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On the benefits of being a little different – Why life needs biodiversity

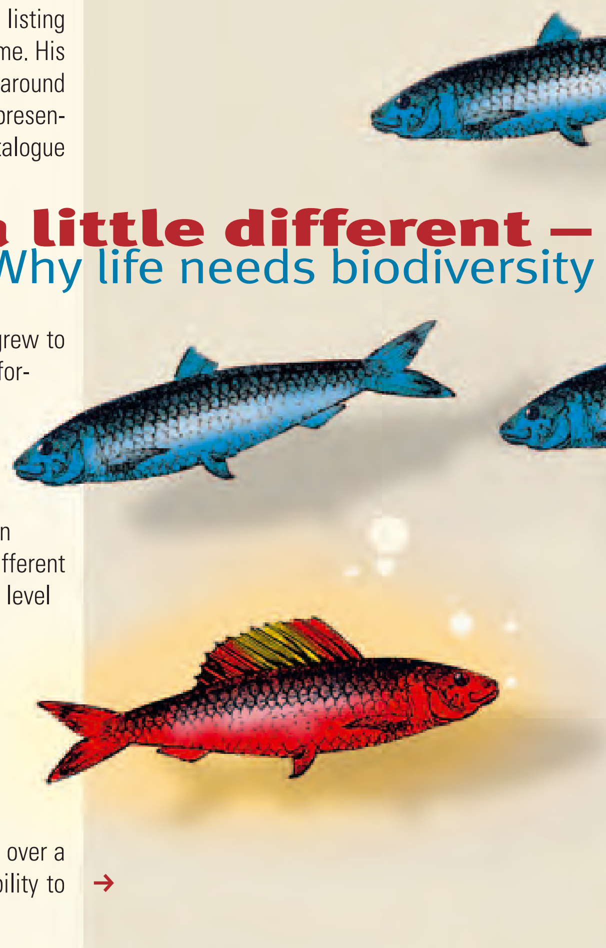
Six billion people live on Earth. Nevertheless, we share this planet with trillions of animals and plants. The value of these numerous plant and animal species is difficult to estimate, and easy to ignore – particularly when the main concern is to ensure that next year's harvest is a good one. Arable land delivers a tangible yield, the value of which is determined directly by market forces. So why do we need 25,000 species of orchids, 1.5 million types of fungus and 400,000 different nematodes? One thing is certain: modern civilization is founded not only on technology and culture, but also to a large extent on a diversity of organisms. Intact ecosystems provide humans with vital commodities and services – such as food, water, construction materials, oxygen, carbon, etc. – at virtually no cost.

SHRINKING MARKET OF POSSIBILITIES

There are complex interactions between the hundreds of species that allow an ecosystem to function. They follow unpredictable patterns and cannot easily be described with simple mathematics. Currently, species are disappearing at least a thousand times, if not tens of thousands of times, faster than they are being replaced, and only now are we beginning to understand how simple ecosystems react to the loss or addition of individual animal or plant species. Over the course of Earth's history, new species or groups of related species have constantly emerged while others have died out. The evolution of new species is the basis for biological diversity. However, on the threshold to the "Century of Biology" the loss of biological species worldwide is increasing at a previously unknown magnitude and rate. Competitive market forces, which over the last two centuries have brought about considerable progress in the way raw materials are tapped, have lead to exploitation at rates that are between ten thousand and one million times higher than the rate at which these natural resources can be renewed. A more profound understanding of the term "biodiversity" is therefore one of the biggest challenges facing science and will make a significant contribution to making our future sustainable.

HOW CAN BIODIVERSITY BE MEASURED?

We are indebted to the Swedish naturalist Carl von Linné for the first systematic listing of all the living species known in his time. His study, published in 1758, recorded around 9000 animal and plant species and represented an important starting point for a catalogue which, over the following 200 years, grew to include over one million species. Unfortunately, however, we still need to classify at least as many new species again, possibly even ten times as many. Furthermore, this extends beyond discovering previously unknown species, as biodiversity exists on different hierarchical levels – on the ecosystem level and on the living community level, of species, population and finally on the genetic level. The latter are the smallest fundamental units on which biological diversity is based. And these are the "motor" of evolution, because all species need a certain diversity of genes distributed over a population so that they retain their ability to →



adapt to changing conditions in their environment. A gene that is rare, but nevertheless exists, could be exactly the right one when a population is forced into a new environment.

