Sustainable Seas Inquiry
Written evidence submitted by the National Oceanography Centre

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Introduction

The National Oceanography Centre (NOC) is a national research organisation, delivering integrated marine science and technology from the coast to the deep ocean and is one of the top five institutions of its kind in the world. With sites in Liverpool and Southampton, it is the UK's leading centre for sea level science, coastal and deep ocean research and technology development.

The NOC is part of the Natural Environmental Research Council (NERC), which is part of UK Research and Innovation, a new organisation that brings together the UK's seven Research Councils, Innovate UK and Research England to maximise the contribution of each Council and create the best environment for research and innovation to flourish. The vision is to ensure the UK maintains its world-leading position in research and innovation.

1. THE IMPACT OF ENVIRONMENTAL CHANGES AND THE LEGAL FRAMEWORK PROTECTING OCEAN BIODIVERSITY

It is important that the UK strengthens legal and regulatory framework for marine environmental protection, but this will only be beneficial if international agreements are reached.

1.1 What forms of pollution are most prevalent in the ocean, and what impact are they having? Where does it come from?

Non-point-source pollution 80% of pollution to the marine environment comes from the land. One of the biggest sources is called non-point-source pollution, which occurs as a result of runoff. Millions of motor vehicle engines drop small amounts of oil each day onto roads and parking lots. Much of this, too, makes its way to the sea. Some water pollution actually starts as air pollution, which settles into waterways and oceans. Dirt can be a pollutant. Top soil or silt from fields or construction sites can run off into waterways, harming fish and wildlife habitats. Non-point-source pollution can make river and ocean water unsafe for humans and wildlife (1).

Microplastics are the most dominant particulate contaminant identified in the global ocean. Emerging evidence for harm to biota, ecosystems, and potentially to human health, currently makes microplastics pollution an issue of enormous concern for society. Moreover, interaction of microplastics with marine particulate organic matter can potentially alter carbon transport to the deep ocean, which has implications for global climate.

The majority of microplastics are generated as a result of breakdown of macroplastics although a small proportion come from microbeads (personal care and cleaning products).

Underwater noise pollution (UNP) can disturb or injure many marine animals, from the largest whales down to microscopic zooplankton. There is growing scientific evidence that the noise pollution we release into the oceans is having a range of negative effects on marine organisms that use sound (2). UNP is caused by use of explosives, oceanographic experiments, geophysical research, underwater construction, ship traffic, intense active sonars and air guns used for seismic surveys for oil and related activities (3).

1.2 What could the UK Government do to reduce it?

Plastics – There needs to be changes to commercial practice related to the manufacture and use of plastics and in the development of recycling methodology. Public education to reduce plastic waste should be enhanced still further. Targeted funding calls for the UK environmental science community should be developed so that the temporal and spatial distribution of plastic pollution is better understood and the potential harms can be assessed in a way which is supported by evidence.

Underwater Noise – In 2017 Cefas scientists published a study which proposes a new methodology to manage the impact of underwater noise on marine life. The work, titled "Marine Noise Budgets in Practice" allows policy makers to measure how much noise pollution a particular marine species or protected area is exposed to, and to set targets to manage pollution levels. The new method considers the population density of marine animals and their exposure to noise pressure across a managed area of ocean to map the risk it poses. In doing so, policy-makers can better target efforts to manage this noise (2).

1.3 What impact is climate change having on the ocean? How important is meeting the goals set out in the 2015 Paris Agreement on climate change for marine biodiversity?

NOC scientists contributed to the 2017 Marine Climate Change Impacts report card. Evidence included findings on one of the world's largest current systems – the Atlantic Meridional Ocean Circulation. The report's key findings were:

- Despite year-to-year fluctuations in temperature over the past decade, a long-term underlying warming trend is still clear. Some of this variability can be accounted for through short-term changes in the strength of Atlantic Ocean circulation, which has been linked to recent severe winters in the UK.
- Climate change is clearly affecting marine species and habitats, but not necessarily in the ways anticipated 10 years ago. Some warm-water marine species such as squid and anchovies targeted by fishers have become more commonplace in UK waters, with clear links to climate change, while for non-native species, other factors (e.g. ballast water, ship hulls) have been more important for their establishment.
- Seabirds in the UK face an uncertain future due to climate change, with the productivity of some species such as fulmars, Atlantic puffins, little and Arctic terns and black legged kittiwakes being negatively impacted by temperature rise, while severe storms are affecting breeding success of razorbills.
- Ocean acidification has become established as a major issue for marine ecosystems, and may be taking place at a faster rate in UK seas than in the

wider north Atlantic. Overall the impacts are expected to be negative, most notably for shellfish growth and harvest in future decades.
- Extreme high-water events are becoming more frequent at the coast due to sea-level rise. However, this has not led to a corresponding increase in coastal flooding to date due to continued improvements in flood defences, emergency planning, forecasting and warning.

