



Oceans and Human Health: A rising tide of challenges and opportunities for Europe



L.E. Fleming^{a, *}, N. McDonough^b, M. Austen^c, L. Mee^d, M. Moore^{a, c}, P. Hess^e,
M.H. Depledge^a, M. White^a, K. Philippart^f, P. Bradbrook^a, A. Smalley^a

^a European Centre for Environment and Human Health, The University of Exeter Medical School, Truro, Cornwall TR1 3AE, UK

^b European Marine Board, 8400 Oostende, Belgium

^c Plymouth Marine Laboratory (PML), Plymouth PL1 3DH, UK

^d Scottish Association for Marine Sciences (SAMS), Oban PA37 1QA, Scotland, UK

^e Institut Français de Recherche Pour L'exploitation de la Mer (IFREMER), Nantes, CEDEX 03, France

^f Royal Netherlands Institute for Sea Research, Landsdiep 4, 1797 SZ 't Horntje, Den Hoorn, Texel, The Netherlands

ARTICLE INFO

Article history:

Received 19 May 2014

Accepted 25 May 2014

Available online 2 June 2014

Keywords:

Harmful algal blooms
Microbial pollution
Anthropogenic chemicals
Marine biotechnology
Climate change
Ocean acidification
Fisheries
Aquaculture
Seafood
Blue carbon
Marine energy
Blue gym
Ocean literacy
Risks
Benefits
EU policy

ABSTRACT

The European Marine Board recently published a position paper on linking oceans and human health as a strategic research priority for Europe. With this position paper as a reference, the March 2014 Cornwall Oceans and Human Health Workshop brought together key scientists, policy makers, funders, business, and non governmental organisations from Europe and the US to review the recent interdisciplinary and cutting edge research in oceans and human health specifically the growing evidence of the impacts of oceans and seas on human health and wellbeing (and the effects of humans on the oceans). These impacts are a complex mixture of negative influences (e.g. from climate change and extreme weather to harmful algal blooms and chemical pollution) and beneficial factors (e.g. from natural products including seafood to marine renewable energy and wellbeing from interactions with coastal environments). Integrated approaches across disciplines, institutions, and nations in science and policy are needed to protect both the oceans and human health and wellbeing now and in the future.

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1. Overviews

Oceans and humans have interacted since ancient times. Over thousands of years, the oceans and seas have served as a source of

food, provided livelihoods, and generated commerce, as well as disseminating people and connecting civilizations around the world. Their importance is reflected in many cultural practices, and is manifest in inspirational art. Inevitably the oceans influence our health and wellbeing. Damaged coastal and marine ecosystems arising from natural disasters or as a result of human exploitation have led to a range of negative consequences for human health (including loss of life); at the same time, there is increasing evidence that interactions with coastal and marine environments may also have important beneficial impacts on wellbeing (Bowen et al., 2006; Fleming et al., 2006; Fleming and Laws, 2006; Walsh et al., 2008; Bowen et al., 2014).

Over the past two decades, the importance of oceans for human health as an area for research, training and policy has been

* Corresponding author. European Centre for Environment and Human Health, University of Exeter Medical School, Knowledge Spa, Royal Cornwall Hospital, Truro, Cornwall TR1 3HD, UK. Tel.: +44 (0)1872258131; fax: +44 (0)1872258134.

E-mail addresses: L.E.Fleming@Exeter.ac.uk (L.E. Fleming), NMcDonough@esf.org (N. McDonough), mcv@pml.ac.uk (M. Austen), Laurence.Mee@sams.ac.uk (L. Mee), mmm@pml.ac.uk (M. Moore), Philipp.Hess@ifremer.fr (P. Hess), M.Depledge@Exeter.ac.uk (M.H. Depledge), Mat.White@Exeter.ac.uk (M. White), Katja.Philippart@nioz.nl (K. Philippart), P.N.Bradbrook@Exeter.ac.uk (P. Bradbrook), A.J.Smalley@Exeter.ac.uk (A. Smalley).

