SCIENTIFIC DIVING IN POLAR REGIONS – THE EXAMPLE OF ECOLOGICAL STUDIES AT THE INSTITUTE OF OCEANOLOGY, POLISH ACADEMY OF SCIENCES

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ABSTRACT

Diving as a tool applied in scientific research has proven itself to be reliable even in difficult polar conditions. The article presents a brief description of the reasons for interest in the polar regions and the advantages of diving as compared with other research methods. Moreover, we shall present a subjective review of the most significant moments from the early history of underwater exploration of the polar regions, as well as provide an insight into the current ecological research carried out by the Institute of Oceanology of the Polish Academy of Sciences in the Arctic and the Antarctic with some details on the nature of these activities.
Key words: ecology, scientific diving, the Arctic, Spitsbergen, the Antarctic.

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INTRODUCTION

The polar regions, although difficult to access and largely inhospitable, have been the subject of human interest for a long time. The first tentative expeditions were essentially profit-oriented with the long term aim of exploiting the rich natural resources.

This was followed by a period of extensive geographic discoveries, exploration of new places on the world's map and first scientific reports. There is no less interest in the polar regions in recent times; in fact there has been a significant surge in studies, especially in the last decade, as a result of the concerns relating to climate change. Of all the regions on Earth, the most rapid temperature increases have been recorded in polar regions such as the West Antarctic Peninsula and the European Arctic (with the increase in temperature there about three times greater than the world-wide average) [1, 2, 3].

Some forecasts have estimated that many of these areas may be seasonally ice-free within just thirty years [4]. Related issues, such as new opportunities for extraction of mineral resources or alternative transport routes, will undoubtedly have geopolitical consequences, as well as become a source of anthropogenic pressure on previously isolated polar ecosystems.

These significant effects mean that the polar regions are the most relevant for scientific experiments in the field, particularly for research on the impact of climate change. It is a common belief that the areas most susceptible to changes are the coastal zones [5], where diving techniques prove to be the perfect research tool. Indeed, experiments based on diving in the polar regions provide valuable information, especially as most of the available data have previously come from analysis of dredged material recovered onto large vessels [6].

These surveys generally tend to avoid the coastal regions that are difficult to navigate or do not have proper cartography, and focus on deeper areas. Furthermore, the traditional sampling equipment used on ships, such as boxcorers and grab samplers, limits observation to certain environmental sectors, and does not necessarily reflect the overall picture. In this respect, nothing can replace direct underwater observation.

Moreover, the said equipment is of limited efficiency, especially in areas with a hard seabed - characterised by limited efficiency, particularly in locations with hard sea beds, i.e. exactlyexactly the type of habitat characterized by the greatest biodiversity. Most organisms living in the oceans are associated with the shallow, rocky bottom. Although there are many hardships and inconveniences associated with diving in polar waters there are significant rewards from gaining access to these relatively under-explored environments with high biodiversity, where there is still the potential for new discoveries.

Being constrained by the extent of the authors' knowledge and limited space, the historical background presented below is incomplete and constitutes merely an attempt to provide a chronological reminder of the most important events connected with the early history of underwater exploration of the polar regions.

According to one of the most comprehensive and detailed reviews [7], the first dive in polar conditions occurred during a German expedition on the ship "Gauss", during the exploration of the then undiscovered regions of the Antarctic south of the Kerguelen Islands. The expedition, carried out between 1901-1903 was directed by Erich von Drygalski, and the first dives, made with classic equipment (a diving suit manufactured by the British company, Siebe Gorman & Co. Ltd.), took place around April 16, 1902. The diver was Willy Heinrich, a shipwright who had learned to dive during service in the Navy.

During the expedition he dived repeatedly under the ice, even with air temperatures as low as -30 ° C. Although the expedition was mainly observational, it was not strictly scientific diving, but consisted mainly of work to seal the hull, make repairs to the rudder or release the anchor chain [7 and references contained therein]. For similar reasons although much later, in 1947, US Navy Lieutenant Commander Tommy Thompson and mechanic Dixon used Jack Brown full face masks and Desco oxygen rebreathers near the Ross Shelf to carry out an inspection of the propellers of the USS Sennet, a submarine which arrived in the region as part of the largest Antarctic expedition in history - "Operation High Jump" [7, 8]. The expedition, officially called a developmental project by US Navy officers, was in fact an attempt to prepare for a possible Cold War conflict in the Arctic.