1.4 What are the effects of ocean acidification now and in the future?

In 2006 there was high confidence that ocean pH was decreasing, and will continue to do so for as long as atmospheric CO_2 continues to increase. The impacts of ocean acidification on marine ecosystems and food webs are largely unknown.

In 2017 global ocean pH continued to decrease. The evidence base is more robust, with longer time-series, and with a wider range of physical-chemical measurements and greater geographic coverage. There is evidence the overall effect of ocean acidification on marine ecosystems will be deleterious, e.g. a risk of substantive reductions in shellfish growth (and harvest) within 50 years, although some algae and seagrasses may benefit from increased availability of CO_2.

Ocean acidification in UK seas over the last 30 years has been happening at a faster rate than for the wider North Atlantic. Interactions with other stressors (e.g. temperature, toxic metals, oxygen and food supply) and species-specific responses need to be considered to better understand impacts on ecosystems (4).

NOC response to the Inquiry into Ocean Acidification

1.4 What more should the Government do to hasten progress towards Aichi targets?

1.5 What outcomes and protections should the UK Government be pushing for at the forthcoming UN negotiations on the conservation and sustainable use of marine biological diversity in the world's oceans?

There is a need to ensure that Marine Scientific Research freedoms in areas beyond national jurisdiction are maintained.

1.6 What is the UK's record on meeting existing obligations under international law and the UN Sustainable Development Goal 14 (Life Below the Sea) in respect of biodiversity?

1.7 Is the UK's current legal and regulatory framework adequate to protect biodiversity given the growing demands which are likely to be placed on marine resources?

The UK is party to the UNCLOS, developing national marine strategy, foresight programmes, developing international marine strategy and adoption of the EU Withdrawal Bill.

2. A SUSTAINABLE BLUE ECONOMY

2.1 How effective are the Marine Stewardship Council's ecolabel and fishery certification scheme at ensuring fisheries are sustainable?

As this is not the NOC's area of expertise, please kindly refer to the Marine Stewardship Council

2.2 Does aquaculture cause less harm to marine biodiversity than fishing? Is aquaculture in the UK adequately regulated to protect biodiversity

Aquaculture is not an area of expertise for the NOC, however, the UK Marine Science and Technology Compendium lists institutes with expertise in this field.

2.3 What could the UK do to promote a sustainable marine economy and achieve sustainable marine and coastal ecosystems management in the Overseas Territories?

The issue concerns sustainable financing for work with the UK Overseas Territories. Given they do not qualify for Aid funding, and receive limited EU and UK funding, it is difficult to maintain or deliver long-term research programmes.

3. THE IMPACT OF MARINE INDUSTRIES, SCIENCE AND INNOVATION, AND BLUE FINANCE

3.1 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?

In general, we are only beginning to understand potential environmental impacts of deep-sea mining and other industrial activities in the deep ocean, and even for shelf and slope O&G activities that are more mature. For the latter, the UK is about to embark on a major experiment in the form of O&G decommissioning – it remains uncertain what the short- to long-term impacts will be on the marine environment. The same applies to sub-seafloor CO_2 storage, a critical measure needed by the UK to decarbonise the economy at scale.

3.2 How is the deep sea mining industry likely to grow in the years ahead?

The metal-rich mineral deposits under consideration for extraction are seafloor massive sulfides (SMS), ferromanganese (FeMn) nodules and ferromanganese crusts (FeMn crusts).

Deep-sea mining is moving fast from a feasibility perspective. In the Netherlands, Royal IHC Mining has been conducting R&D under the Blue Mining and Blue Nodules EU programmes; Belgium company DeM International is planning on trial mining operations in 2020. In 2017 Japan demonstrated successful large-scale SMS extraction off the coast of Okinawa.

While SMS and FeMn nodule mining is likely to occur first, mining of FeMn crusts is likely in the medium to longer-term, owing to their high concentrations of economically important elements that are essential for many new technologies.

