# SPUMS Annual Scientific Meeting 2002

## Scuba diving in remote locations: Antarctica

David McD Taylor

**Key words**
Antarctica, scuba, diving, logistics, ice

**Abstract**
Antarctica is a dramatic continent of immense beauty, both above and below the chilly waterline. It is not surprising, therefore, that those who have the opportunity to dive in Antarctic waters will grasp it. However, the remoteness and extreme weather conditions require great care, skill in logistics, physical fitness, and training. Hence, diving in Antarctica must be approached with a high degree of professionalism and respect for its inherent dangers. The particular difficulties faced by scuba divers in Antarctica include hypothermia, UV light exposure, equipment malfunction, and the dangers posed by marine animals. Also, the difficulties in diving logistics, including expedition preparation, search and rescue, diver recompression and evacuation, are considerable. However, if these barriers can be overcome, the diving is superb. This article discusses the rewards and difficulties of diving in this truly remote location.

### Introduction

By nature, scuba divers tend to be adventurous and thrill seeking.[1] These traits, combined with the ease of international travel, the development of exotic dive sites, and the improved safety of diving equipment, have led to unprecedented levels of diving in remote locations. In the last two decades, Antarctica has been accessible to persons other than 'expeditioners'. Indeed, commercial enterprise now provides many opportunities to visit this continent. Regrettably, few individuals have the opportunity to experience diving in Antarctica.

Australian Antarctic Programs (AAP, formerly Australian National Antarctic Research Expeditions), an organisation funded by the Commonwealth of Australia, has undertaken the great majority of Antarctic expeditions originating from Australia. AAP has undertaken diving programmes in Antarctica over a period of many years. These programmes have collected scientific data on human physiology, marine biology, and ecology. Initially, these diving expeditions were episodic, however, more recently, they have been organised on a regular basis.

Traditionally, most AAP diving programmes have been undertaken at Davis Station. Davis (68°35'S, 77°58'E) is a permanently occupied Australian research station and is situated on the edge of the Vestfold Hills, Princess Elizabeth Land, 4700 km across the Southern Ocean from Perth. The hills are of moderate relief and are penetrated by many deep fjords, which extend inland to the ice plateau.

Davis has relatively mild weather and enjoys a low average wind speed of 20 km.hr$^{-1}$ and clear, still days. The mean temperatures and daylight hours range from 0°C and 24 hours in summer, to -18°C and none in winter. The ambient temperature has the most influence on sea and ice conditions. Fast sea-ice is present from March/April until December/January and may extend several hundred kilometres offshore and reach a thickness of 1.4 to 2.0 m in the late winter.[2–5] Increasing temperatures, winds and ocean swells cause this fast ice to 'breakout' in the spring, although it may remain in the fjords for much longer.

The author had the great fortune to be involved, as both diver and diving medical officer, in two diving programmes during his expedition to Davis. The first, a snorkelling programme, ran during the 1988–89 summer, and involved the collection of algal specimens for research based at Monash University. One memorable dive that summer was undertaken in Deep Lake in the Vestfold Hills – the third saltiest lake in the world. I needed 23 kg of diving weights before I could get below the surface!

The second programme was much more extensive, involving scuba and hookah equipment, and ran for six weeks during the 1989–90 summer. The principal aim of this programme was to photograph marine benthos at various depths to determine the nature of the Weddell seal food source. The programme also involved the collection of an array of marine specimens for the same purpose. The dive team comprised four divers for this programme. Each had extensive diving experience and specific training in the use of drysuits and other Antarctic diving equipment (described below). Diving was possible five to six days per week depending upon the weather conditions. On most days, dives were undertaken at two separate dive sites, with helicopters transferring all personnel and equipment from site to site. The effort involved with checking, packing and moving equipment, as well as gearing up and diving, was considerable.

