

The Mediterranean Sea



At the fish market, fish are often of small size nowadays.

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The Mediterranean Sea

Its biodiversity and the impact of global warming

By Ferdinando Boero

The Mediterranean Sea is a recognised hotspot of biodiversity. With more than 10,000 species, not counting viruses and bacteria, it is the most diverse European sea.

The Mediterranean of today started its history as part of the Tethys Sea, dividing the two mega-continents (Laurasia and Gondwana) that originated from the fragmentation of Pangaea. Five million years ago it became closed, and its tropical biota went through the Messinian crisis, when the connection with the Indo-Pacific was lost and most of the water evaporated. The Sea was reduced to a series of pools in correspondence with its deepest parts, and rivers indented its bottoms and formed canyons. The original tropical biota, of Indo-Pacific origin, became almost extinct. When Gibraltar opened up, Atlantic water filled the almost empty basin, and the new connection with the temperate Atlantic founded a new Mediterranean biota, the ancestor of the present one. Some palaeo-endemics remained, but the old tropical biota vanished, leaving just a fossil record.

Water circulation is the main driver of Mediterranean conditions. Surface Atlantic

water enters from Gibraltar, goes eastward and comes back at deeper levels, with an outflow of Mediterranean waters into the Atlantic. Evaporation is higher than riverine influxes of freshwater, so the salinity of the Mediterranean is higher than that of the Atlantic. Surface waters in the Mediterranean reach 28°C, or more, in the summer, whereas the average winter temperature is 13°C (as in deep waters), even though it can be much lower in the three northern parts and higher in the southernmost parts of the basin. During the winter, the water column is homeothermic, whereas summer stratification is strong. The summer thermocline is shallow in the coldest parts of the basin, and much deeper in the warmest ones. This alternance of a warm and a cold season leads to the prevalence of two main surface biotas in the basin: a summer biota, with many species of tropical affinity, and a winter biota, with species of temperate or even boreal affinity. Since most of the present Mediterranean biota colonised the basin from Gibraltar, the founder species

were more temperate than tropical, and the easternmost parts of the Mediterranean remained “undercolonised” by the new pool of species coming from the Atlantic, probably not because they could not get there, but because they did not find the proper conditions in too warm an area. As soon as a new waterway (the Suez Canal) connected the Mediterranean with the Indo-Pacific, tropical species started to enter the Mediterranean, taking advantage of the semi-tropical conditions of the eastern basin: the so-called Lessepsian migration began. Red Sea immigrants, in a sense, fulfilled the tropical vocation of the Eastern Mediterranean much better than the post-Messinian immigrants from the temperate Atlantic!

Three parts of the basin are crucial for its hydrography: the Gulf of Lions, the Northern Adriatic and the North Aegean. The cold winds of the north cause much lower temperatures there than in the rest of the basin: these “refrigerated” waters tend to sink, going deep, replacing the deeper waters. These are among the few places where deep water is formed at the surface, during cold winters. The Northern Adriatic, furthermore, hosts a boreal biota that has no counterpart in the rest of the

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Reduced coralligenous reef in a sea cave at Otranto, Italy.

Mediterranean. The flagship species of this biota is *Fucus virsoides*, the only *Fucus* of the Mediterranean basin, endemic to the Northern Adriatic, together with a host of other species that live only up there.

Sharp seasonality is the secret of Mediterranean biodiversity. Temperature conditions differ so much in the two seasons (differing by more than 15°C) that they allow the coexistence in space (but not in time) of a tropical and temperate biota. Thus, the Mediterranean is a veritable crossroad of biodiversity, a miniaturised ocean where things happen faster than in the world ocean, so showing what might happen in the future at a wider scale, both in time and space.

Global change and the Mediterranean Sea

The opening of the Suez Canal has no relationship with global warming, but global warming might favour the expansion of tropical species (able to reach the Mediterranean through the new connection) and the establishment of independent populations. This is being called tropicalisation, since the origin of the newcomers is almost invariably tropical.

Another response to global warming is meridionalisation. The species that normally thrive in the southernmost parts of the basin (meridional species) are widening their distribution towards the north.

The whole Mediterranean Sea, thus, is a sensor of global warming, and its tropicalisation and meridionalisation are telling us that the biota is answering to the change in a very fast way, suggesting an adaptation, in terms of species

composition, to the new conditions. Biodiversity is changing, many new species are arriving and the impression might be that there is an increase in the species pool inhabiting the basin. The old species lists are being updated, and the numbers of the inventory are undergoing a steady increase. Does this affect the functioning of ecosystems? This is more difficult to understand. There are many other changes that might affect the functioning of Mediterranean ecosystems besides the increases in temperature and the arrival of tropical species.

