

# **Sea Change: Implications for human health and well-being.**

Michael H. Depledge <sup>1,2</sup>

<sup>1</sup>Plymouth Marine Laboratory,  
The Hoe, Prospect Place,  
Plymouth, PL1 3DH  
UK

&

<sup>2</sup>Peninsula Medical School,  
Tamar Science Park,  
Research Way,  
Plymouth,  
UK

*Abstract*

Climate change is now widely recognised as being one of the greatest threats to human health and well-being in the Mediterranean region in the coming decades. Impacts are being superimposed on those associated with point source and diffuse pollution, habitat and biodiversity loss, overfishing and the development of coastal regions for tourism and industrial activity. This is happening at a time when demographic studies are revealing increased population densities in coastal areas, and indeed, growth in the population of the whole region. In this paper, these issues are reviewed and examined in some detail. The options available to environmental managers and policy makers are discussed. In particular, a shift away from chemical monitoring to biological effects studies is advocated, as is the need for a more integrated approach to policy formulation and implementation.

### *Introduction*

There is widespread recognition that climate change is profoundly affecting life on Earth. Evidence suggests that it will continue to do so for the foreseeable future (May, 2006). A major consequence is that our seas are also changing. As the icecaps and glaciers melt, sea level is rising and ocean currents are altering. One third to a half of anthropogenic CO<sub>2</sub> emissions have been absorbed in the oceans (WBGU, 2006). As this process continues, seawater will become increasingly acidic. Inevitably, these changes in our seas will impact mankind.

The relationship between the status of marine ecosystems and human health is both intimate and complex. The world population continues to grow with 25 to 50% of people living in coastal zones (Bowen *et al*, 2006). As our numbers double over the next 40-50 years, the population of coastal regions will undoubtedly increase still further. Average population density is already 10% higher on the coast than in inland areas and human activities are dramatically reconfiguring the coastal environment. Natural resources are being depleted, natural chemical cycles are being disturbed and enormous quantities of waste are being generated, including toxic chemicals, radiation and heat. It is vital to recognise that anthropogenic pollution of marine ecosystems is superimposed on effects associated with climate change. It is their integrated impact that is leading to changes in biodiversity and damage to ecosystem structure and function, as well as the collapse of fisheries world-wide (Wilson, 2002). Given the dependence of 1 billion people on seafood as their main source of protein, contamination and degradation of the marine environment will have adverse consequences for health and well-being.

The scale of the challenge facing us was acknowledged in the Oristano Declaration “..... *the global coastal environment is under threat through intensified natural resource utilisation brought about by higher densities of settlements, increased shipping, rapidly growing aquaculture production, expanding tourism activities, massive resource exploitation and other activities, nowhere more so than in the coastal marine environment.* All of these issues contribute individually, but more important, cumulatively to higher risks for the global burden of disease (Bowen and Depledge, in press).

### *The changing characteristics of the Mediterranean Sea Region*

The population of the Mediterranean countries was about 450 million in 1996 but will increase by ca.100 million by 2030 (EEA, 1999). In 2000, the 22 countries bordering the Mediterranean Sea accounted for 7% of the World's population, 13% of the world GDP (though decreasing as the Asian economies grow), 60% of the worlds water poor people and contributed 8.3% of the CO<sub>2</sub> emissions (Plan Bleu, 2006).The rising population is enhanced annually by tourism, particularly on the shores of the north-western basin. There are approximately 218 million visitors each year who constitute 32% of global tourism. This number is expected to rise to 235–300 million per year in the next 20 years (EEA, 2006). These demographic changes and the way in which people live probably

represent the greatest threats to the sustainability of the Mediterranean marine ecosystem. Figure 1 vividly demonstrates the growth in human populations living in coastal towns and cities between 1950 and 1995. From 601 coastal cities with a population of more than 10 000 inhabitants, only 69 % operate wastewater treatment plants. The detoxification and removal of pollutants is often inadequate. Untreated or partly treated urban effluents contain significant loads of nutrients and suspended matter that are contaminated with metals and other pollutants. Especially significant impacts occur in southern and eastern Mediterranean countries in contrast to northern countries where efforts devoted to overcoming the problems generated by the use of chemicals are at least partially successful (EEA, 2006, Plan Bleu, 2006). However, throughout the region there appears to be a lack of political willingness to enforce environmental regulation. The southern Mediterranean in particular is growing at the expense of the natural environment since neither the economic conditions nor the required technologies to support management actions are available. According to the European Environment Agency, the top priority in environmental management in the Mediterranean region is to develop the necessary environmental legislation and to enforce it (EEA, 2006).

