DG ENV/MSFD Second Cycle/2016

The 11 Descriptors of the Marine Strategy Framework Directive

Background material-scientific game

Authors

This booklet serves as background material to be used in the context of MEDREGION project - Subtask 1.4.3 Dissemination Action.

MEDREGION
SUPPORT MEDITERRANEAN MEMBER STATES TOWARDS IMPLEMENTATION OF THE MARINE STRATEGY FRAMEWORK DIRECTIVE NEW GES DECISION AND PROGRAMMES OF MEASURES AND CONTRIBUTE TO REGIONAL/SUBREGIONAL COOPERATION

The editorial project has been produced by Salento University (Mario Ciotti, Franca Sangiorgio, Alberto Basset).

Find more information on the project website www.medregion.eu

Table of contents

DESCRIPTOR 1

"The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions"

What is biodiversity?

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 already part of it!

Life on Earth is in an amazing spectrum of sizes, colors, shapes, life cycles and interactions. 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.

Do not remove the sea stars out of the water to play with them or show them to our friends, this simple gesture for us can cause a great injures to them. Let's look them with the mask or let's take a nice photograph.

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 the protection of biodiversity is a prior goal to maintain for improving our and wild specie's quality of life. Preserving habitats and species is the first of the descriptors in the Marine Strategy Framework Directive (MSFD).

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 (**rivet hypothesis**).

In rivet hypothesis each species is compared to a rivet; we do not know how many species can be removed before the plane (ecosystem) falls.

If one begins to take them off, convinced that here 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 me 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 o too many rivets from the wings of the plane!

Which are the causes of the loss of biodiversity? The identified causes are essentially five (Barbiero, 2017):

- the destruction of natural habitats of the species;
- the invasion of alien species;
- the pollution;
- the human overpopulation;
- the exploitation of resources.

Marine biodiversity

The range of marine biological life is hard to imagine. Some marine organisms can live in extremely cold environments, such as in sub-zero waters in polar regions, or within sea-ice, whereas others live in extremely hot habitats, such as hydrothermal vents, where cracks in the earth's crust cause geothermal heating of bottom seawater, up to 400°C. Some organisms live in shallow waters, where there is high exposure to sunlight, whereas others thrive in the deep sea, where there is no light at all.

We often see underwater images showing extremely colorful coral reefs, fish and invertebrates. However, marine life starts with tiny bacteria, viruses and single-celled plants, or plankton, which convert energy from the sun and transform it into food for other small animals in the water column.

Penguins are aquatic birds which lives in very low temperature of Antarctica.

Plankton are preyed upon by larger animals, such as small fish and other invertebrates. These in turn constitute the food of mammals, large fish, such as sharks, and reptiles, such as sea turtles.

Extract from European Commission web site:

"…With **Descriptor 1**, the Marine Directive aims to ensure that biodiversity is "maintained", that is, kept in line with the natural state appropriate to the area in question, and also corresponding to the large-scale, on-going climatic changes, which we are unable to regulate…".

DESCRIPTOR 2

"Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems"

What is a non-indigenous species?

Have you ever thought about what would happen if we took an animal from an ecosystem and put it in a new one? This happens continuously all around the world since the human activities favorite the colonization of species in new environments producing negative effects on ecosystems sometimes in unrecoverable way.

Non-indigenous species (NIS) (=introduced species) are defined as "*Any species transported intentionally or accidentally by a human-mediated vector into aquatic habitats outside its native range.*" by the Convention on Biological Diversity (CBD).

Not all the NIS have biological and economics negative effect to the environments, but some of them YES! The later ones are species which became "invasive" since they show a strong adaptation to the new environment such that they win the competition with the native species; they are called **Invasive Alien Species** (IAS)

by the Task Group 2 of MSFW, and defined as "*a subset of established NIS which have spread, are spreading or have demonstrated their potential to spread elsewhere, and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions*".

NIS can arrive to a new area through three broad mechanisms (Hulme *et al.,* 2008):

- **importation of a commodity**. Some species are sold for garden, aquarium, and farming because of their beauty but sometimes they escape or are intentionally released in the environment.
- **arrival of a transport vector**. Ballast water discharge and fouling of ships cover an important role in species invasion since the number and volume of the cargo ships is increasing in last decades.
- **natural spread from a neighbouring region where the species is itself alien**. The natural and artificial infrastructures connecting different areas are also used from wild species, not only from humans; the Suez Canal and the Gibraltar Strait cover an important role in species invasion with migrate respectively from the Red Sea and Atlantic Ocean to the Mediterranean Sea.

Let's see some non-indigenous species

Just in Italy up to **265** marine NIS have been detected, the most representative among them are the following species:

Callinectes sapidus usually inhabits substrate up to 90 meters below the sea level.

- *Lagocephalus sceleratus*, common name silver-cheeked toadfish, is a fish species of the family Tetraodontidae very well known for the toxicity of its meat which can be also lethal for the humans. It is a widespread species in the Indian and tropical Pacific Ocean.
- *Callinectes sapidus*, common name blue crab, is a crustacean species originating from the western Atlantic coasts. It is a species with very aggressive behavior and fast growth which is prevailing on the native crabs and damaging the fish in the net traps and the net itself. In the last decades, the local population increase the use of this species as food due to the goodness of meat.

- The invasiveness of *Ruditapes philippinarum*. has often been a matter of debate; however, there is no scientific evidence to support its ability to displace the native *R. decussatus* (Turolla, 2008). On the other hand, the introduction of *R. philippinarum* is considered the most relevant socio-economic event in Italian shellfish farming. In fact, with a harvest of 50,000 tons/year, Italy ranks second (after China) in the global production of Manila clams, representing 90% of the production in Europe (Turolla, 2008), whereas the Italian production of the native R. decussatus is less than 1,000 tons/year (Turolla, 2007).

Impact of non-indigenous species

NIS can create an ecological impact on natural environments by predation of native species, by competition with them for food or space and by hybridization with them. The introductions of NIS have been accelerated in the last decades by the rapid globalization processes and increasing, in term of quantity for year, of travel and transport. Ecological impacts of NIS, and consequently of IAS, range from single-species interactions, with reduction in individual fitness of native species, to population declines, local extinctions, or changes in community composition, with a final effect on the ecosystem functions (Blackburn *et al*., 2014; Katsanevakis *et al*., 2014).

In order to reach a GES with respect to D2 a large amount of information on abundance, spatial distribution and impacts on native species of freshwater and marine NIS is needed, particularly the alien ones; the main aim of the European Alien Species Information Network (EASIN) is to increase the access to data and knowledge on alien species actually present in European area through web services and tools following internationally recognized standards and protocols.

