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ARCHAEOLOGICAL DIVING IN AUSTRALIA A MEDICAL PERSPECTIVE

David Millar

Introduction

Why do students, a Qantas pilot, a customs agent and others want to spend two weeks training in archaeological diving? For some amateur (defined here as one who loves a field[1]) divers there is more than the lure of treasure hunting or the sport of wreck diving. In common with the underwater archaeologist, they share a fascination with the past and its reconstruction. The exploration of Australia has left our coast littered with hundreds of underwater time capsules. Until now, no formal training in scientific diving (archaeologist, biologist, oceanographer) has been available in Australia. Eight amateur divers and one professional underwater archaeologist recently undertook the first NAUI/CMAS Divemaster-Scientific Diver Training Course conducted by Sci Dive Australia in Far North Queensland from March 31st to April 15th, 1989.

This article will discuss aspects of such training and the role of the diving physician on such an expedition, which culminated with work on what is probably Australia's most important shipwreck, HMS Pandora.

Underwater archaeology is a relatively new discipline. Pioneering work in Australia commenced in 1969 with members of the Western Australian Maritime Museum inspecting, and later excavating the Dutch East Indiaman, Batavia, (wrecked on the Abrolhos Islands, West Australia, in June 1629)[2,3]. Artefacts raised from this vessel have included sufficient timbers to allow partial reconstruction of the vessel and many items of her extraordinary cargo. These have included a selection of silverware, stoneware jugs, smoking pipes, astrolabes, a pocket sundial and even a portico facade destined for the gateway to the company's castle in Batavia (now Jakarta, Indonesia).

Since then many thousands of archaeological dives have been undertaken on shipwreck sites around Australia, the Indian Ocean, south east Asia and the Pacific Ocean. Also many dives have occurred on wreck sites by sport divers and treasure hunting divers. Archaeological diving will be emphasised in this article.

As in other scientific diving disciplines (biology, oceanography, etc.) formal archaeological training is required for a systematic approach so that the maximum amount of information can be uncovered. The reconstruction of our past through maritime archaeology is a precise, time consuming discipline. Thus the 30 or so professional archaeologists now working around Australia have required hundreds of enthusiastic volunteers to help in their work. Lured by the romance of underwater archaeology, they are then faced with the reality of long arduous days in remote sites, diving at times in hazardous conditions, as shipwrecks are not noted for occurring off calm, balmy white beaches. On top of this there is new equipment and techniques to master. Despite this much valuable work has been done by amateur divers working with professional archaeologists with an excellent safety record.

In Western Australia over 10,000 archaeological dives have taken place[4] over the last 30 years at various sites along the coast. These include the wrecks of the Rapid, Batavia, Lively, Trial, Zuytdorp and Zeewijk to name a few. These sites are usually in less than 18 m, mostly in remote locations and many are exposed to surf (Lively, Trial and Sirius).

A medical officer has accompanied all major field trips in WA. So far no fatalities have occurred. No cases of decompression sickness (DCS) have been diagnosed. One case of cerebral arterial gas embolism (CAGE) has been successfully resuscitated, evacuated and rehabilitated. Three cases of severe marine stings, one stingray and two jelly fish, have occurred. While a number of minor illnesses and injuries have occurred, for example, a salt water aspiration syndrome like condition has been common in new divers to some sites, the safety record has been admirable.

The wreck of HMS Pandora, which sank in 1789, lies in 31-37 m of water on the outer Barrier Reef, at approximately 11°S 144°E. Surface conditions are relatively calm though the local reef configuration produces frequent and unpredictable changes in the ocean currents, even on the sea-bed. Water temperature is 14-16°C (average sea-bed), and

Figure 1. Divers surveying the HMS Sirius site under the surf on Norfolk Island. Photographer Pat Baker.

the visibility, 10-40 m. Expeditions to this site have been mounted on varying scales over four seasons. Considerable sections of the hull remain and the site is rich in artefacts. The lower sections of the vessel have settled largely intact into the sand, still holding the original contents. An early find was medical implements, including ampoules and syringes, from the ship surgeon's cabin, and what is believed to be his watch.