Amongst the first documented cases using diving equipment for scientific purposes in the polar regions, were John Bunt's not entirely successful attempts to collect algae at the beginning of 1957 at the "Mawson" Australian Antarctic station. Owing to practical difficulties with using equipment available (Bunt was equipped with Siebe-Gorman's equipment, Salvus apparatus or helmet) he could only remained submerged for five minutes.

In later years (1962 - 1963) he successfully conducted a more extensive research program, based on S.C.U.B.A gear. After S.C.U.B.A equipment became more widely available the first divers to use the system under the ice in Antarctica were presumably US naval divers who in January 1957 were required to recover body from the wreckage of a tracked vehicle after it crashed through the ice.

During 1961-1962 there was year-round scientific diving (including under-ice) in McMurdo Strait, undertaken by the benthic ecologist Verne E. Peckham on behalf of the Department of Biological Sciences at Stanford University. Peckham dived to a depth of 48 metres using a single cylinder, twin-hose Aqualung regulator and Bel-Aqua/Aquala neoprene suit and woollen underwear for maintaining thermal comfort.

From the start of the 1963/1964 season diving operations for the purpose of scientific research increased significantly, especially in Antarctica. One of the most important figures worthy of mention at this point is Paul Dayton, who made more than 500 dives during more than fifty months in McMurdo.

The work of Dayton and his colleagues, although pioneering, is still regarded as setting the standard in the field of Antarctic benthic ecology [7]. In addition to the US pioneers, dives were also conducted by the British Antarctic Survey (1962, Signy Island), the French CNRS biological station in Roscoff (1962, Kerguelen Islands), Russians (Mikhail Propp, Eugene Gruzov, Alexander Pushkin, 1965/1966, Mirnyy station), Japanese (1968, Syowa station) and New Zealanders (1970, Scott station, McMurdo) [7, 9 and references contained therein].

In 1975, Jacques Yves Cousteau spent four months in the Antarctic with his crew of the "Calypso" shooting his film "Voyage au Bout du Monde". In the northern hemisphere, in the Arctic, the history of polar diving began somewhat later. Our research suggests that the first divers were Canadians, performing rescue operations or working on pipelines (during the second half of the 1950s), and Americans inspecting the hulls of submarines surfacing at the pole (1958).

Civilian diving in the Arctic made by these countries was concerned mainly with oceanographic research, marine biology and geology [10]. The Norwegians, well-known for their polar tradition, probably made their first dives in the Arctic during 1962, and the first diver among them was Per Svendsen, marine botanist at the University of Bergen [11, 12]. Since 1978, there have been annual expeditions to Svalbard, for ecological research, led by Bjorn Gulliksen (who made the first dive on Jan Mayen Island in 1972) [13]. It is worth mentioning that the Russians undertook extensive observations year round directly from the sea ice, presumably influenced by the early Norwegian explorations of Fridtjof Nansen and his ship "Fram".

Diving from these drifting stations was probably used as a research technique for the first time in 1969, with the first dive from the station "North Pole - 18" under the supervision of Vladimir Grishchenko [14].

The origins of scientific diving in Poland dates back to the 1930s and are associated with the activities of the Professor Roman Wojtusiak, a researcher at the Institute of Zoological Psychology and Ethology of the Jagiellonian University. In 1935 Wojtusiak constructed his own open-type diving helmet, modelled on Beebe's device and fed by a simple automotive pump. In the following year, using the facilities of the Marine Fisheries Laboratory in Hel, he conducted his first documented underwater observations in the Puck Bay.

The usefulness of the helmet, its description and the results of the observations, were published by Wojtusiak in a paper entitled "Diving helmet in marine biological observations ", which was published in " Wszechświat" ("The Universe") journal in 1938 [15, 16, 17].

According to Małgorzata Orlewicz-Musiał [15], many people participated in these dives, including the renowned marine biologist Prof. Kazimierz Demel and a daughter of highly regarded marine researcher, Prof. Michał Siedlecki, named Ewa. Prof. Siedlecki personally operated the pump supplying air to the helmet, though he did not dive himself.

In 1955 the first "aqualungs" appeared in Poland. Three of these devices obtained from the company La Spirotechnique in France, together with diving suits, masks, snorkels, and fins, were imported by the Sopot Marine Station of the Polish Academy of Sciences, located in a small building at the entrance of the pier (the beginnings of the Institute of Oceanology, Polish Academy of Sciences established many years later).

