunk reveal its age – only, geological time is much longer: the geological age of Langkawi can be traced back to the early Cambrian period 542 million years ago (Ma), without any major break in the succession of strata until the late Triassic about 210 Ma. Langkawi thus portrays the most complete Palaeozoic history in Southeast Asia.

Remind me about the three main types of rock…

Sedimentary rock *is formed when particles transported by the air, ice or water are deposited. As the sediment deposition builds up, the pressure from the upper layers compresses the sediment into solid layers. Common sedimentary rocks include chalk, limestone, sandstone and shale.*

Igneous rock *(from the Latin word ignis for fire) is formed by the hardening of magma either above or below ground (above ground, magma is known as lava). When this happens underground, the igneous rock formed is known as intrusive (plutonic) rock; when it forms on the surface, as extrusive (volcanic) rock. Underground, magma hardens very slowly, leaving it time to form crystals. In granite for example, the crystals are clearly visible to the naked eye. The faster an igneous rock cools, the smoother its surface, as crystals have less time to form. Extrusive, volcanic rocks cool rapidly and therefore have a smoother surface than below ground. Common forms of extrusive igneous rock include basalt, lava rocks, pumice and scoria.*

Metamorphic rock *has been subjected to heat or pressure so intense that it has triggered a chemical and/or physical change (or metamorphosis). Underground, this change may be caused by the high temperatures at depth or pressure exerted by the rock layers above. Common forms include gneiss, marble, schist and slate.*



The Machinchang Formation (*see map*) dates back to the early Cambrian. It was formed when a large amount of sand was deposited in a shallow marine delta over probably more than 50 million years. This was followed by a long period during which the land was covered by the sea during the Ordovician (499–435 Ma) and early Silurian, as evidenced by the presence of Setul limestone deposits. Limestone indicates that the seas were warm at a time when Malaya – the ancient Langkawi Land – was situated close to the Equator.

The next strata is known as the Singa Formation. It was deposited in a shallow marine environment when the sea flooded the land, under the influence of alternating polar glaciations and glacial melt throughout the Carboniferous (355–296 Ma) and early Permian (295–280 Ma). It was during the early Permian that ancient Langkawi Land broke away from Gondwana and began drifting back up towards the Equator. This warmer environment led to the continuous deposition of the Chuping limestone until the late Triassic.

These rocks were later subjected to a major tectonic movement which resulted in the faulting and folding of the sedimentary strata. Meanwhile, magmatic intrusion was responsible for emplacing granite in the strata of Langkawi. This in turn brought entire rocks to the surface, forming the ancient Langkawi islands. The exposed rocks underwent continuous weathering and erosion, crafting and shaping them into the present unique geological landscape of Langkawi.

Of mogotes and mangroves

Tropical karst landscapes are rare on islands. In Malaysia, this type of landscape is found only in the Langkawi archipelago. Other sites exist in Thailand and Vietnam.

The Langkawi archipelago forms chains of karst hills (mogotes) dissected by deep-cut, narrow gorges and valleys, and isolated rocky islands separated by narrow, shallow straits. The coastlines are mostly rocky, with vertical cliffs that display a variety of features such as sea notches, sea crevices, sea tunnels, sea caves, sea arches and sea stacks. The latter are small, steep-sided islands which rise out of the ocean like jagged shark's teeth.

In Kilim Karst Geoforest Park. The blend between karst hills and coastal mangroves dipping their roots into a welcoming sea make for breathtaking landscapes along the east coast of the Langkawi islands

©Tasik D. Bunting

Onshore, the karst landscape comprises conical hills, concave hills and mogotes with a flat or round top up to 400 m high. The beauty of the karst landscape in Langkawi lies in the harmonious interweaving of mogotes and mangrove forests.

The cradle of ancient life

The geology of the Langkawi archipelago is dominated by shallow marine sedimentary rocks which are generally rich in fossils. Palaeofauna include several species which used to live on the seafloor when Langkawi was flooded by seas. The fossils of families (phyla) which still exist today include: bivalved brachiopods, corals, bryozoa – those colonial animals which, like coral, build skeletons of calcium carbonate –, gastropods, some species of nektonic cephalopod fauna; several species of planktonic forms such as graptolite, tentaculite and crinoid, and various types of trace fossils. The largest fossil found in the archipelago so far is that of a 20-cm long stalked crinoid, or sea lily, superficially reminiscent of a starfish.

