CLIMATE CHANGE IMPACTS ON COASTAL AND MARINE HABITATS OF CYPRUS

Cyprus International Institute for the Environment and Public Health in Association with Harvard School of Public Health

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Global climate change is thought by many to be the most challenging environmental aspect of our century. Other than the major socioeconomical impacts that a change of the climatic regime is expected to have, environmental and public health impacts are due to be very dramatic in virtually all areas of the globe. Certain areas are expected to be affected to a greater extent than others due to their specific climatic and environmental circumstances. This is especially true for islands such as Cyprus (located in the Eastern Mediterranean), which is currently facing a variety of severe environmental problems such as water scarcity, desertification, and habitat loss, problems which are expected to worsen by the effect of climate change. The present paper focuses on climate change impacts that coastal and marine habitats of Cyprus are expected to face as a result of sea level rise, weather alteration, and resource depletion in the area.

Coastal and marine environment of Cyprus

As an island, the coastal and marine environment of Cyprus is of great significance to the island's economy and general well-being of its residents. Cyprus is financially dependent on the tourism industry, an activity which is by 90% concentrated in the coastal area (Loizidou X., 2000). As well as that, three out of four of Cyprus' main cities are located by the coastline. A great percentage of the island's 'natural beauties' is also located near coastal areas such as the Akrotiri peninsula, Cape Greco, and the Akamas' natural reserve.

Current stressors of the coastal and marine environment are presented in 'The Marine Environment in Cyprus' by (Hadjichristophorou M.) and are listed below:

1) Tourism and urban development of the coastal zone
2) Fishing and overfishing
3) Invasive species
4) Coastal defenses and coastal infrastructure
5) Pollution (especially nutrient pollution characterized by eutrophication events).

The National Policy for the marine environment in Cyprus is to a large degree dictated by several EU Directives such as the Water Framework Directive, the Nitrites directive, the Habitats Directive, the Bathing Waters Directive etc. The national policy includes the implementation of the relevant Conventions (mainly the Barcelona Convention and its Protocols and the Bern Convention). Its aims are to protect and manage the marine environment in a sustainable way preserving biodiversity and environment benefiting fisheries and other users of the sea. The implementation of the Directives' requirements and the addressing of issues relevant to these problems is mainly a responsibility of the Department of Fisheries and Marine Research (DFMR), Department of Environment, Public works department (coastal unit), and Department of Merchant Shipping.

Climate change in Cyprus

Climate change is expected to affect the Eastern Mediterranean area in a variety of ways. Most notable impacts reported are the sea level rise, rise of mean temperatures (**Image 1.a, Image 2**), decrease in precipitation events (**Image 1.b, Image 3**), and increase of extreme weather events. These climatic changes are expected to affect the coastal and marine environment in a variety of ways.

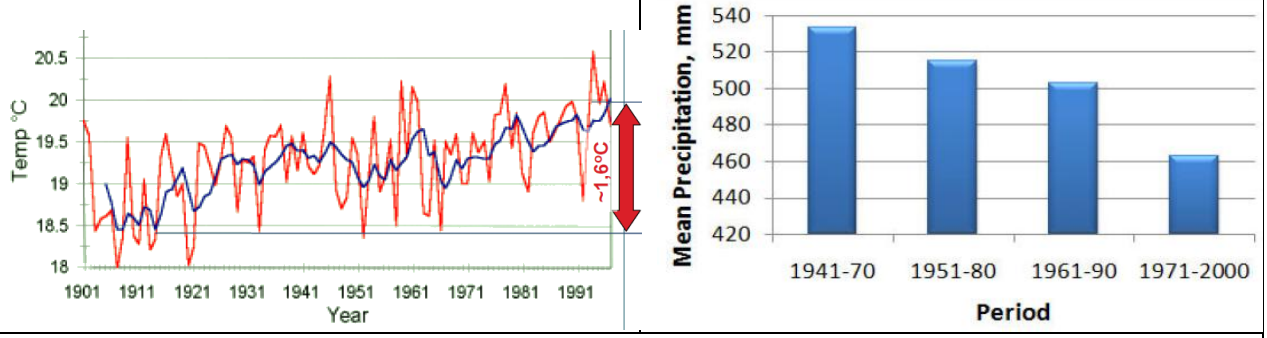

Image 1: a) Rising temperature trend for the last century and b) Mean precipitation decrease in Cyprus for the period of 1940-2000. Source: Cyprus Meteorological Service.