Table 1 shows the incidence of decompression sickness diagnosed to date against the number of dives on the Pandora site[5]. There were 4 cases of joint pain and one with cerebral symptoms and signs. All responded to surface oxygen, or recompression when a chamber was present, in 1983 and 1986. The combined incidence of DCS on the Pandora site then is 0.16% or 1.6 cases per 1,000 dives. No fatality, pulmonary barotrauma or other significant diving related injury has occurred. These figures are similar to those in a report being prepared by the author on six expedition seasons in the Gulf of Thailand diving to similar depths. The estimated risk of DCS using the US Navy tables at this depth (120 feet) is 1.8%6, placing these figures at an acceptable level for a working site. Other figures for scientific diving7[,8,9] also indicate very low mortality and morbidity rates.

While the efforts of various expedition leaders, divemasters and medical officers are commendable, we can further build on these beginnings. A rigid training program will further enhance the safety, productivity and enjoyment of both professional and amateur alike. Consideration of the scientific diving community as a special group is not new and a working group on scientific diving is attempting to set guidelines for training and operation[10]. The UNESCO Code of Practice for Scientific Diving is an extremely comprehensive document on which a draft standard could be based.

Sci Dive NAUI/CMAS Scientific Diver Course

The forerunner of future training programs was conducted recently by NAUI instructors, Jacques and Capkin Van Alphen and their team at Sci Dive Australia. This course was conducted over five intensive days on board the 25 m MV Kanimbla, in Barrier Reef waters while on route to the Pandora wreck site. Guided by three instructors and the author, nine trainees, who were all advanced divers, completed the NAUI Divemaster, Rescue Diver and Deep Diver courses. This prepared the trainees for the next phase, six days of survey work on the Pandora site under the supervision and instruction of Queensland Museum under-