Perhaps the most important find in the Langkawi archipelago is the discovery of several species of cold-water brachiopod that belonged only to the cold temperate Cimmerian Subprovince. Together with the random distribution of glacial marine diamictite (dropstones), these have become key supporting evidence for the theory that, during the late Carboniferous and early Permian, part of ancient Langkawi Land was situated on the periphery of Gondwana near the South Pole. Langkawi fossils are thus vital clues when it comes to dating sediments and determining their palaeo-location and palaeoclimate.

Learning to love geological wonders

Efforts to conserve the Langkawi islands' geo-heritage have not been successful so far. This is because Malaysia has no legal instruments for geoheritage conservation.

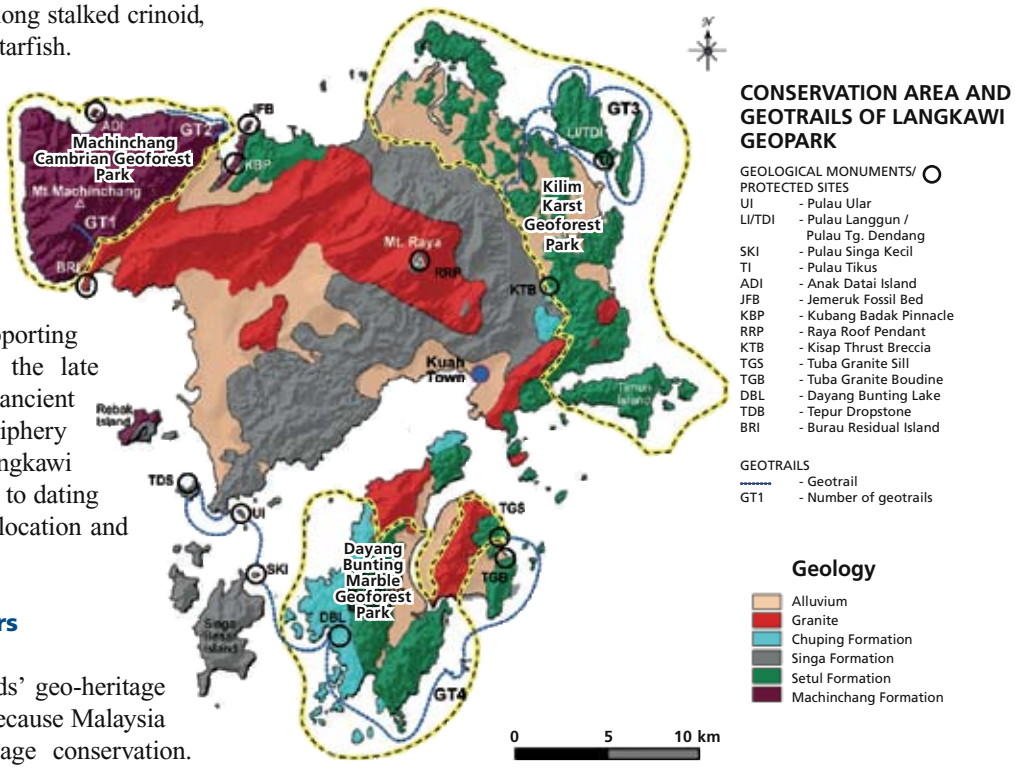
A brachiopod fossil from the early Permian about 290 Ma. This fossil suggests that ancient Langkawi Land had a cold climate. The shell is the clue; it tends to be thicker in cold climates than in warm ones

*A gastropod fossil (*Malayaspira rugosa*) 490 million years old found on Pulau Anak Tikus*

This dropstone, next to a pocket knife given for scale, provides evidence that Langkawi had a cold climate during the late Carboniferous and early Permian

Consequently, most conservation efforts have had to fall back on the National Parks Act or Forest Reserve Act. More broadly, this failure can be put down to a lack of appreciation and understanding among policy-makers and society at large. Langkawi Geopark offers an opportunity to turn this situation around through education.

Knowledge-based tourism is being actively promoted to turn the situation around. The Langkawi Geopark Division has set up a Geopark Information Centre for the public, as well as a number of museums and galleries. Visitors to a particular geosite will find panels, pamphlets and brochures on display there explaining different geological, biological and sociological aspects of the site.