What environmental risks will this bring?

SMS deposits develop around hydrothermal vents in active fields, rich in faunal communities, and in inactive vents that appear to have lower density but higher diversity faunal communities (Levin *et al.* 2016). **FeMn nodules** comprise accreted metallic ore on seabed sediment in the abyssal plains. The most extensive known FeMn nodule deposits are found in the Clarion-Clipperton Zone (CCZ) in the Pacific. **Ferromanganese crusts** form on seamounts and ridges in the open ocean (Fig 1).

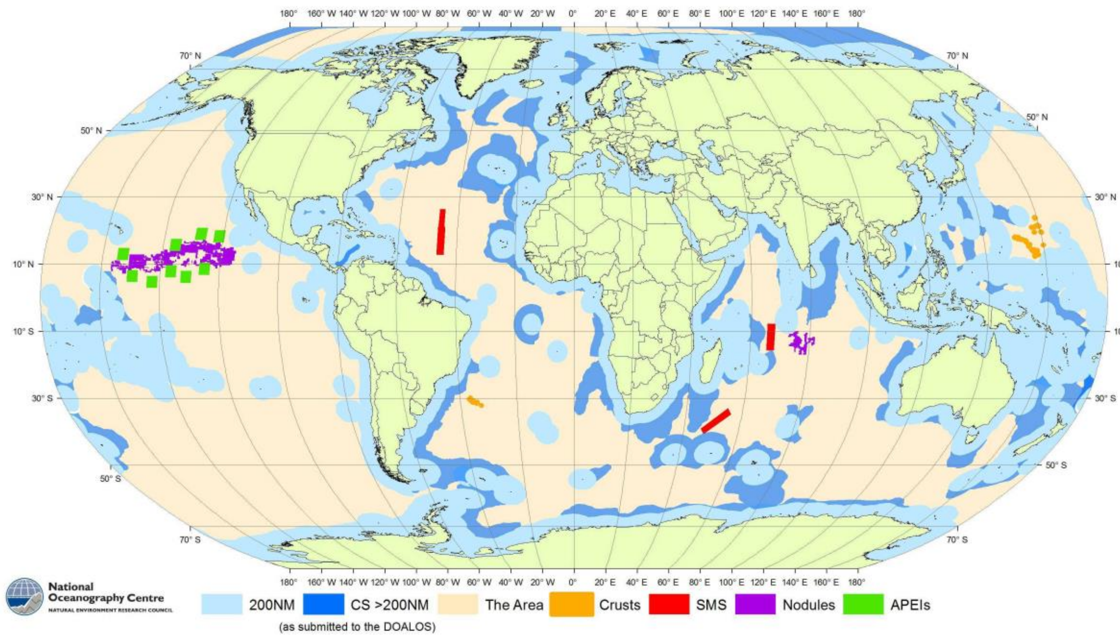


Figure 1. ISA exploration contract areas for the three main metal-rich mineral resource types in the "the Area" beyond national jurisdiction: seafloor massive sulfides, ferromanganese nodules and ferromanganese crusts. The Areas of Particular Environmental Interest (APEIs) in the Clarion Clipperton zone are indicated. Also shown are seabed areas within national jurisdiction (extending to 200 nautical miles and to continental shelves over 200 nautical miles) and the Area. Image: Alan Evans, NOC

Mining machines will compact soft sediment and mobilise sediment. Organisms will be crushed or smothered by sediment plumes, which may be toxic. Plumes may spread over extensive areas, particularly in the case of FeMn nodule mining (Gjerde *et al.* 2016). They may form higher in the water column, affecting plankton, commercial fishing stocks and marine mammals. Noise and light pollution will impact biological communities.

The FeMn nodule field in the CCZ hosts high biodiversity (Amon *et al.* 2016) which provides foundations for other animals (Mullineaux 1987; Gooday *et al.* 2015; Amon *et al.* 2016). Removing FeMn nodules will take away an important habitat that may take millions of years to replenish. The nodules are found in stable environments on soft sediments (Mewes *et al.* 2014), which if disturbed will expose deeper sediment; this may potentially impact sediment geochemistry leading to faunal death and/or impairment of faunal recovery processes. FeMn nodule mining may disturb several hundred km^2 of seabed each year (Smith *et al.* 2008). Such impacts are rare in deep-sea environments and may cause population reductions or even species extinctions.