The first person to use this equipment was Witold Zubrzycki – the pioneer of Polish diving [15, 18]. In 1957 "Wszechświat" journal published an article describing the first attempts to study the underwater fauna and flora using Cousteau-Gagnan regulators [19]. Previously (1952-1954) divers used older style suits and helmets (eg Prof. W. Filipowiak in Szczecin and Dr. P. Ciszewski of the Marine Fisheries Institute in Gdynia) [20].

The first Polish diving in the polar regions was associated with the founding of an Antarctic Station of the Polish Academy of Sciences “Arctowski” in 1977 on King George Island. The first expedition involved a group of divers from the Polish navy, whose task was to determine suitable landing sites for heavy equipment, such as tracked amphibious transporters (PTS) and ferries.

The first instance of scientific diving designed to collect specimens of the benthic fauna took place the very next year (1978/1979) in the vicinity of the station. Initially the divers Maciej Zawadzki and Karol Teliga made use of equipment left behind by the Navy (Seal-type diving suits, Bp regulators, "commando" fins). Dr. Maciej Lipski dived the following year, using personal equipment, along with Ryszard Stępnik [21]. Subsequent dive expeditions took place in 1981, 1988, 1989, 1993 and 1994 [22] with one of the first major research expeditions organized by scientists from the University of Łódź – Prof. Krzysztof Jażdżewski and Jerzy Żychliński in 1988.

A rich diversity of benthic organisms collected from a depth of 5-30 metres served for writing several original research papers [23]. The first dives under the ice with a thickness of 2-3 metres were likely to have taken place in the 1988/1989 season (Dr. Maciej Lipski, Marek Michalak), with plankton samples collected from the open waters of the Scotia sea during the last Antarctic voyage of the r/v "Professor Siedlecki"[21]. Diving has taken place regularly at the "Arctowskim" site since 2003 (Dr. Tomasz Janecki from the Institute of Antarctic Biology and co-workers) [22].

Established in 1983, the Institute of Oceanology, Polish Academy of Sciences (IO PAN) was founded as a direct successor to the Sopot Marine Station. In addition to studying the Baltic Sea the institute is also involved in research in polar regions - mainly in the European part of the Arctic (Svalbard archipelago), but also in Greenland, the Canadian Arctic, Aleutian Islands, Franz Josef Land and the Antarctic (King George Island).

From the point of view of marine ecology, this was mainly a field study on biodiversity in the context of the functioning of ecosystems and the changes they are subject to, including changes evoked by global phenomena, such as global warming or ocean acidification. The areas of particular interest were the coastal areas, the tidal zone, fjords or sea ice, hence diving became one of the most popular tools.

The first dive for ecological research by IO PAN took place relatively late on, in the 1990's. In 1991 Prof. Zdenek Duris led a group of Czechoslovakian biologists and divers to the Calypso station (Marie Curie University in Lublin) located on the south-east coast of Bellsund (western Spitsbergen). The aim of the five-week expedition was to make general underwater observations and to compile an inventory of the Arctic benthos (including photographic documentation); 18 dives (4-43 m) were completed at 9 locations (most in Recherchefjorden, but also near Tomtvika, in Van Keulenfjorden and Van Mijenfjorden).

The expedition managed to acquire a small collection of decapods and organisms associated with macroalgae [24, 25]. In 1992, the Czechoslovakian team took part in a cruise on the s/y Oceania in the region of the Bolsheoya and Tusenoyane islands (south of the Edgoya Island, Svalbard), where a large number of walruses were located. Material collected using S.C.U.B.A diving and photographic documentation was used to describe the feeding areas of these large marine mammals. During this expedition researchers used for the first time a specially prepared "benthometer" [26, 27, 28] - one of the early versions of the Kautski frame [29] which allows for quantitative collection of benthic organisms without loss of material. In 1995, Professor

Duris carried out single dives to collect samples, mainly crustaceans, including the sympagic fauna living under the ice floes [31, 32].

Since 1997, research on Spitsbergen has been carried out on an annual basis [33]. The first of a series of studies were on the ecology relatively under-investigated colonial groups of benthic organisms, the bryozoans - their species richness, distribution and density in relation to various environmental factors [34, 35].

This work has focused in particular on the environment of the Arctic fjord Kongsfjord (79° N), although the research spans the entire Svalbard archipelago and diving has extended to the farthest island - Rossoya at 80° N, and in many remote areas east of Spitsbergen. In total, from about 100 dives 162 taxa were identified representing 82% of the species listed for the entire archipelago and nearly half of all known species of Arctic bryozoans.