Data on the total size of the Mediterranean catchment area are not available. The Nile, Rhône, Ebro and the Po rivers all flow into the Mediterranean Sea. There is also a net inflow from the Black Sea. Overall, however, evaporation exceeds precipitation and freshwater inputs giving rise to a high salinity in the Mediterranean Sea (EEA 2006). The region's seawater is also characterized by having a relatively high temperature (12 to 25 °C), which some have suggested induces high metabolic rates in marine biota (EEA, 2006). Infact, metabolic adjustments probably ameliorate this effect to some extent, but there is no doubt that many marine organisms live close to their thermal limits and oxygen availability is reduced compared to that at lower seawater temperatures. Global warming will exacerbate these effects. The tidal range is less than 50 cm and thus contributes little to mixing, dilution and dispersion of dissolved and particulate polluting wastes. Mediterranean waters are poor in nutrients, exhibit low primary production and low phytoplankton biomass. The fauna and flora is, however, one of the most biodiverse in the world. High numbers of alien species are invading the region, especially via the Suez Canal (EEA, 2006, Plan Bleu, 2006). It is interesting to consider whether these invaders should also be protected from pollutant impacts. If so, then actions should be taken to assess their vulnerability.

One further point that is often overlooked is the impact of dams on the Mediterranean Sea. Clearly, modification of river flow rates in the region will alter freshwater inputs, nutrient and sediment loads as well as pollutant inputs. The construction of the Aswan Dam in 1965, for example, resulted in severe reductions in nutrient inflow into the eastern Mediterranean with severe adverse consequences for biodiversity (Azov, 1991). Currently, hundreds of new dams

are being planned. In Turkey alone, by 1991 164 large dams and 765 small dams had been completed and put into service to ensure the water supply, irrigation, hydropower and flood control. Environmental modification, such as construction of dams, can change the temperature and humidity of the soil and vegetation, which may result in changes in the spread of infectious parasitic diseases such as leishmaniasis. Notably, the outbreak of cutaneous leishmaniasis in the central and southern parts of Tunisia in 1982-83 occurred following the construction of the Sidi Saad Dam (Ben Rachid and Ben Ismail, 1987).

#### *Past and present status of Mediterranean pollution*

Land-based sources of Mediterranean pollution include; sewage and urban runoff, urban solid wastes, persistent organic pollutants (POPs), heavy metals, organohalogen compounds, radioactive substances, nutrients, suspended solids and hazardous wastes. Off shore and marine-based pollution is due primarily to petroleum hydrocarbons from shipping activities and marine litter. 30% of international maritime freight traffic and 20-25% of oil maritime transport is via the Mediterranean Sea. Current environmental problems of the coastal regions are summarized in Table 1.

Exposure to, and effects of, endocrine disruptors, heavy metals and persistent organic pollutants are being documented increasingly for organisms such as marine mammals, living in open waters. (Fossi et al, 2000; Fossi and Marsili, 2001). Along the Mediterranean coastline, 131 'pollution hot spots' have been identified (UNEP/WHO, 2003). These hot spots are point pollution sources or polluted coastal areas which may affect human health, ecosystems, biodiversity, sustainability, or economy. Of these, 26 % are urban, 18 % industrial and 56 % mixed (urban and industrial) (UNEP/WHO, 2003). Additionally, 59 marine areas under threat of becoming pollution hot spots have also been identified along the Mediterranean coastline (EEA, 2006). An unexpected major threat is posed by stockpiles of hazardous chemicals. For example, lindane stockpiles are located at Durres, Albania. Releases have heavily contaminated the area and rainwater has carried the contaminants into the sea. High concentrations of PCBs and pesticides have since been found in marine samples collected from nearby Porto Romano Bay. The human health impact is imminent as thousands of people recently arrived from other parts of Albania and are now living in and around the highly contaminated area (EEA, 2006).

It is noteworthy that the European Union has defined 'hazardous substances' as substances or groups of substances that are toxic, persistent and liable to bioaccumulate; and other substances or groups of substances which give rise to an equivalent level of concern (EU Water Framework Directive 2000/60/EC, Art 2). This definition is perhaps unwise as an enormous number of hazardous substances are not persistent or bioaccumulative, but still leave powerful toxicological legacies following exposure (for example, benzene). Substances tend to persist and bioaccumulate precisely because they do not easily interact with metabolic and physiological processes. Instead, they remain in sanctuary sites, especially fat deposits. This issue clearly needs to be reconsidered.