Extract from Marine Strategy Framework Directive - Competence Centre web site:

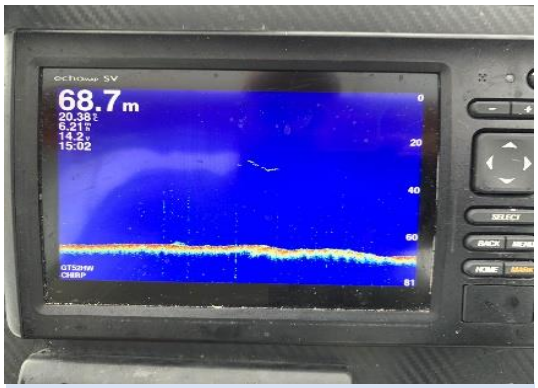
"…This **Descriptor 2** focuses on the assessment of the scale of the pressure and impacts of marine non-indigenous species (NIS) introduced as a result of human activities, in relation to the main vectors and pathways. New introductions of NIS and increases in the abundance and spatial distribution of established NIS should be prevented. It is recognized that there is only limited knowledge about the effects of the NIS on the marine ecosystem, which implies additional scientific and technical development focused on new potentially useful indicators…".

DESCRIPTOR 3

"Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock"

How to catch fish

Often, we can hear from old fishermen how much the sea and the fish's density and size changes respect to the past. The new technologies, as the SONAR and the fish factory vessels, allow to people to catch an impressive number of fishes, affecting fish stocks in the oceans. Fishing is a practice already used by prehistoric men to afford food from the rivers and from the sea. Procuring food resources in the easiest and most constant possible way was and still is extremely important for the development of a society.



Depth Sounder allow to know the depth, the type of seabed, the water temperature and the presence of fish or rocks. In picture is present a marker of a 50 kg tuna hooked few moments after the visualization on the monitor.

The improvement of technologies has allowed this; we have gone from catching fish with a pointed stick (a technique still in use in the most isolated populations) to developing systems that allow us to "see" the fish at a depth of over hundreds and hundreds of meters. Let's see some common technique to catch a fish:

- **Hand-gathering**. Using the hands or some tools like knife to harvest the seabed is a common way to catch crabs, mollusks, and some fish. In America is common the catch of giant catfish using only the hand to keep them from the mouth.

- **Spearfishing**. It is a method of underwater fishing using a spear, harpoon or trident moved by hand or with a mechanical propeller, usually compressed air or speargun rubber. It's a technique which allow to see and choose the prey before acting such as hand-gathering.

- **Netting**. Nets, made by different materials and with different size and smashes, are used to catch many fishes or shrimps. The feature of the nets is realized according to the target species, even if this technique produces an impressive amount of bycatch or direct impact to the seabed (e.g. bottom

trawling). It's the main technique used by industrial fishing.

- **Angling**. Angling is fishing with a hook and either rod and line or hand-held line and can be for both commercial and non-commercial purposes (Pawson *et al*., 2008).

Impact on the Sea

In last decades, the impressive amount of harvesting capacity due to new technologies and consequently to an increasing of food demand bring to face against a serious problem, the decrease of wild fish stock in the oceans. The impact of fishery activity on sea species has been widely described (e.g. Agardy, 2000), it can produce short and long-term effects at different spatial scales on wild population, changing the population abundance and distribution or modifying other parameters such as sex ration and size distribution.

An example of the effect of removal of predators through fishing in wild fish population was found in Kenyan reefs where this remotion led to an expansion of sea urchin population, which a consequently alteration in species diversity and fish biomass (McClanahan and Muthiga, 1988). If we consider the sea as a gigantic forest, we should collect resources with a rate that is slower respect to production rate, if instead this collection rate will override the production rate, we will have a collapse of resources, we have exceeded the **capacity** of the natural system reaching and **overfishing** state.

Some useful definition:

Fishing capacity is the maximum number of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology. Fishing capacity is the ability of a vessel or fleet of vessels to catch fish. (FAO, 1998)

Excess capacity is a short run phenomenon that occurs when a firm produces less than it could under normal operating conditions because of a change in market conditions for input costs, output prices, or, in the case of the fishery, the fish stock abundance (FAO, 2002).

Overcapacity is a long run phenomenon that exists when the potential output that could exist under normal operating conditions is different from a target level of production in fishery such as maximum economic yield or maximum sustainable yield (FAO, 2002).

The concepts of overfishing have their genesis in population dynamics and stock assessment based on a single fish or shellfish target species but in order to optimize the fishing strategy and avoid reaching a "point of no return", many information and attentions should be considered, such as device that help to reduce **bycath**, biological interaction among the species, impact of abiotic factors on species, and last but not temporal scales (Murawski, 2000).

D3 provide three criteria and many indicators in order to assess that the natural populations of all the commercial fish and shellfish are within safe biological limits (Table 1), namely both size range and distribution indicate a healthy stock.

Bycatch is a catch that is either unused or unmanaged. Fishing methods which allow the release of small fishes could help our oceans, rivers, and lakes to maintain the wild population in healthy condition and to preserve the ecosystems functions.

Table 1. Structure of Descriptor 3 according to the European Commission Decision 2010/477/EU. The status of exploited fish or shellfish stocks is identified by three criteria: 1) fishing intensity, 2) stock size and 3) individual size distribution within the stock.

Criterion	**Indicators**
3.1 Level of pressure of the fishing activity	- 3.1.1 Fishing mortality (F) - 3.1.2 Catch/biomass ratio
3.2 Reproductive capacity of the stock	- 3.2.1 Spawning stock biomass - 3.2.2 Biomass indices
3.3 Population age and size distribution	- 3.3.1 Proportion of fish larger than the mean size of first sexual maturation - 3.3.2 Mean maximum length across all species found in research vessel surveys - 3.3.3 95% percentile of the fish length distribution observed in research vessel survey - 3.3.4 Size at first sexual maturation

DESCRIPTOR 4

"All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity".

What is a food web?