Overfishing, for instance, is leading to a sharp decrease in sea urchin predators, and this, in its turn, is causing an increase in sea urchin populations that, with overgrazing, destroy algal canopies leading to barrens that, surely, cause a lower efficiency in the functioning of ecosystems, if efficiency is measured in terms of production. The occurrence of sea urchin barrens, thus, is not linked to global warming, but is a symptom of a global change due to the global impact of fisheries.

Another symptom of overfishing might be the increased frequency of jellyfish blooms, possibly triggered by increased food availability at low levels of trophic networks due to our removal of large fish. A void is formed, rapidly filled by vicariants. The global ocean is shifting from fish to jellyfish, and this is occurring very rapidly in the Mediterranean Sea, since the eighties.

The Black Sea

Another sea that is connected with the Mediterranean, the Black Sea, is paradigmatic in showing what might be the impact of an alien predator in a low-diversity system. The arrival of the ctenophore *Mnemiopsis leydi* led to the impairment of Black Sea trophic networks, with a sharp decline of fisheries yields due to predation by the ctenophore on both fish eggs and larvae and on the crustacean prey of fish larvae and juveniles. The case of *Mnemiopsis* shows what a non-coevolved, alien predator can do when introduced to a more or less closed ecosystem, demonstrating that jellyfish predation has a crucial impact on fish recruitment and has a paramount importance in fisheries. The impact of jellyfish predation is seldom so high as that of *Mnemiopsis* in the Black Sea, but this extreme should teach us that it is unwise to give no importance to gelatinous predators while inferring on the future of fish populations, considering fisheries as their sole source of mortality. A little blob of jelly had a greater impact on Black Sea fish populations than industrial fisheries!

It might happen, thus, that the change we observe is not always linked to changes at a global level, somehow linked to climate change. The increase in sea urchin barrens and in

jellyfish outbreaks are possibly due to overfishing and not to climate change. On the other hand, both tropicalisation and meridionalisation are due to temperature increases, offering more opportunities to species that thrive when temperatures are high. Are the putative changes in the ecosystem functioning of the Mediterranean, if any, to be ascribed more to global warming than to overfishing? Maybe tropical fish are simply replacing the fish that we depleted with our fisheries. But other tropical creatures are arriving, without any human impact on their possible indigenous competitors.

The flora and fauna of the Mediterranean Sea

Lists of Mediterranean species have been compiled for centuries. The first extensive exploration of Mediterranean biodiversity, however, saw its dawn when the activities of the Zoological Station of Naples started. The programme of Anton Dohrn was to prove the theory of evolution by revealing the amount of diversity that was hosted in the Mediterranean, and especially in the Gulf of Naples. Specialists came from all over the world and compiled monumental monographs that are still classics. Paradoxically, the publication of monographs on the flora and fauna of the Gulf of Naples ceased almost at the beginning of the era of biodiversity discovery and, today, they still represent unsurpassed milestones simply because, in many groups, nothing else has been attempted since their appearance.

In recent years, the International Commission for the Scientific Exploration of the Mediterranean (CIESM) produced four fine monographs on the immigrants that entered the Mediterranean Sea, often through the Suez Canal. They cover fish, molluscs, crustacean decapods and algae and are continuously updated through the web page of the Commission (www.ciesm.org). The list of aliens is very long, and it becomes even longer when considering all phyla. Now, more than ever, it is essential to update the old monographs, but this cannot be done by simply adding the new species to the old ones. This exercise leads to an ever-increasing biodiversity. Each species should be investigated throughout the bibliography, so as to ascertain the extent of its distribution through published records, and reconstructing its history. And, if a species has not been recorded for, let's say, one century, there are two possibilities: it either has disappeared, or have not looked for it with the same care as in the past. The identification of a list of missing species is not a red list. Most species are inconspicuous and can be recorded only by specialists. The assessment of biodiversity status can be done only by experts, and this expertise is vanishing. Potential authors for monographs on the fauna and flora of the

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Mediterranean are less and less available, and funding is not available for such enterprises.

It is obvious that taxonomic expertise must be rebuilt and, sooner or later, I am confident that it will. The present-day obtuseness, leading to the dismissal of taxonomy, will be removed because man cannot simply go on without knowing what is around us. Meanwhile, we cannot wait for the arrival of wisdom to do something.

