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MINIREVIEWS

Changing Views of the Interconnections Between the Oceans and Human Health in Europe

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Abstract Early steps in the emergence of the discipline of "Oceans and Human Health" are charted in the USA and discussed in relation to past and present marine environment and human health research activities in Europe. Differences in terminology are considered, as well as differences in circumstances related to the various seas of Europe and the intensity of human coastal activity and impact. Opportunities to progress interdisciplinary research are described, and the value of horizon scanning for the early identification of emerging issues is highlighted. The challenges facing researchers and policymakers addressing oceans and human health issues are outlined and some suggestions offered regarding how further progress in research and training into both the risks and benefits of Oceans and Human Health might be made on both sides of the Atlantic.

Introduction

In Europe, as in other parts of the world, polluting nutrients, industrial chemicals and radionuclides, algal blooms, coastal zone destruction, habitat loss and catastrophic overfishing have all heavily impacted life in marine ecosystems [1]. Major efforts continue to manage and mitigate these threats. Typically, emphasis is placed on ensuring that we do not damage the sustainability of ecosystems or over-exploit marine resources, thereby jeopardising future economic prosperity. However, another way to view these issues is as a mounting threat to the health and well-being of the human population. As our seas and oceans deteriorate, marine biodiversity continues to decrease, seafood quality is falling due to contamination with chemicals and pathogens, and the aesthetic value of our seas and oceans is being lost. How then can we develop better ways of ensuring that marine ecosystems are managed sustainably and that humans continue to prosper around their margins?

Moore et al. (this volume) have provided an overview of the contemporary approach to oceans and human health that is being developed by the Marine Board of the European Science Foundation. In the present paper, we briefly summarise the background of the strongly emerging field of oceans and human health in the USA and compare this with past and present experiences in marine research in Europe, to provide a broader contextual setting for future work.

Transatlantic Influences

As was alluded to above, European scientists and policymakers have been looking with interest over the last 10 to 15 years at research activities in "Oceans and Human Health" in the USA. In this new interdisciplinary activity, the intimate interconnections between marine ecosystem structure and function with human health and well-being are being explored. In its leadership of the development of the Global Oceans Observing System, North American scientists (together with a few individuals from other parts of the world) were far sighted in facilitating the inclusion of research on how the oceans influence human health and

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well-being. The establishment of a "Health of the Oceans" panel in 1997 was a tangible manifestation of this early work [2], as was the United Nations declaration in 1998 of the "International Year of the Ocean" with associated worldwide activities celebrating the importance of the oceans and their interconnections with humans.

In 1999, the US National Research Council published a seminal document summarising many of the important issues associated with oceans and human health: *From Monsoons to Microbes*: *Understanding the Oceans Role in Human Health* [3]. As well as summarising the state of knowledge, this document suggested how current and future efforts should be directed so that future health needs and threats could be anticipated and addressed. Negative effects, or risks, serve as warnings of the potentially damaging consequences of human activities on the oceans, which ultimately lead back to impose major adverse effects on human health. At the same time, these potential impacts have led to the development of new tools and scientific discoveries in the areas of: natural products (or "drugs from the seas"), marine indicators and probes, marine models of human disease, the protection of the marine food supply, and the development of comprehensive worldwide observing systems that generate the possibility of control and prevention [4, 5].

Also notable in this development phase was an oceans and human health symposium entitled "The Interaction Between Healthy Oceans and Human Health" held in May, 1999, at the Bermuda Institute for Ocean Science (formerly the Bermuda Biological Station for Research). A small number of European scientists participated in this event, but in general, the participants list was once again dominated by North American academics and policymakers as well as research students. Ideas that emerged were summarised by Knap et al. [6].

Following these initial steps, the US National Institute of Environmental Health Sciences in collaboration with the US National Science Foundation developed a funding programme of Oceans and Human Health Centers to foment interdisciplinary research and training between biomedical and oceanographic scientists, which were located at the Universities of Hawaii, Washington, and Miami and at Woods Hole Oceanographic Institution. In addition, the US National Oceanographic and Atmospheric Administration funded three of its own centres in Washington State, South Carolina and along the Great Lakes, to expand their activities into research, training and dissemination as part of their Oceans and Human Health Initiative. These and numerous other actions of the US Government to support the development of oceans and human health programmes are reviewed by Sandifer et al. (this volume).

