Biodiversity and Ecosystems

Background material for CASCADE Scientific Game

Authors

The CASCADE Scientific Gaming will motivate students by replicating the excitement of scientific research. The CASCADE Scientific Gaming is developed in the context of the CSCADE Project, an Interreg Italy-Croatia project CASCADE devote to develop a set of concerted and coordinated actions including monitoring (observing and modelling) and management (Maritime Spatial Planning - MSP, Integrated Coastal Zone Management - ICZM, Land-Sea Interaction - LSI) to enhance the knowledge and to evaluate the quality and assess the vulnerability of inland, coastal and marine ecosystems in Italy and Croatia with the final objective to restore endangered species and to support integrated management.

All activities are carried out by the partnership, constituted by 10 Italian, 6 Croatian partners and 4 associated partners, in a balanced mix of administration bodies, agencies, research centers and universities.

Attention is also given to young people through several actions among which a serious game.

More information about the CASCADE project you can find: https://www.italy-croatia.eu/web/cascade


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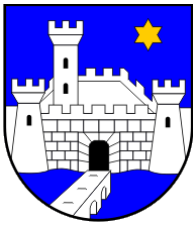

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Background material on Ecology and Biodiversity

Are you interested in becoming a young researcher? Are you going to apply scientific methods to answer challenging questions? Join us – we will get there together.
The Scientific Game focuses on the topic of biological diversity, which is the diversity of ecosystems, species and the genetic pools.

Keywords: diversity, ecosystem, species

What is biodiversity?

Life on Earth is in an amazing wonderful spectrum of sizes, colors, shapes, life cycles and interactions. Have you ever been in a forest, populated by different species of plants and animals? Think for a moment to be there, take a look around, the land, the trees, listen to the sounds of the animals, imagine if you could be a part of that forest ... well, actually you are part of it! This way it will be easier to understand what we are about to tell.
As we all know, we share the planet with other truly remarkable diverse plentiful organisms: each one contributes to increase the variety of the world in which we live. It is a great experience starting an explorative journey to discover the different species of organisms and find out the ecological relationships that give the biosphere its productive features.
However all ecological systems have to be able to support themselves in order to keep their species' variety.

Three different aspects compose biodiversity, or variety:

1. **Genetic diversity**
2. **Species diversity**
3. **Landscape diversity**

Torre Guaceto, Salento Italy

1. Genetic diversity measures the variety of different versions of the same genes within each individual species. Starting by the human species, we can immediately appreciate how important this genetic diversity is. In other words, the genetic diversity consists in the maintenance genotypic heterozygosis, polymorphism, and other genetic variability, which represent an adaptive necessity for all natural populations.

2. Species diversity is the number of different species of organisms that we can find within each community or ecosystem. Two dimensions characterize this concept: the richness of species, or the total number of species in each community, and the uniformity of species, or the relative abundance of individuals within each species. Let's imagine two ecological communities (biocenosis),

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#1

Biological diversity is one of the most valuable goods of our planet. It is the richness of nature that provides us with food, clothes, and medicines, with clean water and protection from natural hazards. Neglecting biodiversity, however, could provoke crop collapses, thirst, diseases and disasters. Think about it and you will understand that protecting biodiversity is critical to maintaining and improving our quality of life.
Before starting with some research questions, let's have a closer look on some concrete examples.

each one counting 10 species and 100 individual plants or animals. Let us pretend that the first community has 50 individuals belonging to the same species, 25 belonging to a second one, and then for each of the other eight species there is a number of individuals going from 1 to 6. 10 individuals for each species, instead, compose the other community.
The species richness of the two communities will be the same (10 species in total): but if we were walking through these communities, we would have the impression that the latter is much more varied and different on the inside than the first one, as there would be more chances of meeting a greater diversity of organisms. Contrariwise, in the first community, we would easily meet individuals belonging to the first or the second species.

