The delivery of science through diving: a review of recent scientific highlights and the framework for occupational scientific diving in Europe

Consultation Document Nb. 2

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1 - Preface

1.1 - Rationale

A joint COST-ESDP workshop "*Strengthening Synergy and Excellence in Diving Supported Science across Europe*" was organised in Brussels (27-28 September 2010) with the following objectives:

- To advance underwater scientific excellence in Europe;
- To promote diving across Europe as a cost-effective and productive research tool;
- To encourage international mobility in the European scientific diving community through the implementation of a practical support framework.

At this meeting, it was decided to set-up and to operate two separate Working Groups in order to sustain a dynamic flow of information between experts, to pursue developing synergies on issues of common interest and to create a climate of confidence to maintain dynamic interactions between experts.

1.2 - Aims

This consultation document aims to inform the marine research community of the opportunities and key challenges associated with Scientific Diving. It gathers different inputs from European Scientific Diving experts to build up a "consultation document" articulated around two main parts:

- Part A: highlighting the contribution that Scientific Diving can make in the performance and improvement of some underwater research areas in order to address the "Grand Challenges";
- Part B: addressing the current management status and performance of Scientific Diving in Europe while identifying specific gaps and needs (contributions have been collected, assessed and summarised by the Working Group leader through questionnaires).

1.3 - Objectives

Scientific Diving is a highly productive, cost-effective "*in situ*" research tool that supports and advances marine research through providing efficient, innovative and targeted techniques and methodologies.

This consultation document aims to provide information on the range of scientific disciplines and research areas that diving can or does support based on multi-disciplinary programmes of observation, assessment and monitoring. For example, Scientific Diving is becoming increasingly important as a relevant monitoring tool in support of policy needs, more particularly to address the monitoring requirements and other programmes of measures set out by the Marine Strategy Framework Directive.

In addition, by identifying current status, gaps and opportunities in the management scheme, the document aims to stress critical issues and provide key recommendations to facilitate a pan-European framework that encourages best practice and foster advances in dive technologies and procedures.

This is a dynamic document and it will be periodically reviewed to incorporate refinements and additions.

2- The contribution of Scientific Diving to perform and improve marine research in addressing the "Grand Challenges"

2.1 - Scientific Diving as a Major Tool to assess global change biology

By **Dan Tchernov,** the *Interuniversity Institute for Marine Science* - Israel

Global change biology is an emerging field that investigates the understanding of the interface between aspects of environmental change and biological systems. In recent years we've witnessed growing interest in this field, particularly in light of the rapid accumulation of evidence supporting global warming and ocean acidification.

Climate change research is spread over many different scientific disciplines. However, because the most abundant and measureable changes due to climate change occur mostly at sea, scuba diving plays a leading role as a tool to improve our understanding of climate change. Coral bleaching is the most abundant phenomenon first to be associated with global warming. Yonge first described bleaching in his famous 1932 seven volume report on the expedition to Low Isles in the great barrier reef [1]. Tom Goreau reported in 1964 a massive bleaching event that was set off by a hurricane that caused substantial flooding of the reef by sediments and fresh water[2]. However, The first manuscript associating coral bleaching to thermal stress was published during 1974. There, Paul Jokiel described for the first time the effect of a hydrothermal effluent from a power station on corals in Oahu, Hawaii[3]. Today, over 1500 articles can be found on the subject of coral bleaching alone. Over the past 10 years there has been almost a five-fold increase in the number of publications per year on the subject of coral bleaching (Figure 1). In most of the cases, scuba diving played a crucial role in retrieving the data. In many cases, scuba diving was used as a tool to collect corals. In other cases, scuba was used to assess ecological or physiological data *in situ*[4-24]. In all cases, it is very clear that this important work could not be done in a manner inflicting least harm to the reefs without the aid of scubadiving.