Starting in 2008, as a result of the rapid expansion in activities in oceans and human health, another initiative was taken to hold a series of prestigious conferences, the Gordon Research Conference and Graduate Research Seminar in Oceans and Human Health, to further consolidate the field as a new scientific discipline [7–9]. At the most recent Gordon Conference held in Maine, USA, in June 2012, discussions led to a consensus that there is now sufficient interest to consider holding a future Gordon Conference on Oceans and Human Health in Europe. It is with this prospect in mind that in subsequent sections, we have briefly highlighted some differences in emphasis in approach between Europe and the USA, and identified a selection of past activities that might be considered as a historical basis for future European oceans and human health research.

Factors Influencing Approaches to Marine Environment and Human Health Research

It is worth emphasising that small differences in terminology used in Europe and the USA may often obscure similarities in approach. For example, it is rare to find "Oceans and Human Health" mentioned as a research theme in Europe simply because Europeans usually refer to "seas" rather than "oceans", for example, the North Sea, the Mediterranean Sea, the Aegean Sea, the Baltic Sea, the Black Sea. Secondly, in the USA, diverse aspects of oceans and human health research have been collected to a small, but increasingly significant, degree under one banner, while the topics in Europe still tend to be dealt with separately.

Another important difference is related to the intensity of human activity in marine ecosystems. This relates, in part, to the lengths of the coastlines of the USA and Europe relative to population size. The US coastline is estimated to be ca.153,646 km long, whilst that of Europe only spans 89,000 km. Conversely, the population of the USA is ca. 312,000,000, whilst that of Europe is more than twice as large at ca. 738,199,000. In the USA, ca. 90 million people are regarded as living by or near the coast, while in Europe, an estimate made on the same basis suggests that there are at least 200 million coastal inhabitants. The very high intensity of human activity in European coastal areas has been a key factor influencing the research agenda. In the Mediterranean Sea, more than 50 % of the coast has been modified by building concrete structures (coastal defences, promenades, marinas, etc.), while across Europe more broadly, approximately two thirds of coastal wetlands have been lost since the beginning of the twentieth century as a result of exploitation of the coastal margin. Eighty percent of marine pollution comes from land-based human activities [10]. It is perhaps unsurprising therefore that overfishing, nutrient and environmental chemical pollution, coastal zone destruction and related issues have attracted most attention from European funding bodies.

Historical Associations Between European Medical Research and Marine Science

Europe has had a long tradition of using marine organisms in the search to understand human physiology and disease. For example, in their Nobel Prize-winning work uncovering ionic mechanism of action potentials, Hodgkin and Huxley performed experiments on the squid giant axon at the Plymouth Marine Laboratory of the Marine Biological Association of the United Kingdom (UK). Twelve other Nobel Prize winners have conducted research looking at fundamental biological processes by using marine models in the 125-year history of the Marine Biological Association, most notably A.V. Hill who received the Nobel Prize in 1922 for discoveries relating to the production of heat in muscle, as well as B. Katz who received the Noble Prize in 1970 for work on neurotransmission. Other notable recent Nobel Prize-winning work in the biomedical sciences stemming from marine research includes R.Y. Tsien's work in the USA on jellyfish fluorescent proteins which led to the discovery of green fluorescent protein, one of the most widely used molecular markers in cell biology in Europe and elsewhere; E. Kandel's research on neurophysiology and neurologic development using the sea slug (aplysia) in the USA and T. Hunt's discovery of cyclins and the regulation of the cell cycle using the sea urchin egg model in Cambridge, UK.

