House of Commons Environmental Audit Committee
Inquiry on Sustainable Seas

Written evidence submitted by the Society *for* Applied Microbiology

Introduction and summary

1. The role of marine microorganisms (e.g. bacteria, fungi and viruses) is a crucial factor to consider when assessing the future of the oceans. Marine environments boast an enormous diversity of microbial life, which functions as a support for all other life in the ocean. Marine microbes may also prove to be rich source of new products, such as drugs and bioplastics, and have the potential to be utilised in future energy production systems and pollution clean-up strategies.

2. However, threats posed by climate change, pollution and industrial activities will likely impact heavily on these organisms, therefore having a downstream effect on the overall ecology of marine environments. More support for research is needed to fully understand these potential impacts.

3. The Society *for* Applied Microbiology (S*f*AM) welcomes this timely opportunity to share a number of issues raised by our members.

What forms of pollution are most prevalent in the ocean, and what impact are they having?

4. **Plastic** – Studies have shown that certain types of bacteria prefer to grow on plastic, meaning that areas heavily polluted with plastics will have different microbial ecosystems to those which are unpolluted.[1] The impacts of this can be potentially devastating. Plastic waste can introduce harmful (pathogenic) bacteria to coral reefs, and has been found to increase the likelihood of coral disease from 4% to 89%.[2]

5. Recent research is shining a light onto how microbes may be adapting to plastic pollution. Marine microbes found on waste plastics may be using the material as a food source, which could inform future research into waste removal strategies.[3]

6. **Oil** – The fate of oil in the environment depends largely on natural communities of oil-degrading bacteria. Oil provides ample ‘food’ for these bacteria, significantly increasing their numbers in the environment. In the case of oil spill events, such

---

[1] https://www.newscientist.com/article/dn23794-plastisphere-microbes-go-to-sea-on-flotsam-fragments/
[2] https://www.nature.com/articles/d41586-018-01239-3
[3] https://www.newscientist.com/article/2132650-newly-evolved-microbes-may-be-breaking-down-ocean-plastics/

as the Deepwater Horizon incident, significant long-term changes to surrounding microbial communities can occur (**Example 1**).[4]

Example 1 – Deepwater Horizon incident (2010)

6.1. During the Deepwater Horizon catastrophe, response teams attempted to increase the rate at which oil-degrading bacteria removed the oil by applying over 7 million litres of Corexit-9500 to the surface of the oil slick. This chemical disperses the oil into small droplets, making them more accessible to microbes.

6.2. This action unexpectedly caused an increase in bacteria which degraded the Corexit instead, which may have impeded the action of the natural oil-degrading bacteria.[5] The long-term effects of this are currently debated, but this example demonstrates that the full impact of response strategies on microbial ecosystems should be investigated and better understood.

6.3. Another distinctive feature of this oil spill was the formation of Marine Oil Snow (MOS): gelatinous residues that deposit on the seabed. Unprecedented quantities of MOS were formed from the Deepwater Horizon spill; up to 14% of the total oil released accumulated on the seafloor in this way.[6] MOS are thought to harbour microbes that are different from those in surrounding seawater, although it is unclear how this might affect microbial communities in the long-term.

7. **Aquaculture, sewage and fertilizer runoff** – Eutrophication (an over-enrichment of nutrients that cause excessive growth of plants and algae) occurs frequently as a result of certain farming and waste disposal practices. Microbial communities are also altered as a result of this process and, in some extreme cases, ‘dead zones’ can arise where reduced oxygen levels affect marine life.[7]

What impact is climate change having on the ocean? What are the effects of ocean acidification now and in the future?

8. **Climate change** – Increases in global ocean temperatures have a number of predicted and evidenced outcomes:

---

[4] Rodriguez-R,L.M., Overholt,W.A., Hagan,C., Huettel,M., Kostka,J.E. and Konstantinidis,K.T. (2015) Microbial community successional patterns in beach sands impacted by the Deepwater Horizon oil spill. *ISME J.*, **9**, 1928.

[5] Kleindienst, S. *et al*., (2015). Chemical dispersants can suppress the activity of natural oil-degrading microorganisms. *PNAS*, **112** (48), p14900-14905

[6] Daly, K. *et al*., (2016). Assessing the impacts of oil-associated marine snow formation and sedimentation during and after the Deepwater Horizon oil spill. *Anthropocene*, 13, p18-33

[7] Traving,S.J., Rowe,O., Jakobsen,N.M., Sørensen,H., Dinasquet,J., Stedmon,C.A., Andersson,A. and Riemann,L. (2017) The Effect of Increased Loads of Dissolved Organic Matter on Estuarine Microbial Community Composition and Function. *Front. Microbiol.*, **8**, 351.

