The world as it is

Managing scientific diving operations in a remote location: the Canadian high Arctic

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Abstract

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Global climate change is expected to alter the Arctic bioregion markedly in coming decades. As a result, monitoring of the expected and actual changes has assumed high scientific significance. Many marine science objectives are best supported with the use of scientific diving techniques. Some important keystone environments are located in extremely remote locations where land-based expeditions offer high flexibility and cost-effectiveness over ship-based operations. However, the extreme remoteness of some of these locations, coupled with complex and unreliable land, sea and air communications, means that there is rarely quick access (< 48 h) to any specialized diving medical intervention or recompression. In 2009, a land-based expedition to the north end of Baffin Island was undertaken with the specific aim of establishing an inventory of the diversity of seaweeds and their pathogens that was broadly representative of a high Arctic marine environment. This account highlights some of the logistical considerations taken on that expedition; specifically it outlines the non-recompression treatment pathway that would have been adopted in the event of a diver suffering decompression illness.

Key words
Scientific diving, remote locations, decompression illness, injuries, first aid, oxygen, medical kits

Introduction

The polar bioregions are the areas of the globe most sensitive to changes in the climate; major regional modifications are already being observed in polar marine ecosystems that have experienced warming.[1] A pole-ward migration of existing and invading species has the growing potential to alter community composition and species abundance. Warming of areas of the polar oceans has already had negative effects on community composition, biomass and distribution.[1] Environmental changes of substantial magnitude have the potential to cause significant ecosystem impact and there has been mounting pressure on the scientific community to understand the present conditions in order to monitor departures from the baseline and to predict any potential consequences. In the polar seas, shallow coastal areas are extremely vulnerable to the effects of climate change principally because of alterations in the types and behaviours of sea ice.[2] Scuba diving is a highly productive and cost-effective research tool in such environments.[3]

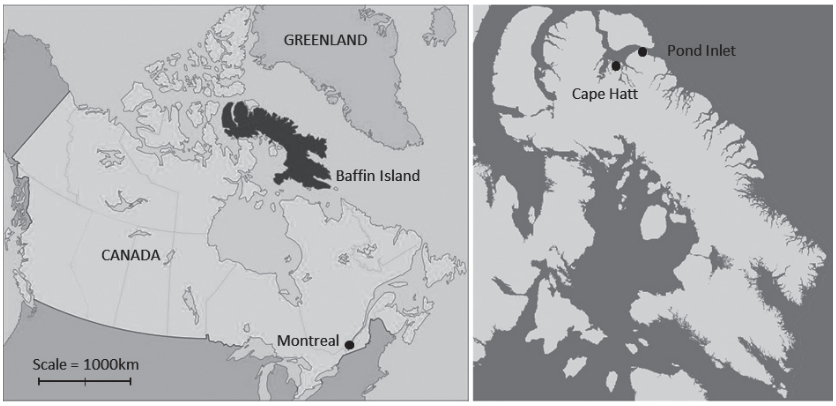
DIVING ACTIVITIES IN POLAR REGIONS

Although both polar regions are typified by having vast surface areas and coastlines but with minimal inhabitation and hugely limited communications, they differ markedly in how scientific field operations are supported. Nations actively engaged in scientific research in the Antarctic tend to maintain permanent or semi-permanent support infrastructure with dedicated methods of transportation. Scientific diving operations in Antarctica are well-resourced and tend to occur close to the main bases which, in most cases, have doctors on-site with good medical facilities and recompression chambers.[4,5] There are relatively few scientific bases in the high Arctic and this, in combination with the remoteness and limited communications of the region, means that most marine science expeditions to the area tend to be research vessel-based. There are few research vessels that are capable of working at high latitudes, they are expensive to maintain and they may be limited in their operational range. There are definite logistical benefits to conducting shallow coastal research in the high Arctic using land-based diving. Decompression illness (DCI) is always a potential end point to any diving activity, and there are additional challenges when diving in cold environments.[6] The employment of diving in a remote location will either need to be supported by a portable recompression chamber or the risk management process will need to take into account alternative methods of treating DCI.