Other European Marine Biological Stations have played an equally important role in the advancement of medicine. The Stazione Zoologica A. Dorn in Naples was instrumental in developing the fields of modern experimental embryology, physiology and genetics. Some of the most influential embryologists of the nineteenth and twentieth centuries worked in Naples, including W. Roux, T. Boveri, O. Warburg (who went on to study respiration in cancerous cells), T.H. Morgan (who also established the basis of chromosome genetics), and H. Driesch's work on the determination of cell fate, the roles of the nucleus and cytoplasm and the biochemistry of development in sea urchin embryos, establishing concepts such as "epigenetic" regulation of development and "chemical embryology". Other workers in Naples, such as J. Loeb, studied regeneration in animals, leading to concepts of the roles of axial gradients in morphogenesis. These landmark studies in biology were echoed around Europe's increasing number of marine laboratories including those in Monaco, Villefranche and Roscoff in France, Plymouth in the UK and Kristineberg in Sweden, amongst several others. Today, marine organisms provide an ever-increasing wealth of marine models for basic biomedical research, which fit well within the overall field of "Oceans and Human Health".

With the advent of large-scale "omics" approaches in marine biology, a number of the marine stations mentioned above are realising the value and necessity of joining forces to create a European infrastructure that will co-ordinate access to modern technology platforms, infrastructure, expertise and facilities that no single marine laboratory can provide. Twelve of the foremost marine laboratories[1] along with the European Molecular Biology Laboratory are currently working together to turn this vision into reality through the European Marine Biological Resource Centre (EMBRC), a European Strategy Forum on Research Infrastructures initiative. The EMBRC has advances in biomedical science, oceans and human health, sustainable ecosystems and anthropogenic impacts as key research themes and will provide access to a range of relevant ecosystems and models [11]. The overall aim is to achieve a step change in marine biological and biomedical research that will match the great advances made in the early twentieth century when many of the marine stations were first established.

These examples serve to highlight the fact that the medical and marine biological research communities have had a long association with one another, but usually in the context of marine scientists providing insights and materials to support biomedical advances. The idea that the marine environment, its structure and processes can have a major bearing on current and future human health and well-being, and public health more broadly, is only now gaining traction in Europe.

The European Union and the Marine Environment

Modern-day governments in many European countries readily acknowledge that marine ecosystems are under continuous pressure from anthropogenic activities. To meet this challenge, the European Commission (the executive body of the European Union) has developed an extensive battery of directives and other regulations that have helped to mitigate threats and protect habitats and biodiversity. Unsurprisingly, despite their efforts, the adverse impacts of the greatest threat, climate change, continue to be increasingly evident and is already threatening the European population, as are the adverse effects engendered by low levels of environmental contaminants and pollutants that pose escalating long-term risks to the environment and human health [12]. It is these two later points that highlight the need to view "Oceans and Human Health" more holistically and as a priority research theme in Europe and beyond.

[1] Partners in the European Marine Biological Resource Centre include: Stazione Zoologica, Naples; Centre for Hellenic Marine Research, Crete; Observatoire Oceanologique, Banyules; Observatoire Oceanologique, Villefranche, Station Biologique Roscoff; Sven Loven Centre for Marine Science, Kristineberg; Scottish Association for Marine Science; Scottish Oceans Institute; Plymouth Marine Science Cluster, Alfred Wegener Institute for Polar and Marine Research; Sars International Centre for Marine Science, Norway; Centre for Marine Sciences, Faro; European Molecular Biological Laboratory, Heidelberg.

The Marine Strategy Framework Directive (Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008) provides the main framework for community action on marine environmental policy [13]. Its implementation brings together several existing directives (such as the Habitats and the Birds Directive, the Water Framework Directive), as well as other directives and regulations addressing waste water treatment, the land-based pollution, the prevention of pollution in maritime transport, environmental impact assessment and the common fishery policy. The aim is to deliver "Good Environmental Status" by 2020 using the following "qualitative descriptors" as measures of progress:

1. Maintenance of biological diversity
2. Non-indigenous species introduced by human activities to be at levels that do not adversely alter ecosystems
3. Populations of all commercially exploited fish and shellfish to be within safe biological limits, exhibiting a population age and size distribution that are indicative of a healthy stock
4. All elements of marine food webs to occur at normal abundance and diversity, and levels capable of ensuring long-term abundance of species and retention of their full reproductive capacity
5. Human-induced eutrophication to be minimised
6. Sea-floor integrity to be at a level that ensures that the structure and functions of ecosystems are safeguarded and that benthic ecosystems, in particular, are not adversely affected
7. Permanent alteration of hydrological conditions not to adversely affect marine ecosystems
8. Concentrations of contaminants to be at levels not giving rise to pollution effects
9. Contaminants in fish and other seafood for human consumption not to exceed levels established by community legislation or other relevant standards
10. Properties and quantities of marine litter not to cause harm to coastal and marine environments and
11. Introduction of energy, including underwater noise, to be at levels that do not adversely affect the marine environment

It is unfortunate that none of these descriptors directly address the health and well-being of coastal communities, or the human population more generally (although threats to individuals from contaminated seafood are mentioned). Threats from marine microbial pathogens and viruses are not specifically mentioned, nor are the impacts of climate change, air pollutants generated through marine activities, and through warming of the oceans or ocean acidification; finally, nor are any benefits to human health and well-being delineated that might accrue from spending time in coastal areas. Nonetheless, it is implicit in many of the marine research programmes that have been (or are being) conducted across Europe that some consideration is given to public health concerns. A few examples are given below. Note that this is by no means a comprehensive list but simply some illustrative cases with which we are familiar.

Health Research Related to the State of European Seas

A wide range of research activities have been undertaken in European seas over the last 150 years. Many have been, and continue to be, under the auspices of regional organisations. In general, whenever human health has been considered, it is usually as a sub-component of a much larger research endeavour.

Around 150 million people live along the 46,000 km of Mediterranean coastline, with an additional 200 million tourists visiting the region each year. Their impact is added to by more than 200 petrochemical and energy installations, chemical industries and chlorine plants located along the Mediterranean coast [10]. Concerns about the decline in the quality of the Mediterranean Sea led the United Nations Environment Programme (UNEP) to introduce the Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (1980, amended in 1996) and the Dumping and Hazardous Wastes Protocols. The marine pollution assessment and control component of the Mediterranean Action Plan, the MED POL Programme [14], undertakes follow-up work. It assists Mediterranean countries in the formulation and implementation of pollution-monitoring programmes, including pollution control measures, and the drafting of action plans aimed at eliminating pollution from land-based sources.

Pollution of the Mediterranean arises in large part due to municipal wastewater treatment and disposal, urban solid waste disposal activities, contributions from atmospheric deposition, release of harmful concentrations of nutrients into the marine environment and storage, transportation and disposal of radioactive and hazardous waste and as a result of the destruction of the coastline and coastal habitats. The preparation and adoption by the Contracting Parties of the Barcelona Convention (2005) of a Strategic Action Programme (SAP MED) of regional and national activities to address land-based pollution is one of the major breakthroughs in the Mediterranean countries' coordinated efforts to combat land-based pollution. It is implied that this, in turn, will reduce risks to human health and the environment.

Another organisation that was one of the earliest to consider "Oceans and Human Health" issues in Europe is the Mediterranean Science Commission (CIESM) [15]. The commission, with members from 22 Mediterranean countries, incorporates a number of different marine-related disciplines involving the biological processes, hydrography, marine

geophysics and chemistry of the Mediterranean Sea, as well as tracking and analysing the impacts of climate change on sea levels and water masses, and changes in marine biodiversity, coastal morphology and bioaccumulation of trace metals in marine organisms. In September 2006, CIESM took the unprecedented step of organising a workshop looking at the relationship between the marine sciences and public health. The monograph that emerged following the event covered a wide range of topics including pollutant toxicity and biomarkers, pathogens and pharmaceuticals in the sea, and climate change and remote sensing, all in the context of potential threats to public health [16, 17].