In recent years, AAP diving programmes have been moved from Davis to Casey Station and are being undertaken regularly each summer. Casey (66°17'S, 110°32'E) lies just outside the Antarctic Circle, on the shores of Vincennes Bay, approximately 3880 km south of Perth. Diving at Casey during the 2002–03 summer season will concentrate upon environmental impact studies as the remnants of a derelict station are removed. In compliance with all AAP diving regulations, a dual hyperbaric chamber is available at Casey for use in the event of a diving accident. The current Casey medical officer and two technicians, all of whom have hyperbaric medicine training and experience, are available to run the chamber. Helicopters and over-snow vehicles are available to evacuate injured divers to the hyperbaric chamber if necessary.

**Why dive in Antarctica?**

Most travellers to Antarctica are interested in the extraordinary beauty of the continent above the waterline. However, what is not realised by most is that the world below this line is as rich and varied in flora and fauna as the world above is poor. Indeed, the comparison is stark. The flora above the waterline runs to a few species of lichen, with the exception of some stunted plants limited to the Antarctic Peninsula. Similarly, the fauna consists of a few species of seals, penguins and other birds. In contrast, the underwater world hosts a wide array of seaweeds and soft corals, an abundance of krill, peculiar fish, nudibranchs, worms and urchins – all species that are not known to temperate or tropical water divers.

One striking feature of Antarctic diving is the clarity of the water. Salinity depresses the freezing point of seawater to approximately -1.8°C and, after the fast ice has formed, the sea is relatively insulated from the winter extremes above. Consequently, water temperature varies little: 0°C to -2.0°C throughout the year.[2–7] Visibility underwater is excellent and typically greater than 100 m.[4,6] It is at its maximum during winter and spring, when the fast ice cover reduces turbulence and sediment suspension and low light intensities depress phytoplankton (algal) growth. Light under the ice may be limited at certain times of the year by short hours of daylight, the low angle of incident light, and ice thickness. Algal bloom may first appear in September and may greatly decrease visibility from December onwards.[3,6]

Apart from open-water and under-ice diving in the sea and fjords, opportunities to dive in glacial melt lakes occasionally present themselves. These lakes are formed from midsummer melt and are located on the upper surfaces of many of the larger Antarctic glaciers, often well above sea level. Like all other water bodies on the continent, these lakes freeze over in the winter. However, temperature fluctuations throughout the year, combined with glacial movement, result in fissuring of the frozen surface. This allows access for light (and divers) to penetrate the sometimes enormous bodies of water below. Diving in these glacial lakes is spectacular. The water is fresh, extremely pure and devoid of all forms of flora and fauna. Hence, the visibility is unsurpassed and the diving is like "swimming in gin". The remarkable features of this type of diving include the cave-like ice formations that make up the roof, walls and floor of the lakes. Indeed, glacial remodelling results in the interlinking of huge ice-bound chambers. These are accessible to the diver and are quite spectacular, as the light penetrating from above continually bounces and refracts off the mirror-like cavern walls.

**Why not to dive in Antarctica**

DIVING SKILLS

Antarctic diving is not for the inexperienced or faint-hearted. All divers must be psychologically and physically fit, and skilled and trained in special ice-diving techniques. They must have considerable experience in deep diving, penetration diving, diving in poor visibility, night diving, and must be skilled in first aid and rescue techniques.[3] AAP runs a diver training course in Australia and Antarctica that familiarises divers with the equipment and techniques that will be used.

ENVIRONMENTAL HAZARDS

Clearly, Antarctica is very cold and subject to dramatic and rapid changes in weather conditions. Although Davis experiences few blizzards, other stations (notably Casey) are subject to life-threatening changes in the weather that may arise with very little warning. Such conditions dramatically affect the wind chill factor and limit visibility to near zero.