The mining footprint of extracting SMS deposits will be smaller than other deposit types. Efforts are being made to protect active vent sites because of their high-density endemic communities. Hydrothermally inactive vent sites are more attractive for mining but are not barren of life (Van Dover, 2011).

Mining FeMn crusts will damage the surfaces of seamounts that are inhabited by fauna, many of which are new to science. These may be long-lived (possibly thousands of years old), and larger individuals may be responsible for much of the reproductive output needed to safeguard future populations. Seamounts may host endemic species, vulnerable to extinction from mining. Some commercially exploited fish species depend on the invertebrate assemblages found on seamounts, which are nursery grounds and hiding places from predators.

Deep-sea mining will degrade habitats, potentially causing extinctions and decreased biodiversity. Other impacts include modified trophic interactions, a risk of transplanting organisms from one mining site to another and lost opportunities to gain knowledge for the benefit of mankind (Boschen *et al.* 2013). The ecosystems of FeMn crusts and nodules are slow-paced and not subject to regular disturbances. Hydrothermal vents, often relatively dynamic habitats, have shown remarkable decadal stability (Copley *et al.* 2007; Cuvelier *et al.* 2011). Recovery from mining may be extremely slow, particularly following loss of important structuring habitats (e.g., nodules, vent chimneys).

In 1989, a disturbance and recolonisation experiment off Peru involved disturbing the seafloor with ~80 plough tracks (Thiel *et al.* 2001). After 27 years, re-investigation showed little observable change to the tracks. While some mobile species moved back into the tracks, there was little recolonization of disturbed areas, with even microbial communities struggling to recover (Gjerde *et al.* 2016). Recovery from commercial-scale mining is likely to be even slower, as both the temporal and spatial scales of disturbance will be larger than those of the experiments. These impacts could cause extinctions and population declines, reducing biological connectivity and reproductive success.

The presence of rare species may be used as an indicator of ecosystem health. Identifying 'indicator' species in the deep sea is currently impossible, preventing specific species-based conservation actions and inhibiting efforts to improve management actions.

What legal protections are in place to mitigate these risks?

Many of these resources are found in 'the Area', which is outside the jurisdiction of individual states, and where exploration and exploitation activities are managed by the International Seabed Authority (ISA). The ISA has developed regulations that govern exploration for the main deep-ocean metal-rich mineral deposit types and is producing regulations that will include environmental provisions for deep-sea mining.

Mineral deposits within national jurisdictions falls under the regulations of coastal states. To date no deep-ocean commercial seafloor mining has occurred but projects are in development, e.g. a mining lease and environmental permit have been granted by the PNG government to Nautilus Minerals Inc. for SMS mining, with Tonga and other Pacific island nations expected to follow.

Seabed mining within national jurisdictions are common. De Beers Group has been mining for diamonds off Namibia for decades. Namibia has deposits of phosphates that have attracted interest by Namibia Marine Phosphate, but approval for this work has not been granted. In New Zealand, Trans-Tasman Resources was recently given consent by the Environmental Protection Authority to mine iron sands, while a request for a mining license for phosphates on the Chatham Rise has been rejected.

Are additional legal protections needed?

It is possible to reduce impacts through good management practices (Durden *et al.* 2017). Extensive research is needed in each area planned for mining to ascertain baseline conditions. This should incorporate high-resolution mapping, and assessments of spatial and temporal patterns in physical and chemical conditions and the faunal communities inhabiting the areas. Ecosystem studies are needed to prevent mining-related ecosystem collapse and ensure that ecosystem services (upon which we rely) will remain during and after mining. Research will enable better understanding of the communities at risk and inform environmental management plans.

Environmental Impact Assessments can assess risks of activity, environmental sensitivities and identify alternatives that may reduce or mitigate impact (Durden *et al.* 2018). Risks are reduced by applying a mitigation hierarchy, whereby risks are: 1) avoided 2) minimized 3) restored or 4) offset. Restoration and offsetting are impractical at present because of biological, technical, financial and legal issues (Van Dover *et al.* 2017). Once risks are reduced, a decision can be made as to whether benefits outweigh costs, environmental or otherwise. If the project is approved, plans can be made for ongoing environmental monitoring. If negative effects become severe, the project can be curtailed. These strategies should be continued until after the project has been decommissioned.