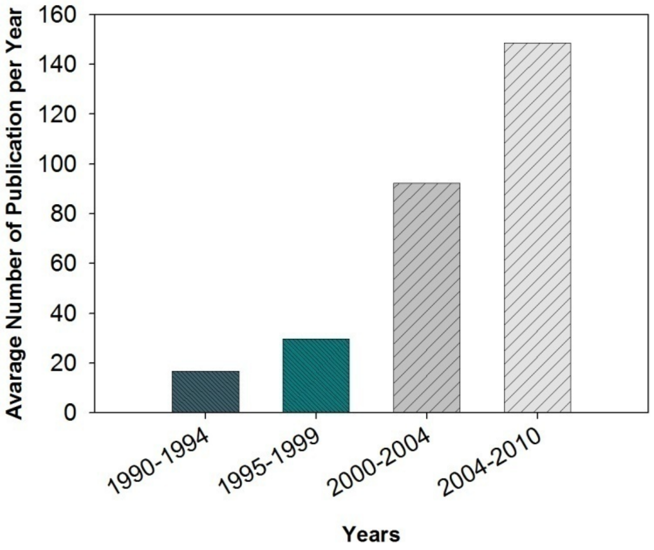

Figure 1: The five year average of peer reviewed publications on a scale of publication per year, on the theme of coral bleaching. The search was preformed from the official ISI web of knowledge website. The minimum record count was set as 5, sorted by years. *http://apps.isiknowledge.com/OutboundService.do?action=go&mode=raService&SID=V1Cd97MJ82C4lC94mcj&product=UA&parentQid=41&db_id=UGB*

A similar case is to be found in the up-and-coming field of ocean acidification (see chapter 2.2). Again, the impact of anthropogenic CO_2 emissions was abundant in the world oceans and was observed by scuba divers who first described this phenomenon and its impact on the fauna and flora. The top cited articles that investigate ocean acidification are mostly carried out using scuba diving as a major tool [25-31]. As can be clearly seen from the data presented in Figure 2, there is a vast increase in ocean acidification research over the last five years. This additional research is performed mainly with the aid of scuba technology.

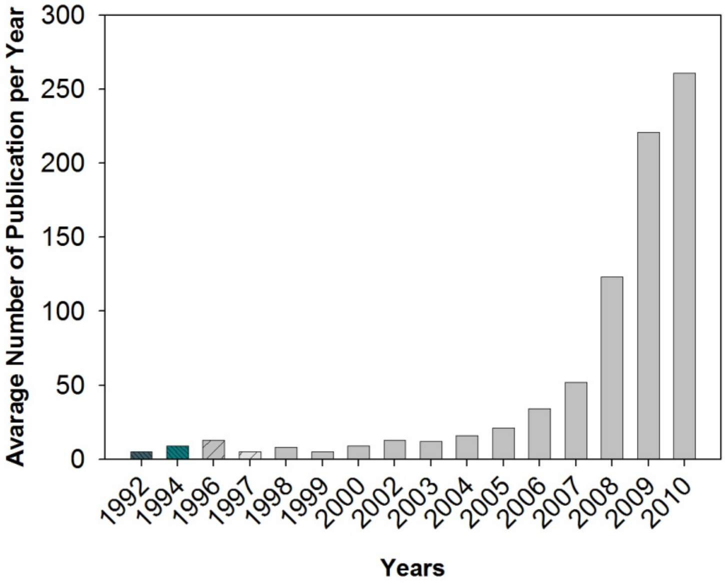

Figure 2: The yearly average of peer reviewed publications on the theme of ocean acidification. The search was preformed from the official ISI web of knowledge website.. The minimum record count was set as 2, sorted by years. [*http://apps.isiknowledge.com/OutboundService.do?action=go&mode=raService&SID=V1Cd97MJ82C4lC94mcj&product=UA&parentQid=41&db_id=UGB*](http://apps.isiknowledge.com/OutboundService.do?action=go&mode=raService&SID=V1Cd97MJ82C4lC94mcj&product=UA&parentQid=41&db_id=UGB)

Another important contribution of scuba technology is within the field of paleoclimate reconstruction. This field is immense in its general impact on the study of earth systems. It is the foundation that supports our whole evolutionary grasp in addition to our perception of the ecological and biogeographic past. In a way, our knowledge of past climate shapes our way of thinking about the main factors that eventually shaped who we are in the grand scheme of natural history. The latter is true since climate is the most powerful driver of evolution. The reconstruction of mass extinction events has become quite relevant in our day and age, unfortunately. Thus, the humble scuba diver that can also combine a scientific skill and a pneumatic drill becomes a key element in our scientific advancements. In this case coring corals on a reef in a least harmful and focused manner is possible only by using scuba technology [32-37]. Needless to say, without the mining of the Earth's past it will be impossible to even attempt to predict anything sensible about future climate. And for this reason it is crucial to keep on improving our diving technology.