Hypothermia may be seen among divers, attendants and support staff, as a result of exposure to low temperatures, wind and wet clothing.[5] Sullivan and Vrana demonstrated a slowly progressive central hypothermia in Antarctic divers.[2] This hypothermia is likely to be a major cause of physiological depletion in divers, and motor and mental deterioration may affect their performance, comfort and safety.[3,5] Peripheral hypothermia results in discomfort of the hands and feet, facial pain, and the loss of peri-oral muscle control if the face is directly exposed to water. Continued underwater exposure results in localised cooling, with the hands and feet exhibiting the most rapid rate of heat loss. These cool rapidly because they have the greatest skin surface area/mass ratio, little subcutaneous fat and relatively little insulation, in order to allow dexterity.[3]

SUNBURN

Ultraviolet (UV) radiation may be intense in Antarctica. The spatial and temporal variation of stratospheric ozone above Antarctica is of regional and global significance to the amount of UV radiation that reaches the ground.[8] Divers and their attendants are at particular risk from UV injury because of their exposure to direct radiation and that reflected from ice, snow and the water. Protection of the skin from sunburn and the eyes from snow-blindness is of great importance, particularly during the long hours of sunshine in the summer.

## DANGEROUS MARINE ANIMALS

The Leopard seal (*Hyruga leptonyx*) is a four-metre, toothy, aggressive predator that feeds on krill, penguins and other seals. It is a remarkable yet gruesome experience to watch as one of these animals catches and skins a penguin by slapping it repeatedly against the water's surface. There have been no reported incidents of these animals injuring divers, but harassment, which necessitated the abandonment of the dive, has occurred. AAP diving regulations forbid diving activity within 400 m of a Leopard seal.[3]

Other seal species may also be of concern. Adolescent male Elephant seals up to 3.5 m in length 'haul out' at Davis in summer. There is a documented incident of an Elephant seal biting a diver on the shoulder. It is recommended that great care be taken if diving in the vicinity of breeding males in violent rut, as an underwater encounter could be most embarrassing!

Killer whales (*Grampus orca*) have a reputation as ruthless ferocious killers that feed on seal, walrus and penguin. Their exact threat to humans is uncertain, but should be considered as an unpredictable and potentially serious hazard.

## UNDER-ICE DIVING

Solo diving is common, with a fully-suited 'buddy' waiting at the surface. This arrangement ensures at least one diver is free from hypothermia and exhaustion at any one time and minimises the risk of decompression illness (DCI).

Access to the water is often difficult. With the changing of the tide, the rise and fall of the fast ice results in the formation of tide cracks that may allow access below the ice. Tides and currents may cause difficulties as in any marine environment, and may even cause diver entrapment by moving ice floes or closing tide cracks in the ice through which the diver entered. Alternative access can be made through seal breathing holes. Weddell seals gnawing their way up through the ice usually make these large holes. However, breathing holes are not recommended for diver access. They are often polluted by the owner seal and may be remote from suitable dive sites. Therefore, the dive team is often left with the task of drilling through the ice themselves. Motorised augers do facilitate this process considerably, although the depth of the ice and the size of the hole required, make this task extremely arduous and time-consuming. Of course, the hole starts to freeze over as soon as it has been dug.

Under-ice gloom may contribute to diver disorientation and claustrophobia, but can be avoided with the use of adequate illumination. The seas around Davis are prone to the usual ocean currents and tides. Fast ice cover, which nullifies the effects of wind and minimises tidal fluctuations, modifies these. However, the sea remains a dynamic force beneath the ice, and dangerous currents may be present, especially near the estuaries and narrow inlets of some fjords.

The author had an uncomfortable experience with the potentially treacherous conditions at Davis. A moderate current hampered a dive undertaken through a tide crack near the narrow neck of a large fjord. Furthermore, the thick ice cover decreased visibility considerably and required the use of a powerful torch. The dive plan was to photograph the benthos at multiple sites at decreasing depths, commencing at 20 m. The dive progressed with difficulty in the darkness and current until the ascent to 10 m. During this ascent, my head suddenly struck an ice 'ceiling' at 12 m of depth and the space between this ice and the seafloor rapidly narrowed in front of me. No further photography was possible and the dive was aborted. Later analysis of the dive and the topography revealed that, as a result of my disorientation in the challenging conditions, I had followed the bottom to the undersurface of a glacier that guarded one side of the fjord inlet – a sobering experience.

## DECOMPRESSION ILLNESS

Antarctic divers are at risk of dysbaric and non-dysbaric diving illnesses as well as illnesses unrelated to diving.[7] In particular, the risks from DCI may potentially be increased for divers in Antarctica because the water is very cold and often dark and the underwater work may be considerable in cumbersome suits.[9] It is testimony to the professionalism of the AAP diving programmes that no diver has suffered DCI or other serious diving injury.