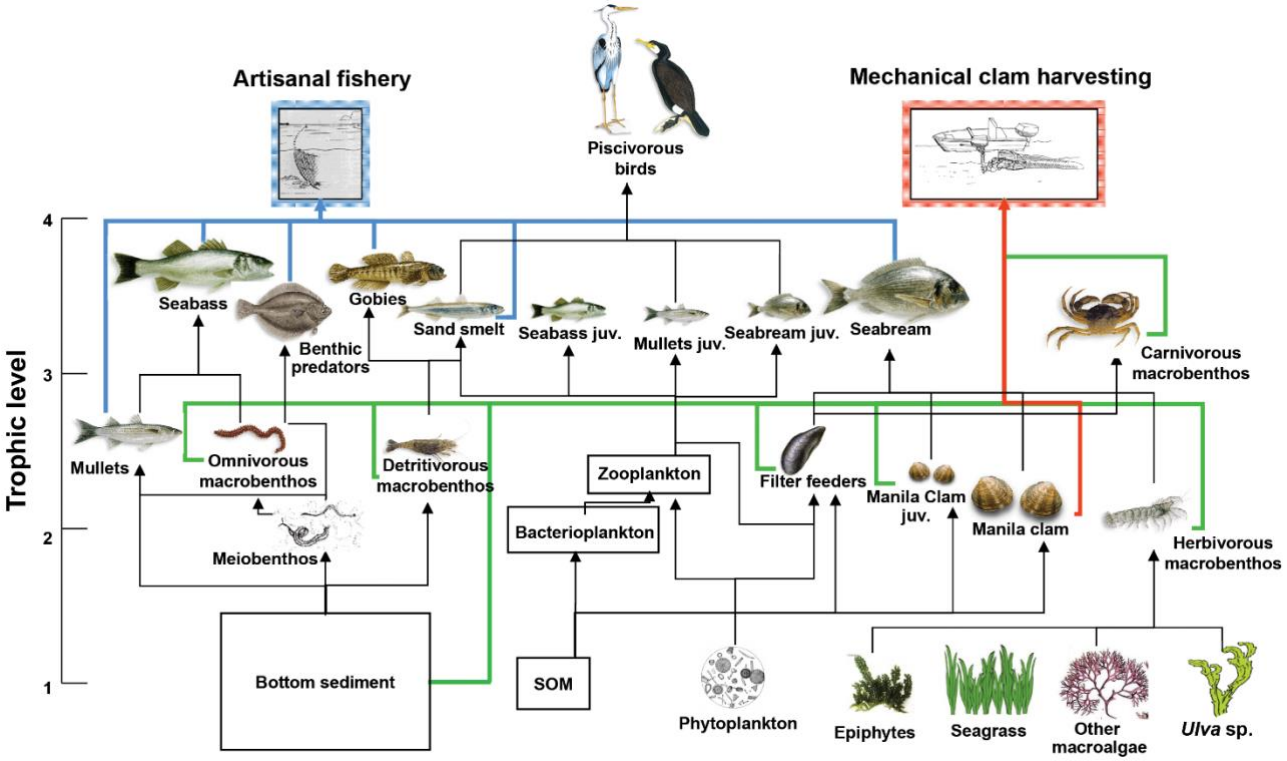
The target of the D4 is similar to the D3 but unlike the previous descriptor, the D4 does not only deal with a single species of fish or shellfish since they are just one element of the food webs.

A **food web** can be defined as "*a network of the overall food relationships between organisms (predators and prey) in a particular environment*". It is a concept, previously known as a **food cycle**, typically credited to **Charles Elton** in his book *Animal Ecology*, published in 1927, who introduced also other important ecological concepts like **ecological niche**.

A food web is usually represented by a "*who eats whom*" diagram in which are present **nodes** and **links**; the nodes represent the species/group of related species and the links, connecting two or more nodes, represent the prey-predator relationships.

We can observe in the figure below a simplified version of the food web of Venice Lagoon, let's go! The energy of the sun is used by *Ulva* (TL=1), a very widespread green algae, to grow up which represent one source of food for macrobenthic herbivorous (TF=2), these small macrobenthic herbivorous are predated carnivorous macrobenthos (TL=3) (*e.g.,* crabs) by which is, in turn, fished and eaten by men.

Trophic level is *"the position of organisms in a food web"*. Each of hierarchical levels in an ecosystem, consisting of species sharing the same function in the food chain and the same nutritional relationship respect to the primary sources of energy.



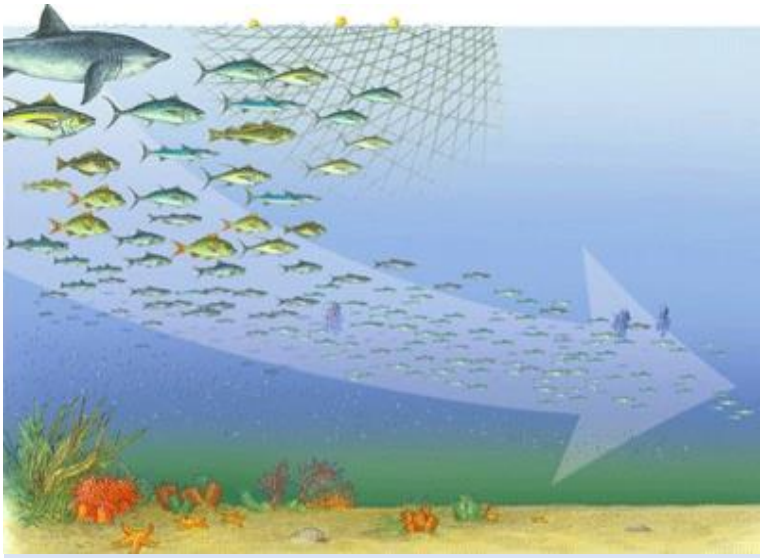
Food web diagram of the Venice lagoon: The same species can have different position in a food web according to the age and the size; smaller seabass can be predated by piscivorous birds while larger seabass is not affected from them. The different colors represent two fishing techniques with the respectively target species (artisanal fisheries in blue, clam fishery in red) and non-target species bycatch during clam harvesting (in green). From Heymans *et al.*, 2014.

Why focus on food webs?

Since all the organisms are directly or indirectly related to each other, the study of food webs is important, first of all to better understand the interactions among organisms and the environments, to decode the energy flow and the circulation of matter in marine ecosystems, and to monitor the accumulation of toxin or pollutants in organisms. The links between species in a food web are complex and changing during time are always happening, in this "unpredictable" situation the two principal anthropogenic pressures on elements of the marine food webs are the excessive *Overfishing* and *pollution*. The consequently changes due to these two disturbance sources will affect the different components (nodes and links) of a food web, through alteration of the population abundance or individual body size and may have an adverse effect on the ecosystem's status.

Overfishing converts an originally stable and efficient ecosystem into one that is stressed, by targeting and reducing the abundance of larger predators, such as tuna, modify the food web and the flows of biomass (and energy) across the ecosystem (*e.g.,* Pauly, 1979; Jackson *et al.*, 2001).