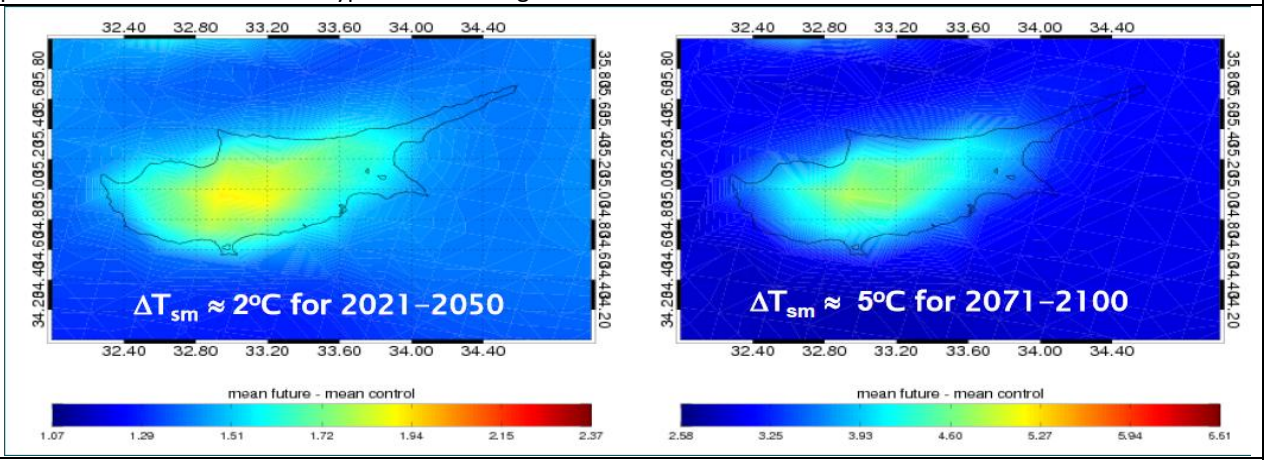

Image 2: Average change in **summer maximum temperatures** (ΔTsm) relative to reference value of ~34oC; source: Giannacopoulos et al., 2008

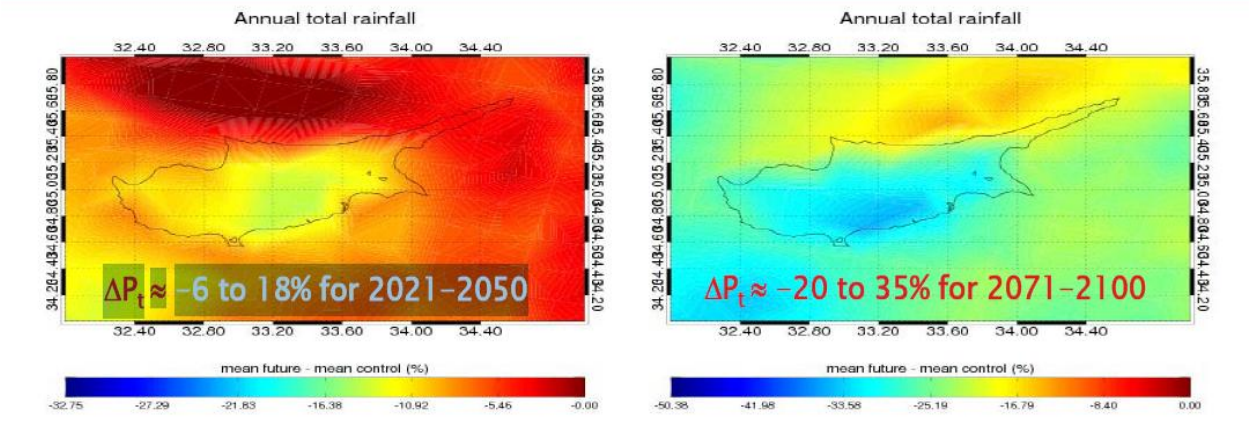

Image 3: Average change in **total precipitation** (ΔPt) relative to reference; source: Giannacopoulos et al., 2008