Two major environmental gradients responsible for their distribution were found: the first involving the processes connected with depth (environmental dynamics, quantity of light), the second connected with the distance from glaciers and the related inflow of suspension and fresh water [36].
The application of diving enabled the study of the whole spectrum of biodiversity and the influencing factors, without being limited to the deep sea bottom and samples collected from ships' decks.

Another project focused on the macroalgae-associated fauna of Hornsund, a fjord on the southernmost tip of Spitsbergen Island. The kelp forms a thick growth on a hard sea bottom within the depth ranges of 5 to 25 m. These algae, fulfill the role of the so-called 'environmental engineers' – causing weakening of water dynamics in the area near the bottom and accumulation of an organic matter.

Moreover, they provide shelter from predators, whereas their tissues are a great substrate for epiphyte fauna, such as the already mentioned bryozoans. Hence, the so-called kelp forests provide a habitat to multiple species of the benthos fauna. In 2003, research was carried out in three different places on Hornsund – near Hyrneodden, Hoferpynten, and in Isbjornhamna Bay.

The collection of this type of material is feasible only with the help of divers. The diver gathers the algae (with the accompanying fauna), into a mesh bag with a 1 mm mesh size, then using a knife, cuts the rhizoid of the algae from the bedrock and transports the collected material to the surface. This method has allowed collection of 403 macroalgae samples representing 9 species of kelp and red algae, including the 3 most common, *Laminaria digitata*, *Saccharina latissima* and *Alaria esculenta*.

Analysis of the samples showed that fauna associated with the algae was dominated by bryozoans and hydrozoans [37]. A total of 208 species of invertebrates were identified, with a particularly high density found in the rhizoids of algae, which form complicated three-dimensional structures.

Among these samples researchers found a new species previously unknown to science, *Halecium arcticum,* described on the basis of specimens collected in Hornsund [38].

Further analysis of collected material allowed identification of the environmental factors impacting on the distribution of species of fauna associated with algae in different parts of the fjord [39, 40], as well as a detailed analysis of the distribution of the amphipod *Caprella septentrionalis* - an organism characteristically associated with kelp forest biocenosis where whole groups of the crustacean feed on leaf surfaces of large algae [41].

During subsequent expeditions in 2005 and 2006, divers collected macroalgae at 10 stations located along the coast of Hornsund. Among other things, the samples were used in the calibration of the acoustic method that identified the distribution and the biomass of the kelp. The work lead to the detailed description of the species composition and biomass of the Hornsund fjord kelp forests [42].

The projects devoted to colonisation and succession in the polar regions (three months in the Antarctic and an ongoing research in the Arctic) are good examples of experimental studies conducted with the use of diving techniques (Fig. 1 a) [43, 44].

Diving has been used to install panels mounted on specially-constructed metal frames secured to the rocky bottom. Colonization of the panels by settling fauna has been monitored annually since 2004. Each year, one set of panels is replaced with a new one, while the rest (three sets) are left in place and regularly photographed. Computer analysis of the high-resolution images is used to recreate development (succession) of sedentary arctic estimate the rate of fouling and interspecific faunal assemblages and competition.

By regular replacement of panels it is also possible to trace the annual influx of organisms and monitor invasive species that have begun to appear in the rapidly changing Arctic environment.

Diving has also been successfully used to collect hermit crabs [45, 46, 47]. The studies devoted in fact to the fauna overgrowing snail shells inhabited by those crabs, were designed to determine the distribution, density and habitat preferences of crabs treated as providers of hard mobile substrate.

In 2009 - 2012 large scale surveys were carried out (approximately 200 dives) using direct underwater observations in Northern Norway and in most of the fjords of western Spitsbergen, operating from a ship or rubber boats. To estimate the density of crabs a frame with an area of 0.5 m^2 was used to count the number of individuals encountered (Fig. 1 b). These observations were carried out across a gradient of depth (30, 20, 10, 6 m).

This study confirmed a very low diversity of hermit crab species, with only two species being found (*Pagurus pubescens* and *P. bernhardus*), perhaps not surprising if we consider that Svalbard is situated near the northern boundary of the range of these crustaceans.