URL: <http://www.ecehh.org>

recognized in the US. This is evidenced by the establishment of a network of dedicated oceans and human health research centres in both academic and government institutions funded by the National Science Foundation (NSF), the National Institute of Environmental Health Sciences (NIEHS), and the National Oceanographic and Atmospheric Administration (NOAA) (National Research Council, 1999; Knap et al., 2002; Laws et al., 2008). With the exception of a few specific regional programmes (e.g. EU BONUS as a joint Baltic Sea regional research and development initiative), Europe has largely failed to promote an integrated interdisciplinary and collaborative research effort in this area on a scale necessary to address the public health implications of rapidly increasing human activity in European seas and oceans, and especially in the coastal zones. The European Union has set a policy objective of achieving “good environmental status” (GES) in European marine waters by 2020 through its adoption of the Marine Strategy Framework Directive (EC, 2008). However, the extent to which the specific measures required to achieve good environmental status are, in turn, linked to human health and wellbeing is limited, and there are important gaps in our knowledge of the complex interactions between the marine environment and human health. Despite the concern for the marine environment which has been translated into the European Union Marine Strategy Framework Directive, there still remains a need, therefore, to link climate change, ecosystem understanding, and life sciences with public health and social sciences (Moore et al., 2013; Depledge et al., 2013).

The recently published European Marine Board position paper on “Linking Oceans and Human Health: A Strategic Research Priority for Europe” (<http://www.marineboard.eu/images/publications/Oceans%20and%20Human%20Health-214.pdf>) highlights the substantive and complex interactions between the marine environment and its ecological status on one hand, and human health and wellbeing on the other, drawing attention to a range of societally important research questions and challenges. The paper makes a strong case for the development and support of an interdisciplinary and collabo-

Table 1

Currently identified issues presenting risks and benefits to human and ocean health.

- Climate change, extreme weather, natural events (e.g. tsunamis)
- Ocean acidification
- Harmful algal blooms (HABs)
- Microbes, antibiotic resistance
- Anthropogenic chemicals, marine plastics/litter, and nanomaterials
- Exotic species
- Sustainable fisheries, aquaculture, seafood, food security
- Coastal communities (including cities) and sustainability, resiliency and adaptation
- Sustainable marine biotechnology, pharmaceuticals, natural products
- Marine models, sentinel species, biodiversity, and one health
- “Blue gym” recreation, and health and wellbeing from the coasts
- “Blue carbon” and marine protected areas
- Marine renewable energy

orative research, training, and policy programme on Oceans and Human Health in Europe.

With this position paper as a reference, a Workshop was held in Cornwall in March 2014 to review recent interdisciplinary and cutting edge research in oceans and human health, specifically the growing evidence of the impacts of oceans and seas on human health and wellbeing (as well as the effects of humans on the “health” of oceans and coastal ecosystems). The interactive Workshop brought together key scientists, policy makers, funders, business, and non governmental organisations (NGOs) from Europe and the US to review the existing research and resources, and to identify gaps and needs with respect to both policy and research on both sides of the Atlantic and beyond (www.ecehh.org/events/oceans-human-health/).

The research and impacts discussed were a mixture of both the negative influences (e.g. from climate change and extreme weather to harmful algal blooms and chemical pollution) and the beneficial factors (e.g. from natural products including seafood to marine renewable energy and coastal wellbeing) of the interactions between the oceans and humans (Table 1 and Fig. 1). Experience and