Elsewhere, northern European countries have demonstrated interest in the impacts of the marine environment on human health. The Helsinki Commission (HELCOM) [18] was established in 1992 following the signing of the Helsinki Convention to protect the Baltic Sea from pollution and is made up of member countries surrounding the Baltic Sea. The aim of HELCOM is to ensure that the Baltic Sea has a healthy marine environment and good ecological status, and is rich in biodiversity. It is hoped that this will then support a wide variety of sustainable economic and social activities within the Baltic Sea. Although not specifically targeting human health, reducing pollution clearly has health benefits. HELCOM has been involved with the reduction of point source discharges of organic pollutants and nutrients, improved treatment of wastewaters resulting in fewer beach closures and restricting or prohibiting the use of hazardous compounds such as dioxins, furans, PCBs and DDT.

Alongside the work of HELCOM, the EU BONUS programme [19] was created to unite marine science with maritime and socio-economic research to address the problem of pollution within the Baltic Sea. The interdisciplinary approach used by BONUS has given rise to a wide range of initiatives including sustainable development research and the creation of policies and regulations to improve the Baltic Sea region [19]. As with HELCOM, BONUS is not primarily aimed at protecting human health, but this is a more general ambition of the programme.

Perhaps of all the European seas, the condition of the Black Sea has given rise to most concern with regard to human health. Extensive contamination with chemical pollutants and microbial pathogens (including *Vibrio cholerae*) has provided incontrovertible evidence of the causal links between marine ecosystem quality and human health [20]. The Black Sea Environment Programme was established in 1991 and initiated in June 1993 under the leadership of the United Nations Development Programme, but with the close involvement of the World Bank and UNEP. A series of reports and publications summarise progress; a milestone was the Black Sea Pollution Assessment (1998) [21].

Beyond the examples provided above, the overarching responsibility for the marine environment of Europe lies with the European Environment Agency (EEA) [22]. The regulation establishing the EEA was adopted by the European Union in 1990. It came into force in late 1993 immediately after the decision was taken to locate the EEA in Copenhagen. Work started in earnest in 1994. Its aim was to provide sound, independent information on the environment. It is a major information source for those involved in developing, adopting, implementing and evaluating environmental policy, and also for the general public. Currently, the EEA has 32 member countries. Its primary remit is environmental protection, but it has also highlighted the fact that a clean environment is essential for human health and well-being. Nevertheless, it has not delved specifically into oceans and human health issues to date. Its strategy has been to employ the "Precautionary Principle" in cases where health impacts might arise due to poor water quality and insufficient sanitation.

Special Concerns: the Case of Health Threats from Invasive Species

Away from the major programmes focussing on the quality of the seas of Europe, a myriad of smaller, targeted marine programmes continue to be carried out that have human health relevance. Topics include, for example, harmful algal blooms, hypoxic zones and invasive species. The latter illustrates the approaches taken. The number of invasive species in Europe's seas increased substantially between the 1960s and 1980s, particularly in the Mediterranean. Their effect on native coastal ecosystems is becoming difficult and costly to control, and of course, there are often deleterious consequences for human health. This issued was reviewed extensively by Keller et al. [23]. A specific example is provided by the comb jellyfish, *Mnemiopsis leidyi*. An explosive growth in its population in the Black Sea occurred after its arrival in ships' ballast waters in the late 1980s. This caused devastation in Black Sea fish stocks, oysters and the indigenous jellyfish population. The invasion even extended into the land-locked Caspian Sea, causing extensive changes to the whole ecosystem [24]. By 1992, the annual financial losses caused by drops in commercial catches of marketable fish were estimated to be at least US$ 240 million. Fish stocks in the Black Sea and Sea of Azov have suffered from the comb jelly eating fish eggs and larvae. For fishing communities, such changes result in severe economic hardship leading to stress, depression and related adverse health effects.

This specific case is illustrative of many other specific concerns relating to the redistribution of marine organisms, often driven by the effects of climate change. Similar events can be found off US shores, such as the invasion of lionfish into the Caribbean Sea and waters along the south-eastern

coast of the USA [25]. Sharing understanding of these cases in the future would be another positive outcome of transatlantic collaborations.