In Overfishing process, fishing activities reduce the stock of fish in a certain area to a level which can be considered unacceptable and dangerous for the species. In addition to the reducing the abundance of certain species, overfishing involves, on a larger spatial scale, a progressive elimination of larger and long-lived species, thus leading to fish stocks composed mainly of smaller and short-lived specie, the size of and the mean of trophic levels gradually decline. This phenomenon is known as **Fishing Down Marine Food Web** (Pauly *et al*. 1998)



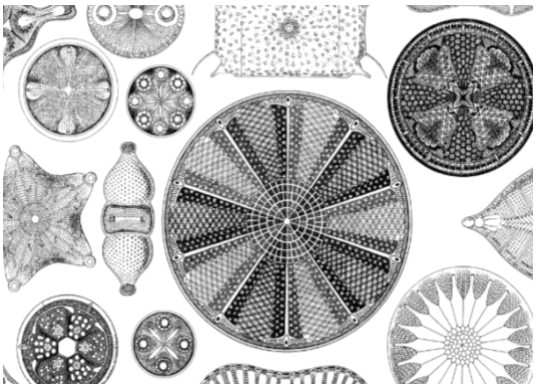
A graphical representation of the **fishing down the food web** process in marine environment (Pauly *et al.*, 1998). Large species (e.g., tuna, shark, blue marlin, …) decrease or disappear and small species, included jellyfish, increase their abundance.

As we can expect, D4 is strictly related to D3, D8, D9 and D10 since the actions to control and reduce the level of fishing activities, contaminats and marine litter are described in these descriptors.

DESCRIPTOR 5

"Human-induced eutrophication is minimized, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters".

What is eutrophication?



Rivers, streams, lakes and coastal areas are threatened not only by chemical pollutants, which are the first things that come to our mind during a discussion about water threats, but also from **eutrophication** which was reported for the first time in 1950s. What is eutrophication? In last decades there were many definitions for eutrophication, in few words is identify as "*the pollution of waters by nutrients (mainly nitrogen and phosphorous)";* in this process there is an increase

of primary production and biomass of algae which may lead aquatic organisms and also human's health. In the last decades there was an increase of global population growth, food production (for agriculture, animal farms and aquaculture), and energy consumption, which is reflected in an increase of sewage discharges and water enriched with chemical fertilizers from agriculture (Smil, 2001); also, atmospheric input is important in nutrients (especially nitrogen) delivery! the atmosphere may contribute up to 40 % of the organic nitrogen inputs in many estuarine and coastal areas (Howarth *et al*., 2002).

Nitrogen and **phosphorus** are naturally introduced in coastal marine areas through the rivers and runoff of rainwater. The increase of human's introduction causes an imbalance of the natural concentration in water with a consequential negative effect on aquatic ecosystems.

This enriched water condition can favorite the uncontrolled growth (**algal bloom**) of aquatic microorganisms, including unicellular algae. Some species of *diatoms* and *flagellates* for example, can cause dangerous blooms by the production of toxins that harm other aquatic organisms and human health. These harmful algal blooms, in the worst case, may render shellfish and fish toxic (affecting in this way their natural predators), or directly cause massive fish and macroinvertebrates kills by **anoxia** producing an impressive amount of natural and economic damage with also transnational implications. There are others negative effects on aquatic ecosystems due to eutrophication, if you are interested to understand all the possible adverse effect of eutrophication check the table below:

Red tide is a phenomenon of harmful algal blooms which occurs when high number (millions of cells per liter) of aquatic microorganisms, such as algae and protozoans, grow out of the control along coastal areas causing the color of the water to turn red, green or brown and anoxic condition that cause death of fish or other organisms.

Table 2. List of the others adverse effect of eutrophication in freshwater and coastal marine ecosystems. Modified from Smith, 2003.

Increase of biomass and changes in species composition of suspended algae, benthic algae and benthic macroalgae
Changes in biomass and species composition of acquatic vascular plants
Displacement of mobile organisms, such as fish
Increase of water column turbidity
Depletion of dissolved oxygen in water
Decreasing of aesthetic values of water body
Decrease of economic value

How coastal eutrophication acts?

We saw briefly the adverse effect of eutrophication, but which are the different steps? Gray in 1992 proposed a realistic model of marine eutrophication processes, describing **five levels** (stages) of ecosystem disturbance starting from the initial effects, where the nutrients arrived in low concentration, to the ultimate effects where the concentration of incoming nutrient is very high. Remember that the nitrogen and phosphorus, when naturally transported in moderate concentration by rivers and streams to coastal areas, favorite the growth of aquatic organisms (1°stage); conversely if the nutrient concentration will continue to increase, there will be in order: changes in algae, and phytoplankton, population's composition as first (2° stage), departure of more sensitive species [such as **juvenile Atlantic cod** (*Gadus morhua*)] and increase of harmful algal blooms (3° stage), mortality of some species and excessive growth of macroalge, as *Ulva* (also known by the common name sea lettuce) (4° stage),and in very extreme case the total dissolved oxygen depletion (anoxia) due to the excessive amounts of organic matter with release of hydrogen sulphide (with a "rot- ten egg" smell) (5° stage).

Ulva sp., commonly known as **sea lettuce**, is a widespread macroalga often involved in blooms.

What have we done?

Since many decades the European Region has been promoting the reduction of the use and discharge of nitrogen and phosphorous compounds into the environment.

The *Nitrates Directive - ND* (1991/676/EEC) aims to protect the quality of European waters preventing the pollution of water through the identification of "*Nitrate Vulnerable Zones*"(NVZ) and raising awareness and encouraging the use of new " *environment friendly*" techniques such as the treatment of wastewater from agricultural and farming sources.

In the same year was established the *Urban Waste-Water Treatment Directive - UWWTD* (91/271/EEC) concerning the treatment and discharge of urban wastewater, industrial wastewater and run-off water. It aims "to protect the environment from adverse effects of wastewater discharges from cities and "certain industrial sectors".

In 2000, the *Water Framework Directive - WFD* (2000/60/EC) commits European member states to achieve good qualitative and quantitative status of all waters by 2015. One major goal of the WFD is the restoration of a good ecological status - GES in all waters, which includes the protection of the waters from eutrophication.

Further, the MSFD provide criteria and indicators to identify if for example the levels of nutrient concentrations and dissolved oxygen concentration have a value which indicate that there is no eutrophication process acting.

DESCRIPTOR 6

"Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected"

The life on the Sea-floor

When someone is asking us about marine life most of the people think to the water column forgetting that an impressive number of species lives near or closely related to the sea-floor (seabed). Swimming with a mask is easy to recognize several bottom types such as rocky sea-bottoms and sandy bottoms; the types of species are depending on the different characteristics of the sea-floor.

Sea-floor is a key compartment for marine life. It includes both the physical and chemical parameters of seabed (e.g. bathymetry, roughness (rugosity), substratum type, oxygen supply, etc.) as well as the biotic composition of the benthic community. Different kinds of habitats for sedentary and mobile marine species are formed inside and above the seabed.

a) Rocky Sea-bottoms

In rocky sea-bottoms is possible to find an explosion of life and colors, the presence of different types of dominant algae (green in shallower layers, brown in intermediate layers and red in deeper layers) offers food and shelter in abundance to hundreds of species of fish, mollusks and crustaceans. Organisms such as white bream, snapper, grouper, scorpion fish, blenny, and octopus, colonize these environments often camouflaging with stones and algae.