From duty-free to geotourism

The decision in 1987 to turn Langkawi Island into a duty-free zone and tourist destination was politically motivated. The aim was to improve local livelihoods and close the economic divide between rural and urban areas. The Langkawi Development Authority (LADA) was established in 1990 to implement this agenda. The brainchild of former premier Tun Dr Mahathir Mohamad, LADA was entrusted with providing the island with basic infrastructure.

In 1996, the Institute for Environment and Development of the Universiti Kebangsaan Malaysia (UKM) signed a first Memorandum of Understanding with LADA to spearhead research on diversifying tourism based on natural resources. In addition to providing administrative backing, LADA began using the research findings to promote the island's geological heritage for the purposes of tourism. At first a trickle, these research findings have since become a steady flow of information, thanks to the setting-up of the Langkawi Research Centre by the UKM in 2002. The centre runs three research programmes: on Geology and Landscape; Biology and Marine Research; and Socio-cultural and Local Traditions.

The highlight of the partnership between UKM and LADA has been the establishment of the Langkawi National Geopark, in 2006, immediately followed by the preparation of Langkawi's candidacy for membership of UNESCO's Global Network of National Geoparks. Langkawi officially become the 52nd member of the network in July 2007. The next step could be to set up an Asia–Pacific Geoheritage and Geopark Network with fellow members of UNESCO's Global Network in China and Iran.

Training course at Langkawi Geopark for tour guides and students to enhance their understanding of the value of geological heritage and the need for conservation. Tour guides and operators are the primary target for the education and training modules the geopark is developing

Outreach programmes in the form of interactive seminars and special talks are also being organized to encourage the public to participate in geopark activities. In parallel, educational programmes are being specially prepared for school children. These activities usually involve the Langkawi Research Centre, Universiti Kebangsaan Malaysia and Langkawi Geopark Division.

A destination with a difference

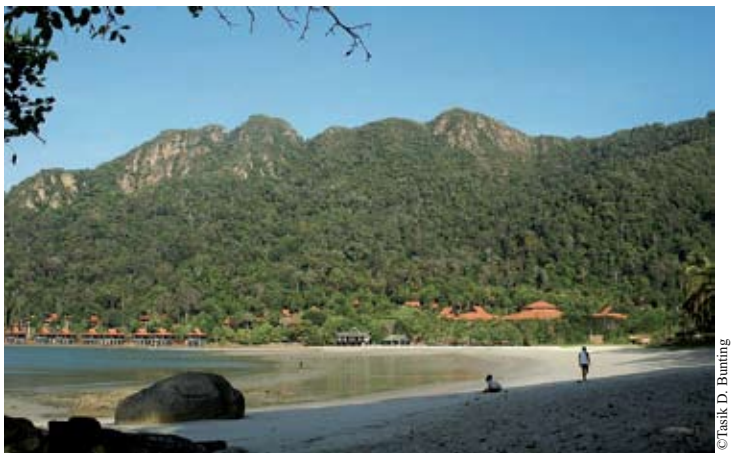
It is for its white, sandy beaches though that Langkawi is famous. Pantai Chenang, Teluk Datai and Tg Rhu are just some examples of the extensive, unspoilt sandy beaches along the limestone terrain which have become beach-recreation heaven for tourists. These are currently the main draw for international tourists visiting the island.

Yet Langkawi also sports rocky and pebble beaches. Rocky beaches with vertical cliffs and rugged, abrasive platforms also have their charms, enveloping the nature wanderer who stumbles upon them in a mystical atmosphere. Where the wave energy is weak, the beach area tends to be occupied by vast mangrove forests.

All along, nature has been the major selling point for tourism in the Langkawi islands. Highlighting the geopark element has further enhanced Langkawi's attractiveness by offering a destination with a difference.

One geotourism product currently being developed are geotrails. Several geosites which share outstanding features, such as caves, karst landscapes and fossils, have been packaged for the public as half-day walking or boating tours accompanied by a guide. Each geosite is equipped with educational interpretive panels, making for a pleasurable *in situ* learning experience.