Bird migration is a striking illustration of how changes to the environment, particularly climate change, accelerate the development of new migratory patterns in central European bird species. Bird migration, particularly partial migration, emerged early on in their evolution. Of the approximately 400 bird species that breed in Europe, 60 percent currently are "partially migratory", i.e. only some of them leave their normal breeding area in the winter months and migrate southwards, while the rest of the population remains. Because it is so adaptable, **partial migration** is a highly successful life form and plays a key role in the transition from purely **migratory** to less migratory to **sedentary birds,** that is those that remain in their breeding area all year round.

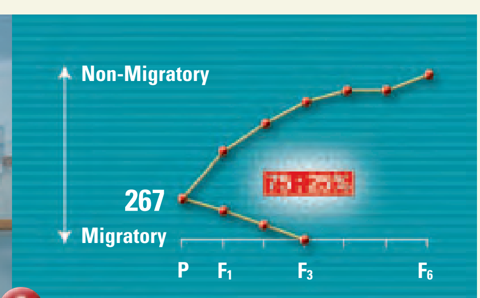
LIFE INSURANCE WICH IS PAID OUT IN GENES

In the 1990s, Peter Berthold and his colleagues at the Ornithological Station in Radolfzell used studies of the blackcap to show that the different forms of migration are indeed under direct genetic control – not, however, by a single gene, but by several: migration and non-migration are so-called polygenetically controlled characteristics. Partially migratory birds have the potential for migration and non-migration. Experiments by the Max Planck researchers showed that under extreme conditions, phenotypically almost pure migratory or sedentary birds are selected **(fig. A)**. The biologists calculated that the transformation of a migratory bird population to an almost purely sedentary population (or the reverse) would only take 25 generations or 40 years. Scientists would say that partial migration has high **microevolutionary potential:** as a genetic trait, it has no disadvantages, but offers the considerable advantage that development under different environmental conditions can be reversed at any time with simple **gene selection.** The researchers therefore assume that the remaining 40 percent of European breeding birds, which include a high proportion of migratory birds, are at least genotypically partially migratory. That means that the animals still have those genes in their genome that bring about sedentary bird behavior or non-migration.

Our native blackbird furnishes us with an example of this development. Until the 19th century, blackbirds were almost exclusively migratory in Central Europe, living a secluded life in woodlands during breeding time and moving to the Mediterranean for the winter. Today, central European blackbird populations are partially migratory, with around half of the individuals remaining in the breeding area for the whole year. This is because environmental conditions have improved steadily for blackbirds. For example, there are more grassy areas in towns and villages that make it easier for them to find earthworms; moreover, bird lovers feed them through both hard and milder winters. These sedentary birds prefer to breed with each other in the more favorable urbanized habitats ("town blackbirds"), whereas the migratory individuals breed in the less favorable, more remote wooded areas ("woodland blackbirds"). Should the greenhouse effect really cause temperatures in our latitudes to rise by several degrees Celsius over the coming decades, researchers expect that numerous species, which are partially migratory today, will become fully or almost fully sedentary – which is now the case for the blackbird population on the Lower Rhine.