Interest in investigating the mesophotic reefs combined with advances in training and accessibility to trimix diving and closed circuit systems ('rebreathers') has enabled us to reach deeper [38-41]. This may prove to be a very important milestone in the history of ocean exploration as we can extend our range to these deeper reefs that prove highly diverse and are perhaps the corals last refuge from the catastrophe looming above. A few authors already declared the mesophotic zone to be a coral safe haven [39,42,43]. This may be the actual origin of scleractinian corals, although there is also evidence for on shore to off shore evolution.

The impact of scuba diving lies beyond the relatively small number of researchers that are implementing these techniques. The latter is rendered true, because this is almost the only tool where a researcher can experience and explore the marine environment first hand, with no filters or adaptors. And in doing so has a much better capability to make scientific advancements that are otherwise impossible. In most cases, without scuba diving many of these discoveries would not be possible. Diving technology markedly evolved over the past century and is greatly responsible for our ability to monitor closely the marine environment in multiple aspects and with minimal damage to the environment.

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2.2 - Scientific Diving as a major tool to assess ocean acidification

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The oceans are a sink for carbon dioxide; they absorb it by means of biological and solubility pumps. Over the past two hundred years the oceans have absorbed about half of the CO_2 produced by anthropogenic activities, mainly fossil fuel burning and cement production. The surface waters of the oceans today contain about 45 µmol*kg-1 excess CO_2 compared with those of the pre-industrial era, and this value is increasing (Brewer et al.,1997).

Consequentially, this uptake has caused an increase in seawater acidity; since 1751, the average ocean pH has already been lowered from 8.25 to 8.14, with a 30% increase in the concentration of H^2. If global emissions of carbon dioxide continue to rise at the current trend, by 2100 the average pH of the oceans could drop by another 0.5 units thereby reaching probably the lowest value in the last hundreds of millennia. (Jacobson, 2005; Raven et al., 2005). This human-induced acidification is at least 100 times faster than ever in respect to the values over the last 100,000 years, and does not allow the ocean buffer enough time to react in order to balance the acidification (OSPAR, 2006). Moreover, based on records of the CO_2 levels in the past 300 Myr and geochemical models, it is supposed that the ocean pH was never below more than 0.6 units than that of current values (Caldeira and Wickett, 2003).

An innovative approach for the development of reliable monitoring techniques for ocean acidification is to study environments where, for natural reasons, higher than normal levels of CO_2 are present. CO_2 emissions in shallow-water have been identified, as example, close to some volcanic islands (in the Mediterranean Sea, Northern Atlantic and Japanese Archipelago) at depths that can be safely reached by scuba divers.

The idea is to use these areas as field-lab to test and validate the most appropriate techniques to detect and monitor the presence of CO_2 values above the baseline and to study the impact of the acidification on the ecosystem (Hall- Spencer et al., 2008; Caramanna et al., 2010).

The main points of the proposed approach can be summarized as follow:

- Identification of the most reliable parameters (such as pH, concentration of dissolved CO_2, DIC, DOC, alkalinity) to be used for ocean acidification monitoring.
- Develop a suite of sensors (such as pH meters, dissolved-gas sensors) for CO_2 detection and monitoring.
- Identify the best platforms to be used for sensors deployment (ROV, AUV, Gliders, surface vessels, buoys).
- Identification of areas with presence of natural higher than normal values of CO_2
- Use these areas as field-lab to test the sensors and the monitoring methodology
- Study the biological impact of CO_2 on the ecosystem considering these areas as “natural analogues” for the worst-case scenario

A big advantage of these shallow-water natural analogues is the very convenient cost/benefits ratio. Due to their environmental conditions (shallow water and coastal setting) it is possible to conduct experiments and tests, by means of surface techniques and by scientific divers, at costs almost negligible if compared to the ones of any high-seas operation.

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2.3 - Scientific Diving as a major tool to conduct in-situ assessments of ecosystem functions of the sea-floor

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Understanding dynamics and functioning of benthic communities in shallow water coastal zones is a grand challenge in marine biology. Our present knowledge of the benthic productivity, respiration, nutrient dynamics, mineralization, nutrition and trophic interactions of/in bottom communities in the littoral (intertidal) and sublittoral in particular is limited, considering its importance for fisheries, aquaculture and recreational services among others. The sublittoral refers to the depth zone where sunlight reaches the sea-floor. It is characterized by high primary production making the sublittoral the location of the majority of sea life. The functioning of hard bottom communities in this depth zone is particularly difficult to study because of the poor accessibility for instrumentation operated from the sea surface. The 3D complexity and bottom rugosity of these habitats hamper sampling of the organisms or the water in the benthic boundary layer remotely. In order to study these habitats in situ assessments are required.

