# The new CIESM Tropicalization Programme – effects of climate warming on Mediterranean key taxa

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**SUMMARY**

In the Mediterranean Sea, where some 30 % of species are endemic, changes in biodiversity are occurring at unprecedented rate. In particular, the warming of Mediterranean waters is accelerating the establishment of tropical species and the retreat of temperate species towards colder areas of the Basin. This ongoing process of Mediterranean "tropicalization" remains poorly understood, based on fragmented, occasional, usually local observations. The importance of investigating causes for these changes is a matter of urgency.

The overall aim of the CIESM programme is to use reliable, representative biological macrodescriptors to track at basin-scale the effects of tropicalization of the Mediterranean Sea on marine biodiversity. The programme will implement a systematic, long-term field monitoring of changes in Mediterranean biodiversity, in particular the expansion of "warm-water" species (with affinity to warmer waters) and the retreat of "cold-water" species (with affinity to colder waters).

## EFFECTS OF CLIMATE CHANGE ON DISTRIBUTION RANGES OF MEDITERRANEAN SPECIES

Climate change is affecting the whole earth: scientific evidence for significant effects in the oceans and seas has been available in recent years (IPCC, 2001; 2007). Climate change will lead to warming waters, increased frequency of extreme precipitation events, winter floods and summer droughts, and increased storminess. The Mediterranean Sea, with its peculiar location at the cross-road between the Atlantic and Indo-Pacific biogeographic domains, the magnification of climatic signals in its enclosed basin, and the unique biodiversity (28% of species are endemic) represents a remarkable case study to investigate the influence of climate change on biodiversity. The CIESM Hydrochanges Program has detected several signals of change in the Mediterranean Sea (Millot *et al.*, 2006). *In situ* long-term measurements of temperature and salinity recorded at the Strait of Gibraltar show that the deep waters outflow through the Strait of Gibraltar is warmer (~0.3 °C) and saltier (around 0.06 units saltier) than 10 years ago. An increase in temperature and salinity has been recorded also in many other areas of the Basin (e.g. Tyrrhenian Sea; Sicily Channel, see Fuda *et al.*, 2007). In shallower waters, stratification will likely occur earlier and extend deeper in the water column. Results from the CIESM MedGLOSS Program indicate a sea level rise at several locations along Mediterranean coastlines and in the eastern Basin in particular. Sea level rise, along with increasing coastal erosion, will impinge low lying deltas, saltmarshes and lagunal systems.

Two types of responses by biodiversity and ecosystems to global environmental change can be envisaged: direct climate-driven effects and indirect effects due to human mitigational strategies and adaptational actions (i.e. sea defences, de-salination plants, enhancement of irrigation).

Furthermore, there will be interactions between different scales if impacts: global climate driven change will likely interact with regional (overfishing, eutrophication) and local impacts (sea defences, point source pollution).

Changes in sea temperature, apparently small, can have dramatic effects on the biology and diversity of communities. The mass mortality of gorgonians (e.g. *Paramuricea clavata*) and many other invertebrates, that affected several areas of the Ligurian and Provençal coast as a result of a sudden increase in temperature in the water column, is a clear example of the fragility and vulnerability of marine ecosystems (Torrents *et al.*, 2008; Cerrano *et al.*, 2000; Perez *et al.*, 2000). Other changes in the biodiversity are less evident, as they occur gradually over a much longer period of time or indirectly, through loss or modification of habitats necessary for the survival of species. Nevertheless, they can be serious and may result in species loss or permanent alteration of ecosystem functioning.

Susceptibility to global climate change will vary depending on the type, biology and physiology of organisms. The complex geological history of the Mediterranean Sea, its connections with the Atlantic and the Red Sea, and its climatic and hydrologic regimes have led to the coexistence in the Basin of boreal, temperate, sub-tropical and tropical species.

There are cold temperate species which take refuge in particular habitats: examples include *Fucus virsoides* in the north Adriatic; *Laminaria rodriguezii*, restricted to the western Basin at depths where the water temperatures do not exceed 15 °C; the crab *Carcinus* and the polychaete *Nereis diversicolor* in lagoons and estuaries, the hake *Merluccius merluccius*, the whiting *Merlangus merlangus*, the poor cod *Trisopterus minutus* and the Norway lobster *Nephrops norvegicus* in the deep waters. In the Atlantic, northern species can retreat northwards as well as into deeper waters (Perry *et al.*, 2005), whilst the only possible retreat in the Mediterranean is to deeper waters. Furthermore, as changes in water stratification will lead to warmer water extending deeper, cold-temperate, shallow water species will have no possibility of shifting to deeper waters. As some of these cold water species are already at risk from overfishing, a much more precautionary approach is required before relating their changes in abundance and distribution to climate warming.

Mediterranean species also face competition from Erythrean immigrants (see CIESM Atlases of Exotic Species) now expanding into the western basin. Climate change is known to increase the probability of success of invasion of non-native species by facilitating their recruitment (Stachowicz *et al.*, 2002). In the last decades there has been a significant increase in the introduction of tropical, alien species that settled permanently in Mediterranean habitats, sometimes even replacing native species (Galil, 2007b; Occhipinti-Ambrogi, 2007; Streftaris *et al.*, 2005). Climate warming is also favouring native warm water species such as the dusky grouper (*Epinephelus marginatus*), the barracuda (*Sphyraena viridensis*) and the ornate wrasse (*Thalassoma pavo*), which are extending their distribution ranges northwards.