The mining company carries out the environmental management, however, additional regional management is necessary to achieve wider conservation objectives. Decisions about mine site placement, the number of active mines, and designation of MPAs, are best made by the agency responsible for the regulation of mining within a region. In the case of deep-sea mining, this is principally the ISA. To date, the spatial allocation of exploration areas has been driven by contractor applications to the ISA in areas of interest. However, a regional management plan has been made for the CCZ (Wedding *et al.* 2013), which includes nine areas, known as Areas of Particular Environmental Interest (APEIs) (Figure 1), where mining cannot currently occur. These APEIs are peripheral to the central CCZ, which has the highest FeMn nodule densities, and they each consist of a 200 x 200 km protected zone, surrounded by a 100 km buffer. The APEIs are geographically close enough to allow for biological connectivity with the proposed mining areas so recolonisation can occur after mining has ceased. Preservation Reference Zones (PRZs) monitor the effects of individual projects, and, by being representative areas where mining cannot occur, may also act as protected areas.

For the impacts of deep-sea mining to be minimized, there must be cooperation between stakeholders at national and international level: industry, policymakers, scientists, NGOs, and members of the public whose livelihoods depend on ocean resources. The ISA needs to continue to enforce strategic planning and management, on local and regional scales for all areas in which there is interest in mining, if it is to stand by its commitment to ensure the harmful effects from deep-sea mining are minimised and that deep-sea mining proceeds in an informed and careful manner in the future.

The main 'bottle necks' are the legislative environment, especially around: (i) the environmental impacts and mitigations, and (ii) the sharing of the common heritage of mankind, i.e. the revenues that may flow from deep-sea mining. Both are in development by the International Seabed Authority.

Many scientific questions remain, including: the impact of sediment plumes on benthic fauna and their vulnerability; a descent resource model for the deposits; processing and metal extraction.

Text based on paper in prep by Dr Dan Jones (5), et al, *plus input from Dr Bramley Murton and Dr Angus Best*

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

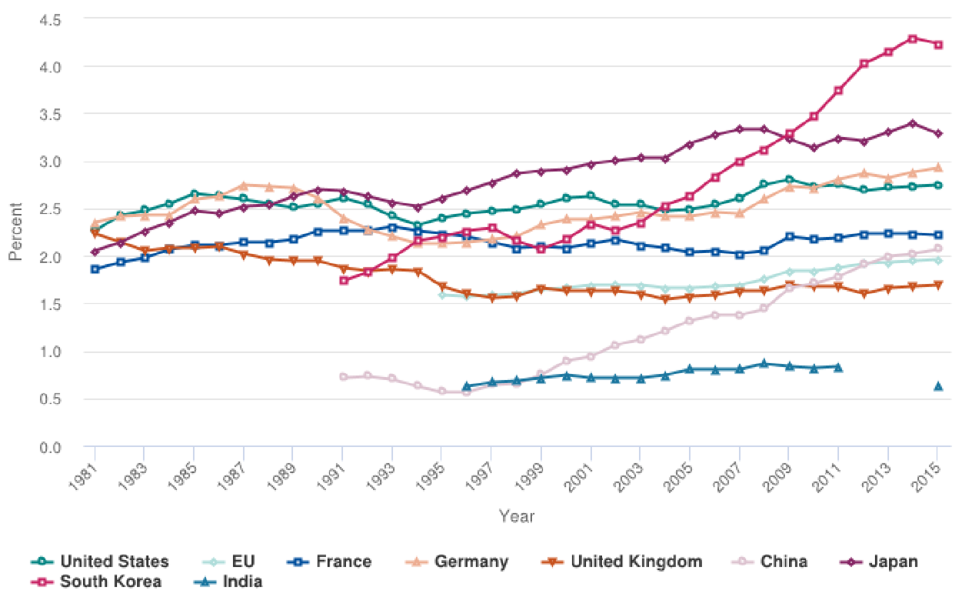
The 2017 Government paper, *UK Collaboration on Science and Innovation* refers to the UK intention to invest in research and innovation, and notes that Government has made a commitment to raise research and development spending as a proportion of GDP to 2.4% by 2017 and to 3% over the longer term (6).

A 2018 Nature news article notes that Germany has plans '*over the coming years […] to increase the country's overall research spending from just under 3% of gross domestic expenditure to 3.5% by 2025*. *This would bring Germany into third place globally on the proportion spent on research and development, behind only Israel and South Korea'* (7).