A temporary alternative to a species focus can be habitats. There is a problem of terminology here. The EU Habitats Directive, in fact, gives the impression that terrestrial environments make up an amazingly vast variety of conditions, hence a very high number of listed habitats, whereas marine environments are so monotonous as to be almost dull, with an amazingly generic and short list of habitats that deserve protection. The number of marine habitats has to increase, but first there should be agreement about what is a habitat. So far, this agreement has not been reached and there are far too many lists of marine Mediterranean habitats.

What is a habitat?

"A particular type of environment regarded as home for organisms" – this is one of the definitions in the Oxford English Dictionary. Being terrestrial organisms, we tend to identify habitats with the ground, and we did the same for the sea. There will come a time for discussing pelagic habitats, but now let's concentrate on benthic ones. We need some classification, and this can be done only by the identification of shared features, leading to lump items of the same kind. Having to do such an exercise, I would divide habitats into two great categories: primary habitats, made up of physical features of the bottom and of the

surrounding physical environment, and secondary habitats, made up of habitat-forming species that have their own primary habitat but that, in themselves, are habitat for other species.

Secondary habitats (i.e. habitat-forming species) can be of two kinds. Some are perennial, like *Posidonia oceanica* meadows, the most typical Mediterranean habitat type. Some others are seasonal, like many algal canopies made up of algal species in the warm season and by hydroids in the cold season. Perennial habitat-forming species, furthermore, can be bioconstructors, leaving their dead bodies in place, where they become the constituents of the "physical" component of the habitat itself. The main representatives of bioconstructions in the Mediterranean Sea are the already mentioned *Posidonia* meadows and coralligenous formations, made up of coralline algae, bryozoans, cnidaria, serpulids and many other organisms that form permanent concretions with their dead bodies. The difference between *Posidonia* meadows and coralligenous formations is that one is monospecific (the sea-grass) whereas the other is multispecific.

It is obvious that, for management reasons, the list of habitat-forming species and of bioconstructors, in particular, is extremely informative on priorities for protection. One might identify a physical habitat, saying: 'rocky cliff of calcareous nature, with mild exposure to wave action, divided into belts characterised by different values of light penetration and water movement.' This is not enough. Such a physical habitat might be a barren caused by overgrazing by sea urchins, or a flourishing algal canopy at shallow depths and a gorgonacean forest at deeper levels. In other words, habitats must always be characterised at two levels: the physical and the biological. Taxon-oriented ecologists might be very detailed in defining habitats from a biological point of view, arriving at defining a habitat by the presence of their pet species. A habitat type that potentially hosts a species with particular features, in this framework, might acquire further value if that species were present, but might be valuable anyway, as a prerequisite for the presence of that species. Eventually, everything might become extremely important, as it probably is. Species and habitats might be very important because they are very abundant, and define the features of an entire region, as happens for *Posidonia* meadows in the Mediterranean, or they might be very important because they are the "home" of species that are highly threatened, as is the case of partially submerged marine caves with a pebble beach at the bottom, where monk seals find refuge.

The majority of habitats, however, do have intermediate features between these two



Pelagia noctiluca in the Mediterranean.

extremes, and it is particularly important to improve the definition of what is a habitat and what are the features that make it valuable from a conservation point of view.

A microcosmic ocean

The Mediterranean Sea, with its sharp seasonality, is a crossroads of different environmental features. Its position, connected with the Atlantic and now, via the Suez Canal, with the Indo-Pacific, allows the encounter of much different biota that merge in a megacosm that is not biased by untenable experimental conditions (as are micro- and mesocosms over long time-scales). Human pressures are heavy, with a north shore that is economically advanced, and eastern and southern shores that are undergoing tumultuous development, all together forming the first place in the world in terms of touristic attraction and, on the other hand, among the first places in terms of sources of instability. The responses to change are rapid, both in the natural and in the human realm. There is no other so variegated and diverse a place in the world. This richness is so far a disadvantage from the point of view of our understanding of it. The great complexity and diversity of the Mediterranean makes it less tractable from both an experimental and a modelling point of view than any other part of the planet. Each time you find a rule at some part of the Mediterranean, the falsification of its generality (and so its very validity, as a rule) becomes evident at some other part of the Mediterranean itself. Once a given situation is fully understood, it suddenly changes and one has to restart from scratch.

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