The Lake of the Pregnant Maiden is one of the most beautiful landscape features in Dayang Bunting Marble Geoforest Park. This dolina lake, or sink hole, was created by the collapse of a cave system. It may have been part of a depression within a karst topography. The Pregnant Maiden has always drawn tourists to the Langkawi islands



These hotel facilities on the shorefront have been designed to blend in with the forest beneath the flank of Machinchang

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Thickly bedded sandstone exposed along the rocky beach of Pasir Tengkorak. The cross-bedding pattern appears as a mostly horizontal line in the rock, providing clues as to the direction in which water flowed when this rock was submerged by shallow seas during the Cambrian period (542–500 Ma). The sandstone has been intruded by light-coloured rock in a slanting pattern; this is quartz dyke of igneous origin and is approximately 220 Ma. Cross-bedding is a common sedimentary feature in the upper part of Machinchang Formation

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This one-stop public information centre in the Machinchang Cambrian Geoforest Park houses a collection of major rock types and unique rock samples and fossils, together with geological maps and posters illustrating the geological evolution of Langkawi

Geotrails have so far been identified for Kilim Karst Geoforest Park, Dayang Bunting Marble Geoforest Park and Machinchang Cambrian Geoforest Park (*see map page 21*).

Enhancing a sense of belonging

Just three of the Langkawi islands have human settlements: Pulau Langkawi, Pulau Tuba and Pulau Dayang Bunting (*pulau* being the Malay word for island). Most of Langkawi's 88 000 inhabitants live on the largest island, Pulau Langkawi. It was once a sleepy fishing village where predominantly Malay livelihoods depended upon traditional activities such as fishing, rice-paddy planting and rubber tapping. Small businesses were mostly limited to the town of Kuah and were run by the island's small community of Chinese settlers.

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Traditional fishing village in Langkawi Geopark. Fishermen tend to use small boats and nets to catch fish along the coastline

Between 2000 and 2006, the number of tourists visiting Langkawi Geopark each year grew from 1.5 to 1.8 million before leaping to 2.3 million last year. Thanks to the well-planned infrastructure, there is an adequate number of townships and hotels to support the growing tourism industry. In turn, tourism has helped to improve infrastructure by financing better facilities for the hospital, schools and colleges on the island.

With the advent of tourism, the island has undergone a transformation. Tourism has generated employment for locals as guides, boat operators and hotel and restaurant staff. Most of the fresh seafood supplied to hotels is caught by local fishermen and the seasonal fruits and vegetables served by the hotels are supplied by local growers. Some locals work as taxi drivers. Others have opened small shops selling food or souvenirs. Some work as contractors or labourers on projects for small-scale infrastructure development.

Lately, with the establishment of geotrails, the community has created a co-operative to manage the boat tours and guides. A second co-operative, this time in Kilim Karst Geoforest Park, offers fishermen an opportunity to diversify their livelihoods. Whereas before, the co-operative used to work with tour operators, now it manages tourist activities itself as a team.

Although the geopark concept is still a recent phenomenon in the hearts and minds of local people, geotourism has generally been well-received. The ongoing support of the locals will be essential to protecting Langkawi's georesources while creating a sense of belonging.

Those dependent upon natural resources for a living have particularly welcomed geotourism. Recently, a group of fishermen shared their views on the knowledge they had gleaned from attending geopark awareness-building programmes in their village. 'We shall have to be careful when we collect seashells living on rocks,' one reflected afterwards, 'as we might damage ancient fossils that have been there for millions of years.'

Ibrahim Komoo,
Sharina Abdul Halim and Tanot Unjah[17]

16. For a geological timeline of the Palaeozoic, see A World of Science, *January 2008; on karst landscapes, see the April 2008 issue*

17. All three are affiliated to the Institute for Environment and Development (LESTARI) of the Universiti Kebangsaan Malaysia

Diary

6–9 October
The ocean in a high CO_2 world II
2nd interdisciplinary conf. to assess what is known about ocean acidification and establish research priorities. On the first, see *A World of Science*, October 2004. (See also p. 13.) Monte Carlo (Monaco): *m.hood@unesco.org*

8–10 October
Sustainable land use and water management
Intl conf. of Sino-German project on Ecological Research for Sustaining the Environment in China (ERSEC) to exchange and integrate research results. Min. of S&T, Min. of Education, Beijing Municipal Bureau of Forestry and Parks, CNC-IHDP/IGSNRR, Chinese Academy of Sciences, UNESCO Beijing: *www.unesco.org/beijing-new/index.php?id=2478*