Arising problems and issues needing to be addressed

Coastal Areas Inundation and Erosion

Mean sea level trends reported by NOAA for the Mediterranean indicate a rise of 1.15 millimeters/year with a 95% confidence interval of +/- 0.22 mm/yr based on monthly mean sea level data from 1905 to 2001 which is equivalent to a change of 0.38 feet in 100 years. A prospective study (Marcos *et al*) of the Mediterranean Sea level rise based on several scenario models for climate change, indicate that the level of the whole Mediterranean sea can rise by between 3cm and 61cm on average over the 21st century as a result of the effects of warming.

Sea level rise can result in coastline topography reshaping, and morphological alteration of coastal areas. It is not exactly known how coastlines will respond to a rise in the mean sea level. On the theoretical basis of Parametric Equilibrium Models such as the Bruun rule (Encora, coastal portal), for certain areas, a 1m rise in sea level could mean a 100m landward retreat of the shoreline. However, this is a simplified coastal engineering model which is not necessarily indicative of the actual changes that may occur at any given shoreline.

Many coastal areas of Cyprus have been suffering from severe erosion during the last 30 years, such as the coastlines of Larnaca and Limassol (Parari M., 2005). With sea level rise on the way, the problem of erosion could be exacerbated in these areas, inducing safety threats for infrastructures such as Larnaca airport, desalination stations, and power plants, increasing dangers arising from potential storm surges, and increasing the economic demand for coastal defences.

Low-lying areas will be significantly prone to sea level rise impacts and will be threatened with inundation risk and greater exposure to storms. Such areas include current Natural 2000 sites such as the Akrotiri peninsula wetland, the Akamas Coastal/Marine Protected area and especially the Lara/Toxeftra Turtle Reserve, Cape Greko marine caves, and other environmentally sensitive areas such as Poli Chrysochous coastline which is a significant green and loggerhead turtle nesting site, and the Larnaca salt lake, a refuge of flamingoes and other migratory bird species.

Another major problem presented by sea level rise is 'coastal squeezing', a term that refers to coastal morphologies that would otherwise readjust to the rising sea by retreating landwards, but are currently obstructed by physical or anthropogenic barriers such as coastal infrastructure. Such examples are sand dunes, or wetlands lying in front of built up areas. As a rather large percentage of Cyprus coastline is developed, coastal squeezing can become a real issue for specific areas such as the area of Kokkinochoria, Limassol, Larnaca, and Paphos.

Sea level rise can also impact marine ecosystems by inducing superlitorral and supralittoral inundation and general changes in the structure of marine ecosystems. The endemic marine plant species zonation is characterized by the maximum depth limit tolerance of each marine plant. Alteration in sea level, salinity, and temperature can affect the long term spatial distribution of these plants. *Posidonia oceanica* has a maximum depth tolerance limit of 42 meters in Cyprus, *Cymodocea nodosa* predominates shallower waters 2-10 meters, shallow *Cystoseira spp.* habitats are found in (0-37m), and *Caulerpa prolifera* and *Halophyla stipulacea* are found in deeper waters. (Hadjichristophorou M., 2000). However, the impacts to zonation are expected to be very long term, and mostly affected by temperature and salinity changes.