SENSITIVITY OF HIGH-LATITUDE COASTAL ECOSYSTEMS

Macroalgae are an essential element of coastal ecosystems and the degradation of macroalgal vegetation communities can affect the entire ecosystem in an area.[7] Benthic marine algae make significant contributions to high-latitude coastal primary productivity and energy fluxes, exceeding or equalling the production of primary producers in more temperate systems.[8] In the Arctic, floristic knowledge of

Figure 1
Map showing the location of Baffin Island (dark shading) in respect to the nearest recompression chamber at Montreal; the inset of Baffin shows the locations of Pond Inlet and the Cape Hatt field camp



the diversity of macroalgae is fragmented, particularly in the American Arctic.[9] Macroalgae of the Arctic region are considered to be very sensitive to a reduction in ice coverage because the life histories of many macroalgae are regulated by temperature and photo-regimes and the periodic physical presence and absence of sea ice, to a range of impact depths, may drive recruitment of some taxa.[10–13] There are predictions that seaweed composition and abundance will change with elevated temperatures; however, those predictions vary regionally and without a detailed baseline inventory it will not be possible to measure or monitor change as or if it happens.[7,11,13]

It is becoming increasingly accepted that pathogens impact the overall structure of natural communities as well as the flow of energy and matter within ecosystems.[14] Previous studies have suggested that climate change may be contributing to increasing numbers of pathogenic epidemics that have the potential to exert devastating effects on ecosystems.[15] However, many of these conclusions are inferred or cannot be explained with any certainty because baseline estimates for pathogen populations are lacking. In particular, there is an almost complete gap in knowledge, especially in the high Arctic, concerning the pathogens of marine algae, many of which are lower oomycetes.[16]

This account presents the methods employed to investigate the macroalgal communities and their associated pathogens in the Cape Hatt region of northern Baffin Island in the Canadian high Arctic during the summer of 2009. The study was diving-based and an outline is given of the risk management for the diving operations and the safety procedures that would have been used if there had been an incident of DCI or other clinically significant diving injury.

Methods

The expedition was staged from Pond Inlet, north Baffin Island from mid-August to early September 2009. Weather permitting, there are either one or two scheduled flights a day between Pond Inlet and Montreal; the approximate flying distance is 3,700 km. Flight routes differ but there are usually no fewer than three stops on the way with the total transfer time varying between 11 and 32 hours. A field camp was established at Bay 11 in Eclipse Sound, on Cape Hatt (72^{O} 27.8'N 79^{O} 50.4'W[17]), which is approximately 85 km to the west of Pond Inlet (Figure 1). Transport between the field camp and Pond Inlet was only by boat; depending on weather and sea ice conditions, transfer time between the two locations was 4–7 hours.

Sampling and recording was undertaken using scuba; there were four divers and the diving adhered to the risk assessment principles of the 1997 UK Diving at Work Regulations.[18] All the diving was shore-based; the divers dived in pairs both attached to a single 100-metre "*L*" lifeline with a surface tender plus a dive supervisor (Figure 2). The lifeline prevented the divers from drifting too far from the point of entry/egress while maintaining communication between the dive supervisor and both divers in the event of top-side having to terminate a diving operation. All dives were conducted with the availability of a fully independent breathing supply (secondary cylinder and regulator, Figure 2); diving was insured to a maximum operational depth of 15 metres only. Between two and six diving operations were undertaken each day. Dive tasks included collecting seaweed specimens and sediment samples, and taking photographs and video footage (Figure 3).