Scientific Diving is the essential tool to explore the functioning of this habitat. By scientific diving, instruments can be precisely installed/placed underwater and tailored for measurements in time and in depth, which cannot easily be taken otherwise. This way exchange of nutrients and fluxes of matter, oxygen and bicarbonate in the bottom water interface are determined, which give insight in the turnover of matter and the productivity of the benthic community.

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2.4 - Scientific Diving in the Polar Regions

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Introduction

Approximately four decades ago scientists were first able to enter the undersea polar environment to make biological observations for a nominal period of time. Since those first ice dives in wetsuits without buoyancy compensators and with double-hose regulators lacking submersible pressure gauges technology has advanced. Today's scientific ice divers have the potential of extending their observational and experimental depths and times to limits never before available. Novel ice diving techniques have expanded the working envelope based on scientific need to include use of dive computers, oxygen-enriched air, rebreather units, blue-water diving and drysuit systems. With the advent of new technology greater scientific productivity is being achieved.

The employment of diving in the Polar Regions affords many advantages to the scientist. Principally, the ability to dive under ice provides the capability to undertake science in a restricted environment at relatively low cost. Divers, using a small number of holes in the ice can sample over a wide area and generate high levels of experimental replication. Much attention is currently targeted at the physics and ecology of the underside of sea-ice and diving allows fast and effective access to these environments. In addition, divers are an accurate and reliable method for deploying, maintaining and retrieving monitoring equipment from under-ice environments. With or without ice, diving is a relatively cost efficient technique for researching remote locations that, without the capability of the divers to work in such environments, would require the use of more expensive research vessels.

Diving in extreme environments requires specialist training and equipment. These needs are reviewed in detail in the 2007 proceedings of the *International Polar Diving Workshop* (Sayer and Lang, 2007). However, accepting the increased risks and demands of conducting scientific diving operation in Polar Regions, the overall safety record for polar diving is good, and does not differ from that of normal scientific diving (Sayer *et al*., 2007).

European scientific diving in Antarctica is limited to a small number of nations who either have research stations in Antarctica and/or have bases on sub-Antarctic islands. Infrastructure support is generally good in Antarctica because of the close association of the diving programmes with the research bases. This situation is slightly different in the Arctic where, as well as established research bases, scientists have access to wider provider-base for, usually commercial, support of expeditions/fieldwork (e.g. Sayer *et al.,* 2011). The main multi-national European Arctic research station is at Ny Alesund on Spitzbergen. This has good support services for diving. In both Antarctica and the Arctic there is potential for supporting diving operations from research vessels.

This report gives a brief review of some of the recent European scientific achievements that have occurred in the Polar Regions through the use of scientific diving.

Recent EU Polar research programmes employing diving

The ecology of ice-scour: Although ice scouring has been implicated as a highly significant factor in structuring Polar benthic communities, few studies have examined the effects in shallow Antarctic seas (Peck et al., 1999). Recent long-term projects have measured both the frequency and intensity of ice-scouring at shallow water sites (Brown *et al.,* 2004; Smale *et al.,* 2008). Iceberg impacts were recorded by monitoring the damage, or destruction, of purpose made impact markers laid in accurate grids on the substrate. Scuba divers resurveyed the grids at 3 monthly intervals and recorded the number of damaged and destroyed markers. Divers then carried out subsequent dives to replace the damaged or destroyed markers. During winter, resurveying of the sites was frequently carried out through winter sea ice. The research estimated the scouring frequency of shallow-water

Antarctic habitats and demonstrated that water depth, study site and season are all significant factors effecting scouring frequency. Further research has found significant effects of ice scouring on species richness and abundance (Smale et al., in press). This ongoing research is showing that ice-scour has an important and highly significant role in structuring shallow water Antarctic communities.