13–14 October
Non-renewable groundwater resources
First intl conf. to facilitate better management, as contribution to Intl Year of Planet Earth. Organized by National Ground Water Association (USA), Institute for Water and Watersheds (Oregon State University, USA), UNESCO-IHP and World Bank. Portland (USA): *www.ngwa.org/development/conferences/details/0810135055.aspx*

14–16 October
Role of hydrology in water resources management
On how hydrologists can exert more influence on project management and how water managers can capitalize on hydrological expertise. Organized by IHP Committee of Italy, co-sponsored by IAHS and UNESCO. Capri (Italy): *crescenzo.violante@iamc.cnr.it*

15–17 October
Sustaining Arctic Observing Networks
Workshop within Intl Polar Year to finalize SAON report to Arctic Ministerial Council in November. UNESCO-IOC to help provide report's ocean component via Global Ocean Observing System (GOOS). Helsinki (Finland): *www.arcticobserving.org/*

21–23 October
Dispute resolution over national and international water resources
Training course for high-level international civil servants exposed to complex professional issues related to fresh-water management, within UNESCO-IHP programme From Potential Conflict to Co-operation Potential (PCCP). At UNESCO-IHE Institute for Water Education, Delft (Netherlands): *l.salame@unesco.org*

28–31 October
Negotiating skills for cooperation-building over water in Middle East
Advanced course for trainers in the art of cooperation and trust-building in water-sharing in Middle East. Organized by UNESCO-IHP's PCCP programme. Hosted by World Water Assessment Programme, Perugia (Italy): *l.salame@unesco.org.*

31 October
Mondialogo engineering awards
Deadline for student project proposals targeting poverty reduction and climate change: *www.mondialogo.org; t.marjoram@unesco.org*

3–6 November
World urban forum
4th session organized by UN-Habitat, on improving urban poor's access to shelter, clean water, sanitation etc, achieving environment-friendly, sustainable urban growth. UNESCO to showcase projects on education for sustainable urban development, water governance and how to preserve the social fabric when revitalizing historic parts of a city, based on UNESCO/UN-Habitat toolkit Historic districts for all. Nanjing (China): *www.unhabitat.org; www.unesco.org/shs/urban; www.unesco.org/mab*

4–7 November
Relevance of biosphere reserves for testing sustainable development approach
Intl workshop to gather substantive input for foreseen MAB Action Plan for Rwanda (2009–2013). UNESCO Nairobi with Rwanda NatCom for UNESCO, Rwanda Tourism Board (ORTPN) and Rwanda Environmental Management Authority. Kigali (Rwanda): *n.raondry@unesco.org*

10 November
World Science Day
For Peace and Development: *www.unesco.org/science/psd; d.malpede@unesco.org*

10–12 November
Biodiversity and eco-systemic services
1st intergov. conf. for establishment of intergov. platform on biodiversity and eco-systemic services (IPBES). Kuala Lumpur (Malaysia): *http://ipbes.epeerreview.com/app/Index.aspx*

13 November
Water for peace
Intl conf. with two roundtables on: Fragile states, crisis situations and conflict ; and Water, vector of cooperation and legal and institutional frameworks. Contribution to World Water Forum in March 2009. UNESCO-IHP with Fondation Chirac (France): *l.salame@unesco.org*

17–19 November
Research for health
Global ministerial forum co-sponsored by Council on Health Research for Development, Global Forum for Health Research, Govt of Mali, WHO, UNESCO, World Bank. Bamako (Mali): *www.bamako2008.org; j.hasler@unesco.org*

18–21 November
1st World landslide forum
Implementing 2006 Tokyo Action Plan on International Programme on Landslides. Tokyo (Japan): *b.rouhban@unesco.org*

25–27 November
GOOS regional forum
Guayaquil (Ecuador): *t.gross@unesco.org; www.ioc-goos.org*

2–5 December
Promoting STI policy and management capacities in African universities
Regional Forum within UNESCO/African Union Programme of Action to catalyse action on the development of S&T postgraduate programmes in African universities. Obafemi Awolowo University Ile-Ife (Nigeria): *sc.stp@unesco.org; f.osotimehin@unesco.org*

New Releases

Water and Peace for the People

By Jon Martin Trondalen. UNESCO-IHP PCCP/UNESCO Publishing, ISBN: 978-92-3-104086-3, €38.00. English edition launched at UNESCO on 11 September. Arabic and Hebrew editions due out by December, 246 pp.