Camouflage can help animals to remain unnoticed by predators or prey. Let's find the fish (*Serranus cabrilla*) in the picture.

b) Sandy Sea-bottom

The sandy bottom is, composed of granules ranging from 2 to 1/16 millimeters mixed also with small stones, can seem a lifeless environment if you look too quickly BUT nothing could be more wrong! Most of the organisms present are excellent diggers or have camouflage colors, just think to the sole, the weever, the sand

crab, the clams and the lugworm, a marine worm very well-known and used by fishermen. On sandy bottoms we also find the Posidonia meadow, which plays important ecological roles; it acts as a refuge and food source for many species, it also decreases the erosion of beaches and helps oxygenate the coastal environment.

Biogenic habitats

An important role in marine environment is covered by biogenic habitats which are habitats created by plants and animals which have a large variety in size and structure. Among these habitats we have coral reefs, worm reefs, marsh grasses and oyster beds. All these biogenic habitats provide cover many ecological functions for an impressive variety of species, making their protection an essential step of the conservation of marine diversity.

Posidonia oceanica, an endemic species of the Mediterranean, is declining in different areas due to pollution, ship anchoring, trawling, and hydrogeological alterations caused by the construction of artificial reefs and ports. The habitat of *Posidonia oceanica* is protected by the Habitat Directive (92/43/EEC) and is classified as a highly threatened priority habitat.

Potential impacts on the Sea-floor

Descriptor 6 focus on the safeguard benthic ecosystems but how can be preserved such ecosystems so variable in structures? Let's remember that human activities which can impact on the sea-floor integrity differ between inshore and offshore environments mainly due to the depth (Rice et al., 2012).

In inshore environments, some of the main disturbance sources are:

- Fishing
- Eutrophication
- Dumping
- Extraction of sediments
- Port dredging
- Hydrocarbon exploration
- Pollution events

Effect of bottom trawling on a *Lophelia pertusa* grounds at a depth of 200 m. L. pertusa is a reef building, deep water coral Critically Endangered for IUCN red list. Photo from Hall–Spencer and Allain, 2002.

In offshore environments, the main anthropogenic disturbance which is affecting the sea-floor is bottom trawling. Bottom trawling is a form of fishing which is affecting marine ecosystems by destruction of non-target benthos. This fishing technique, even if acts on a local scale, have a relevant ecological effect since most of the marine organism depends on a specific habitat-substrate according to their life cycle stage. Although the damage caused in shallower coastal waters has been well documented, less is still known about the effects of deeper trawl activities (Hall–Spencer and Allain, 2002; Jones, 1992).

Let's see another example, the harvesting of *Lithophaga lithophaga*, an edible marine bivalve, is illegal since it is necessary to break the carbonate rocks in which it lives (it protects itself from predators by digging into carbonate rocks). The destruction of the rocks produces a habitat loss and a consequent decrease of the species in that barren area.

DESCRIPTOR 7

"Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems"

The life on the Sea-floor

Descriptor 7 focus on hydrographical conditions of the Seas and Oceans. Its study includes bathymetry, shape and property of shoreline, currents, tides, and waves, including the chemical–physical characteristics of the water, such as temperature, salinity, PH and turbidity.

Chemical–physical characteristics of the water determine, with other factors, the distribution of marine species, and the dispersion of some life's cycle stage (many organisms exploit marine currents to colonize new environments).

In order to understand if alterations of hydrographical conditions by anthropogenic activities can cause, directly or indirectly, a negative impact on marine species, long-term data acquisition are needed especially if the studied area is a wide area; the management and the monitoring of the well-being status of a 100 Km2 marine area is simpler respect to control larger areas, such as an Ocean.

The amount of **in situ** measurements and **satellite** observation are much and much larger in the second case.

The size of the areas is not the only parameter which determines the complexity in monitoring marine areas, coastal areas for example have a high variability due also to the proximity of the land. The rivers input and runoff of rainwater bring to marine waters an impressive amount of nutrient and sediment, although the last one is decreasing in last years for the dams.

Hydrography is "*the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defence, scientific research, and environmental protection*" (IHO, 2009).

Permanent hydrographical alteration can occur, and their degree depends on the degree of anthropogenic modification and the period over which such change occurs. These alterations are usually caused by infrastructure building activities, such as extensions or alterations to the coast with breakwater, or the building of artificial islands and other infrastructural works such as power stations and offshore installations.

Pressures on hydrographic conditions

Man has changed and altered terrestrial and marine environment over the millennia to benefit, often without worrying about the consequences that his actions would have. Fortunately, in the last decades there is a greater interest in reversing this trend, even if there are still many sources of disturbance that can have a negative impact on a local scale in marine environment.

Let's see some of them:

- Infrastructure construction on the coast and offshore, that can also generate underwater noise;
- Artificial channel creation, that alters the water circulation and may favorite alien species entrance;

- Navigation channel dredging, that can remove physically species and create anoxic condition;
- Maritime traffic, that can modify normal route of marine species, as whales;
- Sand extraction, that can create anoxic condition in the surrounding area;

Recent studies provide information on the impacts of dredging pits on surrounding hypoxia. Is well known how low dissolved oxygen concentration can change the structure of the species which lives on the sea-floor (e.g. Thompson *et al.*, 2021).

- Changes in freshwater inputs, that can alter the nutrient inputs;
- Decreasing of solid matter from rivers; that favorite the erosion of beaches.

DESCRIPTOR 8

"Contaminants are at a level not giving rise to pollution effects."

Fighting contaminants

The rapid growth of human populations in proximity of waters has led an increasing amounts and numbers of chemical elements and compounds in lakes, rivers, streams and coastal environments.

The growing interest in this topic and the negative effects of these compounds on the environment have led to the introduction of strict rules and inter-regional directive in recent decades. In 2000, with the Water Framework Directive these **hazardous substances** were identified and regulate across the European Union and a clear list and definition of these hazardous substances (**contaminants**) were found: "substances or groups of substances that are toxic, persistent and liable to **bio-accumulate**, and other substances or groups of substances which give rise to an equivalent level of concern".

Sources of contaminants

Most of the contaminants found in the marine environment derives from pesticides, anti-foulants, heavy metals, pharmaceuticals and organic compounds (especially nitrogenous and phosphorous compounds). They can derive from an impressive number of anthropogenic sources such as:

- Land based industry and farming

- Aquaculture;
- Pollution produced by ships;
- Extraction of fossil fuels (oil, gas, coal);
- Pollution produced by ships.