### *Future threats to the Mediterranean region*

As well as continued problems with current pollutants, widely recognized, emerging marine issues for the Mediterranean region include biological invasions, overexploitation of fisheries resources, expansion of aquaculture, natural hazards and ecological quality status, and the increasing appearance of Harmful Algal Blooms (HABs), EEA, 2006). With regard to the latter, it has been estimated that the socio-economic impact of HABs in Italy, Greece and France is already around 329 million euro per year (EEA, 2006).

The forementioned list presents a rather limited view of future challenges. In the broadest sense, population growth and redistribution, and socio-economic developments, together with climate change are likely to be the greatest threats. More specifically, several new chemicals are beginning to pose problems including organobromine compounds used as flame retardants; for example, the brominated diphenyl ethers used in electronic components, plastics and textiles (Dewailly and Knap, 2006). Halogenated phenolic compounds (HPCs) are also a cause for concern although they are not routinely measured. HPCs include the hydroxyl metabolites of PCBs and pentachlorophenol (PCP). Their distribution in the Mediterranean marine environment is not well known, nor is the extent of the threat they pose to human health. However, in Canada, HPCs have been found in seafood and in the human consumers of the seafood. Dewailly and Knap (2006) also identify perfluorooctane sulfonate (PFOS) as a threat. It is very persistent and appears to be an increasingly common contaminant found in Mediterranean marine mammals (Kannan *et al* 2005). Although suspected of being an endocrine disruptor the evidence is inconclusive.

The increase in coastal population densities and the ageing of the northern European population is resulting in the extensive use and release of pharmaceutical agents (Jones *et al*, 2004). This deserves special attention (see Budzinski and Togola – this volume) and may represent a worrying insidious threat to both biota and human beings. For example, the use of cancer chemotherapy agents is increasing by 10% year on year in some countries in northern Europe and residues are now measurable in some European rivers. These will eventually pass to the sea. En route, however, river water is often abstracted for use as drinking water for humans.

As new analytical methods become available with increased sensitivity, there will, no doubt, be many more organic chemicals that raise concerns. However, perhaps more attention should be given to assessment of the biological effects associated with exposure to these chemicals and to complex mixtures of contaminants. Measuring chemical residues, such as the persistent organic pollutants as recommended by the Stockholm Convention, may be far too complex and expensive for many of the countries surrounding the Mediterranean Sea. It seems unwise to add one chemical after another to the list of substances that should be measured.

Biomonitoring studies have been conducted around the Mediterranean Sea for more than 30 years. They involve measuring chemical residues in tissues of marine organisms, usually mussels, thereby demonstrating bioavailability (the Mussel Watch programme, Goldberg, 1975; CIESM, 2002). These programmes are valuable in that they identify mussels and other seafood in the local area that are unfit for human consumption and they also provide useful information concerning trends in contaminant release and bioavailability. However, they do not help to assess the integrated impact of contaminants and environmental stressors on the health of populations and communities of marine organisms, or effects on ecosystem structure and function. For this, the biomarker approach offers a more practical, ecologically relevant way forward (Depledge and Galloway, 2005). Biomarkers are biochemical, cellular, physiological or behavioural responses of organisms that signal exposure to or adverse effects of anthropogenic chemicals and radiation (Depledge, 1994). Biomarker response can provide early warning of pollution exposure and effects that then inform management actions. It is essential that suites of biomarkers are used in a weight of evidence approach, and in combination with chemical residue information (Depledge, 1989, Depledge *et al*, 1992).

At least two trends are emerging in biomarker research. The first reflects the realization that both the costs and the availability of expertise may limit the feasibility of measuring either chemical residues or biological responses in organisms in many of the poorer countries around the Mediterranean Sea (and indeed, in developing countries world-wide). This has been addressed through the development of the RAMP programme (Rapid Assessment of Marine Pollution) which is a pilot programme of the Global Oceans Observing System (Depledge, 2000; Galloway *et al*, 2002). It involves the use of rapid, easy to use, inexpensive measurements of chemical pollutants and biomarkers that permit a preliminary assessment of the state of the coastal marine environment. A second trend to emerge is the development of increasingly sophisticated methods for measuring patterns of biomarker responses. This involves use of the very latest techniques emerging in the fields of genomics and proteomics, and is at present an expensive option. However, it is highly likely that these techniques will rapidly become cheaper, simple to use and robust (see papers by Hamilton and Bebbiano- this volume).