The Benefits of Oceans to Human Health and Well-Being

There is no doubt that threats from the oceans to human health and well-being have dominated the oceans and human health research agenda since work began in this area. However, over the last few years, there has been increasing interest in the potential benefits to health and well-being that can be obtained from the marine environment. In both Europe and the USA, efforts to derive novel pharmaceuticals have received support, with the obvious opportunities they offer for new treatments for disease and creating profits for the pharmaceutical industry.

In Europe, another area of growing interest is the value of marine ecosystems to the health of individuals and, more broadly, to public health. For example, work is underway to promote more active, outdoor lifestyles to help combat obesity and related diseases, as well as combating depression and other psychological disorders. One programme, the "Blue Gym" [26], tries to encourage participation in activities in coastal areas such as swimming, sailing, surfing and kayaking, but also gentle coastal walks and rockpool rambles. Key to such an approach is for researchers to gather the evidence as to whether such initiatives actually lead to a reduction in the incidence of disease and improve well-being. Other work across Europe, especially northern Europe, is addressing why marine environments are viewed so positively by individuals compared with other natural environments, or in comparison with urban environments. In a recent investigation in the UK, evidence obtained indicates that those living near the coast tend to be healthier than those living inland, following adjustments for differences in economic status and age [27]. Of interest, the greatest positive effects to health from coastal living were seen for the most socio-economically deprived communities. This is an aspect of oceans and human health research that merits much more attention.

Oceans and Human Health Horizon Scanning

Concerns over the lack of preparedness for unexpected environmental and human health threats have stimulated a growing interest in Europe in horizon scanning, the intention being to identify, at an early stage, important new threats that may affect us in the coming years. Horizon scanning is not just based on a wide range of speculations, often without any evidential basis, but is a much more structured and systematic activity in which expert opinion is solicited and used to guide the exploration of diverse trends and likely developments that are just beginning to emerge as areas of potential concern or opportunity. Such issues can then be monitored, and if persistent, efforts made to mount appropriate actions to mitigate, adapt or take advantage of them. Recent examples of threats that could have direct or indirect implications for human health and well-being include: microplastic contaminants in the sea, hypoxic ocean areas, domestication of marine species, mining in the deep oceans, methane venting from beneath the ocean floor and new observations regarding warming of the oceans that suggest the likelihood of sea level rise in excess of current predictions [12, 28, 29]. Adverse effects on human health and well-being may be manifest directly, for example, as a result of exposure to contaminants ingested in seafood or through coastal flooding, or indirectly as a result of a redistribution of marine species leading to a fall locally in seafood availability or due to methane releases from the oceans exacerbating global climate change. These and other threats are also being considered in the USA.

Summary and Conclusions

This brief overview demonstrates that whilst not overtly recognised, Europe has had a long history of research activity that falls within the field of "Oceans and Human Health" research. As in the USA, European research using marine organisms has led to numerous major medical discoveries that have not only improved health, but also created commercial opportunities. Similarly, exploitation of marine resources has provided healthy food and has made an important contribution to the European economy. This, in turn, has helped to lift some out of poverty and has resulted in general improvements in health and well-being. Investigations of threats to humans from the marine environment have had a long history, with focussed long-term collaborative investigations being conducted in the Mediterranean Sea, the Baltic Sea, the Black Sea, the North Sea and various sub-regions and specific locations within these marine areas. Another key ecosystem service provided by the coastal seas of Europe has been to promote tourism.

The relationship between the status of marine ecosystems and the health and well-being of coastal populations has received less attention, usually in an indirect general manner on both sides of the Atlantic, but with increasing interest in Europe. Studies relating the direct consequences of specific changes in marine ecosystems or their component organisms to specific health consequences, or particular diseases, are relatively rare.

With regard to marine pollution by industrial and agricultural chemicals, radiation or microbial pathogens, research

efforts have nearly always been devoted to implementing controls and regulations that help to clean up and protect the marine environment, without emphasising the specific benefits of reducing adverse effects on health or their associated economic and social costs. Making these connections more explicit must be a key future objective if health threats from the marine environment are to be taken seriously by the public, health professionals, policymakers and politicians.

