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Potential Hazards and Threats on the Stability of the Ecosystem emanating from Global Change(WP2)

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Introduction

The Mediterranean and the Black Sea, due to their relatively small size, are very responsive to stresses that would affect oceanic basins at a much slower pace. Over the next decades, while pressures on ecosystem are expected to rise, it is imperative to predict possible scenarios depicting the future state of the two seas since they will probably reflect the future state of the world ocean.

The evaluation of a described pattern, after the identification of the processes leading to it, should be done by using the “tools” provided by ecological theory, so to take scientifically sound decisions about our future behaviour. The present report, thus, is aimed at putting the findings reported in Deliverable 1 into a theoretical framework, so to develop a series of evaluations and projections on the possible future of SES.

Past and present policies of the European Union are based on key concepts, stemming from prevailing theories. Popular examples are: the precautionary principle, the ecosystem approach, the importance of habitats for biodiversity management and protection. A leading perception of the value of biodiversity, stemming from ecological economics, is not linked to its intrinsic value but on the benefits that we might draw from it, in terms of goods and services. Ecosystem stability is perceived as one of the advantages deriving from conservation, so to have a constant flow of benefits from the protected environment. The concept of stability, however, has been challenged in its generality since several decades.

The concept of stability

Ecosystem stability is seen as a “good” property of the environment, implying that there is a “good” state of ecosystems, usually identified with the amount of goods and services that they provide us. A stable ecosystem, thus, is an ecosystem that can be steadily exploited, while respecting the turnover of the resources extracted from it. A sister concept to this assumption is that human impact is the only perturbation to ecosystem stability. If man were not impacting on ecosystems, they would remain stable. The paradigm of this attitude is the conceptual basis of fisheries research. Before the recent application of the ecosystem approach, fisheries research considered just the target species (the resource) and man (the impact). The case of *Mnemiopsis* in the Black Sea clearly shows that this approach to fisheries science is simply wrong. It is true that man introduced *Mnemiopsis* in the Black Sea but, after its arrival, the ctenophore alone exerted a higher pressure on fish populations than industrial fisheries. Evidently, there are other forces that can cause shifts in ecosystem functioning, besides those of man.
The concept of stability is based on a twin concept: climax. Climax is the core of equilibrium ecology and stems from empiric observation on the state of temperate, terrestrial ecosystems and communities. The temperate forests, dominated by one or few tree species are a textbook example of climax communities. In these cases, few long-lived species dominate the landscape and form themselves the core of the communities.
Ecology started its history with the description of ecological patterns and processes in temperate areas of the northern hemisphere, and the stability found there (in form of climax communities) influenced the general principles drawn from these observations. In the Seventies of the last century, however, the generalization of studies from tropical areas led to non-equilibrium ecology, with an opposite view to the one envisaging the climax as the

"optimal" state for a community. The study of tropical rain forests and coral reefs, in fact, led to the identification of the importance of diversity. Diversity, in these communities, is just the contrary of the dominance of few, monopolizing species (just as those of climax) and intermediate disturbance is seen just as a positive impact on the systems, preventing monopolization of communities by few species. Non-equilibrium ecology, thus, identifies three main states of communities. A high-disturbance state (i.e. stressed), dominated by few opportunistic species, an intermediate-disturbance state, dominated by high diversity allowing co-existence of specialist and opportunistic species, and a low-disturbance state, dominated by few specialized and long-lived species. For the sake of biodiversity, thus, the intermediate-disturbance state is the most conducive to high levels of species coexistence. The coexistence of species with different ecological features, furthermore, allows a given community to face nearly all types of conditions, since the pool of species represents all the possible answers to all possible potential regimes of disturbance.

The two expectations (the stability of climax and the instability of intermediate disturbance) are not mutually exclusive. Stability is more appropriate to describe high latitudes (usually with a low diversity); instability is more appropriate to describe low latitudes (usually with a high diversity).

From land to sea

These leading (and contrasting) views mostly derive from land-based studies. Their transfer to the sea requires some adjustment. The main difference between terrestrial and marine environments resides in the structure and function of landscapes. On land, plant cover is the backbone of the landscape, with a very high stability due to the long life of the leading species (e.g., trees). In the sea, primary production is performed mainly by protists that do not form landscape and that are characterized by fast turnover and short life cycles. The only part of marine communities that look like terrestrial ones are the rocky bottoms, where long-lived species (algae, sponges, cnidarians, bryozoans, molluscs, tunicates) are a constant feature of the environment (it is not surprising, thus, that we institute Marine Protected Areas on rocky bottoms). Soft bottoms, on the contrary, are usually colonized by faunas with fast turnovers, unless they are inhabited by sea grasses.