However, a large number of individuals was recorded (sometimes up to 44 individuals / m^2 with an average of 10 / m^2) with a large number and diversity of fouling organisms found on shells (over 110 species), suggesting that hermit crabs may constitute an important component of the shallow-water habitats of the areas surveyed. Indeed, when making the comparison of similar natural and artificial substrates (live snails and rocks), the shells used by hermit crabs generally support a larger number of species and individuals, creating a unique substrate for biodiversity.

This trend was particularly visible in areas with a soft bottom (e.g. near Diabasodden, Isfjorden), where hermit crabs are often one of the few providers of firm substrate [47]. In order to extend knowledge of the observed regularity and to determine which factors, except the crabs, influence biodiversity of these communities, divers conducted also underwater field experiments, by deploying frames with different types of substrates (natural shells, artificial shells cut from granite, pebbles) in four places at Spitsbergen (two close to Bjorndalen and two near Grumantbyen) and four in Northern Norway (Kvalsund and Grotfjord). After one year spent on the seabed the materials were successfully located and recovered [48].

The first and so far only, diving-based Antarctic expedition conducted by IO PAN took place in the summer of 2010/2011 during the 34th expedition to King George Island. During nearly four months of residence using the facilities of the ideally located Polish Antarctic Station, the researchers were able circumnavigate a larger part of Admiralty Bay, performing altogether 173 dives of total time exceeding 83 hours [49].

Apart from several smaller projects, involving sampling of diatoms associated with macro-algae [50], sediment cores (Fig. 1 c), or the sinking and recovery of rocks using flotation bags (for colonisation experiments) [51], the efforts focused mainly on determining the diversity, distribution, abundance and biomass of echinoderms.

These parameters are particularly interesting in the context of circulation and deposition of carbonates and the changing pH of the water (acidification), currently the most important problem affecting seas and oceans next to climate change. Sea urchins, starfish, ophiurids, holothurians and crinoids with their vulnerable to dissolution carbonate skeletons in times of an increasing carbon dioxide concentration in the atmosphere are a perfect object for this type of research.

The assumed objectives were realised by performing field observations, sampling of specimens and preparing photographic documentation of seabed within 1m^2 frames pre-placed at 20 stations of sea bottom and positioned at different depths along a transect (30, 20, 10 and 6 m) (Fig. 1 d, e).

Within the total analysed area of 90 m^2 of the sea bottom the researchers confirmed the occurrence of 23 species of echinoderms. Of the sampled material the most diverse were the starfish (15 species, including one not recorded previously in the family Pterasteridae) and the highest biomass was accounted for sea urchins (mainly of the species *Sterechinus neumayeri*).

On average for each 1m^2 of the seabed area there were 7 specimens represented by 2 species, which shows how important component of the Antarctic benthos are echinoderms.

In addition, although there was a high dependency between the studied communities and the depth, induced by physical factors (resulting in a larger number of specimens at depth), no clear trend was observed in their distribution.

Despite the fact that the masses of carbonate skeletons show significant differences between species, laboratory analyses have shown that echinoderms as a group have a significant impact on the supply of carbonate in the sediment in the local carbon cycle.

Calculations indicated a mean value of 13 g carbonate (Ca, Mg, $SrCO_3$) per square metre of seabed. In the light of the results obtained, sea urchins appear to be amongst those organisms that are most vulnerable to projected changes in pH and water chemistry [52]. In 2012, an underwater survey of over 80 dives totalling nearly 60 h was repeated in the Arctic [53], and this will enable a thorough comparison of areas that are geographically distinct but are affected by similar environmental factors.

The extending spectrum of diving activities and the related scientific results led to a scientific collaboration with American scientists from the University of Fairbanks, Alaska. In 2011, scientists from IO PAN were invited to participate in a study of the impact of nuclear tests in the coastal marine systems in the Aleutian islands, located in the North Pacific. In addition, studies were initiated on bryozoans from these previously under-investigated regions of the world with all of the sampling undertaken by diving.

Recently launched projects (2012, 2013) were located in the Arctic, Spitsbergen, in the region of the large fjord system of Isfjorden, which provides a wealth of diverse habitats. The first aim is to describe the sea anemones present in the shallow littoral zone (0-30 m), which often create a very rich and diverse grouping yet no profound studies have so far been devoted to them. In addition to the collection of samples for analysis of histological and genetic representatives of this group (fig. 1.f), divers used underwater photography (fig. 1.g).

