High-Impact Research Supported by Scientific Diving

A synopsis prepared by the European Scientific Diving Panel of the European Marine Board

www.marineboard.eu/scientific-diving-panel
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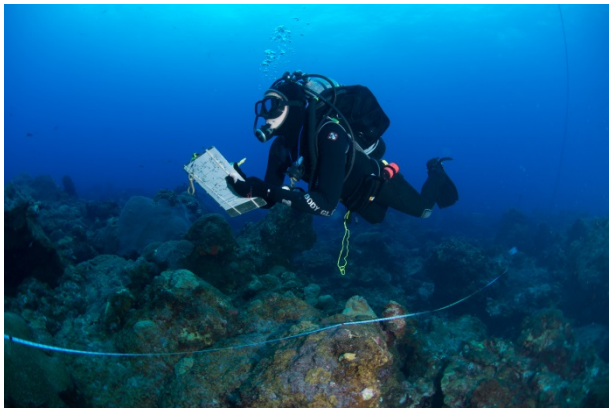
Scientific diving is a cost-effective high-quality research tool that is capable of supporting a wide range of scientific disciplines, often in complex environments within operationally rapid timeframes. Scientific diving can also provide unique multidisciplinary datasets for marine and maritime assessments that add value to data from other ocean observation platforms. One of the objectives of the European Scientific Diving Panel (ESDP), facilitated by the European Marine Board, is to highlight the trans-disciplinary use of diving and the potential to deliver high-impact science using a research tool that is often low-cost, flexible and easy to employ. A recent survey, at a European scale, has collated over 60 articles published during 2011-2015 in journals with ISI Impact Factors of 5 or higher, which were dependent in some way on the use of scientific diving. These are listed at www.imbe.fr/to-highlight-benefits-of.html?lang=en. Here we provide an overview that focuses on seven different research disciplines (Ecology, Climate Change/Ocean Acidification, Science-based Archaeology, Geochemistry, Polar Biology, Conservation Biology and Genomics) using examples of studies where the use of diving has been essential for the delivery of high-impact science.

Ecology: Mora *et al.,* 2011. Global human footprint on the linkage between biodiversity and ecosystem functioning in reef fishes. *Plos Biology* **9,** e1000606. Impact Factor (2011) = 11.452

Difficulties in scaling up theoretical and experimental results have raised controversy over the consequences of biodiversity loss for the functioning of natural ecosystems. Using a global survey of reef fish assemblages, this study showed that in contrast to previous theoretical and experimental studies, ecosystem functioning (as measured by standing biomass) scales in a non-saturating manner with biodiversity (as measured by species and functional richness) in this ecosystem. The field study also showed a significant and negative interaction between human population density and biodiversity on ecosystem functioning (i.e., for the same human density there were larger reductions in standing biomass at more diverse reefs). Human effects were found to be related to fishing, coastal development, and land-use stressors, and currently affect over 75% of the world's coral reefs. These results indicated that the consequences of biodiversity loss in coral reefs have been considerably underestimated based on existing knowledge and that reef fish assemblages, particularly the most diverse, are greatly vulnerable to the expansion and intensity of anthropogenic stressors in coastal areas. All data on reef fish assemblages were obtained using standardised scientific diving techniques (predominantly transect-based); over 6000 sampling units were obtained from almost 2000 reef locations worldwide. The photo shows a diver identifying and counting fish that occur 1-metre each side of a temporary transect.

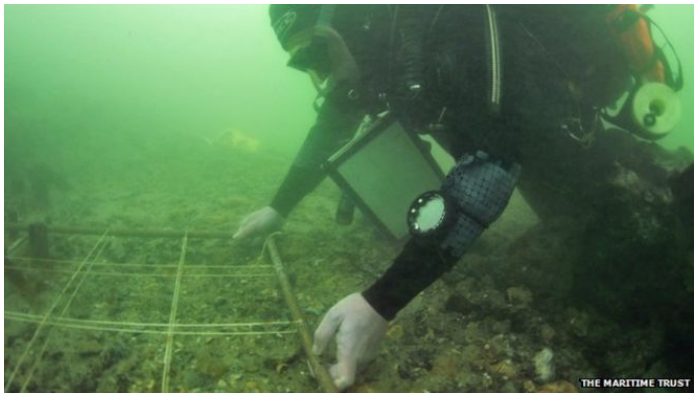


Climate Change/Ocean acidification: Garilli *et al.,* 2015, Physiological advantages of dwarfing in surviving extinctions in high CO_2 oceans. *Nature Climate Change* **5,** 678-82. Impact Factor (2014) = 14.547