In the case of marine habitats, thus, stability is not the same as for terrestrial ones. A sister concept to stability is more applicable to the marine environment: multiple stable points. Stability, according to this view, is both dynamic and recurrent. It is true that the spring bloom of plankton is an episode in the yearly story of the ecosystem, but its occurrence is regular every year, representing a sign of stability. Trees lose their leaves and produce new ones at the onset of the following favourable season, their stability is evident by the presence of their trunks; phytoplankton is stable due to the quantity of resting stages in bottom sediments, leading to the following bloom.

The modelers of the dynamics of systems with fast turnovers, furthermore, developed another concept: the lottery model. It applies very well to the case of plankton. There is a prize to win, in terms of nutrients for phytoplankton, and of phytoplankton for planktonic grazers, and so on, and there are many tickets, each represented by a species. Every year, the winning ticket(s) of the lottery can change, with shifts in the dominance of the system by temporarily leading species. This is almost the rule with plankton, but the same is apparent from long-term fisheries series. The rapid turnover of resources, when a system is characterized by high diversity, usually leads to great changes in the structure of the system. Abundant species become rare, rare species become abundant. The perception of these changes is usually linked to a decrease in stability, unless a less profitable abundant species is replaced by a profitable and formerly rare one. In this case, instability is “good”.

A single European policy?

The leading concepts of ecology, we have seen it, were mostly developed from observations on terrestrial communities based in the temperate to cold part of the northern hemisphere. When transferred to the sea, these studies were mostly carried out in the intertidal zone of temperate regions. The relative simplicity of these systems (with few species represented by great biomasses) is conducive to the identification of principles and models. These models and principles became general, i.e. they were applied also to regions that do not share these features. The Southern European Seas, for instance, are characterized by very small tides and by a high number of species, each represented by small biomass. The thermal excursion of SES is great, in comparison with that of NES, with the spatial (but not temporal) coexistence of two biota: a cold-temperate one in the cold season (at least in the coldest parts of the basin) and a tropical one in the warm season.

It is obvious that the two seasonal systems are very different in features and it is also obvious that the greatest biological diversity (in terms of different adaptations) of the European marine biota resides in the SES.

This peculiarity is not recognized by proper legislation. The Habitat directive of the EU, for instance, rightly recognizes the habitat level as being crucial for the protection of biodiversity. Out of 198 habitat types recognized to be of European importance, however, only 9 are marine. They are:

1. Sandbanks which are slightly covered by sea water all the time
2. *Posidonia* beds
3. Estuaries
4. Mudflats and sandflats not covered by seawater at low tide
5. Coastal lagoons
6. Large shallow inlets and bays
7. Reefs
8. Submarine structures made by leaking gases
9. Submerged or partially submerged sea caves

The analysis of these habitat types shows that few of them apply to Mediterranean situations. Furthermore, habitats nr 1 and 4 are typical of seas with large tidal excursions (mostly NES), whereas habitats nr 3 and 5 are almost inland waters or ecotones. Also the list of marine species in the Habitat directive is far from representing the biodiversity of SES, whereas terrestrial species are considered in great detail.

The analysis of the Habitat directive, thus, reveals a land-based approach with a tendency, then, to concentrate on marine aspects that regard only marginally the peculiarities of SES.

Future editions of the directive need to be greatly re-elaborated so to include the core of marine biodiversity of the European Seas, both as habitat types and as species.

The threats to the integrity of SES can stem only from a proper appreciation of the targets of possible impacts.

Hazards and threats

The list of hazards and threats to SES ecosystems has been made repeatedly by international organizations such as UNEP (e.g. MEDPOL).
A commented list of possible threats and hazards is:

1. Urban pollution, deriving from untreated sewage. The SES are densely populated, with great urban agglomerates. The cities and towns of the northern shore are often treating their sewage waters, but this is not the case in the southern shore, with great inputs of organic matter in the sea. This leads to eutrophication. A recent issue is the discharge of great quantities of antibiotics with sewage, this leading to changes in the genetics of marine bacteria. Urbanization is often linked with tourism. Millions of people move to SES coasts during the summer, using infrastructures that are then left unused for most of the year. The dense overcrowding of coastal areas for short periods prevents the efficacy of sewage treatment, since treatment infrastructures need calibration according to the intensity of use. If treatment plants are used, they reach their functioning regimes when the wave of tourists is over. The places with the highest potential for tourism attraction are quickly spoiled by development of tourist infrastructures that will never reach a good level of efficiency due to intrinsic features (too many people in too short time windows). The overload of nutrients due to urban (and agricultural) pollution is called eutrophication. The first impact of eutrophication is a higher turbidity, with low attractiveness of the water for tourist uses and, usually, with some threat to human health. Higher nutrient inputs can enhance production, but sometimes they lead to outbreaks of noxious species, including toxic dynoflagellates leading to Noxious Algal Blooms.
2. Agricultural pollution: agricultural practices imply the use of large amounts of fertilizers and pesticides. They are carried to the sea by both rivers and terrestrial runoffs. The rearing of both terrestrial and aquatic animals is often based on the use of hormones and antibiotics that arrive at sea with sewage and rivers and interfere with marine biota in a still poorly explored way. The use of genetically modified organisms for agricultural use (including aquaculture) can lead to genetic pollution of natural populations.
3. Industrial pollution (including oil). The Northern shore is heavily industrialized, with heavy impacts on the environment in terms of pollution. Oil refinement, and the passage of oil tankers, is also a great hazard for the environment, due to the possibility of accidents during shipping and discharging. The southern shores are rapidly developing and there is no indication that the mistakes made on the Northern shores will not be repeated on the Southern ones.
4. Coastal erosion. Coastal urbanization had a great impact on the dynamics of the littoral, leading to the impossibility for the natural geological evolution of the coastal zones. The barrage of rivers and the extraction of sand prevent natural beach replenishment. The regression of *Posidonia* meadows and the overfishing of molluscs prevent the formation of biogenic deposits (in form of leaves and shells) that buffer the impact of wave action. The rigid defenses used to contrast erosion, furthermore, are of great aesthetic impact, spoiling the landscape (the Italian Adriatic coast is now protected by an almost continuous wall) and preventing its evolution.
5. Overfishing. Industrial fisheries represent a direct impact on the natural populations of marine species. The employed techniques, from illegal ones like date mussel fisheries to legal ones like trawling, have a great impact also in terms of habitat destruction and on the impoverishment of the natural populations of non target species. Aquaculture is

heavily impacting on natural fish populations since the reared species (mostly *Dicentrarchus labrax* and *Sparus aurata*) are carnivores and their food derives from the packaging of smaller fish into pellets. In this way, we extract small fish from natural populations (since we have destroyed most large fish) and then feed them to the larger fish that we rear.

6. Transport of alien species. The arrival of alien species to SES occurs via transport in ballast waters, ship hulls fouling, aquaculture. Most aliens simply die off in non favourable environments for their well being, but some can flourish and build up large populations that interfere with ecosystem functioning. The cases of *Mnemiopsis* and of *Caulerpa* species are extreme, but there are many other instances of alien impact on SES ecosystems.
7. Global warming. Climate change, with the tendency to a warmer period, is also caused by human activities. This is causing the arrival of exotic organisms from nearby basins, mainly the Red Sea through the Suez Canal, with the acclimatation of many species. The phenomena linked to this impact can be divided into two categories: meridionalization (species formerly living in the southernmost parts of SES move to the northernmost parts), tropicalization (species of tropical affinity become established in the SES, changing their biota).
8. Increase of success rate of opportunistic species that form huge populations in short time frames. The removal of large and long-lived species leaves space to short-lived and fast reproducing species. Noxious algal blooms, jellyfish blooms (both from alien or native species), mucilages, etc. have great impacts on ecosystem functioning. In the light of the intermediate disturbance hypothesis, the success of opportunistic species indicates high levels of general disturbance to the biota, with strong impacts on long-lived species. In this case, “instability” is surely a bad state for the system.