8.1. ‘Thermal stress events’ (such as the Florida Keys coral bleaching event of 2014)[8] have been linked to disease outbreaks in coral.[9] Nutrient availability is altered in coral under thermal stress (increase in phosphorus uptake for example)[10] and diseases such as Dark Spot Syndrome (DDS), which may be at least in part caused by fungal infection, also increased in prevalence. Furthermore, significant changes in coral microbiomes[11] have been linked to these stress events.[12]

8.2. Increases in *Vibrio vulnificus* infections (see **Example 2**).

Example 2 – *Vibrio vulnificus*

8.2.1. *Vibrio vulnificus* is a bacterium found in marine environments, where it is mostly associated with shellfish. When ingested, the bacteria can cause acute gastroenteritis and septicaemia, and is responsible for over 95% of seafood-related deaths in the US.[13]

8.2.2. This pathogen is rarely found in water with temperatures below 13ºC. Heatwave events have been shown to increase risks associated with these bacteria; it is possible that rising coastal temperatures are linked to recent increases in the geographical spread of reported *Vibrio* infections. If climate change further increases coastal and sea temperatures, *Vibrio* may become a concern for countries in which it previously carried low risk.

8.3. Stratification of seawater – increases in ocean temperature leading to declines in dissolved oxygen in the oceans,[14] altering the transport of nutrients from deep water to surface-layer plankton (see **Section 10** for details on the effects of changing nutrient availability).[15]

8.4. Harmful cyanobacterial ‘blooms’ – for example, warming of the US West Coast in 2015 resulted in a massive toxic bloom of *Pseudo-nitzschia* plankton, which produces the neurotoxin domoic acid.[16] Although human

---

[8] Manzello,D.P. (2015) Rapid Recent Warming of Coral Reefs in the Florida Keys. *Sci. Rep.*, **5**, 16762.

[9] Mera,H. and Bourne,D.G. (2018) Disentangling causation: complex roles of coral-associated microorganisms in disease. *Environ. Microbiol.*, **20**, 431–449.

[10] Ezzat,L., Maguer,J.-F., Grover,R. and Ferrier-Pagès,C. (2016) Limited phosphorus availability is the Achilles heel of tropical reef corals in a warming ocean. *Sci. Rep.*, **6**, 31768.

[11] **Microbiome** – the microorganisms in a particular environment (including the body or a part of the body).

[12] Wang,L., Shantz,A.A., Payet,J.P., Sharpton,T.J., Foster,A., Burkepile,D.E. and Vega Thurber,R. (2018) Corals and Their Microbiomes Are Differentially Affected by Exposure to Elevated Nutrients and a Natural Thermal Anomaly. *Front. Mar. Sci.*, **5**, 101.

[13] Baker-Austin,C. and Oliver,J.D. (2018) Vibrio vulnificus: new insights into a deadly opportunistic pathogen. *Environ. Microbiol.*, **20**, 423–430.

[14] Keeling,R.F., Körtzinger,A. and Gruber,N. (2009) Ocean Deoxygenation in a Warming World. *Ann. Rev. Mar. Sci.*, **2**, 199–229.

[15] Hutchins,D.A. and Fu,F. (2017) Microorganisms and ocean global change. *Nat. Microbiol.*, **2**, 17058.

[16] https://oceanservice.noaa.gov/news/sep15/westcoast-habs.html

illness from ingesting domoic acid-contaminated fish can be rare (although life threatening), this toxin can have profound economic impacts: in May 2015, the razor clam fishery lost an estimated $9.2 million due to closures throughout Washington state. Associated ecological impacts will also carry a significant cost.

9. **Ocean acidification** – often considered to have a more significant effect on marine biodiversity than increases in temperature:

    9.1. Coral microbes are believed to have a wide range of functions, particularly in the nutrient cycle; reduced diversity could affect the nutrient composition of oceans and therefore have a knock-on effect on marine life.

10. **Nutrient shifts** – Differences in nutrient availability (such as nitrates) are also predicted to have significant effects (see **Section 8.3**).

    10.1. A study on phytoplankton suggests that while they can generally adapt to changes in temperature and light, they are less able to adapt to reduced availability of metabolites such as nitrates.[17]

    10.2. Warmer conditions combined with lower nutrient availability may shift phytoplankton communities toward smaller-celled organisms, potentially resulting in reduced storage of particulate carbon via the 'biological pump' – contributing further to climate change.[17]

What is the environmental impact of marine industries, such as deep-sea mining, and how effectively does the Government and the International Seabed Authority regulate them to mitigate their environmental impact?

11. **Oil** – see **Section 6** and **Example 1**.

12. **Aquaculture**

    12.1. The presence of antibiotic residues in the environment increases the risk that potentially harmful microbes will develop drug resistance. This is a significant issue in open aquaculture systems generally in developing countries where antimicrobial drugs are usually administered to fish, mixed with food, in doses that can be proportionally higher than those seen in livestock farming.

    12.2. Not only can residues of antibiotic drugs remain in fish products, but undigested feed and fish faeces containing antibiotic residues can remain in the water and sediment around fish farms for an extensive period of time. Some studies suggest that 70–80% of antibiotics given to fish are excreted

---

[17] Irwin,A.J., Finkel,Z. V, Müller-Karger,F.E. and Troccoli Ghinaglia,L. (2015) Phytoplankton adapt to changing ocean environments. *PNAS.*, **112**, 5762–5766.

into the water and can further alter the microbial communities present, with antibiotic-resistant bacteria becoming more prevalent.