At all times (24 h per day) during the field component of the expedition, surveillance was maintained in the event of an approach from polar bear (*Ursus maritimus* Phipps). This included times when diving operations were underway; there was always an armed lookout in addition to a tender and dive supervisor in accordance with guidance given in Lang and Sayer (Figure 4).[4]

The emergency evacuation protocol in the case of a diving-related medical problem was based on the probability of not being able to reach a recompression facility within a

Figure 2
Preparing a shore-based diving operation; the divers were tended from the shore using a 100-m "*L*" lifeline; the support diver (right) acted as an in-water stand-by to the science diver (left); note the use of secondary bailout cylinders (photo courtesy of Olivier Dargent, Nice, France)

timescale of 24–48 hours. An emergency transfer service was possible from Pond Inlet to Montreal with the capability of transferring divers at a cabin pressure equivalent to an altitude of 214 metres. The health centre at Pond Inlet had sufficient medical and oxygen supplies to stabilize a diver prior to onward transfer; this included a chest drain and Heimlich valve and the capability to carry out urinary catheterisation, if required. The following emergency procedure was developed primarily to cover stabilization in the field plus onward transfer to Pond Inlet.

- On retrieval the diver would be kept supine, warm and dry if possible.
- The diver would immediately be placed on 100% oxygen with enough oxygen for the transfer to Pond Inlet.
- The diver would be given two litres of isotonic fluids initially followed by one litre per hour until they had passed urine; the diver would be given buccal prochlorperazine maleate (*Bucastem*) in the event of any vomiting. The non-steroidal anti-inflammatory drug diclofenac sodium would be administered at 100 mg initially, followed by 50 mg eight hours later.
- A satellite phone would be used to inform the health centre at Pond Inlet while initiating the transfer process on to Montreal.
- An assessment, guided by remote input from medics trained in diving medicine, would be made at Pond Inlet regarding the necessity for onward transfer.

Surface oxygen was available in the field through a Divers Alert Network (DAN) Extended Care Rescue Pack but with additional oxygen bottles capable of delivering a total of at least 360 minutes of oxygen to a single diver; included in the pack were masks that could support breathing and non-breathing divers. An advanced field medical kit was also taken; in addition to an enhanced variety of dressings and bandages, the kit included a Guedal airway set (five pieces) and a manual bag resuscitator. Extra drugs carried included: diclofenac (anti-inflammatory/analgesic); codydramol (paracetamol/dihydrocodeine, analgesic); cefradine (antibiotic for chest, skin, urinary infections); ciprofloxacin (antibiotic for ear, chest, skin, urinary infections); prochlorperazine (anti-emetic); loperamide (anti-diarrhoeal); and chlorphenamine (anti-histamine for

Figure 3
Scientific diver performing a video transect of a seaweed-dominated Arctic ecosystem (photo: Martin Sayer, NFSD)

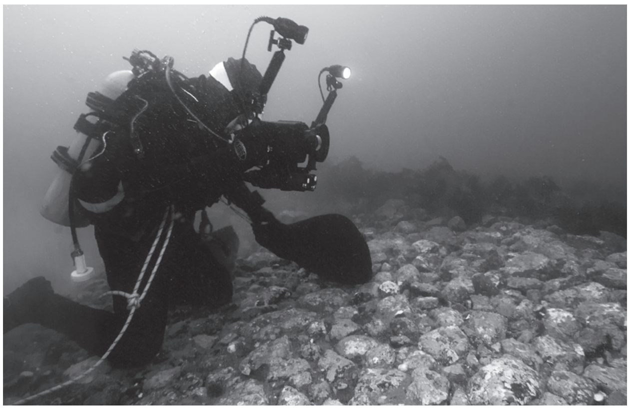


Figure 4
A diver filling cylinders using a portable air compressor while also keeping watch for any approaching polar bear (note the rifle); (photo: Martin Sayer, NFSD)

allergic reactions). A large volume of rehydration sachets (Dioralyte™) was also taken; all water was boiled, with a volume always available for immediate use.

Results

Exactly 50 diving operations were completed with a total underwater time of 29.7 hours in 12 different locations around the Cape Hatt area. The average maximum operating depth was 10.4 metres' sea water (msw) with an absolute maximum of 15.0 msw. The diving operations generated over 10,000 underwater images, over 20 h of video footage and hundreds of live isolates, herbarium specimens and samples. There were no diving or non-diving incidents; the emergency treatment protocol for an injured diver was not tested.