Diver exhaustion is another potential problem. This may result from hypothermia, heavy underwater work, cumbersome suits and the demands of the diving programme, combined with insomnia during the long hours of summer daylight.

### Diving equipment in Antarctica

The Antarctic environment, particularly the cold, has peculiar effects upon both diving and non-diving equipment. It is most frustrating to press your camera shutter button only to find that the batteries have frozen and all power is lost. This difficulty is usually overcome by removing camera batteries and storing them inside outer garments until immediately prior to camera use.

## SCUBA REGULATORS

The recreational scuba regulator is prone to malfunction in Antarctic diving conditions, mainly as a result of ice crystal formation within the regulator mechanism.[3,6] This may result in jamming or 'freeze-up'. Ice crystals, once generated, may plug orifices or interfere with the movement of first stage components. Fortunately, first stage freeze-up nearly always causes malfunction in an open or free-flow position.[3,6] Moisture in the exhaled breath or water in the chamber forming ice around the demand lever causes second stage freeze-up. It is more likely to occur if the second stage is purged or allowed to free flow, which rapidly decreases the regulator temperature. Unlike the first stage, second stage freeze-up may result in no air getting to the diver.

It is recommended that regulators be dried completely after the post-dive rinse, and that no water be allowed to enter the second stage prior to immersion. Ice formation on the external surfaces of the first and second stage assemblies is also possible. Special regulators are available that minimise these freeze-up problems by various insulation features surrounding the two stages. The attachment of a small 'pony' cylinder to the main scuba cylinder is highly recommended. This small unit has its own regulator and is a completely separate air supply that may be utilised in the event of main regulator freeze-up.

SURFACE SUPPLY

Surface air supply is an effective alternative to scuba equipment. A bank of large cylinders may be used to provide the supply, with air being delivered via an umbilical hose. This has the advantage of eliminating the scuba first stage, and provides a very large reservoir of air and an effective safety line to the diver. These air banks have the disadvantage of being extremely heavy, and require either helicopter or sled transport.

The Kirby-Morgan helmet or 'band mask' is a device that encloses the diver's entire face and has been used extensively on AAP expeditions (Figure 1). It has the advantage of incorporating the second stage into the relatively warm air within the mask, avoids very cold water from contacting the face and allows the diver to communicate with the surface via an intercom system. However, the helmet is cumbersome and time-consuming to don, creates substantial water drag, restricts head movements, and requires a considerable amount of familiarisation training.

DIVING SUITS

Ten millimetre wetsuits are sufficient for the hardy, but cumbersome in Antarctic conditions. The variable volume drysuit has become popular, as it provides excellent insulation from cold and wind and avoids the cold discomfort of changing out of a wet suit. The Poseidon Unisuit has been used extensively on AAP expeditions. It is built from closed cell foam neoprene with nylon lining both sides, and is donned through an access sealed by a waterproof zipper. The suit is inflated by an inlet valve connected to the diver's air supply, and exhausted by a second valve adjacent to the diver's shoulder. Thus, two-valve manipulation allows for complete buoyancy control. However, drysuits have their own disadvantages. They are time consuming to don, are bulky, and may cause considerable water drag and exhaustion of the diver if considerable swimming is required. Also, dangerous over inflation of the suit may be caused by inflation or exhaust valve freeze-up or malfunction, and may require the diver to vent excess air through a wrist seal. Considerable drysuit experience is recommended prior to their use in Antarctica.

Diving gloves require modifications for cold water conditions. Ideally, a neoprene mitten glove is worn to allow the fingers to warm each other. However, this arrangement causes loss of dexterity and most gloves are a compromise, with separate compartments for the thumb and index finger. The addition of hot water into the gloves immediately prior to the dive prolongs the time before finger discomfort ensues.[3]

**Communications**

Communications are particularly important in any Antarctic programme, diving or otherwise. The interpersonal communications of those in the diving team must be good, with an adequate designation of personal responsibilities and responsible leadership. Communication between the dive team in the 'field' and the support station needs to be fail-safe in the case of emergency. Radio schedules, spare radios and batteries are prerequisites.