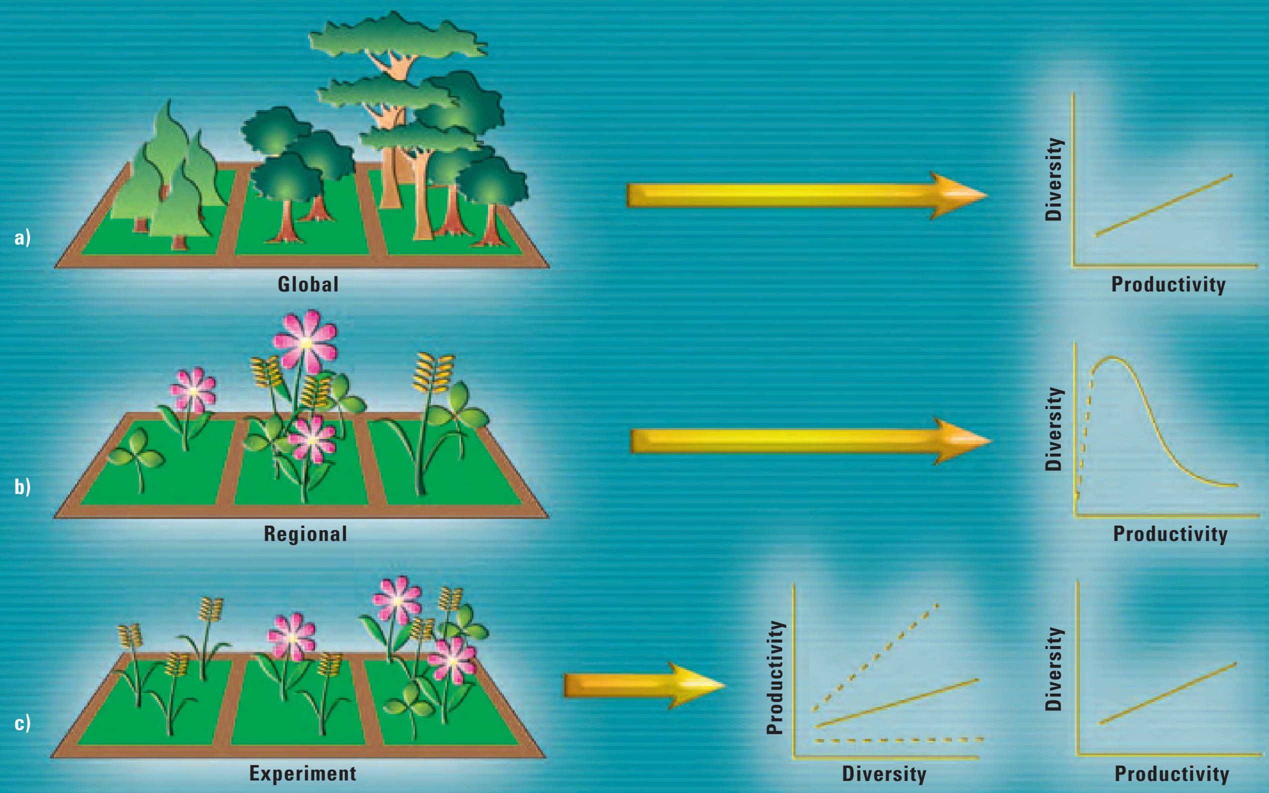
LONG DISTANCE FLIERS, BUT NO BONUS MILES DISCOUNT

The benefits of over-wintering at home are obvious: the birds have the choice of the best territories and can occupy them earlier; an earlier start to breeding improves the prospects for replacement and additional broods. Furthermore, the death rate falls as a result of milder winters. A warmer climate would therefore allow the sedentary bird population to grow significantly. A large number of sedentary birds could therefore fill new ecological niches and populate a much wider area than is currently the case. However, that would mean serious problems for our migrating birds. Extensive investigations in England have shown that the population density and population development of migratory birds are directly dependent on the population size of the sedentary birds living in their breeding area. Especially birds that return home late from a distant migration can only occupy the



A

◂ **Max Planck researchers used a population of blackcaps to show that it is possible to breed almost purely migratory birds or almost entirely sedentary birds from such a population within three to six generations using experimental selection - equivalent to microevolution in nature. Partial migration in these birds is like a type of dial that allows selection of larger or smaller proportions of the migratory birds in a population, depending on the environmental requirements.**



▲ In plants, the relationship between diversity and productivity is a spatial issue. Viewed globally, diversity increases with productivity from the poles to the equator (a). The tropical rainforests are the most productive and biodiversified land ecosystems on Earth. On a regional scale the diversity decreases with increasing productivity starting at a certain point. This means that some plant species flourish so well in some places that they increase biomass, but also oust other species (b). On the other hand, the experiment revealed a positive correlation between productivity and diversity. The researchers can only change the "diversity" parameter and measure the productivity as a response to this change (c). An unmanipulated ecosystem, however, behaves in exactly the opposite way: the productivity changes depend on the availability of nutrients, water and light, and as a result, diversity also changes.

habitats that the sedentary birds and species with shorter migrations leave free for them. For garden warblers and blackcaps this association has been directly shown in experiments: when black caps (which return home much sooner) were trapped in a trial area at the time the garden warblers arrived, many more garden warblers settled there than is normal (garden warblers are often driven away deliberately by the very aggressive black caps). **Climate change** (according to ornithologists' forecasts) could gradually oust long-distance migrators from our native bird world. Should birds that migrate to Africa succeed in overwintering in the Mediterranean, the shorter migration distances, among other things, might enable them to make up the losses in their numbers. There are already signs that this is happening: for example, more than 15 bird species, which previously spent the winter months only in Central and South Africa, now overwinter in small, but increasing numbers in the Mediterranean. These also include our house martins and white storks.