The European Union has demonstrated a commitment to dealing with health threats associated with contaminants in seafood. So far, however, less effort has been expended on considering the wider implications of increasing body burdens of marine contaminants and those from other sources on the incidence of diseases in the rapidly ageing European population [30], or of how climate change will affect future contaminant concentrations or the availability of seafood species, or how the rapid rise in obesity across Europe relates to changing patterns of seafood consumption. It is these new areas that merit greater attention.

Despite the enormous body of marine research across Europe, it is evident that work on each of the aspects described above has tended to be conducted in "silos". For example, work on marine pollution and climate change has been conducted without much regard to the changing health of coastal populations; the short- and long-term relationships between coastal flooding and marine pollution have also received little attention. Coastal degradation and habitat lost are seldom, if ever, considered in relation to the health benefits that might be acquired by spending time in coastal areas [27].

With regard to researchers from different fields, the usual "invisible barriers" and narrowed visions continue to hamper interdisciplinary work. It is relatively rare for marine biologists, ecologists and ecotoxicologists to find themselves in discussion with medical doctors, public health researchers, social scientists and economists about the effects that changes in the marine environment might be having on human health and well-being. Similarly, policymakers responsible for regulating marine transport spend little time with other policymakers responsible for protecting human health, or those responsible for mitigating climate change, for example, from the emissions and wastes produced by the shipping industry. Promoting a strong dialogue between researchers and policymakers also continues to pose as a challenge. Policymakers in departments of health are more likely to be focussed on the provision of good services in hospitals rather than on the latest research indicating that living by the sea, or spending time in coastal areas, reduces the risk of succumbing to diseases and has positive effects on well-being in the first place [27].

As a result of burgeoning interest within the European Commission, as evidenced by the European Science Foundation Marine Board White Paper, the prospect of re-energising efforts in Europe to explore the interconnections between the oceans and human health in research and training is now tantalisingly close. To do this in close collaboration with North American scientists and, indeed, those elsewhere in the world is an exciting prospect.

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References

1. Bowen RE, Depledge MH (2006) Rapid assessment of marine pollution. Mar Pollut Bull 53:541–544
2. Intergovernmental Oceanographic Commission (2007) Health of the oceans, GOOS report 40. UNESCO, Paris, pp 1–110
3. National Research Council (1999) From monsoons to microbes: understanding the oceans role in human health. National Academy Press, Washington, DC
4. Fleming LE, Broad K, Clement A, Dewailly E, Elmir S, Knap A, Pomponi SA, Smith S, Solo Gabriele H, Walsh P, Oceans and Human Health (2006) Emerging public health risks in the marine environment. Mar Pollut Bull 53:545–560
5. Fleming LE, Laws E (2006) The overview of oceans and human health. Oceanography 19(2):18–23
6. Knap A, Dewailly E, Furgal C, Galvin J, Baden D, Bowen RE, Depledge M, Duguay L, Fleming LE, Ford T, Moser F, Owen R, Suk WA, Unluata U (2002) Indicators of ocean health and human health: developing a research and monitoring framework. Environ Heal Perspect 110:839–845
7. Bowen RE, Halvarson H, Depledge MH (2006) The oceans and human health. Mar Pollut Bull 53:631–639
8. Laws E, Fleming LE, Stegeman J (2008) Overview of NSF NIEHS and NOAA oceans & human health centers. Mini-monograph: research in oceans and human health. Environ Health 7(2):S1:1–5
9. Walsh PJ, Smith S, Fleming L, Solo-Gabriele H, Gerwick WH (eds) (2008) Oceans and human health: risks and remedies from the seas. Elsevier, New York, ISBN: 9780123725844
10. EEA (2006) The changing face of Europe's coastal areas. European Environment Agency, EEA Report No. 6/2006, Copenhagen, Denmark, ISBN 92-9167-842-2
11. EMBRC (European Marine Biological Resource Centre) (2012). http://www.embrc.eu/. Accessed 26 September 2012
12. Sutherland WJ, Aveling R, Bennun L, Chapman E, Clout M, Cote IM, Depledge MH, Dicks L, Dobson AP, Fellman L, Fleishman E, Gibbons DW, Keim B, Lickorish F, Lindenmayer DB, Monk KA, Norris K, Peck LS, Prior SV, Scharlemann JPW, Spaling M, Watkinson AR (2012) A horizon scan of global conservation issues for 2012. Trends Res Ecol Evol 27:12–18
13. Fossi MC, Casini S, Caliani I, Panti C, Marsili L, Viarengo A, Giangreco R, Notarbartolo di Sciara G, Serena F, Ouerghi A, Depledge MH (2012) The role of large marine vertebrates in the assessment of the quality of pelagic marine ecosystems. Mar Environ Res 77:156–158
14. MED POL (2012) (UNEP-marine pollution assessment and control). http://www.medpol.unepmap.org/ and http://www.unepmap.org/index.php?module=content2&catid=001017003. Accessed 30 July 2012
15. CIESM (2005) http://www.ciesm.org/about/index.htm. Accessed 23 August 2012