In conclusion, these two communities are marked by a different uniformity of species (evenness), or different species' abundance. High evenness is generally accompanied by high diversity.

3. Last but not least, diversity is characterized by **landscape diversity**, meaning by landscape a heterogeneous territorial area, consisting of a group of ecosystems interacting with each other, which is repeated in a similar form in contiguous zones. The landscape is the level of organization of environmental systems, interposed between the ecosystem and the biome. A landscape can be composed by different ecosystems.

Summarizing, biodiversity not only refers to the existence of millions of types of organisms, but it has a broader meaning, as we can find biodiversity at different levels of the spectrum of biological organization, from genes, to communities, to landscapes.
We can state without any doubt that the concept of species is essential to define biodiversity; but what does the term *species* exactly mean?

Species: definitions and number

When Linnaeus (1707-1778) began drafting the system of scientific nomenclature, the classification of organisms was based only on the physical characteristics of the adults. Recently, taxonomists have introduced other features to differentiate the species. Over the years multiple alternative definitions of species have been proposed, each one relying on different criteria: **i) the concept of reproductive isolation**; a species consists of all organisms potentially capable of reproduction in nature, and able to give birth to fertile offspring; **ii) the concept of phylogenetic of species**; which emphasizes the cladistics affinity (the degree of relationship) among taxa **iii) the concept of evolution of species,** which takes into account that 'evolutionarily significant' populations may be found within a group of genetically similar organisms.

In the late 1800s, the century of great explorative expeditions, scientists were confident that each major living species would be discovered and named. The explorations, however, mainly focused on the most charismatic species, such as birds and mammals. Nowadays, recent studies conducted on more conspicuous organisms such as insects and fungi clearly show that millions of new species and varieties are yet to be studied. Clearly, if we do not know that a species exists, we cannot either know the interrelation that it might establish with its abiotic environment, hence its function within an ecosystem remains "unknown".

We can find several estimations of the number of existing species. Let us take into consideration the tropical insects: some taxonomists have estimated that there are over 30 million species, however according to other studies there are no more than 4-6 million species. Invertebrates make about 70% of known species. This group constitutes the vast majority of organisms yet to be discovered and might constitute 95% of all existing species. Shortly, if it is already hard to establish with certainty what a species is, it becomes even more complicated when it comes to bacteria or viruses. We know that there is a huge number and great variety of these organisms, physiologically or genetically different from each other. Moreover, it is not enough to be aware of the existence of a species, but it is crucial to know more about the interactions among species, and between species and abiotic components of ecosystems.
Although, the concept of diversity relies on that of species; biodiversity is even broader, which including the measure of richness and complexity of biological communities, taking into account the number of ecological niches, trophic levels and ecological processes which impact on the **functioning of ecosystems** by their ability of capturing energy, sustaining food webs and recycling materials on the inside.

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Look at the market! So much food there! Did you know that we owe most of it to hardworking bees (honey bees) but also to their wild "sisters"? Animals pollinate approximately 80% of all flowering plant species; the main pollinators are insects, bees above all. When they feed, those animals move pollen from one flower to another, in this way bees and other pollinators provide us with a wide variety of food, mainly horticultural crops.
However, many species of bees are endangered! Their habitats are being destroyed due to agricultural or construction management or poisoned by pesticides. Maintaining the diversity of bees and the plants they pollinate is nowadays an issue for many research studies, conservation and policy activities.

Fruit stall in a market in Barcelona, Spain.
Photo: Daderot/Wikimedia.