Impacts on biodiversity

One of the biggest ecological threats of climate change is the impact on biodiversity. During the Pleistocene, temperature changes, changes in sea level and extreme climate events had taken place (CBD, 2003) causing severe biota responses such as changes in biological communities, landscapes and biomes, changes of species distribution, speciation, immigration and extinctions (Cronin *et al*., 1999; CBD 2003, Lovejoy and Hannah, 2005; Mayhew *et al*., 2008). In general, biota tends to respond to climatic changes in three ways: species changes in geographical range; species adaptation to new environmental conditions; and species decline and extinction (Rousou M., 2009).

As the climate warms, environmental niches will present changes in size by becoming narrower and in distribution, by moving polewards or upwards (cited in Lewis, 2006). The first recorded climate change induced species extinction was the Costa Rica's golden toad *Bufo periglenes* (UNEP, 2007; IUCN, 2008). The Galapagos emperor penguin populations Terre Adélie declined by 50 percent (UNEP, 2007). Chevaldonne and Lejeusney (2003) reported that the mysid *Hemimysis speluncola* had decreased in numbers, it had disappeared from most marine caves, with the exception of the two coldest regions of the Mediterranean Sea and it had been replaced by the warm-water species *H. Margalefi.*

The strategic location of the island of Cyprus between three different continents, in a marine territory characterized by a variety of indigenous species, and its proximity to natural and manmade nautical channels which favor species migration and relocation, have turned Cyprus into a biodiversity hotspot. The marine flora and fauna of Cyprus is characterized by great diversity and low biomass, making it vulnerable to the effects of climate change. Changes in temperature, salinity, and nutrient levels can be the starting point of any of the three courses induced by climatic alteration. Levantine basin is characterized by high temperature and salinity, as well as low nutrient levels, making it a challenging biological niche which constantly tests species' tolerance limits to physical components.

Invasive species enter into the Mediterranean through the Gibraltar straits, the Suez Canal, and by being carried in ballast water of ships. The commonest route for migration of species to the Levantine basin is the Suez channel, from where Lessepsian migratory species find their way from Red sea into the Mediterranean. Biological invaders are considered a threat for endemic species as they can present adjustment advantages, causing them to displace or replace naturally occurring species from their habitats. As the Red sea is characterized by generally higher temperatures than the Mediterranean, a rise in average water temperature in the Mediterranean waters, can offer an adaptive advantage to invasive species, causing the displacement of other, endemic species. Such examples of invasive species in Cyprus are the recent sightings of *Lagocephalus suezensis.* which appear to be growing in numbers, *Caulerpa racemosa, Siganus luridus, Siganus rivulatus, Etrumeus teres, Fistularia commersonii,* and a lot of other species, reaching up to a total of 300 Lessepsian species (Psomadakis *et al.*), of which 65 are fish (Golani *et al*., 2006). Especially threatened from invasive species migration are species listed as endangered (**Table 1**) on which potential research should be primarily focused.

Other than invasive species, local biodiversity is also threatened by immediate changes taking place as a result of climate change. For example, marine habitats of neuralgic importance, such as *Posidonia oceanica* meadows, are very sensitive to salinity, temperature and sedimentation alterations. As the meadows produced by this marine plant function as nursery grounds for juvenile fish, reproductive fields, and fisheries stock replenishment areas, potential loss of the meadows would result in catastrophic consequences for the marine biodiversity of Cyprus and commercial fisheries.

Table 1: List of protected fauna species found in Cyprus (Hadjichristophorou M., 2000)