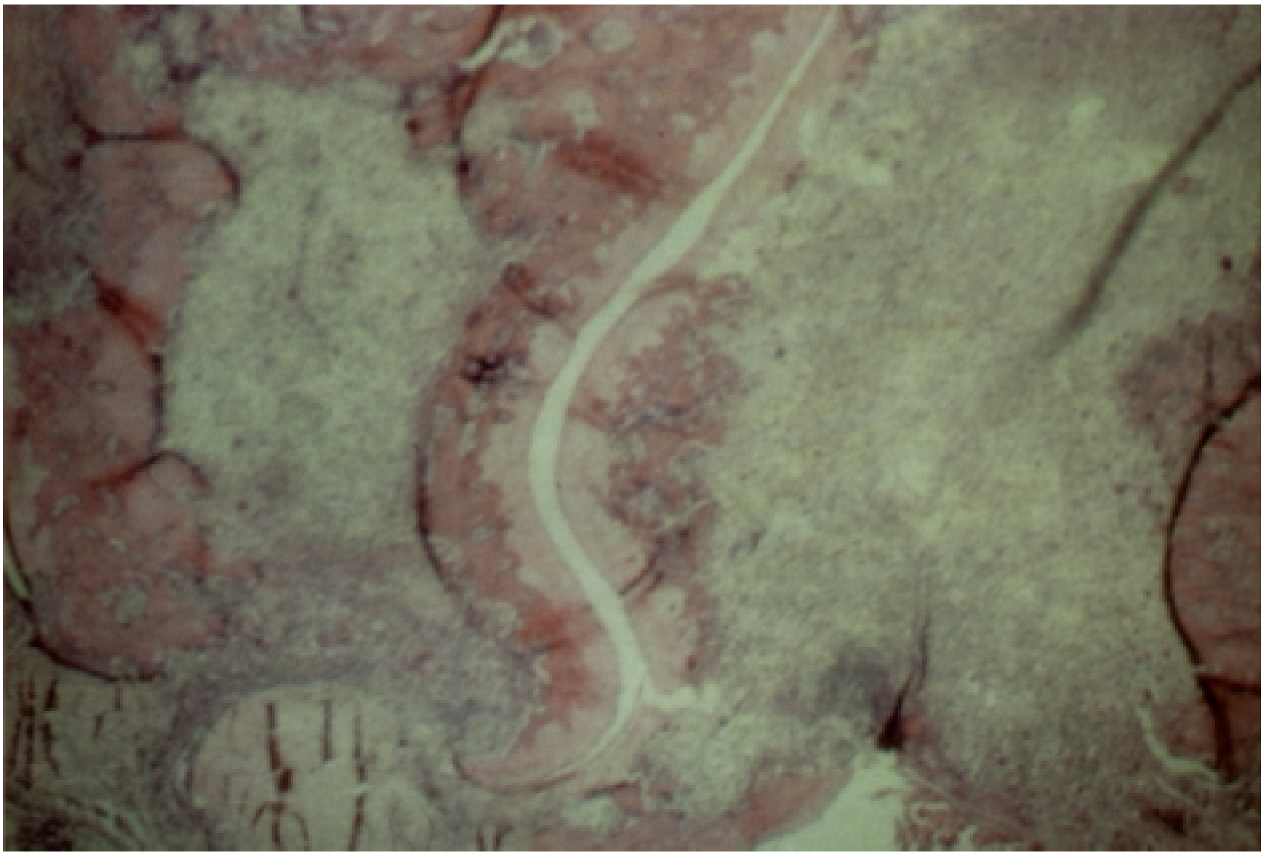

FIGURE 5. A typical haematoxalin and eosin stained section cut through the hind ankle joint of a control rat 28 days after adjuvant injection. **Both illustrations on this page are from the paper by Dr Fiona Andrews which starts on page 125**

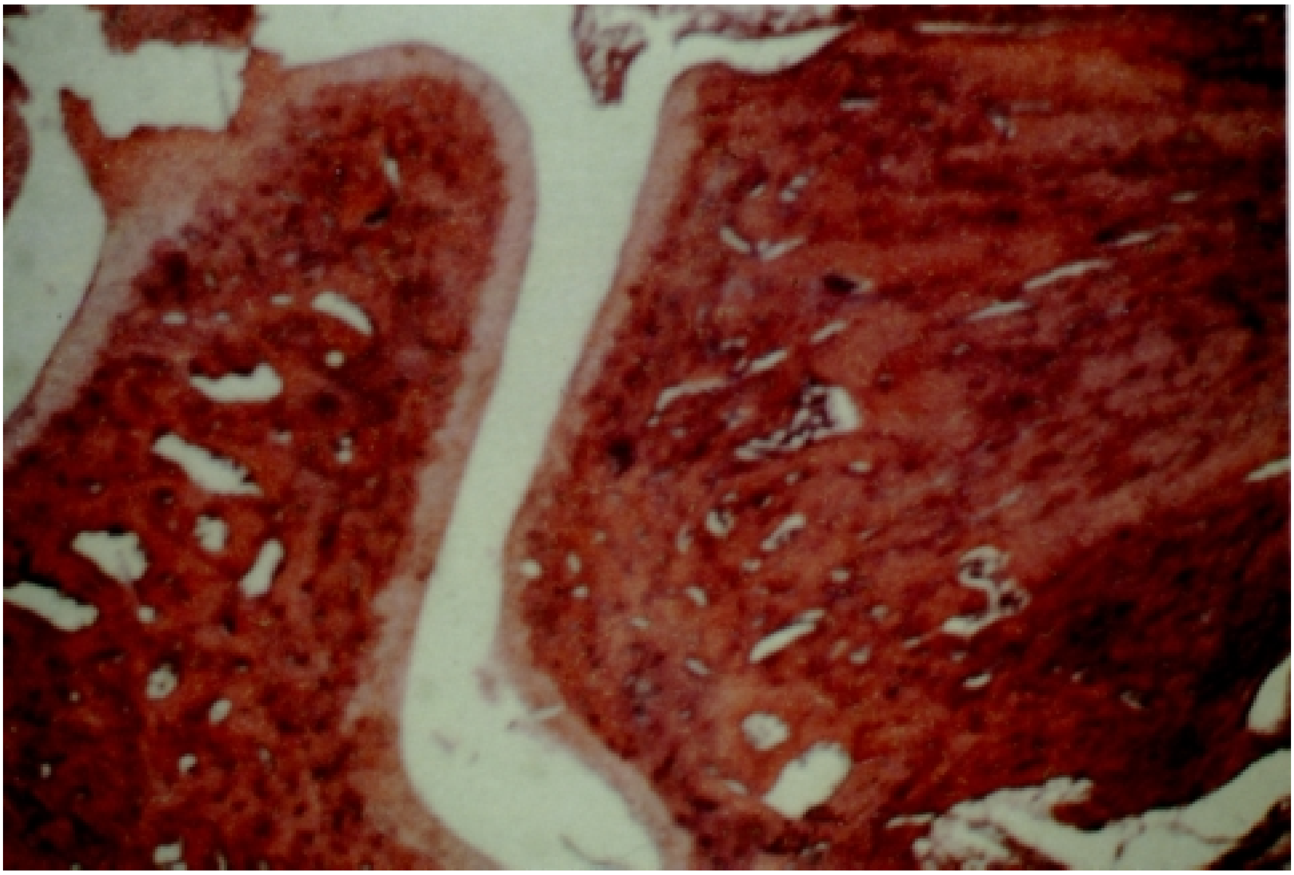

FIGURE 6. A typical iron deficient rat joint section 28 days after adjuvant injection.with very little inflammation.