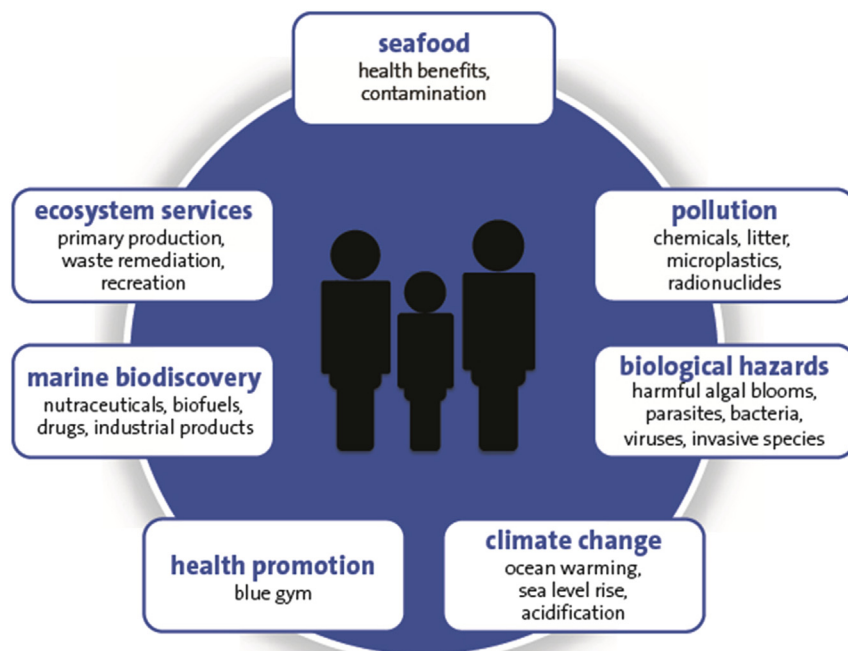


Fig. 1. Risks, benefits and opportunities of oceans and human health.

lessons learnt from the U.S. over the past two decades were discussed. In addition, there was exploration of the existing evidence for the interactions between the impacts on human health and wellbeing and changing marine ecosystems, and the identification of information and data gaps and resource needs, with a “horizon scanning” exercise by the participants (Table 2). Finally, policy interactions and other needs for exploring and addressing oceans and human health were discussed. The resulting series of recommendations to take this emerging topic of oceans and human health forward in the EU and beyond (Table 3) were summarized in a prepared concise summary statement, “Message from Bedruthan: unanimous call for a coordinated, transnational and interdisciplinary Oceans and Human Health research programme in Europe” (<http://www.ecehh.org/wp-content/uploads/2013/11/Message-from-Bedruthan.pdf>).

2. Main messages

Overall, the Workshop identified new research evidence and questions, and important opportunities in the area of benefits from interactions with the oceans for human health and wellbeing. These ranged from promising business opportunities within marine biotechnology, aquaculture, and marine energy to new evidence suggesting that interactions with coasts and the marine environment may offer significant benefits for both physical and mental health (http://ec.europa.eu/maritimeaffairs/policy/ocean_energy/forum/index_en.htm; EU Commission 2009; EU Commission 2012; Wheeler et al., 2012; White et al., 2013a, 2013b). The Workshop also identified a number of areas for

Table 2
Horizon scan of future oceans and human health priority areas.

- Integrated monitoring, surveillance, and interpretation of emerging risks and impacts on both ecosystems and human health and wellbeing
 - Climate change and extreme weather on coastal areas
 - Interactions between anthropogenic chemicals (including pharmaceutically active compounds, plastics and nanoparticles) and ocean acidification
 - New Harmful algal bloom organisms and toxins associated with global warming and anthropogenic influences
 - New pathogenic microbes and changing antibiotic resistance
 - Cumulative effects of mixtures and low level exposures of chemicals and microbes in food chain and ecosystems
 - Impacts on wellbeing as well as acute and chronic disease as well as on vulnerable populations (including rapidly changing demographics)
 - Economic and valuation impacts
- Opportunities and risks around aquaculture, “Blue carbon,” marine energy, and marine biotechnology
 - Cumulative direct and indirect impacts on ecosystems and on human health and wellbeing
- Ocean and coastal observing and forecasting integrated with terrestrial and atmospheric
 - Apply beyond climate and weather to microbes, chemicals, other marine-human interactions
- Interactions between marine and all ecosystems and human health and wellbeing
- Other areas important to oceans and human health research, training and policy: Modelling, forecasting, and prediction; Ecosystems services and planning; Economics and valuation; Law and governance; Trade, transport and commerce; “Green” technology innovations and applications; Communication, dissemination, community engagement; Ocean Literacy; Citizen science

Table 3

Major recommendations for oceans and human health: the way forward.