Seasonal Ecological Studies: Diving (and under-ice diving in particular) has supported a wide range of year round studies on the physiology and ecology of specific marine species or animal groups (e.g., Barnes and Clarke, 1994; Stanwell-Smith and Barnes, 1997; Brockington, 2001; Brockington and Peck, 2001; Brockington *et al.,* 2001; Fraser *et al.,* 2002ab; Fraser *et al.,* 2004; Bowden, 2005; Bowden *et al.,* 2006). These studies have required considerable amounts of diving to collect animals for physiological experiments, or to allow in situ observations or photography. In turn these studies have provided important insights into how Antarctic ectotherms are adapted to living in an environment characterised by a stable thermal regime, but a highly variable food supply.

Studies of the transport and fate of pollutants in the Arctic: The Arctic region is a seemingly pristine, remote environment, yet there is increasing evidence that it is greatly impacted by anthropogenic metal contamination. The source of contaminants primarily lies outside the Arctic region, with sediments potentially providing a major sink for these anthropogenic inputs. Heavy metals are attributed to adverse effects on the health of biota and indigenous populations, because of their toxicity and bioaccumulative tendencies within the environment. Two metal contaminants of major concern are lead (Pb) and mercury (Hg). Both are ubiquitous anthropogenic pollutants with elevated concentrations being reported throughout the Arctic environment. Diving, and under-ice diving in particular, permits retrieval of shallow water sediment cores for assessment of contamination.

Sea ice research: Over recent decades the Arctic has warmed more than any other region of the world (ACIA, 2005). This warming has been accompanied by a reduction in the amount of perennial (multi-year) ice within the Arctic Basin (Johannessen *et al.,* 1999, Comiso, 2002); a decrease in the extent of sea ice of about 15% (Francis *et al.,* 2005) as well as a decline by some 40% in the thickness of summer sea ice (Rothrock *et al.,* 1999, Wadhams and Davis, 2000) with an accompanying reduction of some 73% in the frequency of deep pressure ridges (Wadhams and Davis, 2001). This reduction is set to continue with coupled models predicting the disappearance of summer sea ice extent by 2040 (Holland *et al.,* 2006). The near-seasonal disappearance of sea ice will influence among other things, ocean-atmosphere feedback, ocean stratification and vertical mixing. This in turn will affect primary productivity, ecosystem function and carbon cycling.

Understanding the dramatic and significant changes that are presently occurring within the Arctic region and their effect on global climate is beyond the scope of any one nation. The European Union encourages member states to form consortia to address major climate change issues. Diving has supported many of these consortia through relatively easy methodologies that permit direct access to the underside of pack ice for biological, chemical and physical monitoring.

Zooplankton research: Zooplankton research currently includes all aspects of modern marine sciences and the key topics concern: 1) understanding zooplankton natural biological dynamics; 2) zooplankton as potential food source for marine organisms; 3) identifying the role of zooplankton organisms in transfer of matter and energy (lipids) through food webs; and, 4) consequences of climate-induced modification of matter and energy transfer. Modern technologies for zooplankton sampling have included light (optical plankton counters, OPC) or sound (echosounders, sonars, acoustic doppler current profiler-ADCP). In studying fragile forms such as comb jellies, medusae or appendicularians, sampling by divers is necessary (Lundberg et al., 2006).

Arctic marine food webs: The structure and energy flow in Arctic marine food webs has been studied by stable isotopes of carbon and nitrogen to determine carbon sources and trophic levels (Dahl *et al.*, 2003; Søreide *et al*., 2006). Trophic transfer of energy from zooplankton to seabirds and seals has been studied by means of fatty acid trophic markers (Falk-Petersen *et al.,* 2002, 2004, 2007) which became carbon fixed during spring bloom and transferred as fatty acids to top predators within 6 months (Falk-Petersen *et al.,*1990). Trophic levels, determined by stable isotopes, are used as a continuous variable against bioaccumulation of persistent organic pollutants (POPs) to determine their bioaccumulation potential in Arctic marine food chains (Hop *et al.,* 2002). Some compounds, such as trans-nonachlor and PCB-138 and PCB-153, show high food-web bioaccumulation factors, determined from regression slopes of TL against POPs (Hop *et al.*, 2002).