ALLOTMENT GARDENS FOR RESEARCH PURPOSES

Changes to certain environmental parameters can therefore lead to completely new geographical population distributions and to a different combination of species within an ecosystem. Researchers at the Max Planck Institute for Biogeochemistry in Jena are also investigating the correlations between species diversity and ecosystem processes. One of the most comprehensive experiments on this subject was the EU BIODEPTH project carried out between 1996 and 1999. Using a standardized experiment design, 480 meadow plots were established in eight locations in Europe and various native plant species sown in them. The researchers varied the number and combination of species in each of these miniature gardens. They reduced the number of species in the four square meter sections from 16, 8, 4 and 2 species to a monoculture, meaning one remaining species. In addition, they divided the plants into species groups with similar characteristics, called "functional groups", and varied these over the trial grounds. In order to keep the plant combinations consistent, the researchers needed to regularly weed the fields. Over a period of three years, the ecologists recorded a series of ecosystem characteristics and processes throughout Europe. One of their most fundamental questions was whether the **diversity of plant species** affects the **productivity** of an ecosystem. Evaluation of the results showed that the most northerly and the most southerly locations generally delivered lower →

▲ **After being sown in the spring (a), the plants in each of the meadow plots are already well grown in July (b). In the BIODEPTH experiment, all the plots had "cabling" underground to collect ground water (c).**

➔ biomass values (hay yield) than the locations in Central Europe. However, there was one unmistakable trend: both the number of species and that of the functional groups influenced productivity. The mini-gardens with less plant diversity actually built up less biomass than those with a wider range of species or functional types.

These results, which were published in the journal SCIENCE, seemed to confirm an assumption made by Charles Darwin in his 1859 book "The Origin of the Species": *"If a plot of ground be sown with one species of grass, and a similar plot be sown with several distinct genera, a greater number of plants and a greater weight of dry herbage can thus be raised".* Nevertheless, some researchers remained skeptical: one of the main objections was that the results were appropriate for ecosystems that had been set up as an experiment, but could not necessarily be translated to natural, existing ecosystems **(see box page 3)**. In the course of this discussion, therefore, a series of new research projects was initiated including one looking at whether the results could be translated to natural plant populations.

NICHE DIVERSITY – A KINGDOM FOR ONE AND ALL

BIODEPTH is now considered one of the most outstanding EU projects. "In our first attempts we were able to show in experiments that ecological differences between species result in resources such as light, water and nutrients being used more effectively as the number of species increases," explains Ernst Detlef Schulze, Director at the Institute in Jena. Scientists call this **niche complementarity.** For example, different types of plants take root in the ground in different ways and make optimum use of the available water. On the other hand, if only a single species grows in the ecosystem, all the plants take root at the same depth. They then compete for less water and grow less well.

In Spring 2002, the Max Planck researchers launched a project in the Saale Valley near Jena that surpasses the previous experiments in its size and planned duration (10 years). On an area the size of 13 soccer fields, they created 400 meadow plots and sowed 495 different mixtures of meadow plants **(fig. B)**. These came from a pool of 60 plant species that could be assigned to four different functional groups. Five months after sowing, the meadows were mown for the first time and the plants sorted into species and weighed. The results of earlier experiments were confirmed: species-rich meadows produced more biomass than species-poor meadows. In order to establish how far meadows with fewer plant species make less efficient use of the available nutrients (some plant species need a lot of nitrogen, others need more phosphorus), the researchers take regular samples of water. As excess, that is, unused, nutrients leach into the ground, they pollute the ground water. A rise in the content of certain nutrients in the water sample would be proof that species-poor systems cannot utilize the diversity of niches on offer.

It is not yet settled how far the results from the meadow experiments can be applied to woodlands. Given the increasing storm damage of recent years, there are increased calls for woodland restructuring. However, there has been little investigation into the possible advantages of moving from species-poor to biodiversified and structure-rich populations. In spring 2003, the biogeochemists launched a new project that is unique throughout the world: BIOTREE. Over the next two years, 250,000 trees will be planted on a total of 80 ha of fallow land. These trees will be subjected to scientific examination over the coming years and decades. Instruments in the soil, on the vegetation and on a meteorological measurement tower will record the processes and changes to the soil, the vegetation and the atmosphere as the forest grows. Perhaps when its benefits are scientifically proven, humans will feel moved to protect the biological richness of the Earth.

Key words: bird migration, partial migration, migratory birds, sedentary birds, microevolution, genetic selection, climate warming, biodiversity, productivity, biomass, niche complementarity

Further reading: Conservation and Biodiversity, W. H. Freeman and Company / Scientific American Library / HPHLP, New York, NY, 1998

Internet: www.cbd.int
www.biodiversityhotspots.org
http://investigate.conservation.org

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