TABLE 1

Season	Total Dives	Underwater Hours	Cases of Suspected DCS
1983	686	275.9	1
1984	800	364.94	2
1986	1435	568.5	2
1989	160	60.6	0
Total	12	3081.94	5

water archaeologist, Peter Gesner. All objectives of the fieldwork were completed without incident and in a very professional manner.

Scientific Diver Training

One aspect of this article is to examine the major components of such training in the light of this recent course.

DIVER SELECTION

Medical Fitness

All participants had been cleared by approved diving doctors, prior to departure. This is essential for a uniform standard.

Physical Fitness

Working with various equipment underwater and in the hazardous conditions that wreck sites often present, surf, currents, low visibility, requires an above average level of cardio-vascular (endurance) fitness. While this is generally accepted, no assessment of cardio-vascular fitness at the time of the medical or prior to an expedition occurs in most instances. Minimum levels have been suggested for sport divers[11] such as13 METS, which is equivalent to 12 minutes of the Bruce Protocol using a treadmill or bicycle ergometer. While such formal testing may not be practical or popular, a pre-set water fitness test could be established for participants to pass before being permitted to dive.

The Sci Dive course water skills test consisted of a 50 m underwater swim, with a maximum of 2 breaths allowed during the swim, a 400 m swim in 10 minutes, a 50 m tow of a "victim" and a 812 m swim in 18 minutes in scuba gear. All participants completed this test. Strict adherence and enforcement of a set standard of fitness is essential for continued safety. This was certainly so on the Pandora site, where heavy exertion at depth will greatly increase nitrogen uptake. Over exertion and resultant carbon dioxide build-up produced occipital headaches on two occasions, both rapidly responding to 100% oxygen over 5 minutes.

Psychological Fitness

Some degree of psychological stress is inevitable on an extended trip such as this and indeed is part of the selection process. The aim on an expedition is to minimize stresses wherever possible.

Adaptation to a new environment, equipment, and techniques are major stresses. These were well addressed on the course as Phase I allowed a gentle and progressive adaptation.

Long hours of theoretical and practical sessions followed by an examination on all aspects of these were other causes of stress. Well defined goals, a positive, caring attitude by the instructors and the trainees' enthusiasm, were key factors in minimising this. Structured free time is essential for extended field trips. The opportunity to simply sit and do nothing is a real luxury.

Food quality and quantity, sleeping arrangements etc. greatly influence attitude and group interaction. In this case a comfortable boat with good catering an a competent and enthusiastic captain and crew greatly contributed to group harmony. Fresh water showers backed up by an effective desalinator and calm safe anchorages at night, enhanced comfort and sleep.

The ability to have minor ailments promptly attended to minimise the stress of such physical ailments is essential in remote locations.

The combination of all of the above, together with open communication in the form of regular briefings and debriefings, achieved the goal of forming a cohesive working group.

EQUIPMENT

Progressive familiarisation with the diving and scientific equipment in Phase I, gave trainees ample opportunity to feel comfortable with their equipment. Of great concern was the marked discrepancy between some of the depth gauges used. There were variations of up to 10 m on