What to do

The advised actions involve:

Improve the understanding of ecosystem functioning

Even though this seems a rather logic issue, basic research on biodiversity and ecosystem functioning is far from being pursued in a strategic way. With the European Register of Marine Species, the EU made a first inventory of its fauna and flora, but the regional faunas and floras are mostly uncovered by monographic work on the various groups, allowing for the identification of biodiversity at species level. It is still very difficult to give a name to a species, unless it is a very common one. Furthermore, it is also difficult to identify aliens (unless they are obvious). Many parts of SES (especially in the southern shore) are almost unexplored in terms of biodiversity. The list of habitat types is far from being representative and the presently available categorizations are often contrasting, depending on the expertise of those who formulated them. The mapping of the distribution of both species and habitats is far from being known. These gaps in knowledge of the structural aspects are even greater when functional aspects are considered. The great success of experimental ecology, aimed at uncovering functional aspects, carried out in NES regards mostly intertidal habitats, easy to reach and to manipulate. Their low diversity and high accessibility is conducive to experimental hypothesis testing. In SES, tides are negligible and subtidal biodiversity is very high. This makes experimental ecology less feasible, even though, in recent years, great advances have been done in this respect, at least in some parts of SES. Biodiversity inventories, with the publication of faunas and floras, and the test of hypotheses on ecosystem functioning, based on experimental work, are essential to build up a basic knowledge on the "normal" functioning of ecosystems. Since fluctuations and variations are the norm in environments like marine ones, where biodiversity has a fast turnover rate, it is imperative that observations are not based on short terms, since what might be identified as "normal" might represent just one of the multiple "normal" states that the system can reach. The required actions are manifold:

- ⇒ Enhancing existing monitoring activities, identifying possible improvements of the existing operational oceanography projects in order to improve our capacity to monitor (and possibly predict) interannual variability.
- ⇒ Deploy additional dedicated networks (Reference to CIESM "Hydrochange" project). Focus on measuring trends of hydrographic properties in deep isolated basins and volume fluxes across Straits. Find a reference level for all tide-gauges measurements. Improve assessment of air-sea and riverine fluxes for the two seas. Deploy dedicated moorings for improvement of air-sea bulk formulas for Mediterranean and Black Sea regions.
- ⇒ Improve understanding of physics regarding the exchange of the two seas. Develop models where the two Seas are fully coupled, as well as fully coupled with the atmosphere.
- ⇒ Improve the understanding of the role of teleconnections on the system, as well as the way teleconnections will be affected by global warming.
- ⇒ Possibly, identify means for international organizations to contribute to nationally funded long-term monitoring projects.
- ⇒ Make a complete biodiversity inventory for SES, both in terms of species and habitat types.
- ⇒ Map the distribution of habitat types as is being done just for *Posidonia*.
- ⇒ Build conceptual models of ecosystem functioning and test its variation with proper experiments, coupling physical change with biotic change, and vice versa.

Acquire the conceptual tools for distinguishing between "normal" and "altered" and to detect the sources of alteration

In the Ligurian Sea, in the last few years, the fisheries of anchovy gave insufficient yield (in comparison to the past). This was recognized as an altered state of a normal situation, and many causes have been called to explain this phenomenon. Along with the decrease of anchovy, great blooms of the neustonic hydrozoan *Velella velella* occurred in large areas of the Western Mediterranean, even though almost no scientific report on this event has been published. *Velella* is known to feed on the eggs and larvae of anchovies. Chances are good that the impact of predation of these gelatinous carnivores impaired the recruitment of anchovies, causing the collapse of fisheries for this species. The link between the two phenomena has not been made, and now it is too late to test if the two events were linked. Knowing the cause for a given event leads to different management decisions. If the decrease is due to over fishing, then the decision is to decrease the pressure of fisheries, but if the reason for the decrease is failure of recruitment due to predation on eggs, then fisheries have no major role in the event.

A "stable" ecosystem is an ecosystem that does not change or that changes in a predictable way. The "instability" we perceive derives from a deviation from a recognized norm. Sometimes the deviation might be recognized by standard monitoring (e.g. an increase in temperature linked to global warming is perceived by routine oceanographic monitoring), whereas other deviations just as the sudden presence of *Velella*, cannot be recorded if one is not prepared to face the unexpected. Changes in ecosystem functioning derive, thus, from changes in the drivers of ecological processes. These drivers can be either physical (e.g. temperature increase) or biological (sudden bloom of opportunistic species that forms a huge population for a short time and then disappear, arrival of an alien species that impacts on other components of the biota, etc.). A third explanation is that the changes are driven by human activities that must be mitigated. Usually the three drivers are not mutually exclusive. Natural systems are driven by multiple causality, so that it rarely occurs that a single cause might explain a given situation.