- Creation of an integrated, international and interdisciplinary training and collaborative research programme in oceans and human health, with ongoing stakeholder engagement
 - Policy makers, healthcare providers and public health practitioners, coastal managers, etc
 - Potential for innovation and sustainable development as well as ocean stewardship
- Creation of integrated international and interdisciplinary training and collaborative research programme in oceans and human health, with ongoing stakeholder input
- Development of a theoretical framework with interdisciplinary metrics which integrates oceans and human health into existing and future EU Directives (e.g. Marine Strategy Framework Directive, Water Framework Directive) and funding opportunities (e.g. Horizons 2020, collaborations with US NSF, NIH, NOAA) starting at the regional level moving to the international and global
- Development of long term surveillance and monitoring programmes with broad scope; and for positive sustainable case studies demonstrating behaviour change
- Emphasis on benefits and opportunities not just risks with sustainability, inter/multidisciplinary, inter-institutional, holistic view and linkages across research areas and disciplines, understanding the value of the oceans and seas

concern, particularly current and future interactions between climate change, ocean acidification, microbial and chemical pollution (including plastics), and their impacts on coastal and marine ecosystems as well as seafood and food security (IAP, 2009; Boxhall, 2012; Redshaw et al., 2013; Koelmans et al., 2014; Wyles et al., 2014). In addition, there was an appreciation of the complexity of these interactions, presenting both risks and opportunities to the health of both humans and the ocean and coastal ecosystems.

The interactions and discussions between the participants identified that integrated approaches across disciplines, institutions, and nations in science and policy are needed to protect both the oceans and human health and wellbeing now and in the future. Furthermore, improved collaborations across academia, business, government, civil society, and NGOs with ongoing stakeholder input will be essential for moving forward this new area of science, research, training, and policy forward.

It was noted that the majority of participants, all experts in their fields and representing diverse institutions, had never interacted before; and few had previously viewed their own research through the lens of oceans and human health. The participants stressed the importance of long-term funding and support for interdisciplinary science and training in oceans and human health to create a sustained programme of research and a vibrant interdisciplinary community of interested researchers, trainees, policy makers and other stakeholders (e.g. the Gordon Research Conference and Graduate Research Seminar in Oceans and Human Health biannual since 2008 <http://www.grc.org/programs.aspx?year=2014&program=ohh>). They identified six essential areas to build the capacity for oceans and human health research in Europe:

- 1 community building (among researchers as well as policy makers and other stakeholders)
- 2 international cooperation (collaborations among researchers and other stakeholders, as well as evidence of the global nature of oceans and human health)
- 3 strategic analyses (identifying priority knowledge gaps and the necessary research infrastructure and resources to address them)
- 4 human capacities (improving interdisciplinary training)
- 5 policy assessment and support (integrating oceans and human health within the existing and future EU policy framework) and

6 stakeholder engagement and knowledge transfer (including ocean literacy, citizen science and the promoting the link between of ocean stewardship and human wellbeing).

Finally, the gap in understanding of these interactions and the value of marine ecosystems for human health and wellbeing among researchers, policy makers, healthcare providers and public health practitioners, and the general public was identified as a particular concern by the conference participants. Ultimately, the ability to communicate and engage with these disparate but important stakeholder communities will determine the future health of both humans and the oceans.

Acknowledgements

The authors would like to acknowledge the contributions of all the participants in the Oceans and Human Health Workshop (Bedruthan Steps, Cornwall, UK; March 20–21, 2014) with more information available at www.ecehh.org/events/oceans-human-health/; and the authors of the European Marine Board White Paper on Oceans and Human Health (<http://www.marineboard.eu/images/publications/Oceans%20and%20Human%20Health-214.pdf>). Funding was provided by the European Marine Board, Oostende, Belgium; the European Regional Development Fund Programme 2007 to 2013 and European Social Fund Convergence Programme for Cornwall and the Isles of Scilly (European Centre for Environment and Human Health, the University of Exeter Medical School, Truro, Cornwall, UK); Plymouth Marine Laboratory (PML), Plymouth UK; Scottish Association for Marine Sciences (SAMS), Oban, Scotland; the Institut Francais de Recherche Pour L'exploitation de la Mer (IFREMER), Nantes, France; the European Community's Seventh Framework Programme (FP7/2007 – 2013) within the Ocean of Tomorrow call under Grant Agreement No.266445 for the project Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors (VECTORS).