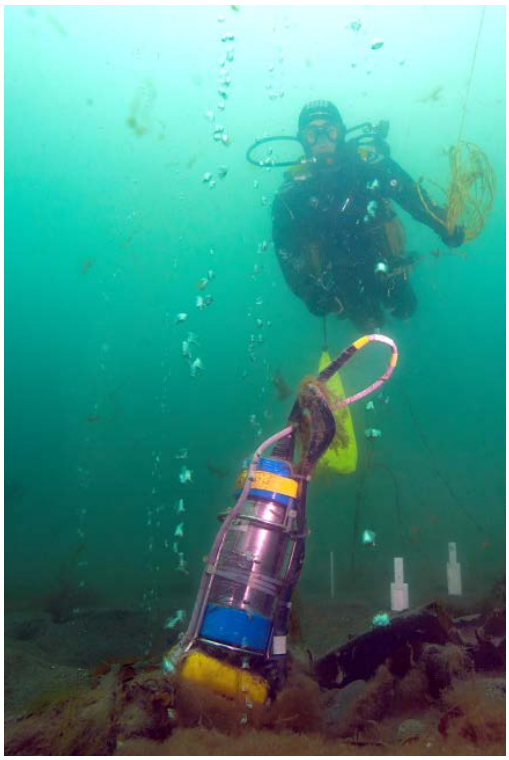
Excessive CO_2 in the present-day ocean–atmosphere system is causing ocean acidification, and is likely to cause a severe biodiversity decline in the future, mirroring effects in many past mass extinctions. Fossil records demonstrate that organisms surviving such events were often smaller than those before, a phenomenon called the Lilliput effect. This study showed that two gastropod species adapted to acidified seawater at shallow-water CO_2 seeps were smaller than those found in normal pH conditions and had higher mass-specific energy consumption but significantly lower whole-animal metabolic energy demand. These physiological changes allowed the animals to maintain calcification and to partially repair shell dissolution. These observations of the long-term chronic effects of increased CO_2 levels forewarn of changes we can expect in marine ecosystems as CO_2 emissions continue to rise unchecked, and support the hypothesis that ocean acidification contributed to past extinction events. The ability to adapt through dwarfing can confer physiological advantages as the rate of CO_2 emissions continues to increase. The gastropods used in this study were collected by scientific divers at naturally-occurring CO_2 seeps and compared against those found at sites with ambient sweater pH (see photo).

Science-based Archaeology: Smith *et al.,* 2015. Sedimentary DNA from a submerged site reveals wheat in the British Isles 8000 years ago. *Science* **347(6225),** 998-1001. Impact Factor (2014) = 33.611

Scientific diving in the Solent, UK enabled the recovery of submerged samples to be analysed for evidence of sedimentary ancient DNA (sedaDNA). New methodologies developed by the Maritime Archaeology Trust enabled stratified sediments to be recovered from an 8,000 year old, Mesolithic, archaeological site that is now 11m underwater. Analysis of the material revealed profiles compatible with human activity. This included the presence of canis, interpreted as either dogs or wolves; bovidae being bison or auroch; deer; members of the grouse family and rodents. The sedaDNA within the floral profile provided evidence of the changing local environmental conditions and identified strong signatures of einkorn, which is domesticated wheat associated with the Neolithic. It was sampled from an archaeological context that is 2000 years older than currently known as wheat is not otherwise recorded as arriving to Britain until after 4,000 BC. The results were the first ever to be analysed from an underwater site and they have profound implications on our understanding of the Mesolithic (hunter-gathering) – Neolithic (farming) transition in Britain. To validate the pioneering research it was necessary to survey the seabed to record the inter-relationship of deposited sequences and interpret the taphonomic processes (photo, courtesy of the Maritime Trust.

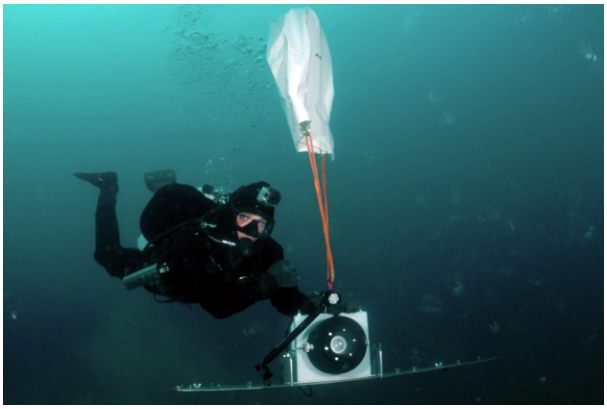


Geochemistry: Blackford *et al.,* 2014. Detection and impacts of leakage from sub-seafloor deep geological carbon dioxide storage. *Nature Climate Change* **4,** 1011-6. Impact Factor (2014) = 14.547