Improve public awareness for environmental problems

The cultures represented along SES usually have low sensitivity to environmental issues. In the past, human impacts were little because human activities were intrinsically of low impact. This partially justifies the low concern that SES populations have for environmental integrity: in the past the problem did not exist. The use of chemicals in agriculture is rather recent and is not yet perceived as having a negative impact on both the environment and human health, so it is often left without control. Technology is going at a faster rate than culture. The building of tourist settlements along beaches and coastal zones in general is usually seen as a positive development of local economies, disregarding the impact on littoral dynamics, in form of erosion and sewage discharges. Technology is rapidly improving our power in respect to the environment, magnifying our potential impact. Only the perception of the importance of nature preservation as part of a local culture can build an attitude in local populations leading to the preservation of the potentials of the environment in terms of goods and services for our species. The institution of Marine Protected Areas, in this framework, is not only aimed at preserving particular portions of the environment. Its main objective is to promote public awareness towards the importance of a good environmental quality to obtain a good quality of life. Environmental protection is often seen as an impediment to development. This negative perception is to be changed with proper policies involving local communities with the aid of media such as the press, television, and especially public education in schools. A bridge is to be built, connecting the scientific world and the general public, and scientists are to be taught how to communicate their findings, especially to decision makers (including EU officials). The feeble perception of the peculiarities of SES in the EU Habitat Directive is an example of scant sensitivity of decision makers towards the problems of SES.

Problems within the scientific community

After the Rio de Janeiro convention on biological diversity, decision makers became fully aware of the importance of a much diversified environment in terms of species coexistence. A great gap in our knowledge is just the recognition of species, since only a little portion of the biological diversity has been properly described. It should have been expected, then, that a host of studies on biodiversity would have been financed. In fact, great funds became available for the study of biodiversity but, paradoxically, the science that basically recognizes biodiversity, i.e. taxonomy, entered in a state of crisis. The scientific community did not recognize the importance of taxonomic research, so that the money for biodiversity mainly went to initiatives that provide “services” to taxonomy but that, however, do not pursue taxonomy per se. Taxonomy even disappeared or became severely reduced from university curricula.

Decision makers, thus, decided to invest in biodiversity research but the main experts in biodiversity, taxonomists, did not get much of this funding. Very little funding became available for revisionary work or for the preparation of regional faunas, most of the funding being used to build up databases. Based on unreliable data.

The National Science Foundation of the United States of America launched, at the end of the last century, the Partnership for Enhancing Expertise in Taxonomy, recognizing that taxonomic expertise was vanishing in the USA, and that this loss was having a negative impact on future policies of biodiversity protection. No similar initiative has been launched in Europe, where the USA policy that led to the disappearance of taxonomy has been embraced. The USA realized that it was a mistake, and now we are in the favourable position of avoiding this mistake (since there are still some taxonomists in Europe).

The problem of taxonomy disappearance is not linked to decision makers, it is due to positions within the scientific community. The Impact Factor system, developed by the commercial Institute for Scientific Information, stemmed from the necessity of enonomizing efforts in scanning the scientific literature to build databases to sell to scientists. Zoology was not a profitable field, since the Zoological Record fills the niche of documenting zoologists with the advances in their field. Museum journals, for instance, are usually deprived of an Impact Factor. This commercial aim has been and is being used also to evaluate the scientific performance of researchers. The result is that taxonomists have very low impact factors and have, thus, a low respectability in the scientific community. Funding that should go to them, then, is attracted by other fields that mimick taxonomy (e.g. databasing).

If Europe wants to have a sound inventory of its biodiversity in terms of species and on species distribution, it has to invest on taxonomy, building human capacities that can tackle the study of biodiversity from a molecular, morphological and ecological point of view. The steering committees that advise Framework Programmes must comprise also taxonomists with a broad expertise, not restricted to Museum curation only. Besides databasing, some EU financed programmes were aimed at making museum type specimens available. This is not enough. The main need for taxonomy is bibliographic information, and no programme is aimed at making it available.

Obviously, the advice of the scientific community on how to pursue a biodiversity policy in Europe did not cover all the needs for such a policy. For once, we should copy the USA, with their Partnership for Enhancing Expertise in Taxonomy.

Conclusion

The issues raised in this report call for an adjustment of the attitudes of both the scientific community and the decision makers. Since the environment is constantly changing, it is of paramount importance that historical series are made available, both for abiotic and biotic features of SES. The general tendency to sustain focused action stemming from short term programmes, with continuous focusing on different contingencies (see the history of the Adriatic in the deliverable on ecosystem functioning), avoid the historical reconstruction of the features of ecosystems, with the understanding of proximate causes and loss of vision of ultimate ones. The scientific effort to reach this new vision of environmental studies is great, but it is the only possible way to understand a rapidly changing world and, hopefully, design the proper measures to make it viable for human well-being.