The threat posed by plastics in the Mediterranean Sea is growing. Millions of metric tons are produced annually and significant quantities end up in the marine environment (Galgani *et al*, 2000). In some parts of the Mediterranean Sea enormous numbers of plastic bags have accumulated offshore resulting in the death of marine mammals, fish and invertebrates. More worrying still is the finding that as plastic wastes degrade they are often reduced to fine and ultrafine particles that become incorporated in sediments (Thompson *et al*, 2004). These particles in turn are ingested by deposit feeders. Effects are largely unknown but early evidence suggests that plastic particles do bind chemical pollutants to their surfaces and may affect bioavailability.

Trends in chemical production in the future warrant closer inspection. Many chemical manufacturers envisage increased production in Asia and that their activities will be geared more to the needs of an estimated 1 billion new consumers in Asia over the next 10-20 years. In Europe, a different pattern is starting to emerge with successful advances in nanotechnology and in producing genetically modified organisms (Royal Society, 2002; 2004; Owen and Depledge, 2005). Up to 25% of industrial manufacture will be achieved using nanotechnologies with investment in excess of US\$16 trillion anticipated over the next 10-20 years. New antifouling materials involving nanoparticle coatings are already being tested on boats, booms and other structures in the marine environment. Cerium oxide nanoparticles added to diesel fuel increase fuel efficiency by up to 30% in land-based vehicles and plans are underway to use them in shipping. There are many other examples of nanotechnology applications, but as yet little attention has been paid to the likely fate and effects of nanomaterials in the marine environment.

The political situation in several countries surrounding the Mediterranean Sea is unstable and is a cause of concern, not only in its own right, but because of potential pollution impacts. Oil spills resulting from the recent war in Lebanon provide one such example.

#### *Policy challenges*

The key challenge in developing policies to combat pollution threats in the Mediterranean Sea and elsewhere is to ensure that an integrated approach is adopted based on the best available scientific evidence. Assessing the toxicity of individual chemicals, setting safe limits and monitoring their concentrations in the environment will not suffice. Exposure to pollutants invariably occurs in complex mixtures, for example, following the discharge of sewage or industrial effluents. In the coming years the bioavailability of pollutants will be influenced by rising seawater temperatures and increasing acidification. It is easy to imagine how this might increase the bioavailability of some heavy metals, but there may also be effects on the bioavailability and persistence of organic pollutants.

The changing nature of pollution threats in the Mediterranean Sea will have to be considered and factored into new policies and regulations. Climate change will affect precipitation rates and outflow from catchments discharging into Mediterranean coastal areas. This in turn, will influence both the timing of release and the amounts of pollutants delivered via this route. The types of pollutants discharged will also change significantly. Policies and regulations will have to address the socio-economic changes that occur as industrial manufacture over the coming years shifts increasingly from northern Mediterranean countries to those in the south, or more likely still, to other regions of the World, especially Asia. A range of complex mechanisms link chemical pollution to human health and well-being and these are of growing significance in affluent Mediterranean countries. Impacts of chemicals on human health not only occur via the food supply or air pollution, but also indirectly through damage to coastal ecosystems.

In the southern Mediterranean, the METAP (Mediterranean Environmental and Technical Assistance Program) has provided valuable insights in the relationships between environmental pollution, ecosystem degradation, economic burdens and threats to human health and well-being (METAP, 2006). Algerian coastal communities east of the capital Algiers provide examples of both heavily degraded coastal areas and coastal areas that have been relatively well preserved. Studies show that uncontrolled urbanization and poorly regulated environmental pollution are the main causes of degradation costs. Urbanization and industrial installations create economic deficits by polluting water and air and by generating waste. Total costs were estimated to be between 4 and 9 % of the GDP of the pilot area. The greatest costs were related to effects of coastal degradation on health. This included losses of recreational opportunities, ecosystem services, in particular availability of ground water, and productivity of agricultural and natural systems (METAP, 2006).

There is growing evidence that humans benefit from spending time in natural ecosystems (see Depledge, 2006). Exercising and relaxing in natural environments have important health benefits and have been shown to be valuable in the treatment of mental disorders. The financial consequences can be quantified and are significant.

All of the above need to be reflected in a new suite of integrated environmental, human health and long term economic policies for the Mediterranean region. If natural and aesthetically pleasing ecosystems continue to be lost as a result of pollution and habitat destruction then Mediterranean countries and their populations will be the poorer.

*Dedication.*

This paper is dedicated to the memory of my mother, Edna May Depledge (1926-2006).

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