VERTEBRATES	INVERTEBRATES
Mammals *Monachus monachus* (SPA) *Delphinus delphis*(SPA) *Stenella coeruleoalba*(SPA) *Tursiops truncatus*(SPA) **Reptiles** *Chelonia mydas* (SPA) *Caretta caretta*(SPA) [*Mauremys caspica* (NL)] [*Natrix natrix cypriaca* (NL--FW)] **Fish** *Aphanius fasciatus*(SPA) *Hippocampus hippocampus*(SPA) *Hippocampus ramulosus*(SPA) *Mobula mobular*(SPA) **Amphibia** [*Bufo viridis*(NL--FW)] [*Hyla savignyi (* NL--FW)]	**Arthropods** *Ocypode cursor* (SPA) [*Potamon potamios* (NL)] [*Artemia salina* (cysts) (NL)] **Molluscs** *Charonia tritonis*(SPA) *Erosaria spurca* (Cypraea spurca) (SPA) *Luria lurida*(Cypraea lurida) (SPA) *Tonna galea* (SPA) *Lithophaga lithophaga*(SPA) *Pholas dactylus*(SPA) *Pinna nobilis* (SPA) **Echinoderms** *Asterina panceri* (SPA) *Ophidiaster ophidianus* (SPA) *Centrostephanus longispinus*(SPA) **Porifera** *Axinella polypoides*(SPA) *Axinella cannabina*(SPA) *Geodia cydonium*(SPA)

SPA --Annex II of SPA protocol
NL--specifically protected under national legislation
NL—FW protected as freshwater fauna under the Fisheries Regulations (protected Fish. RegReg273/90). [ ] Denotes freshwater/inland water species273/species

Pollution

The main marine pollution concern in Cyprus is nutrient pollution. The eastern Mediterranean area is characterized as ultra-oligotrophic (Hadjichristophorou M., 2000), indicating a very low load of nutrients and low primary productivity. As primary productivity in the area is nutrient-limited, even a small amount of nutrient load can affect the sensitive balance of the ecosystem, causing eutrophication events. Such events have been reported over the last 15 years with the ephemeral filamentous macroalgae *Cladophora spp*. that was observed in summers of 1990, 1991, 1998, 2004, and 2005 in some coastal areas (Liopetri/Ayia Napa, Limassol) of Cyprus (Images 4-7) , causing nuisance problems on the shore (Hadjichristophorou M.,2000).

Eutrophication events can cause oxygen deprivation in the areas they are occurring, and certain species' bloom can be even toxic for aquatic and human life. Under the Nitrate Directive, the Department of

Fisheries and Marine Research of Cyprus is responsible for the implementation of its requirements for coastal waters which are monitored regularly for nutrients and chlorophyll-a.

Although nutrient loading is not expected to increase as a result of climate change, increased temperatures are known to favor eutrophication events. Water temperature increase due to global warming can greatly exacerbate these events by increasing metabolic rate of the plants, reproduction rate, and spatial dispersion.

Image 4: Nissi Beah eutrophication event (Hadjichristophorou M., 2000)

Nitrate directive – Monitoring Areas

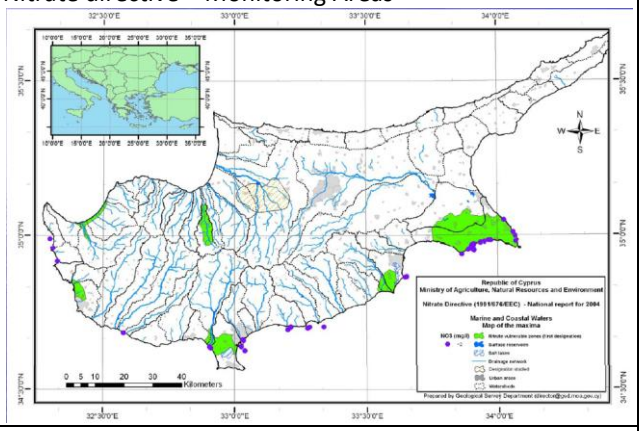

Image 5: Monitoring areas under the nitrate directive EU (Hadjichristophorou M., 2000)

Image 6: Nissi beach eutrophication event (Parari M., 2008)

Image 7: Nissi beach Cladophora bloom (Parari M., 2008)

All of the above problems and many others constitute a major threat that will present itself gradually through climate change and can result in disruption of fisheries activities, recreational use of beaches, and natural treasury loss. For this reason, close monitoring and data collection is suggested for all of the indicated parameters, especially for areas and species which are in immediate danger as mentioned above. As well as that, the constitution of a special climate change impact committee could present to be of great use in implementing and guiding government actions towards achieving sustainability of the affected species and habitats.

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