Ultraviolet radiation (UVR): Ultraviolet radiation (UVR) may have a negative effect on both pelagic algae and macroalgae in shallow waters (Wiencke et al., 2000; Leu et al., 2006a). The effects of UVR on lipids, fatty acids and nutritional quality of Arctic marine algae and zooplankton have been studied in Kongsfjorden and experimentally in Ny-Ålesund (Leu et al., 2006a, 2006b, 2007). If the UV-radiation alters the lipids in phytoplankton these changes in food quality may be transferred to zooplankton. However, it was found that food quality is not the weak link in an Arctic food web exposed to UVR. Instead, hydrography determines the importance of light effects: Photosynthetic Active Radiation (PAR). Light stress might be of substantial importance for spring blooms at ice edges under strongly stratified conditions and rapidly changing light intensities. Trophic transfer of these effects is only likely under stable conditions, but may be of increasing importance because of climatic changes. Ice algal production makes up 16-22% of total primary production in the northern Barents Sea.

Long-term monitoring of benthos: Long-term marine ecological projects are rare in Arctic waters but one project has monitored an Arctic macrobenthic community in relation to climate variability (Beuchel *et al*., 2006). Two monitoring sites have been photographed annually by scuba divers since 1980: Kvadehuken in Kongsfjorden and a location in Smeerenburgfjorden on north-west Spitsbergen. Permanently marked hard-bottom areas at 20m depth are photographed annually by scuba divers. Changes in community composition (Shannon Wiener species diversity H’) was related to changes in the North Atlantic Oscillation index and its manifestations.

Seaweed and oomycete diversity in the marine Arctic: Global climate change is expected to alter the Arctic and Antarctic bioregions faster than any other marine environment on Earth. A series of ongoing studies are employing diving to investigate the diversity and diseases of the region’s little-known macroalgae (seaweeds). The major objectives of the research are complete an inventory of the seaweed flora of the Arctic and to characterize the seaweed-associated, eukaryotic pathogens, such as oomycetes (Sayer *et al*., 2011).

Ecology, physiology and genomics of Antarctic marine invertebrates: Recent studies have continued to investigate the physiological, genomic and ecological mechanisms by which Antarctic marine invertebrates cope with life in the cold, but rapidly warming, waters around the Antarctic Peninsula. Long term studies of the impact of icebergs on benthic communities; dynamics of encrusting and sediment communities, environmental monitoring of pollution and inter-annual variation in reproductive status are ongoing.

Whole genome analyses have shown that a commonly occurring limpet, whose shell structure varies widely with water depth, is in fact one population (Hoffman *et al*., 2010b). Investigating why shells vary so widely is crucial to understanding the capacity of calcified organisms to resist the effects of ocean acidification. Similar tools have also been used to show population structure differences between broadcast spawning and brooding reproductive modes (Hoffman *et al*., 2010a). These results have implications for understanding gene flow and populations capacities to respond in changing environments.

Genomic techniques, including microarrays and high through-put 454 sequencing, have been used to investigate which genes respond to environmental stressors such as ocean warming. Two 454 datasets have been made publicly available, thus generating new tools and resources for both polar and non-polar marine biologists (Clark *et al*., 2010).

Further evidence has been found that Antarctic marine invertebrates have very poor ability to cope with increased temperature. The Antarctic limpet takes between 3 and 9 months to adjust its whole animal physiology to an elevated temperature. Studies of the mechanisms underlying this capacity to cope with change are ongoing (Lurman *et al*., 2010; Morley *et al.,* 2010; Obermüller *et al.,* 2010; Peck *et al.,* 2010; Thorne *et al.*, 2010; Truebano *et al.,* 2010; Hoffman *et al.,* 2011; Morley *et al.,* 2011).

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2.5 -Scientific Diving as a Major Tool for the Assessment and Control of bio-invasions

By **Jorge Miguel Rodrigues Fontes**, *University of the Azores* - Portugal

Marine ecosystems are globally under threat due to resource over-exploitation, habitat loss, pollution and climate change. The introduction of non-native species is considered to be one of the greatest environmental and economic threats and, along with habitat destruction, the leading cause of extinctions and resultant biodiversity decreases worldwide (Baltz, 1991; Nentwig, 2007; Pimental et al., 2000).

Marine organisms move naturally around the world and have done so for millions of years, yet, the speed and volume at which marine organisms are transferred today due to globalization is unprecedented (Ruiz and Hewitt, 2009). Shipping is considered the major vector for biological invasions in the marine environment (Gollasch, 2007; Grigorovich et al., 2003). It is estimated that 7.000 species are carried around the world in ballast water every day and 10 billion tones of ballast water are transferred globally each year (De Poorter et al., 2009). As a result, numerous species are now moving far beyond their natural ranges into new areas. Many of these are unable to survive in the new areas but some adapt and thrive, taking over the native species, affecting biodiversity and human livelihoods, these are the invasive species.