What if the countries in the Middle East had no choice but to get along in order to share the region's meagre water resources? This is the starting premise of this practical guide to resolving these entrenched crises. While the demand for water grows, driven by population growth and economic development, scientists predict the Middle East could be the first region to cope with a dramatically reduced amount of water. The situation is already alarming. Salinity is rising in major watercourses like the Euphrates and half the population of the region's large cities lacks an adequate drinking water supply. A UNDP (2005) report indicates that 80% of rural Iraqi families drink unsafe water. This guide also examines the conflicts in the Upper Jordan River between Israel and Syria around the Golan Heights, between Israel and Lebanon over the Wazzani Spring and the longstanding water dispute between Palestinians and Israelis. Challenges confronting Turkey, Syria and Iraq in sharing water of the Euphrates and Tigris Rivers are also assessed.

Arsenic in Groundwater

A World Problem

Produced by Netherlands Chapter of International Association of Hydrogeologists and Netherlands National IHP Committee, sponsored by UNESCO's Division of Water Sciences. ISBN 978-90-808258-2-6, English only, 125 pp,

High levels of arsenic in groundwater contaminate drinking water and irrigated crops. Arsenic can be naturally produced and transported by weathering processes and microbial activity but also by anthropogenic activities, such as metal mining, groundwater abstraction and the manufacture of arsenic-based pesticides. Provides state-of-the-art knowledge of all aspects of arsenic in groundwater. Download: www.iah.org; to order: *janpiet.heederik@inframn.nl*; for background, contact Michael van der Valk: *info@hydrology.nl*

Groundwater Resources Assessment under the Pressures of Humanity and Climate Change (GRAPHIC)

A Framework Document

Produced by UNESCO-IHP with partners that include US Geological Survey, Research Institute for Humanity and Nature (Japan), University College London (UK), English only, 32 pp. 2nd Edition. See also pages 6 and 14.

Updates the framework for UNESCO's four-year old GRAPHIC programme. GRAPHIC addresses global issues via case studies of key aquifer systems and prototypes for investigations around the globe. The broad range of subjects, study methods and regions will be adjusted to accommodate new partners and emerging trends within this ongoing collaborative effort. Outlines preliminary guidelines and criteria for selecting regional case studies. Download from: *www.unesco.org/water/ihp/graphic*

EDUCAIDS Resource Pack

Produced by UNESCO, lead agency of EDUCAIDS, in close collaboration with ministries of education, UN agencies et al. English and Portuguese, other language editions to follow.

Provides technical guidance on developing and implementing policies, determining resource allocations and implementing programmes for education and HIV, within UNAIDS Global Initiative on Education and HIV & AIDS (EDUCAIDS). Integrates five essential components: quality education; content, curriculum and learning materials; educator training and support; policy, management and systems; and approaches and illustrative entry points. Includes 35 technical briefs. Launched at XVIIth International AIDS Conference (Mexico City, 3–8 August 2008). For details: *www.educaids.org/ aids@unesco.org*

Corrigendum

In the July issue of *A World of Science*, in the introduction to *Livestock in a Changing Landscape* (New Releases), we should have stated that global meat production tripled between 1980 and 2002 (and not between 1998 and 2002).

A World of Science *is a quarterly newsletter published in English, French, Malay (Dunia Sains: www.akademisains.gov.my), Russian (www.unesco.ru) and Spanish by the Natural Sciences Sector of the United Nations Educational, Scientific and Cultural Organization (UNESCO), 1, rue Miollis, 75732 Paris Cedex 15, France. All articles are free of copyright and may be reproduced providing that* A World of Science *and the author are credited. ISSN 1815-9583. Printed in France by: Watelet. This issue was printed in 10,650 copies. Director of Publication: Walter Erdelen; Editor: Susan Schneegans; Lay-out: Yvonne Mehl; Register for free e-subscription: y.mehl@unesco.org – Free print subscription for libraries and institutions: s.schneegans@unesco.org, fax: (331) 4568 5827.*
Cover image: Artist's impression of a city in the year 2100 (Image: Eduardo de Mulder and Rœl Savert)