Photos taken of the areas of the seabed inside the frames allowed determination of the species composition and abundance of sea anemones in different locations in the fjord at 30, 20 and 10 m depth and made it far easier to recognize individual species of sea anemones which typically otherwise lose their original shape and colour during preservation. Moreover, attempts were made to develop and calibrate a method to enable rapid and effective assessment of the size of the organisms, based only on the pictures [54]. The study also provided an opportunity to observe previously unreported observations of interspecies relationships between the sea anemones *Cribrinopsis similis*, *Hormathia nodosa* and *Urticina crassicornis* and crabs of the genus *Hyas* spp and leads us to hypothesise that the crustaceans shelter under the tentacles of sea anemones to seek refuge from predators [55].

The most recent project aims to describe the impact of large seabird colonies on marine ecosystems. These birds feed in the sea and nest on land, often in colonies of up to several thousand individuals. Such a large mass of organisms accumulated in a small area can have significant effects on the surrounding environment.

In addition, with the exception of Antarctica, for most of the studied sites, the surface of the sea has not frozen at all for a few years and the main source of ice in these regions is calving from glaciers, icebergs and drifting ice carried by currents. Much has changed since those first, pioneering days of polar diving. Of course, the water remains just as cold (in the vicinity of the Antarctic continent it can be as low as -1.8° C) [58], while on the west coast of Spitsbergen in the summer it is usually 2-4° C), but recent technological progress has taken place to improve the conditions for working underwater in the cold. Currently diving in the polar regions is not dissimilar from diving in winter in temperate regions.

Today's dry suits and electrically heated vests allow divers to stay underwater for as long as 90 minutes maintaining normal body temperatures even in water with a temperature close to zero. In addition, full-face masks not only provide the capability for vocal communication but further increase thermal comfort.

The breathing of warm, moist air using a rebreather provides even greater convenience, however the rapid advance in close-circuit technologies, in combination with the widespread use of artificial breathing mixtures (i.e., nitrox and trimix) allowing for longer diving at greater depth, has not yet translated into their wider use in the polar regions. The main reason for this is probably due to high costs and a slightly higher risk connected with this type of diving.

The low temperature, complicated evacuation and long distances to hyperbaric chambers means that the vast majority of dives in the polar regions are planned as non-decompression dives.

Rebreather technology, because of the absence of exhaled respiratory factor, have been used in studies conducted during the Norwegian expeditions to investigate the delicate communities of flora and fauna formed at the interface between ice and water [59], and is likely to become commonly-used equipment in the Polish institutions. Up until now, the standard equipment used by the team from IO PAN has mainly been single cylinders and small and light twin-cylinder sets convenient for diving operations from the deck of small rubber boats.

The recognised and reliable regulators adjusted to working at low water temperatures (e.g. Apeks TX 50 and its next versions) have not found a better replacement yet.

Therefore, the equipment is the same, whereas the procedures and the logistics of the dives are slightly different due to the fact that the places where they are executed are remote and characterised by quite changeable environmental conditions (strong winds, high waves, currents, changeable ice conditions). For expeditions conducted by the IO PAN usually most of the heavy equipment is transported to the area of research on vessels.

The vessel used for Spitsbergen is the s/y Oceania - the only Polish research vessel involved in oceanographic research in the open ocean, in continuous use since 1987 (fig. 1. j). Small, lightweight but sturdy rubber boats (Bombard C5, fig. 1. k, l) with outboard motors are used on site, being sufficient for comfortable transportation of three divers with a supplies for two dives.

For more remote locations, two boats are employed providing a greater level of security in the event of failure. Equipment on the boats, in addition to echosounder and standard rescue equipment (heaving line, first aid kit, oxygen kit, flares), includes additional supplies of fuel and duplicate tracking and communication devices (marine GPS, spot, VHF radio, satellite phone). Additionally, each diver is provided with a water-proof radiotelephone which they take with them underwater. On Svalbard, due to the potential risk from polar bears, a firearm is also required. In general, we follow the generally accepted principles and procedures used in the polar regions [60, 61], recently reviewed during international workshops on these issues [62]. Optimal teams consist of three persons, which allows individuals to do two dives per trip. While two divers are at work underwater, one remains on the boat to provide surface cover. The usual surface interval between dives is one hour. The majority of dives last for 60 minutes and are typically to a depth of 30 metres, although single reconnaissance dives have been made to a depth of 60 metres in the Fuglefjella area (Isfjorden).