References

- Bowen, R.E., Halvarson, H., Depledge, M.H., 2006. The oceans and human health. *Mar. Pollut. Bull.* 53, 631–639.
- Bowen, R., Depledge, M., Carlarne, C., Fleming, L.E. (Eds.), 2014. *Seas, Society and Human Wellbeing*. Wiley, Publishers, UK.
- Boxhall, A., 2012. New and Emerging Water Pollutants arising from Agriculture. OECD. <http://www.oecd.org/tad/sustainable-agriculture/49848768.pdf>.
- Communication from the Commission to the European Parliament and the Council – Building a sustainable future for aquaculture – A new impetus for the Strategy for the Sustainable Development of European Aquaculture (SEC(2009) 453) {SEC(2009) 454}/* COM/2009/0162 final */.
- Communication from the Commission to the Council and the European Parliament on “Blue Growth: opportunities for marine and maritime sustainable growth”, adopted on 13 September 2012.
- Depledge, M.H., Harvey, A., Brownlee, C., Frost, M., Moore, M.N., Fleming, L.E., 2013. Changing views of the interconnections between oceans and human health in Europe. *Microbiol. Ecol.* 65, 852–859.
- European Commission (EC), 2008. Marine Strategy Framework Directive 2008/56/EC. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:EN:PDF>.
- Fleming, L.E., Laws, E., 2006. The overview of oceans and human health. *Oceanography* 19 (2), 18–23.
- Fleming, L.E., Broad, K., Clement, A., Dewailly, E., Elmir, S., Knap, A., Pomponi, S.A., Smith, S., Solo Gabriele, H., Walsh, P., 2006. Oceans and human health: emerging public health risks in the marine environment. *Mar. Pollut. Bull.* 53, 545–560.
- Interacademy Panel (IAP), 2009. IAP Statement on Ocean Acidification. <http://www.interacademies.net/File.aspx?id=9075>.
- Knap, A., Dewailly, E., Furgal, C., Galvin, J., Baden, D., Bowen, R.E., Depledge, M., Duguay, L., Fleming, L.E., Ford, T., Moser, F., Owen, R., Suk, W.A., Unluata, U., 2002. Indicators of ocean health and human health: developing a research and monitoring framework. *Environ. Health Perspect.* 110, 839–845.
- Koelmans, A.A., Gouin, T., Thompson, R., Wallace, N., Arthur, C., 2014. Plastics in the marine environment. *Environ. Toxicol. Chem.* 33, 5–10.
- Laws, E., Fleming, L.E., Stegeman, J., 2008. Overview of NSF NIEHS and NOAA Oceans and Human Health Centers. Mini-monograph: research in oceans and human health. *Environ. Health* 7 (2), S1:1–5.
- Moore, M., Depledge, M.H., Fleming, L.E., Hess, P., Less, D., Leonard, P., Madsen, L., Owen, R., Pirllet, H., Seys, J., Vasconcelos, V., Viarengo, A., 2013. Oceans and human health (OHH): a European Perspective from the Marine Board of the European Science Foundation (Marine Board-ESF). *Microbiol. Ecol.* 65, 889–900 <http://dx.doi.org/10.1007/s00248-013-0204-5>.
- National Research Council, 1999. *From Monsoons to Microbes: Understanding the Oceans Role in Human Health*. National Academy Press, Washington, DC.
- Redshaw, C.H., Stahl-Timmins, W., Fleming, L.E., Davidson, I., Depledge, M.H., 2013. Potential changes in disease patterns and pharmaceutical use in response to climate change. *J. Toxicol. Environ. Health Part B Crit. Rev.* 16, 285–320.
- Walsh, P.J., Smith, S., Fleming, L., Solo-Gabriele, H., Gerwick, W.H. (Eds.), 2008. *Oceans and Human Health: Risks and Remedies from the Seas*. Elsevier, ISBN 9780123725844.
- Wheeler, B.W., White, M., Stahl-Timmins, W., Depledge, M.H., 2012. Does living by the coast improve health and wellbeing? *Health Place* 18 (5), 1198–1201.
- White, M.P., Alcock, I., Wheeler, B.W., Depledge, M.H., 2013a. Coastal proximity, health and well-being: results from a longitudinal panel survey. *Health Place* 23, 97–103.
- White, M.P., Pahl, S., Ashbullby, K., Herbert, S., Depledge, M.H., 2013b. Feelings of restoration from recent nature visits. *J. Environ. Psychol.* 35, 40–51.
- Wyles, K.J., Pahl, S., Thompson, R.C., 2014. Perceived risks and benefits of recreational visits to the marine environment: integrating impacts on the environment and impacts on the visitor. *Ocean Coast. Manag.* 88, 53–63.