Analysis of the available data shows that not all habitats are equally important as sites for colonization but the reason for this remains unknown. Also, most invasions in marine systems are described from temperate latitudes (Ruiz et al., 2009), but if this is due to (i) higher species diversity in the tropics and invaders just following this cline, (ii) more research attention or density of marine stations in temperate regions, or (iii) higher shipping activity between western economies, still needs to be examined.

Another observed pattern of invasions is that non-native communities are more often found in bays and estuaries than on open coasts (Pyle et al., 2008; Wasson et al., 2005). Because the marine non-native species predominate in coastal shallow areas (bays and estuaries) (Ruiz et al., 2009) divers are usually the first to sound the alarm and, in many cases, diver based tools are the most adequate control and eradication methods. Eradication is very hard and expensive, thus the best strategy is to prevent the introduction of alien species in the first place. Surveillance, monitoring and early detection are critical, as they increase the chance that a new arrival can be dealt with before it turns into a major new invasion (Anderson, 2005). Scientific divers are in the first line of defense as they are the most competent detect the early arrival of non native, potentially invasive, species and, in many cases, produce a quick response and achieve eradication or control. Eradication of an alien species in a marine environment although very hard, is not impossible and when eradication is not feasible, some form of control may be achievable, even though this will need to be ongoing.

The best know case of early detection and successful eradication of a dangerous non native species was the case of the green algae, *Caulera taxifolia* (Mediterranean strain), in southern California (USA). The alien alga was discovered in June, 2000, by a team of scientific divers documenting the status of native eelgrass beds (*Zostera marina*). Importantly, *C. taxifolia* was immediately recognized as non native flora, and the competent authorities quickly notified, who then made contacts with those scientists and managers involved with aquatic invasive species control and eradication (De Poorter et al., 2009). The almost immediate onset of *in situ* eradication treatments, 17 days after the discovery of *C. taxifolia*, as only possible due to the training and preparation of the scientific divers, which allowed early detection and immediate eradication action. The rapid deployment of equipment and the associated treatments resulted from the fortuitous presence of a scientific dive team that was already working in the area, and their commitment toward the eradication goal.(Ruiz et al., 2009)

Diver based operations are, in many cases, the only effective tool available to prevent, contain and control marine invaders, but are not the only option. For example, Australia is dealing with the invasion of *C. taxifolia* by smothering the colonies with sea salt, dropped from a specially designed platform. Nevertheless, both the mapping of salt drop targets and the assessment of treatment results need to be done by experienced divers. Independently of how eradication is achieved, confirmation is always necessary, and diving based operations are still the most effective and reliable means available to extensively monitor and confirm that there is no re-growth.

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3 - Current management status and performance of Scientific Diving in Europe: identification of specific gaps and needs

Summary of questionnaires sent to partners in November-December, 2010

3.1 - Training

By **Jouni Leinikki**, *Alleco* - Finland

3.1.1 - Certification system

The European countries can be divided into three categories:

- The first and the most common situation is that there is no nationally recognized system for certification of professional scientific divers. In these countries, a diver license issued by any internationally recognized diving certifications are accepted. Such countries include Croatia, Cyprus, Estonia, Greece, Italy, Latvia, Lithuania, Malta, Poland, Portugal Spain and Turkey.
- The second category includes countries without a specific scientific diver certification system, but the diving scientists are seen as commercial divers. The training requirements in these countries are generally the same as for the other professional divers, and the recreational licenses are not adequate. For example, the Netherlands, Norway and Denmark belong to this category.
- The third category countries have a national licensing system for scientific divers. They are not similar to each other, though. In Bulgaria and Finland, scientific diving is also allowed with a recreational diving license, while in Germany and Sweden, a national license or ESD card issued by any country is required. In France, the legislation is moving towards accepting the ESD standard licenses issued in other countries. HSC in UK provides a list of the licenses accepted for different kinds of underwater work, including scientific and archaeological diving.