12.3. Regulation of antibiotic use in aquaculture is relatively poor in developing countries, although slow progress is being made. Innovet-AMR, a new partnership between the UK government's Global AMR Innovation Fund and Canada's International Development Research Centre (IDRC), seeks to tackle antibiotic resistance in aquaculture and agriculture in low and middle-income countries. The initiative will fund and support research into innovative solutions to reduce antibiotic usage, including research into alternative measures such as animal vaccines, prebiotics and probiotics.[18]

13. **Agriculture**

13.1. As previously discussed, run-off from fertilisers in coastal areas causes eutrophication of the water column, leading to oceanic ‘dead zones’ and an imbalance in essential nutrient cycling reactions.

14. **Deep-sea mining**

14.1. Researchers have investigated metal-rich ocean crusts (targets for mining), finding that these crusts have distinct associated microbial communities. Microbes (bacteria and archaea) may even be implicated in the *formation* of these metal-rich crusts. Mining these crusts will inevitably change deep-sea microbial communities by removing some species and introducing others from the surface or other environments.[19] The diversity of ocean floor microbial communities is only partially understood, so the impact and potential damage of mining activities on these ecosystems is currently unknown.

How well has Government supported UK marine science and innovation? What more could the Government do to promote a sustainable blue economy?

15. **An increased focus on microbial diversity in our oceans**

15.1. By promoting global research on microbial diversity within marine environments, we would hope to obtain a better idea of what exactly constitutes a ‘healthy’ marine ecosystem. This knowledge could be used to set reliable microbial diversity targets, particularly in areas that face significant reductions in overall marine diversity (such as coral reefs).

---

[18] http://www.cidrap.umn.edu/news-perspective/2018/04/new-uk-canada-initiative-focuses-amr-livestock-aquaculture

[19] Liao,L., Xu,X.-W., Jiang,X.-W., Wang,C.-S., Zhang,D.-S., Ni,J.-Y. and Wu,M. (2011) Microbial diversity in deep-sea sediment from the cobalt-rich crust deposit region in the Pacific Ocean. *FEMS Microbiol. Ecol.*, **78**, 565–585.

15.2. To further assess the impact of various pressures on our oceans, studies on the microbial diversity within different areas over a time-series is vital. Long-term studies such as these are traditionally harder to fund and sustain for long periods of time, given their open-ended and repetitive nature. These initiatives are vital, as highlighted by the wide number of research publications promoted by the Intergovernmental Oceanographic Commission of UNESCO.[20]

15.3. The UK is in a privileged position with access to diverse oceanic areas across the globe, so could use its influence to promote the creation of integrated research networks. These networks could encompass current initiatives in the UK, UK Overseas Territories and their significant marine domains, focusing on standardised and integrated approaches to data collection and interpretation.

15.4. The UK Government could encourage marine-based businesses to invite surveyors of microbial biodiversity to be present at their marine sites (e.g. on oil rigs or fishing vessels).

16. **Future technologies and better industry practices**

16.1. Marine microbes re a rich source of potential new products, such as medicines[21] and bioplastics.[22] Microbial 'upcycling' of non-biodegradable plastics such as PET into biodegradable plastic products like PHA is an emerging practice, with research currently focused on reducing the costs associated with these processes. This presents a potential sustainable solution for both production and degradation of plastic products.

16.2. As discussed above, marine microorganisms already play a role in oil spill clean-up strategies and have the potential to be used in other bioremediation activities. Researchers have also investigated the potential of marine microbes as producers of sustainable energy through producing biofuels[23] and harvesting sunlight.[24]

16.3. The UK Government could support research and development into these technologies, through the Industrial Strategy Challenge Fund or small business incentives. Taking an example from the United States, HelioBioSys Inc. received support from the Department of Energy's Small Business Vouchers program, which enabled the company to establish

---

[20] http://unesdoc.unesco.org/images/0024/002470/247014e.pdf
[21] Gerwick, W.H and Fenner, A.M, (2013). Drug discovery from marine microbes. *Microbial Ecology*, **65**(4), p800-806.
[22] Narancic, T. and O'Connor, K.E., (2017). Microbial biotechnology addressing the plastic waste disaster. *Microbial Biotechnology*, **10** (5), p1232–1235
[23] http://ec.europa.eu/environment/integration/research/newsalert/pdf/280na3_en.pdf
[24] https://www.technologyreview.com/s/407581/engineering-bacteria-to-harvest-light/

research collaborations to investigate the use of marine *Cyanobacteria* to produce potential biofuels.[25]

About the Society for Applied Microbiology

17. The Society *for* Applied Microbiology (S*f*AM) is the oldest microbiology society in the UK, representing a global scientific community that is passionate about the application of microbiology for the benefit of the public. Our Members work to address issues involving the environment, human and animal health, agriculture and industry.

    S*f*AM works in partnership with sister organizations and microbiological bodies towards enabling microbiologists to inform policymaking within the UK, in Europe and worldwide.

May 2018

[25] https://www.sciencedaily.com/releases/2017/08/170821135052.htm