The development of underwater research techniques, including equipment to improve thermal comfort and extend the dive time in polar waters, as well as the continuous growth of interest in the world of science processes in coastal zones in the polar seas, are likely to lead to the intensification of research using diving in these regions. Past experience and the results of research conducted by the Institute of Oceanology are undoubtedly a solid foundation for future research.

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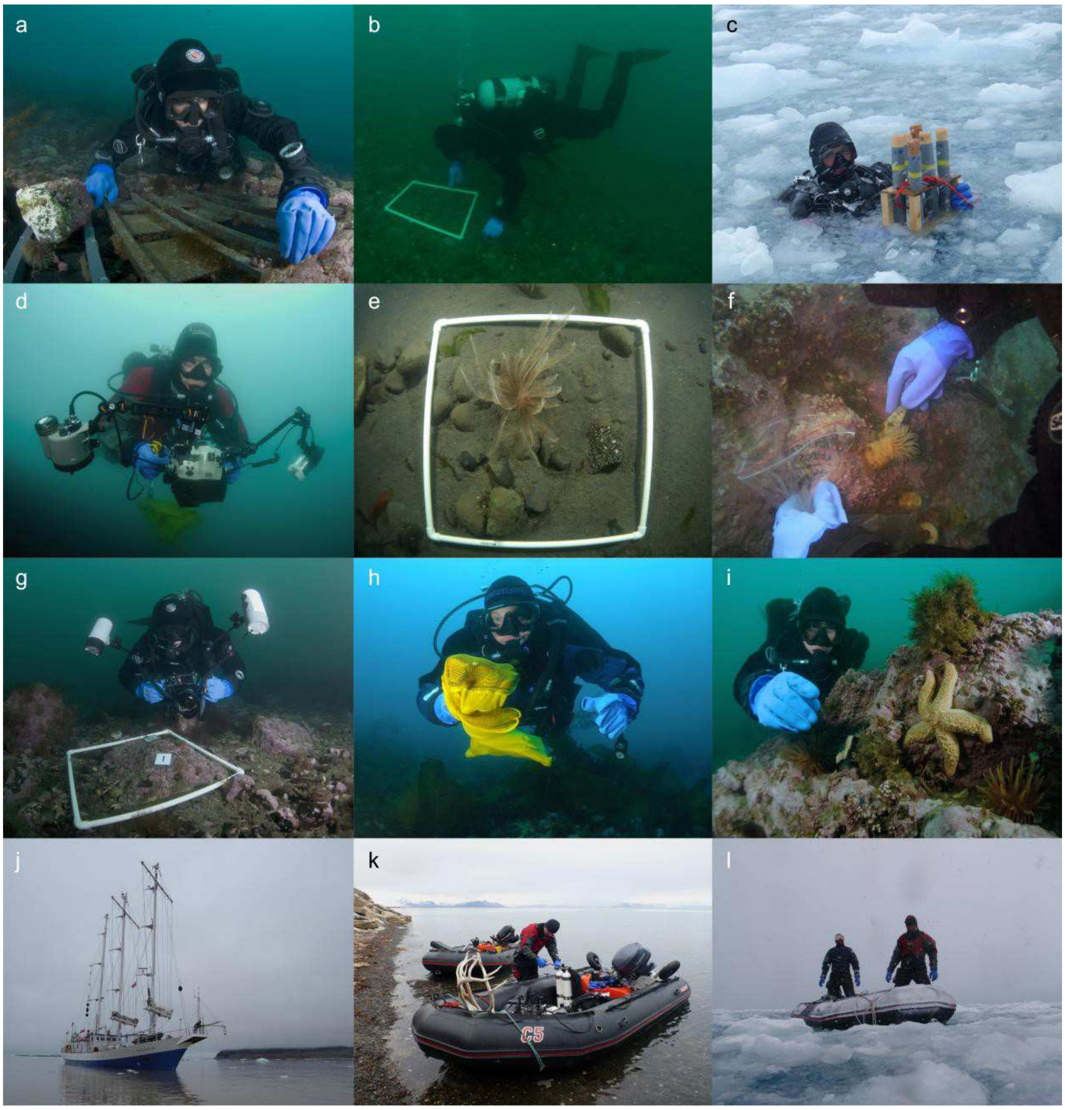

Fig.1. Examples of ecological research conducted with the use of diving techniques by IO PAN. Description provided in the text. Photos a, c, g – Piotr Kukliński; b – Agnieszka Kostrzyńska, d, e, h-l – Piotr Bałazy; f – Michał Saniewski.

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