Red Mason bee, Osmia rufa.
Photo: Karsten Seidelmann

Benefits of biodiversity

Food - The human species takes advantage of other organisms in many ways, often without even realizing it, at least until a particular species or community is about to disappear or already gone! Some organisms may appear obscure or irrelevant, but if one looks further, it is possible to see how they play crucial roles in ecological systems, or find out that they are the source of genes or drugs that one day might become fundamental.
First of all, we must point out that all the food consumed by humans comes from other organisms. Many species of wild plants could make important contributions to the food supply; others could be the source of genetic material necessary to improve crop plants.
The ecologist Meyer has suggested that the human species could use up to 80,000 species of edible wild plants. It is considered that some Indonesian villages use nearly 4,000 species of indigenous plants and animals to obtain food, medicinal substances and other useful products. The possible domestic use, or the option of an extensive cultivation, of these species has been investigated only for a few of them. For instance, in 1975 a study found that out of 250 edible fruits present in Indonesia, only 43 are cultivated extensively.

Ecological benefits - The life of the human species is inextricably linked to the environmental services provided by other species. The formation of the soil, disposal of waste, purification of air and water, recycling of nutrients, the absorption of solar energy and management of hydrological and biogeochemical cycles, they all depend on biodiversity.
Although there is no absolute certainty, it seems intuitively true that a community with more species of organisms is better able to withstand interferences or recover after disturbances.
As a consequence of the lack of understanding of the complex relations existing between organisms, we find ourselves surprised and impressed by the effects of the removal of apparently irrelevant members of a certain biological community.
Although we often seem to forget, most of the wild species provide a very useful service by killing pests and pathogens.
It has been estimated that 95% of the potential pests and pathogens existing in the world are tackled by

other species which, either preying on or competing with them, manage to maintain ecosystems balanced. Many unsuccessful efforts to fight pests with synthetic chemical compounds have shown that biodiversity itself provides those essential biological services able to destroy pests.

Cultural and aesthetic benefits – Millions of people enjoy going hunting, fishing, camping, flora and wildlife watching, etc., all outdoor activities which often constitute a good opportunity to practice some physical exercise. In addition, they often have a positive impact on one's psychological and emotional state.
In many cultures, the contact with nature implies the involvement of the spiritual dimension; a particular landscape or species may be related to the identity of a population or carry special meanings.
Observing and protecting nature are activities that take on a moral and religious meaning. At the same time, they also have a specific economic value.
40% of American citizens enjoy wild fauna and flora in some way: some go hunting or fishing, others practice wildlife watching and take pictures. It has been estimated that U.S. citizens spend about 204 billion dollars per year in recreational activities related with flora and wildlife. This cost would be comparable to what is spent to buy new cars, (about 81 billion dollars per year).
Ecotourism is certainly a good form of sustainable economic development, but it requires great care in its practice not to abuse the places and cultures involved.
For many, the mere knowledge of the existence of a species is enough to protect and conserve it, regardless from watching and photographing activities: it is the so-called existence value.

Tree frog , Hyla arborea. Photo: S.Meyer

Loss of diversity - The ecologists Paul and Anne Ehrlich have compared the loss of biodiversity to the removal thousand rivets (the nails that hold the panels together) from the wings and fuselage of an airplane (HYPOTHESIS OF RIVET).
If one begins to take them off, convinced that there are thousands more than necessary, it may happen that, at a certain point, the wings break down and the aircraft crashes suddenly. In a similar way, many human activities bring species to the brink of extinction, without even giving the time to realize which role they play in the ecosystems. Generally speaking more alterations of important processes and functions take place in the same ecosystems, higher becomes the risk of ending up like that reckless guy who had taken off too many rivets from the wings of the plane!

Threats to biodiversity

Destruction and reduction of the habitat - It is important to understand how living species have been evolving over millions of years, but it is even more important to see how they have been co-evolving, adapting one to the other in order to be able to coexist within certain areas defined by specific chemical physical climatic characteristics. Any change in this balance could lead to significant losses of biodiversity.