Marine biofouling can be defined as *"the unpleasant accumulation of species (microorganisms, animals and algae) on artificial surfaces in sea water"* that cause high frictional water resistance, deterioration of the coating and introduction of species into environment. On the other hand, **Anti-foulants** paints prevent these accumulations but they are composed by pigments, solvents, metals, and organic and organometallic **biocides** which are reported to be extremely toxic also for marine ecosystems.

There are also natural oceanographic and geological factors, (e.g. submarine eruption), that can be responsible for the increasing of contaminants (such as heavy metals).

Effects of contaminants

Contaminants can potentially degrade the quality of marine waters and can damage marine ecosystems functioning in multiple pathways and intensity (i.e. acute or chronic): modifying the respiration and oxygenation structures, decreasing the individual growth rate, altering the normal physiology of species.

In some cases, since the contaminant is diluted from volume of the seas and oceans, can happens that pollution incidents may not be detectable in shot-time but only after the appearance of negative effects due to the chronic exposure.

In very acute situations contaminants can increase the mortality of sensitive species, decreasing the overall biodiversity, which in turn, consequently in a decrease in ecosystem functioning (e.g. Cardinale *et al.*, 2012)

Habitat-forming species are *"spatially dominant species that create a complex matrix in which smaller organisms can refuge from predators".* The presence of these species in benthic habitats favorite species richness and ecosystem functions.

In some other case, contaminants cause of diseases in endocrine systems, which consequently affect adversely the individuals of marine organisms.

Lastly, contaminants are particularly fatal for species which live on the sea-floor

such as habitat-formers species and the species depending from them. Coral reefs, seaweeds, plants and bivalves are common habitat-formers in the overall marine systems and represent the most diverse and valuable habitats (Costanza *et al.*, 2014).

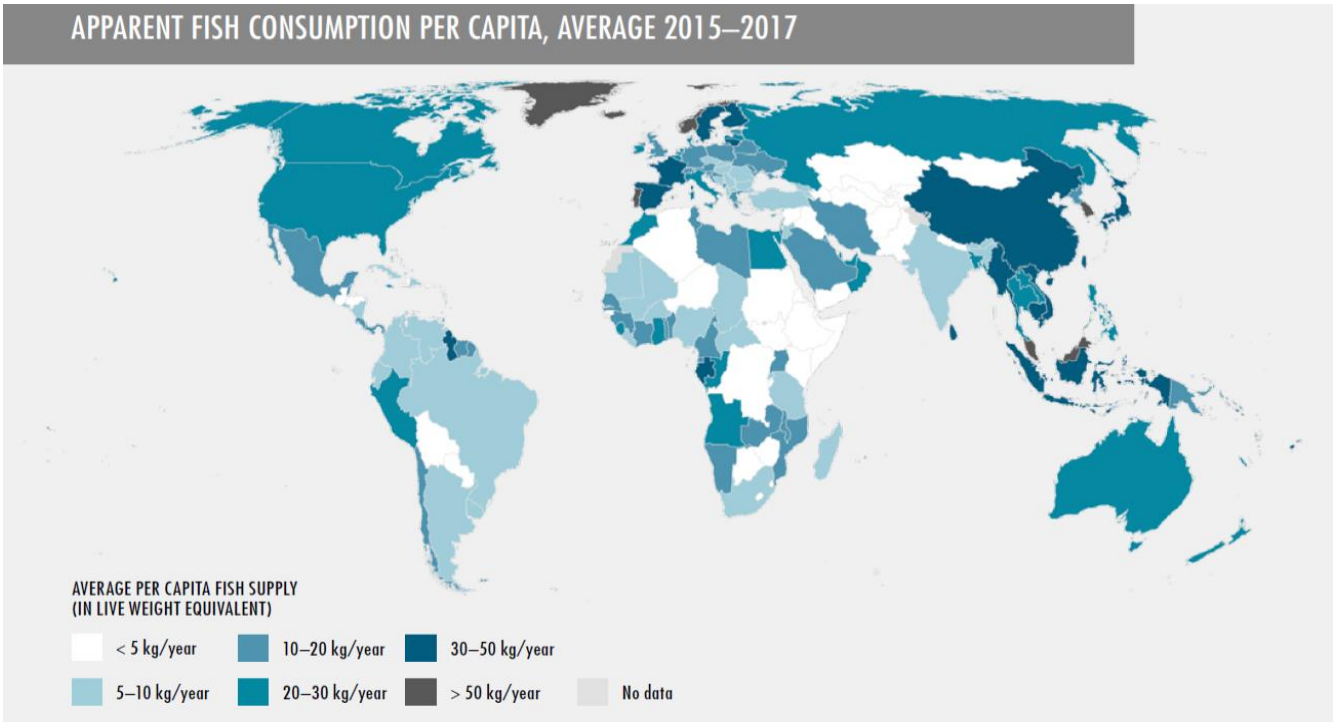
More knowledge is being gained about the impressive negative effects that contaminants have in both fresh and marine ecosystems. In addition to the monitoring, the total amount of the most harmful compounds must be reduced in favor of more ecological and less negative impacting solutions.

DESCRIPTOR 9

"Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards"

Fish and seafood

Descriptor 9 is closely related to descriptor 8, it focusses on contaminants in marine ecosystems since marine fish and other seafood (e.g. crustaceans, mollusks) cover important role for human. The seafood consumption is not homogeneous around the world but depends on several geographical features; actually, Japan, the United States of America and Europe have the the higher proportion of seafood consumption.



Monitoring and reducing the quantities of hazardous substances in the oceans is necessary and especially helpful for our health. A large amount of food from the sea is consumed all over the world. If the hazardous substances enter in the oceans, they may also pollute aquatic organisms and end up in our dishes. In the image above it is represented the consumption per capita all around the World, from FAO, 2020.

Accumulation of contaminants in seafood

How is seafood consumption related to contaminants? Simple, the previously definition of contaminants refers to compounds that bio-accumulate, namely that enter in the body of organisms. These compounds may enter and accumulate in the body of aquatic organism while they are eating or breathing, mainly from the mouth, skin, gills and digestive organs, this process, that is happened not only in marine environment but also in the terrestrial one, is known as bioaccumulation. Unfortunately for us the situation is more complicated, the contaminants are assimilated by the organisms they go up in the food web, (which we have seen previously) and become more and more

Biomagnification is the process by which contaminants are passing from one trophic level to the next one. Tunas may have higher levels of heavy metals respect to sardinian fish.

concentrated in organisms; we are in front of a **biomagnification** process.

For better understand, a tuna will have a higher concentration of contaminants than its prey, that's why its consumption is recommended to few times for month. Remember that "**We Are What We Eat**".

Most of the anthropogenic sources that we sow previously in descriptor 8 increase levels of contaminants in tissue of fish and seafood.