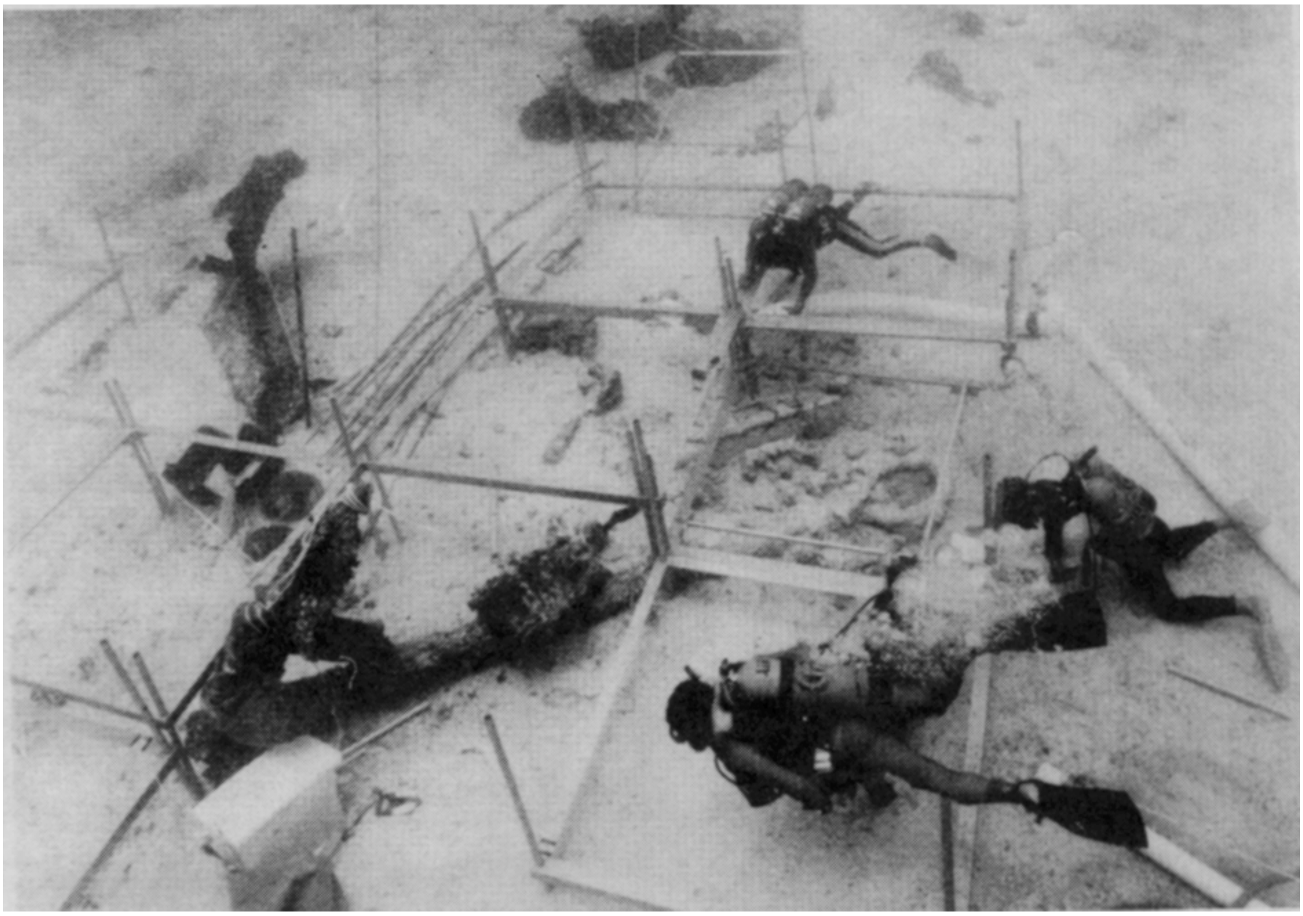

Figure 2. Divers working on the HMS Pandora site. Photographer Pat Baker.

the bottom at 30 m. On an ever changing deep site, such as this, constant accurate depth assessment is essential to diver safety. Completing set tasks, meant using either the 33 m or the 36 m limits where applicable. We wished to keep the safety stop time to not more than 5 minutes for diver comfort. We had sufficient accurate gauges for our work. A shore based depth gauge testing facility would certainly be useful for gauge checking and calibration prior to expeditions.

ENVIRONMENT

Transposing individuals from around the country, or worldwide, to a new diving environment is a stress which is often under estimated. In most of us, there is some fear of the unknown as each dive site is unique in respect of water temperature, sea conditions, underwater topography, marine life, etc. On this occasion, this stress was minimised by the slow gentle work-up to deep diving, taking 5 days to reach 36 m, giving ample opportunity for acclimitisation to the Pandora site. Nitrogen narcosis was watched for and was not a major problem. On one occasion, a team of divers did become fixed on the idea of completing a set task despite insufficient time. This emphasised the need for setting realistic, well rehearsed tasks and the allocation of a time keeper on the bottom for each dive.

TECHNIQUES

Diving Techniques

Some of these techniques, for example emergency procedures, are relevant to all scientific diving expeditions. Considerable refinement of the methods and training on advanced diving techniques has been achieved in recent years. Basic and advanced sport diving training in Australia, by the major organisations, (FAUI, NAUI, PADI) is of an exceptionally high and uniform standard. In this instance the NAUI Divemaster and Rescue Dive modules were well presented and completed by all trainees. Essential techniques covered were emergency ascents, rescues, first aid, treatment of marine injury and illness, and evacuation procedures. The reality of practicing rescues in a remote location was disturbing for some but a useful learning experience for all of us. Overlearning and problem solving are key aspects of this training.