## The need for a long-term, cross-basin program on Mediterranean tropicalisation

Current investigations on the effects of climate warming on biodiversity and more specifically on the tropicalization process are relatively fragmented, temporally patchy and geographically limited. The need for a long-term, basin-scale programs aiming to monitor the effects of climate change on Mediterranean species is clear. The establishment of a systematic, standardized monitoring program on tropicalization impacts across the Basin will allow a proper interpretation of biodiversity changes, that is, discriminating between local and regional factors and disentangling short term fluctuations (“noise”) from longer term change (“signal”). Furthermore, impacts of climate change on the preservation of Mediterranean biodiversity and its natural environments have become a matter of great concern not only for specialists but also for the wide community in all riparian countries. Such a program will provide deeper understanding of patterns and trends characterizing the status and distribution of Mediterranean species, thus helping stakeholders (environmental managers, coastal planners, policy makers) in formulating of appropriate management and conservation strategies.

The challenge of the new CIESM Tropicalization Program is to monitor at regional level changes in the geographic range of distribution of key selected marine species in relation to climate change. The program will:
- review and integrate existing information on past and current status of selected taxa;
- identify a set of "sentinel species" which can reliably represent indicators of climate change;
- track the geographic expansion of "warm-water" species (with affinity to warmer waters) and the retreat of "cold-water" species (with affinity to colder waters);
- record mass events (invasions, blooms, mass mortalities) in the Basin;
- relate changes in abundance and distribution ranges of Mediterranean species to the variability and trends of the hydro-climatic environment;
- establish a long-term, dedicated "Mediterranean Network" to detect and monitor major changes in key species in response to climate.

### Selecting species as reliable macro-descriptors of climate change

As Mediterranean ecosystems are subject to both natural and anthropogenic pressures, the difficulty is to identify climate-specific impacts on species. We already know that species respond to changes in the climatic environment by shifting geographically (Fields *et al.*, 1993; Southward *et al.*, 1995; Parmesan, 1996; Sagarin *et al.*, 1999). Hence monitoring changes in the species range of distribution can provide a good estimation of the effects of climate change on Mediterranean biodiversity.

There are two categories of species that will likely signal changes in the hydro-climatic conditions. First, the species most vulnerable to warming, characterised by a combination of some of the following ecological traits: affinity to cold waters (e.g. ice-age relict species) coupled with stenothermy/stenohalinity, sedentarity, low recruitment and dispersal rates, limited vertical distribution, species threatened by human driven factors (i.e. overfishing) or already rare in the past. On the other hand, increasing temperatures and salinity will reduce the hydrological gradient between the western and eastern basins, thus facilitating the westward and northward range extension of warm water Mediterranean species and particularly Erythrean species. An increase in sea temperature will also favour the reproductive output and recruitment success of this type of organisms (Walther *et al.*, 2002; Herbert *et al.*, 2003).

### The basis of the CIESM Tropicalization Programme: historic archives

The selection of climate macrodescriptor species will be based on an in-depth study of available historic information on Mediterranean macrobiota. In the past, and in contrast to current research "priorities", taxonomy and biogeography of the marine fauna and flora were considered two fundamental subjects of study for early marine biologists. In the Mediterranean, there is a wealth of information and inventories of marine species compiled in the last century by illustrious taxonomists. CIESM archives (Congress papers, special publications, *Fiches Faunistiques*) represent one of the richest source of historic records dating back to the 1920s. Other local and national data (time series from the Marine Stations, Museum collections, grey literature) will complement the CIESM archives.

The *Fiches Faunistiques de la mer Méditerranée*, published by CIESM between 1927 and 1934, provide a detailed account of the morphology, ecology and biogeography of 476 Mediterranean species, belonging to nine taxa. For certain taxa such as the Asteroidea and the Rajidae, there are descriptions for almost all species recorded to date in the Mediterranean Sea, allowing to assess the dynamics of a full taxonomic group in response to change. In the Asteroidea group, some species probably will respond differently to climate warming: for example, *Opidiaster ophidianus* original description indicates that this species was distributed only in the warmer areas of the Mediterranean Sea, while *Anseropoda placenta* and *Luidia sarsi*, a cold-temperate species quite common in the north Atlantic, appeared to be restricted to the deep waters in the Basin. In the Rajidae family, most of the species have a northenly distribution and in the Mediterranean (Western Basin) they generally inhabit the deep, colder waters, especially in the north Adriatic and the North Aegean (*Dipturus oxyrinchus*, *Leucoraja melitensis*, *L. circularis*, *Raja brachiura*). Warming of waters could further endanger these species which are in a vulnerable status due to overfishing.

Past and current information on species geographic distribution will be then compared and analysed to screen those species that have shown fluctuations and geographic shifts in relation to changes in climatic conditions.

## PLANNED ACTIVITIES AND EXPECTED OUTCOMES

After the careful selection of key macrodescriptors of change, which will be made as a concerted decision by expert partners, field surveys will be carried out across the basin in strategic areas such as the species distribution limits (including depth ranges), biogeographic transition zones (e.g. Sicily Channel) and cold spots (e.g. North Adriatic). Data will be then analysed and correlated with hydro-climatic trends from field (e.g. Hydrochanges, MedGLOSS) and satellite data.

The expected Programme outcomes will include: the identification of species most threatened by increasing warming of waters and climate-related events and thus in need of special protection; the development of dynamic, web-interfaced, databases with interactive distribution maps providing information on taxonomy, ecological traits and geographic trends of climate-indicator species; the publication of scientific collaborative articles in international journals and expert reports synthesising trends in Mediterranean marine biodiversity.

Acknowledgements
The CIESM Tropicalization Program is financially supported by the Prince Albert II of Monaco Foundation.