In order to better understand the environmental impacts of leaks from a marine sub-surface carbon capture storage facility and to investigate how leaks or potential leaks could be detected, a world-first experiment consisting of an artificial carbon dioxide release from below the seabed was undertaken in 2012. The need for accurate deployments and re-deployments of measurement equipment (photo; courtesy of the UK National Facility for Scientific Diving), the retrieval of biological and sediment samples within very specific areas of the release site and the in-situ measurement of escaping gas volumes, necessitated an extensive scientific diving programme. Diving was also employed to determine the most optimum experimental site prior to the programme's initiation and to map the site prior to the beginning of the experiment. Diving also proved to be an essential tool (through observation, photography and videography) in recording the progress of the experiment and the physical interactions and impacts arising from managing a large multi-partner, multi-discipline research programme.

Polar Biology: Berge *et al.,* 2015. Unexpected levels of biological activity during the Polar night offer new perspectives on a warming Arctic. *Current Biology* **25,** 2555-61. Impact Factor (2014) = 9.571



Polar regions are subjected to the most visible climate change driven effects. The areas most susceptible to changes are its coastal zones, where diving techniques prove to be the perfect research tool. The main objectives of this study concerned feeding strategies and trophic links in this highly seasonal ecosystem. It is known that in polar regions, with their pulse spring/summer production, prolonged periods of total darkness, and high levels of disturbance, necrophagy is a frequently used feeding strategy. In order to compare the composition of shallow-water scavenging fauna, investigate interactions among scavengers, and check consumption rate between the two contrasting seasons of Polar Night and Day, scuba diving was used. Three different-type of baits were deployed by divers on seabed and monitored by time-lapse cameras for several days in January (Winter, Polar Night) and August 2015 (Summer, Polar Day, see results on www.polartimelaspe.net). Despite polar night winter conditions recorded material revealed an abundant, active and species-rich shallow-water scavenging community. The level of experimental complexity (e.g. the requirement to set precise distance and angles between the camera and the photographed bait in complete darkness) meant that this study was only achievable with the use of scientific diving. Divers used lifting bags to move the heavy camera systems underwater, sometimes under ice (photo; courtesy of Institute of Oceanology, Polish Academy of Sciences)

Conservation Biology: Dailianis *et al.,* 2011. Genetic diversity of the imperilled bath sponge *Spongia officinalis* Linnaeus, 1759 across the Mediterranean Sea: patterns of population differentiation and implications for taxonomy and conservation. *Molecular Ecology* **20,** 3757–72. Impact Factor (2011) = 5.522

This study examined genetic diversity of the iconic sponge species *Spongia officinalis* at its native Mediterranean extent range. Collection of more than 500 samples from 11 locations was conducted either by scuba diving, non-destructively removing just the amount of tissue required for genetic analyses, or by surface air supply accompanying professional sponge divers (photo; courtesy of the Hellenic Centre for Marine Research) at depths 4-42 metres. The findings for the first time provide an insight regarding divergence patterns of the species at the regional and local scale, serving as a baseline study to support the effective management of this valuable and vulnerable marine resource.

Genomics: Romiguier *et al.,* 2014. Comparative population genomics in animals uncovers the determinants of genetic diversity. *Nature* **515 (7526),** 261-3. Impact Factor (2014) = 41.456

Genetic diversity is the amount of variation observed between DNA sequences from distinct individuals of a given species. This pivotal concept of population genetics has implications for species health, domestication, management and conservation. Levels of genetic diversity seem to vary greatly in natural populations and species, but the determinants of this variation, and particularly the relative influences of species biology and ecology versus population history, are still largely mysterious. This study showed that the diversity of a species is predictable, and is determined in the first place by its ecological strategy. The study investigated the genome-wide diversity of 76 non-model animal species by sequencing the transcriptome of two to ten individuals in each species. The distribution of genetic diversity between species revealed no detectable influence of geographic range or invasive status but was accurately predicted by key species traits related to parental investment: long-lived or low-fecundity species with brooding ability were genetically less diverse than short-lived or highly fecund ones. The analyses demonstrated the influence of long-term life-history strategies on species response to short-term environmental perturbations, a result with immediate implications for conservation policies. A significant number of the aquatic species used in this study (e.g. nemertine worms, crabs, limpets, sea squirts, sea urchins) were collected in targeted and non-destructive ways using scientific diving but also over a range of geographical locations. The photo (courtesy of PROTEKER) shows sampling of the burrowing sea urchin *Abatus cordatus*, endemic to Kerguelen Islands. Using a dredge or any other towed gear from the surface or a suction apparatus by diving would have destroyed such a fragile species making further analyses impossible.