One of the main threat to the survival of many species is related to the alteration of territories caused by man while increasing the land dedicated to agriculture or livestock, pursuing widespread deforesta- tion, insisting in the development of urban and com- mercial areas. Moreover, the construction of barriers (such as roads and power lines) causes the fragmentation and reduction of a habitat into small portions, partially or totally separated from each other, preventing the free move- ment of the species within the territory.
Cutting down forests and converting grasslands into agricultural fields are the two classical ex- amples of habitat destruction. Today forests cover only half of the area that they did once, and the primary forest, whose structure and resources are necessary to the survival of many species, is reduced to 1/5 of the area it used to occupy. Most of the more productive and species-rich grasslands have been converted into agricultural or pasture areas, also because

Maldive Islands, air view

of the increasing of human population. Men destroy habitats in many ways, by extracting resources, mining, building dams and overfishing.

The mining cultivation of open lands, for example, removes a whole layer of land along with everything that is situated on their surface. Waste resulting from mining activities, toxic materials inclusive, could bury valleys and streams. The construction of dams submerges the essential habitat of the waterways below reservoirs of water, destroying the food resources and reproductive habitat of many aquatic species.

Some fishing methods are unsustainable: trawling, for instance, uses to trails heavy nets on the sea bottom, causing the removal of every organism and the destruction of the seabed structure. The result is the loss of all forms of life. Often, it is not enough to preserve small and scattered areas to save species.

Large mammals, such as tigers and wolves, need large areas, free from human incursions, in order to survive. If the areas are scattered into isolated portions and intermediate zones prevent migration, some species can be profoundly affected by environmental disasters such as natural catastrophes or epidemics.

In addition, this situation might prevent interbreeding and increase the possibility of developing genetic defects.

Invasive species - A serious threat to native species is constituted from deliberate or accidental introduc-

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Wheat fields have transformed much the Montana landscape (straw baled after the wheat harvest in late summer). Photo: Matt Lavin from Bozeman, Montana, USA/Wikimedia.

The **second example** deals with the importance of genetic diversity using the example of crops.

There are 75,000 edible plant species, but just three of them provide 50 per cent of our food. These crop species are wheat, rice, and maize. The problem is that we have become highly dependent on a few varieties of these crops. Research studies indicate that the world's centres of crop diversity remain inadequately protected and that we may have already eradicated three quarters of the planet's agricultural crop genetic diversity. However, we need the maintenance of biodiversity to ensure the existence of crops that are able to resist to diseases and climate change.

Edge of a cornfield of maize (Zea mays) in Saxony (Germany). Photo: Christian Fischer/Wikimedia.

Forbidden access to a natural reserve near Vigo, Spain

tion of alien species.
Non-native species are called invasive, or exotic, undesirable, destructive, harmful species: they are organisms that proliferate in a new territory in which there are no predators, pathogens and limitations of resources, which would have maintained their population under control in the indigenous environment. Men have always been introducing organisms into new habitats: recently their shipping rate has been increasing in proportion to the increase of speed and volume of aerial, maritime and land traffic. Men carry species around the world in so many ways: some are deliberately introduced, for aesthetic or economic benefits. Other travels in ships' ballast tanks, in wooden boxes, they find their way through passengers' luggage or containers, they hide inside potted plants, and even in people'sshoes!

Corn, wheat, rice, cattle, chickens, honey bees, they all are organisms introduced in the United States, together with about 50,000 species over the last 300 years, which have been producing social and economical benefits. Always considering the example of the United States, we can see how other non-native species have been causing environmental or economic damages. We mention here the example of an aquatic plant, native of Europe, Asia and Africa, which had been introduced through the ballast water of ships in North America towards the end of the 19th Century. Its name is water milfoil (*Myriophyllum spicatum*), and it belongs to the family of *Aloragacae*. This plant is characterized by a rapid growth and the tendency to form a dense layer on the water surface; the result has been the expulsion of the indigenous vegetation, the prevention of the flow of water and the addition of a barrier to fishing, swimming and navigation. This plant has been spread by humans via the vessels and tow-lines carrying some of its fragments. It is possible to hold back the plant using herbicides and techniques of mechanical harvesting, but its costs are quite expensive. In addition, these methods may damage not only the water milfoil, but also other species we would not want to hit. It has been proved, that a particular kind of beetle (*Euhrychiopsis leconiei*) acts as an agent of biological control against the water milfoil, as its adults and larvae feed on milfoils. Generally speaking, biological control is an effective way to "hold back" harmful species without damaging the ecosystem as a whole.