16. CIESM (2007) Workshop Monographs no 31: Marine sciences and public health—some major issues. Geneva (Switzerland), 27–30 September 2006, 128 p
17. Depledge MH (2007) Sea change: implications for human health and wellbeing. Commission Internationale pour l'Exploration Scientific de la mer Mediterranee (CIESM) Monograph 31:23–28
18. HELCOM (2012) The Helsinki Commission. http://www.helcom.fi Accessed 23 August 2012
19. BONUS (2012) Baltic Sea research programme. http://www.bonusportal.org/. Accessed 30 July 2012
20. Prüss-Üstün AC, Corvalán C (2006) Preventing disease through healthy environments. World Health Organisation, Geneva, ISBN 92 4 159382 2
21. Mee LD, Topping G (eds) (1998) Black Sea pollution assessment. Black Sea Environmental Series, 10:1–380
22. European Environment Agency (2012) http://www.eea.europa.eu/. Accessed 26 September 2012
23. Keller RP, Geist J, Jeschkes JM, Kuhn I (2011) Invasive species in Europe: ecology, status, and policy. Environ Sci Eur 2011(23):1–17
24. Karpinsky, M.G., Shiganova, T.A. and Katunin, D.N, (2005). Introduced species. In: The Caspian Sea environment. Hdb Env Chem 5(P): 175–190
25. NOAA (2009) National Oceanographic and Atmospheric Administration. http://www.oar.noaa.gov/spotlite/archive/2009/articles/lionfish_invasion.html) and (http://oceansandhumanhealth.noaa.gov/). Accessed 26 September 2012
26. Depledge MH, Bird W (2009) The blue gym: health and wellbeing from our coasts. Mar Pollut Bull 58:947–948
27. Wheeler BW, White M, Stahl-Timmins W, Depledge MH (2012) Does living by the coast improve health and wellbeing? Health Place 18(5):935–1208
28. Sutherland WJ, Clout M, Cote IM, Daszak P, Depledge MH, Fellman L, Fleishman E, Garthwaite R, Gibbons DW, De Lurio J, Impey AJ, Lickorish F, Lindenmayer D, Madgwick J, Margerison C, Maynard T, Peck LS, Pretty J, Prior S, Redford KH, Scharlemann JPW, Spalding M, Watkinson AR (2010) A horizon scan of global conservation issues for 2010. Trends Ecol Evol 25(1):1–7
29. Sutherland WJ, Bardsley S, Bennun L, Clout M, Cote I, Depledge MH, Dicks LV, Dobson AP, Fellman L, Fleishman E, Gibbons DW, Impey AJ, Lawton JH, Lickorish F, Lindenmayer DB, Lovejoy TE, MacNally R, Madgwick J, Peck LS, Pretty J, Prior L, Kent SV, Redford H, Scharlemann JPW, Spalding M, Watkinson AR (2011) Horizon scan of global biodiversity issues for 2011. Trends Res Ecol Evol 26:10–16
30. Depledge MH, Tyrrell J, Fleming LE, Holgate ST (2013) Are marine environmental pollutants influencing global patterns of human disease? Mar Environ Res 83:93–95