3.1.2 - Training institutions and facilities

In most countries with a certification system for scientific divers, university institutions take the responsibility for SD training even though the final examination is partly (e.g. in Germany) done by the examination board for professional divers. In Finland, Norway and Sweden, scientific divers are fully trained by the same institutions as other professional divers. In Sweden, the scientific diving methodology (and diving supervisor training for AESD) takes place in the universities, while the basic professional SCUBA training is given by diving schools authorized by the Armed Forces.

Training facilities are well suited for scientific diving at the university research stations etc., while the commercial divers' training facilities can be out of line. For example, while professional diving schools have excellent training pools and docks for welding and concrete casting, they seldom have a good natural shore to practice biological sampling. In AWI - Center for Scientific Diving at Helgoland (AWI-CSD), scientific divers can work and practice at a specially built underwater research area.

3.1.3 - Courses

The prerequisites of the offered scientific diving courses vary from almost nothing to the advanced level recreational diver (CMAS P3 or equivalent). The length of training also depends on this: if the divers are required to have advanced diving skills on entry, the scientific methodology and other skills required for the European Scientific Diver level can be taught in 1-2 weeks. The longest courses are in Finland, where the students are only required to have an academic background and the ability to swim. During the following 18 months, they take extensive training in variable conditions and subjects equaling an effort of 40 weeks. At the end they will pass the national examination after which they are allowed to apply for an Advanced European Scientific Diver license. Foreigners are generally welcome to participate in the national SD courses.

3.1.4 - Future needs

In most countries the most urgent needs seem to concern recognition of professional scientific diving by law. Without any status, it is difficult to develop any other aspects, including specific training. In Sweden, there is a wish to move also the basic professional parts of the SD training to scientific institutions in co-operation with the SSDC. Another wish was to form an international network of scientific diver training, which would also provide access to scholarships and funds for students to finance their participation in the training abroad.

3.2 - Insurance

By **Øivind Strand**, *Institute of Marine Research* – Norway

In several countries (UK, France, Germany, Italy, Sweden, Finland, Norway) it is stated that professional scientific divers is legally required to be insured by the employers through their work insurance (health and safety). In Bulgaria, Cyprus and Greece liability for scientific diver insurance seem to be regulated by central authorities, while other countries do not have legal requirements though most of them refer to use of the DAN recreational insurance.

Most of the countries requiring insurance responsibility by employers also refer to this requirement for visiting divers. Some of these countries (Finland, Germany, Italy) refer to DAN insurance which will be accepted. In Bulgaria the visiting diver should be insured by at a Bulgarian insurance institution. In UK they "employ" (short term contract?) visiting divers for inclusion in employer's insurance. Other countries do have specific insurance requirements for visiting divers.

3.3 - Medical examination

By **George Petihakis**, *HCMR* - Greece

Most countries require an annual medical examination accompanied by the appropriate certificate preferably by a doctor specializing in hyperbaric medicine. In some countries this is mandatory, in others not.

Varying degrees of requirements apply as scientific divers are considered as recreational divers in some countries and as professional divers in others. There are countries which require strict medical tests, within a very specific framework that result in obtaining a medical certificate for working underwater. As far as guest scientific divers are concerned, most countries will accept a relevant medical examination from the divers' home country although this is at the discretion of the host country that may require further examinations to take place.

Annex 1 – Participants of the joint COST/ESDP Workshop "*Strengthening Synergy and Excellence in Diving Supported Science across Europe*" (Brussels, 27-28/09/2010)

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Annex 2 – ESDP 2011 membership

MEMBER STATE	Organisation	ESDP MEMBER
Belgium	MUMM Royal Belgian Institute of Natural Sciences (RBINS)	Alain Norro a.norro@mumm.ac.be
	Marine Board-ESF Secretariat	Aurélien Carbonnière acarbonniere@esf.org
Finland	Finnish Scientific Diving Committee	Pirkko Kekalainen pirkko.kekalainen@gmail.com
France	Centre National de la Recherche Scientifique (CNRS)	Jean-Pierre Féral jean-pierre.feral@univmed.fr
Germany	Alfred Wegener Institute (AWI)	Philipp Fischer philipp.fischer@awi.de
Italy	Italian Association of Scientific Divers	Giorgio Caramanna giorgiocaramanna@yahoo.it
Sweden	University of Goteborg	Roger Lindblom roger.lindblom@gu.se
UK	National Environmental Research Council (NERC)	Martin Sayer mdjs@sams.ac.uk