Insular ecosystems are particularly susceptible to invasive species. Let us take into consideration the case of New Zealand, this big island has been evolving for thousands of years without predators, as a consequence it has now become very susceptible to the introduction of alien species. It is useful here to remind a theory, known as 'biogeography of islands', which explains precisely the dynamics and balances between immigration and extinction of species on islands, meaning by island all ecological habitats separated by the surrounding ones.

Protection of biodiversity

Protection of habitats and ecosystems - As it is commonly acknowledged by many experts, scientists, policy makers and operators who stand for the defence of ecosystems, that it is more useful and profitable to get engaged for the conservation of ecosystems and preservation of biodiversity on a continental scale, rather than fighting small battles to protect only the rarest or most popular species. There is a risk to spend a lot of money in trying to protect species whose populations have been already reduced to such low numbers of individuals that are already genetically doomed to extinction. Moreover, spending huge resources to breed plants or animals in captivity cannot guarantee their future survival, if their natural habitats, suitable to release these species, had already disappeared.
Think to the so called "flagship species", like the mountain gorilla (*Gorilla gorilla beringei*) and the royal tiger (*Panthera tigris tigris*), they are able to breed in zoos and parks, but the ecosystems in which they once lived do not exist anymore.
Another paradox concerns natural reserves; some species are "protected" in these areas, but what actually happens is that adjacent areas, which host a much bigger number of endangered species than the reverses, remain undefended.

To tackle this issue, a new approach called gap analysis has been thought, this focuses on the elaboration of diversity protection plans concerning wider areas, including the whole community or ecosystems, and avoiding any kind of breaks or interruptions inside the protected zone.

Management of endangered species – Over the years we have become gradually aware of the damages that humans and their actions have been causing to the ecosystems, plants and animals with whom we share the planet. National laws and international treaties have become necessary to allow the protection of biodiversity and preserve the health of ecosystems.
Parks, wildlife refuges, nature reserves, recovery programs, have been set up for the sake of nature and to allow the recovery of impoverished populations. If some results have been achieved, a lot is still to be done: starting by clarifying what biodiversity is. Nowadays many people are in favor of the reduction of pollution and protection of endangered species, at the same time investigations have proved that only few understand what biological diversity is and why they should care.
Let's consider the case of American Buffalos. In 1874, a bill envisaging the protection of the American Buffalos was presented to the Congress of the United States, unfortunately at the time, most legislators believed that wildlife, including the American Buffalo and nature in general, was so prolific and abundant that human activities would have never managed to impoverish it. They were clearly wrong. Over 19th Century, the American Buffalos' population had fallen from about 60 million to a few hundred individuals. At that point, many states started issuing laws to protect species and impose restrictions on hunting and fishing. The aim was not to preserve the species for their value and function within the ecosystems, but to safeguard them for human purposes. Still, those laws proved to be effective: thanks to the restoration of natural habitats, sowing of food crops, transfer of reproductive strains, construction of shelters and nests, protection of species during their breeding process and other conservation measures, the populations of some species, including the common turkey (*Meleagris gallopavo*), and the bride duck (*Aix sponsa*), were restored.

Recovery plans of the species - If a species is included in the list of endangered ones, a recovery plan has to be drafted describing in details how these populations should go back to sustainable levels. It shall be necessary to estimate the related costs, foresee policy actions, and be prepared to tackle possible interferences with local economic interests. Moreover, it has to be considered that, if a species is endangered, it is likely that its habitat is compromised, along with its chances to survive. Endangered species often serve as indicators of the state of health of an entire ecosystem and act as "protectors" of others which are less well-known.