A 2018 paper by the US National Science Foundation notes that '*China has grown its R & D spending rapidly since 2000, at an average of 18% annually. […] China's growth rate is exceptional'* (8) and shown in Figure 2, below, for the period 1981 – 2015.

Figure 4-7

Gross domestic expenditures on R&D as a share of gross domestic product, by the United States, the EU, and selected other countries: 1981–2015



EU = European Union.

Note(s): Data are for the top eight R&D-performing countries and the EU. Data are not available for all countries for all years. Data for the United States in this figure reflect international standards for calculating gross expenditures on R&D, which vary slightly from the National Science Foundation's protocol for tallying U.S. total R&D. Data for Japan for 1996 onward may not be consistent with earlier data because of changes in methodology. Data for Germany for 1981–90 are for West Germany.

Source(s): National Science Foundation, National Center for Science and Engineering Statistics, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2017/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre, data.uis.unesco.org, accessed 13 October 2017. See Appendix Table 4-12.

Science and Engineering Indicators 2018

Figure 2 taken from NSF 2018 report (8)

Figure 2 shows that South Korea is the lead nation for Gross Domestic Expenditure on R&D as a share of Gross Domestic Product. In this figure the UK's position, up to 2015, is second from bottom, thus the goal to increase to 3% in the long term is warmly welcomed by the NOC. We look forward to Government continuing to work towards enabling the UK to become a powerhouse of world-class research and technology capability.

As a historical maritime nation, ocean research provides the UK with a philanthropic, non-threatening and acceptable means to interact with coastal states, for promoting mutual economic development for societal benefit, as well as projecting UK soft power. For example, the NOC uses NERC research ships RRS *James Cook* and RRS *Discovery* to promote UK enterprise, innovation and scientific endeavour in events held for national and international marine stakeholders, e.g. government representatives, UK marine industry representatives, students, school children and the public. The ocean links nations. The UK should instigate major marine scientific expeditions in partnership with rapidly developing nations like India, China, Bangladesh, Vietnam, as well as Commonwealth countries, to address major societal challenges around e.g. seafloor resources exploitation and environmental protection. Topics included O&G, hydrates, CO_2 storage, geo-hazards (landslides, tsunamis, volcanoes) etc.

3.3 What national or international measures could the UK pursue to minimise the impact of marine resource extraction, such as sand mining, aggregate dredging and deep-sea mining?

The UK should lead the world 'by example' by creating a detailed, multi-layered seafloor map of the UK marine EEZ showing all types of marine usage, which can be a reference point of best practice for marine spatial management and environmental protection (MPAs etc.). It is not possible to effectively manage the UK EEZ if it has not yet been mapped. Like the Ordnance Survey of the 19th Century, the NOC and partners (e.g. the UK Hydrographic Office, Maritime and Coastguard Agency) could achieve the equivalent reference maps for the UK EEZ and UK OTs, at high resolution. These can be combined with satellite observations and ocean system modelling of processes (winds, tides, waves, sea level, etc.). This expertise could be exported worldwide, and would also contribute to the global Seabed 2030 seabed-mapping programme.

3.4 Is private sector finance available to support sustainable blue industries? What could the Government do to promote 'blue finance' and investment in a sustainable marine economy?

A suggestion might be that Government could instigate a programme of start-up loans for new maritime businesses (similar to student loans, that would be repaid over time, based on income success, or for proportion of equity, or written off if fail). Currently, too few innovators set up start-up companies due to a lack of capital financing and/or red tape, and invest in apprenticeships and other training in the high tech marine sectors. Private finance would surely follow Government pump-priming initiatives and reduce some of the investment risks. Government could run high profile competitions for investment in new marine high technology business ideas.