Discussion

The Arctic could be the defining environment in the continuing debate surrounding climate change. Whereas much discussion and concern has focused on the effects to humankind and top predators, the present study concentrated on developing a baseline against which the potential consequences of change to the ecology of primary producers could be measured. Studies on the identification, classification and cataloguing of the macroalgae and oomycete samples are ongoing and will be reported on elsewhere.

There is no evidence to suggest that diving in cold water presents any elevated risk of developing decompression sickness, although being cold during the decompression phase of a profile (either in the water or immediately following a dive) may not be favourable.[6] Therefore, in the present study, diving in cold water was not considered to be a major element of the part of the project plan that assessed the risk of DCI. In addition, the shallow nature of the study environments plus the applied insurance limits meant that this expedition carried a very low risk of a diving-related incident. However, the remoteness of the field site was a management concern and there were a number of potential bottlenecks in the transfer route from the dive site to a suitable recompression facility.

The management of mild or marginal DCI in remote locations was the subject of an international workshop in 2004.[19] There were elements to the present study that negated many of the workshop discussions: principally the total lack of any compression chamber within many thousands of kilometres of the study site and the unwillingness to even consider in-water recompression techniques because of limited supplies of oxygen, compressed air and the ambient temperatures. Therefore, the only option was to develop an evacuation plan based on non-recompression therapy.[20]

The basis of this non-recompression treatment pathway was to make use of the commonly used adjuncts to recompression therapy, namely breathing 100% oxygen and fluid replacement.[20] The use of antiplatelet agents was also advocated, although it was acknowledged that anti-inflammatory inhibitors were likely to provide an additional treatment mechanism. In addition, keeping a patient supine is known to increase nitrogen washout by about 50%. Adjunctive therapies are employed routinely prior to and during emergency recompressions. Although there can be difficulties in determining the true extent of the benefits, normobaric oxygen and aggressive fluid resuscitation would be considered basic first-aid treatments for divers suffering from DCI (with the caveat that aggressive rehydration should be avoided for divers with a suspected isolated cerebral arterial gas embolism).[21,22] Rehydration therapy using isotonic fluids is not always accepted by the patient and so, if intravenous delivery is not an option, then the management plan should consider employment of buccal prochlorperazine maleate to reduce fluid loss through vomiting.

Traditional management pathways for the treatment of DCI favour seeking rapid recompression. In the present study, the risk assessment process balanced time to treatment against the probability of any incidence of DCI being mild or marginal. That probability was, in turn, managed by limiting depth. There is evidence to suggest that in cases of mild or marginal DCI, no significant disadvantages to long-term clinical outcome are caused by delayed treatment, although the intensity of the symptoms (still mild or marginal) may increase with delay (> 17 h).[23,24]

DCI was the main health concern for this expedition simply because it was an example of a medical emergency that had never been seen locally by healthcare staff and there was no immediate access to a recompression facility. Polar bear attacks were also a major concern although these are exceedingly rare and the ferocity of polar bears has probably been overemphasized.[25] Although firearms were carried at all times, their efficacy in deterring bear attacks has been questioned.[26] However, there was good local experience of bear-inflicted wounds and planning for an attack was based on having to treat major trauma in the field with immediate transfer to the Pond Inlet health centre. Hypothermia was also a major concern as any incident would have to have been treated in the field. Diving operations were limited by distance and transfer time back to the field base where re-warming was possible; foil blankets were carried in the field first-aid kit. Other injuries and medical incidents planned for included: diarrhoea/vomiting; slips and trips (elevated risk because of shore-based diving operations); burns (tent fires); infections (particularly ears, chest and urinary) and allergic reactions.

Scientific exploration in remote locations that is dependent on diving should always consider the availability of a suitably equipped research vessel. Where that option is not available, alternative strategies exist within the framework of assessing and managing risk.

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