A few terms are used to describe species considered

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Our **third example** shows the importance of the sustainable use of ecosystems' resources. Around 500 million people are relying on fish and seashell as their principal source of animal protein. However, more than 50% of global fish stocks are fully exploited and 25% over-exploited, depleted or recovering from depletion. Many fisheries have already collapsed, and others are predicted to do so. It is of high importance that many more marine ecosystems will be put under protection. Nowadays, only 1% of marine environments are protected areas.

Fisherman in the port of Concepción (Chile).
Photo: Andre Künzelmann/UFZ.

rare or endangered:
- **Keystone species**: species with significant effects on the ecological functions and whose elimination would affect many other species of the ecological community;
- **Indicator species**: species related to specific biotic communities, successional stages, or a specific set of environmental conditions;
- **Umbrella species:** species requiring large extents of relatively undisturbed habitats to maintain viable populations. Saving these habitats has normally a positive impact on other species; i.e. the African elephant.
- **Flagship species:** species perceived as particularlyinteresting or attractive, to whom people react in an emotional way. They can trigger a wider interest in the preservation of biodiversity; i.e. the Giant Panda, the WWF's symbol.

A few years ago, species like the alligator of the Mississippi, white-headed sea eagle, peregrine falcon were considered endangered in the United States.

The populations of these species have been registering a remarkable growth since the implementation of recovery plans.
The ESA, the Endangered Species Act, is a US law which has proved to be very effective in protecting endangered organisms. At the same time, this law is not very much liked as it can limit property rights and economic benefits in those pieces of land hosting species threatened with extinction or endangered (the latter ones are those considered to be in imminent danger of extinction, while the first refers to those species which are likely to become endangered in the near future).

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Spruce forest. Photo: Jens Halves.

#5

The **fourth example** deals with the importance of healthy forest ecosystems for water flow regulation.
Forests and forested wetlands impact the timing and magnitude of water runoff and water flows. Some forest ecosystems act as sponges, intercepting rainfall and absorbing water through their root systems. Water is stored in porous forest soils and debris, and then is slowly released onto the surface waters and groundwater. Through these processes, forests recharge groundwater supplies; maintain baseflow stream levels, and lower peak flows during heavy rainfall or flood events.
Scaling down from forests to trees, we see that every single tree provides the habitat for the plant and animal species living on it. It offers lots of natural goods: space to live and rest, food, water and shade. Many of those species compete with each other, eat leaves and fruits, hunt preys, lay eggs in nests or hollows and dig shelters in the trunk or under the tree's roots.

Mangrove forest on Honeymoon Island, Dunedin Florida.
Photo: Egerterson 1222/Wikimedia.

JOIN US
PLAY THE RESEARCH GAME!

There are many other examples of biological diversity. Open your eyes and you will see them just round the corner or on your way to school.

We are sure that you agree on the fact that everyone should participate in saving our resources and biodiversity. We could be much more effective if we knew what we are going to protect.

Become a young researcher! Start with a research question, take samples, gather data and analyse them. Doe this sound too complicated? Don't worry; we will lead you on this way.

Useful links

Anno della biodiversità 2010 http://www.biodiversita2010.ch

Belgian biodiversity platform http://www.biodiversity.be

Biodiversa www.biodiversa.org

Biodiversity knowledge http://biodiversityknowledge.eu/index.php

Convention on Biological Diversity http://www.cbd.int http://www.cbd.int/rio
https://www.cbd.int/doc/strategic-plan/2011-2020/ Aichi-Targets-EN.pdf http://www.cbd.int/sp/targets/
http://www.cbd.int/convention/text http://www.cbd.int/2010/welcome/ http://www.cbd.int/2011-2020/

Diversitas
www.diversitas-international.org

Fondation pour la recherche sur la biodiversité http://www.fondationbiodiversite.fr

International platform for biodiversity and ecosy- stem services
http://www.ipbes.net

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