Contaminants contained in food are defined by the article 1 of legislation Regulation (EEC) No 315/93, subsequently updated, in as *"any substance not intentionally added to food which is present in such food as a result of the production (including operations carried out in crop husbandry, animal husbandry and veterinary medicine), manufacture, processing, preparation, treatment, packing, packaging, transport or holding of such food, or as a result of environmental contamination"*.
The maximum levels of contaminants in edible tissue follow Commission Regulation (EC) N. 1881/2006, moreover the contaminants absent in this Regulation should be established through regional or subregional cooperation.

Maintain the maximum levels of contaminants in edible tissue of fish and seafood lower respect to the levels in regulatory EC is one of main goal to reach GES.

DESCRIPTOR 10

"Properties and quantities of marine litter do not cause harm to the coastal and marine environment"

Marine litter

Every year millions of tons of litter produced mostly from land-based activities enter in the oceans. Most of the waste that we produce reaches the oceans through improperly discarded or from wind and run-off of the rivers.

Marine litter (marine debris) is a huge problem and threat to marine life. Many marine mammals, seabirds and fish die each year from being entangled in or ingesting marine litter.

The garbage that we are not wasting correctly enters into the marine environment causing health problems to all the aquatic animals, including marine mammals and birds. They can be trapped in lost or abandoned fishing nets and some species, as sea turtle and birds, may mistakenly eat garbage getting choked.

Marine litter often consists of abandoned nets, packaging material and plastic containers. Ropes and nets can also be dangerous to large marine animals, such as seals, whales and dolphins, and cause deep cuts in the skin; many whales were found with long nets tangled to their tail or fins. In addition, many marine animals

and seabirds eat plastic since they mistake plastic litter for food, which can cause obstructions in the respiratory and digestive tracts.

The **marine litter** is defined as *"any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment"* according to the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA).

Main sources of marine litter:

One common way to categorize the origin of marine litters is the division between **sea-based** and **land-based** input (Veiga *et al.*, 2016).

The sea-based origin refers to the litter that is **directly** released into the seawater by any maritime activities:

- Shipping;
- Fishing;
- Offshore installations;
- Dumping of refuse at sea.

Land-based origin refers to activities which produce litter directly on the coast (e.g. beach tourism), but also to the litter produced in areas and successively arrived to the sea by anthropogenic or natural causes;:

- Industry;
- Littering produced on beaches and coastal areas;
- Illegal dumping into the marine water;
- Discharging of land litter thought rainfalls and rivers.

The fishing industry accounts for 10% of marine litter around the world. Nets and fishing gear (lost or thrown away into the ocean) became **ghost nets** which continue trapping fish for many decades.

Plastic and microplastic

Marine litter is mainly composed by **plastic**, due to the common use in industry and the high persistence of synthetic polymers in the marine environment. In addition to the negative effects listed in previous paragraphs, another problem of plastics is their fragmentation in smaller piece, this can occur through solar UV-radiation (**photodegradation**) and physical damage such as impact with the coast.

Microplastics are *"small pieces of plastic litter with diameter smaller than 5 millimeters"*. They can be ingested by aquatic animals, from the smallest to the largest, and transferred throughout the food webs, this was observed in many laboratory studies (e.g. Setälä *et al.*, 2014).

Independently from the size, in order to reach the GES is necessary to know the composition, the amount and the spatial distribution of litter (and microlitter) on the coastal area, in the all the water layer including the sea-floor.

DESCRIPTOR 11

"Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment"

Energy?

Descriptor 11 is focusing on the introduction of **energy** in marine environment; it is referring not only to electricity but also to underwater noise, light, heat pollution and radio waves. This descriptor includes an impressive amount of heterogeneous group that can be difficult to associate, let's see together some examples to understand.

- The first example is the building of foundations for an **offshore platform**; during pile-driving procedure is released an impressive amount of energy (as noise and vibrations) which is audible from marine organisms also from more than 30 km distance.
- Another example is the warm water produced by thermal power plants and nuclear power plants that need to cool power generation equipment. That warm water may alter the local community of marine organisms.
- Also the underwater noise produced by the engine of vessels disturb marine organism which try to avoid the most common navigation routes.

Main sources of energy in marine environment

There are many sources of anthropogenic activities that introduce energy into marine water mainly related to our benefit such as fishing, transport, mining and construction. Let's see some sources of energy:

- Shipping for transport, tourism, recreation boats and fishing boats produce noise thought their engine systems;
- The use of SONAR (Sound Navigation and Ranging) during navigation;
- Construction of buildings in marine environment (e.g. offshore oil and gas platforms);
- Research for fossil fuels in to the water;
- Cooling water systems for industry;
- Military activities.

Let's focus on underwater noise

Many aquatic species are able to generate and detect sounds in nature, such as marine mammals, fish and crustaceans (e.g. Popper *et al.*, 2004). It's common to find videos in which dolphins or whales communicate to each other using vocalization. They use sounds to locate and catch food, to coordinate each other, attract mates, to ward off predators. The sound is used also to recognize a habitat, many larvae recognize the coral reef where they need to go and placed (Vermeij *et al.*, 2010).

From an ecological perspective, **underwater noise** can be defined *"a sound characterized by high level of vibrational disorder that masks other sounds and that negatively affects wild organisms"*.

Since natural sounds are so important for organisms, underwater noise can be considered as the most dangerous form of energy.

As we previously explain, the reef sound is used by larvae of fish and invertebrate to orient during the first period of their life. A simple boat noise may disrupt this

crucial process, exposing these organisms to higher predation risk (Holles *et al.*, 2013).

Descriptor 11 provide that each member state shall consider the spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources in order to maintain as lower as possible the introduced energy in marine environment.

References

Agardy, T. (2000). Effects of fisheries on marine ecosystems: a conservationist's perspective. ICES Journal of Marine Science, 57(3), 761-765.

Barbiero, G. (2017). Ecologia affettiva. Come trarre benessere fisico e mentale dal contatto con la natura. Milano, Mondadori.

Blackburn, T. M., Essl, F., Evans, T., Hulme, P. E., Jeschke, J. M., Kühn, I., et al. (2014). A unified classification of alien species based on the magnitude of their environmental impacts. PLoS biol, 12(5), e1001850.

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., et al. (2012). Biodiversity loss and its impact on humanity. Nature, 486(7401), 59-67.

Costanza, R., De Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., et al. (2014). Changes in the global value of ecosystem services. Global environmental change, 26, 152-158.

FAO. (1998). Report of the Technical Working Group on the Management of Fishing Capacity. La Jolla, United States, 15-18 April 1998. FAO Fisheries Report No. 586. Rome, FAO.

FAO. (2002). Report of the Expert Consultation on Catalysing the Transition Away from Overcapacity in Marine Capture Fisheries - Rome, 15-18 October 2002. FAO Fisheries Report No. 691. Rome, FAO.