References

1. NOAA (2017) *What is the biggest source of pollution in the ocean?* [on-line]. Available at: https://oceanservice.noaa.gov/facts/pollution.html

2. Merchant, N (2017) "Marine noise budgets" – a new method to manage the impact of underwater noise [on-line]. Available at: https://marinescience.blog.gov.uk/2017/11/08/marine-noise-budgets-a-new-method-to-manage-the-impact-of-underwater-noise/

3. Ocean Mammal Institute *Underwater Noise Pollution* [on-line]. Available at: http://www.oceanmammalinst.com/aboutunp.html

4. MCCIP (2017). Marine Climate Change Impacts: 10 years' experience of science to policy reporting. (Eds. Frost M, Baxter J, Buckley P, Dye S and Stoker B) Summary Report, MCCIP, Lowestoft, 12pp.

doi:10.14465/2017.arc10.000-arc Available at: http://www.mccip.org.uk/media/1770/mccip-report-card-2017-final-artwork-spreads.pdf

5. Jones, D, Amon, D, Chapman, A (due to be published) *Mining Deep-Ocean Mineral Deposits: What are the Ecological Risks?*

References in this paper

Amon DJ, Ziegler AF, Dahlgren TG, Glover AG, Goineau A, Gooday AJ, Wiklund H, Smith CR (2016) Insights into the abundance and diversity of abyssal megafauna in a polymetallic-nodule region in the eastern Clarion-Clipperton Zone. Scientific Reports 6:30492

Boschen RE, Rowden AA, Clark MR, Gardner JPA (2013) Mining of deep-sea seafloor massive sulfides: A review of the deposits, their benthic communities, impacts from mining, regulatory frameworks and management strategies. Ocean and Coastal Management 84: 54-67

Copley JT, Jorgensen PBK, Sohn RA (2007) Assessment of decadal-scale ecological change at a deep Mid-Atlantic hydrothermal vent and reproductive time-series in the shrimp *Rimicaris exoculata*. Journal of the Marine Biological Association of the United Kingdom 87: 859-867.

Cuvelier D and 7 coauthors (2011) Community dynamics over 14 years at the Eiffel Tower hydrothermal edifice on the Mid-Atlantic Ridge. Limnology and Oceanography 56(5): 1624-1640.

Durden JM and 7 coauthors (2017) A procedural framework for robust environmental management of deep-sea mining projects using a conceptual model. Marine Policy 84: 193-201

Durden JM and 5 coauthors (2018) Environmental Impact Assessment process for deep-sea mining in 'the Area'. Marine Policy 87: 194–202

Gjerde KM and 12 coauthors (2016) Implications of MIDAS results for policy makers: recommendations for future regulations. Seascape Consultants, Romsey

Gooday A, Goineau A, Voltski I (2015) Abyssal foraminifera attached to polymetallic nodules from the eastern Clarion Clipperton Fracture Zone: a preliminary description and comparison with North Atlantic dropstone assemblages. Marine Biodiversity 45: 1-22

Levin LA and 17 coauthors (2016) Hydrothermal Vents and Methane Seeps: Rethinking the Sphere of Influence. Frontiers in Marine Science 3: 72

Mewes K and 5 coauthors (2014) Impact of depositional and biogeochemical processes on small scale variations in nodule abundance in the Clarion-Clipperton Fracture Zone. Deep-Sea Res Pt I 91: 125-141

Mullineaux LS (1987) Organisms living on manganese nodules and crusts: distribution and abundance at three North Pacific sites. Deep-Sea Research 34: 165-184

Smith CR and 4 coauthors (2008) The near future of the deep seafloor ecosystems. In: Polunin N (ed) Aquatic Ecosystems: Trends and Global Prospects. Cambridge University Press, Cambridge, pp 334-349

Thiel H and 5 coauthors (2001) The large-scale environmental impact experiment DISCOL—reflection and foresight. Deep-Sea Research Pt II 48:3869-3882

Van Dover CL (2011) Mining seafloor massive sulphides and biodiversity: what is at risk? ICES Journal of Marine Science: Journal du Conseil 68: 341-348

Van Dover CL and 14 coauthors (2017) Biodiversity loss from deep-sea mining. Nature Geoscience 10: 464-465

Wedding LM and 7 coauthors (2013) From principles to practice: a spatial approach to systematic conservation planning in the deep sea. Proceedings of the Royal Society B: Biological Sciences 280:20131684

6. HM Government (2017) *Collaboration on science and innovation* [on-line]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/642542/Science_and_innovation_paper.pdf

7. Schiermeier, Q (2018) *German scientists hope for windfall from incoming government* In Nature **553**, 388 [on-line]. Available at: https://www.nature.com/articles/d41586-018-01026-0

8. NSF (2018) *State of US science enterprise report shows US leads in S&E as China rapidly advances* In National Science Foundation [on-line]. Available at: https://www.nsf.gov/news/news_summ.jsp?cntn_id=244271&org=NSF&from=news

In case of query

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