Communication with surface attendants is essential in under-ice diving, especially if the diver is diving alone. In this situation, there can be no immediate reliance upon a buddy diver in the event of emergency. All under-ice divers must be attached to a lifeline that can be used as a communication line via a series of pre-determined tugs. The lifeline also allows the diver to find the entrance hole and the rescue diver to find the diver, if necessary. The wires of the Kirby-Morgan helmet intercom system run with the lifeline. This intercom is an ideal system but, like many things in Antarctica, is prone to malfunction.

**Logistics**

Equipment assembly, maintenance, and transport to Antarctica are an exhaustive process. Attention must be given to the adequacy of spare parts and contingency plans devised in the event of unforeseen circumstances. In particular, consideration needs to be given to the provision of a recompression chamber for use in the event of a diving injury. Clearly, the expense and logistics involved in the transport and commissioning of such a chamber are considerable.

Dive site selection and camp movement may be undertaken by helicopter or over-ice vehicles. Helicopters are usually used during the summer when over-ice transport may be limited by melting and cracking of the sea-ice. Camp facilities include a fibreglass 'apple' hut, tents, heating and cooking

**FIGURE 1**
**DIVER SUITED READY TO DIVE IN ANTARCTICA**

equipment, radio gear, rescue equipment, bedding, and spare clothing, as well as the diving equipment. Food and fuel for several days are carried in the event of a blizzard and isolation in the 'field'.

## Conclusion

Diving in Antarctica is exhilarating and has its own special rewards. Whoever has the opportunity to experience this extreme diving is strongly encouraged to do so. It must be remembered that for every hour spent underwater there are hundreds of hours of planning, preparation and training. Neither should the difficulties and dangers be minimised. Most of the difficulties encountered involve maintenance or malfunction of the specialised equipment required. However, a well-prepared Antarctic diving expedition is likely to be one of life's unparalleled experiences.

## References


1 Taylor D McD, O'Toole KS, Auble TE, Ryan CM, Sherman DR. Sensation seeking personality traits of recreational scuba divers. *SPUMS J* 2001; 31: 25-28

2 Sullivan P, Vrana A. Trial of in-water oxygen recompression therapy in Antarctica. *SPUMS J* 1992; 22: 46-51

3 *Diving operations handbook 1990*. Hobart: Australian National Antarctic Research Expeditions, 1990

4 Robinson C, Hill HJ, Archer S, Leaky RJG, Boyd PW, Bury SJ. Scientific diving under sea ice in the Southern Ocean. *Underwater Technology* 1995; 21: 21-27

5 Dick AF. Thermal loss in Antarctic divers. *Med J Aust* 1984; 140: 351-354

6 Pollock NW. Southern exposure: scientific diving in the Antarctic. *Proceedings, 6th scientific diving symposium: Diving for science – 1991*. Vancouver: Canadian Association for Underwater Science 1993: 7-12

7 Milne AH, Thomson LF. Medical care of divers in the Antarctic. *Arctic Med Res* 1994; 53: 320-324

8 *Antarctic Science – the way forward*. Antarctic Science Advisory Commitee, Canberra: Department of the Arts, Sport, the Environment and Territories, 1992. ISBN 0 642 18064 0

9 Edmonds C, Lowry C, Pennefather J. *Diving and Subaquatic Medicine (third edition)*. London: Butterworth and Heinemann, 1992



*Associate Professor David McD Taylor MD, MPH, DRCOG, FACEM is Director of Emergency Medicine Research, Royal Melbourne Hospital, Victoria, Australia and formerly Medical Officer, Davis Station, Antarctica in 1989.*

***Address for correspondence:***
*Emergency Department, Royal Melbourne Hospital*
*Grattan Street, Parkville*
VIC, 3050 Australia
***Phone:*** *+61-(0)3-9342-7000*
***Fax:*** *+61-(0)3-9342-8777*
***E-mail:*** *<David.Taylor@mh.org.au>*