FAO. (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en

Gray, J. (1992). Eutrophication in the sea. pp. 3–15. In: Colombo, G., Ferrari, I., Cecherelli, V.U. and Rossi, R. (Eds.). Marine Eutrophication and Population Dynamics. Olsen and Olsen,Denmark.

Hall–Spencer, J., Allain, V., & Fosså, J. H. (2002). Trawling damage to Northeast Atlantic ancient coral reefs. Proceedings of the Royal Society of London. Series B: Biological Sciences, 269(1490), 507-511.

Heymans, J. J., Coll, M., Libralato, S., Morissette, L., & Christensen, V. (2014). Global patterns in ecological indicators of marine food webs: a modelling approach. PloS one, 9(4), e95845.

IHO. (2009). Proposal to Approve New Definition of Hydrography; in: IHO: 4th Extraordinary International Hydrographic Conference, June 2–4, 2009, Monaco, Report of Proceedings; pp. 38–40, Monaco, IHB – International Hydrographic Bureau.

Katsanevakis, S., Wallentinus, I., Zenetos, A., Leppäkoski, E., Çinar, M. E., Oztürk, B., et al. (2014). Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. Aquatic Invasions, 9(4), 391-423.

Holles, S., Simpson, S. D., Radford, A. N., Berten, L., & Lecchini, D. (2013). Boat noise disrupts orientation behaviour in a coral reef fish. Marine Ecology Progress Series, 485, 295-300.

Howarth, R. W., Sharpley, A., & Walker, D. (2002). Sources of nutrient pollution to coastal waters in the United States: Implications for achieving coastal water quality goals. Estuaries, 25(4), 656-676.

Hulme, P. E., Bacher, S., Kenis, M., Klotz, S., Kühn, I., Minchin, D., et al. (2008). Grasping at the routes of biological invasions: a framework for integrating pathways into policy. Journal of Applied Ecology, 45(2), 403-414.

Jackson, J. B., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., ... & Warner, R. R. (2001). Historical overfishing and the recent collapse of coastal ecosystems. science, 293(5530), 629-637.

Jones, J. B. (1992). Environmental impact of trawling on the seabed: a review. New Zealand Journal of Marine and Freshwater Research, 26(1), 59-67.

Katsanevakis, S., Wallentinus, I., Zenetos, A., Leppäkoski, E., Çinar, M. E., Oztürk, B.,et al. (2014). Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. Aquatic Invasions, 9(4), 391-423.

McClanahan, T. R., & Muthiga, N. A. (1988). Changes in Kenyan coral reef community structure and function due to exploitation. Hydrobiologia, 166(3), 269-276.

Murawski, S. A. (2000). Definitions of overfishing from an ecosystem perspective. ICES Journal of Marine Science, 57(3), 649-658.

Pauly, D. (1979). Theory and management of tropical multispecies stocks: a review, with emphasis on the Southeast Asian demersal fisheries.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., & Torres, F. (1998). Fishing down marine food webs. Science, 279(5352), 860-863.

Pawson, M. G., Glenn, H., & Padda, G. (2008). The definition of marine recreational fishing in Europe. Marine Policy, 32(3), 339-350.

Popper, A. N., Plachta, D. T., Mann, D. A., & Higgs, D. (2004). Response of clupeid fish to ultrasound: a review. ICES Journal of Marine Science, 61(7), 1057-1061.

Rice, J., Arvanitidis, C., Borja, A., Frid, C., Hiddink, J. G., Krause, J., et al. (2012). Indicators for sea-floor integrity under the European Marine Strategy Framework Directive. Ecological indicators, 12(1), 174-184.

Servello, G., Andaloro, F., Azzurro, E., Castriota, L., CATRA, M., Chiarore, et al. (2019). Marine alien species in Italy: a contribution to the implementation of descriptor D2 of the Marine Strategy Framework Directive. Mediterranean Marine Science, 20(1), 1-48.

Setälä, O., Fleming-Lehtinen, V., & Lehtiniemi, M. (2014). Ingestion and transfer of microplastics in the planktonic food web. Environmental pollution, 185, 77-83.

Smil, V. (2001). Enriching the earth: Fritz Haber, Carl Bosch, and the transformation of world food production. MIT press.

Smith, V. H. (2003). Eutrophication of freshwater and coastal marine ecosystems a global problem. Environmental Science and Pollution Research, 10(2), 126-139.

Thompson, L., Maiti, K., White, J. R., DuFore, C. M., & Liu, H. (2021). The impact of recently excavated dredge pits on coastal hypoxia in the northern Gulf of Mexico shelf. Marine Environmental Research, 163, 105199.

Turolla, E., 2007. Atlante dai Bivalvi dei mercati italiani. Grafiche Adriatica, 95.

Turolla, E. (2008). L'allevamento della vongola verace nel Delta del Po. Grafiche Adriatica, Taglio di Po, 111.

Veiga, J. M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., et al. (2016). identifying sources of marine litter. MSFD GES TG Marine Litter Thematic Report. JRC Tech Rep (EUR28309 EN).

Vermeij, M. J., Marhaver, K. L., Huijbers, C. M., Nagelkerken, I., & Simpson, S. D. (2010). Coral larvae move toward reef sounds. PloS one, 5(5), e10660.

Useful links

- Convention of Biological Diversity (CBD):

www.cbd.int/

- European Alien Species Information Network (EASIN):

https://easin.jrc.ec.europa.eu/easin

- European Commission:

www.ec.europa.eu

- FAO - The State of World Fisheries and Aquaculture 2020:

http://www.fao.org/documents/card/en/c/ca9229en/

- International Hydrographic Organization (IHO):

https://iho.int/

- Marine Strategy Framework Directive - Competence Centre:

https://ec.europa.eu/environment/marine/good-environmental-status/

- MEDREGION Web site:

www.medregion.eu

- The Nitrates Directives (ND):

https://ec.europa.eu/environment/water/water-nitrates/index_en.html

- Marine sustainability in an age of changing oceans and seas:

https://mcc.jrc.ec.europa.eu/documents/201605032025.pdf

- Water Framework Directive (WFD):

https://ec.europa.eu/environment/water/water-framework/index_en.html

- Regulation (EC) N. 1881/2006 for contaminants in foodstuffs:

https://eur-lex.europa.eu/legal-content/IT/ALL/?uri=celex:32006R1881

MEDREGION

SUPPORT MEDITERRANEAN MEMBER STATES TOWARDS
IMPLEMENTATION OF THE MARINE STRATEGY FRAMEWORK DIRECTIVE
NEW GES DECISION AND PROGRAMMES OF MEASURES
AND CONTRIBUTE TO REGIONAL/SUBREGIONAL COOPERATION

Contacts: mario.ciotti@unisalento.it
franca.sangiorgio@unisalento.it