This expedition used deep diving techniques, based on the NAUI training module. The United States Navy (USN) decompression tables were used as a basis for dive profiles with added safety factors consisting of:

1. Bottom times not exceeding the USN no-decompression limits (NDL).

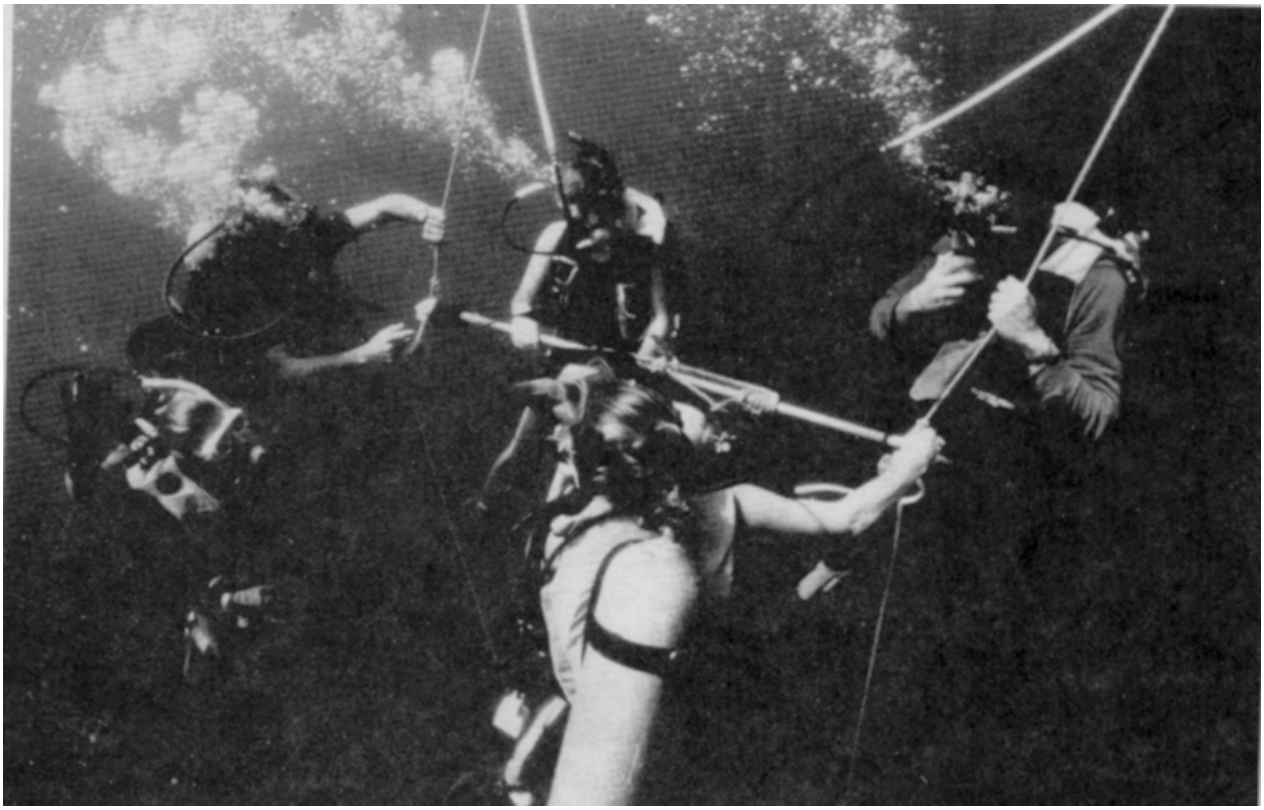

Figure 3. Divers on the decompression bar during a safety stop at the HMS Pandora site. Photgrapher Ian Hodson.

2. A slower ascent rate of 9 m/min, up a buoyed line attached to the stern anchor of the Pandora.
3. A compulsory safety stop at 3 m for 5 minutes on all dives. A heavily weighted decompression bar was slung from the midship section of a Zodiac inflatable which was attached to the stern anchor buoy. This proved quite stable. Each diver breathed 100% oxygen for 3 minutes of the 5 minute stop. This was delivered from an 'E' size cylinder (7 'E' size oxygen cylinders were carried), using Harris regulators with hookah hoses and demand valves. While this may be considered controversial by some, it must be emphasised that this procedure was used strictly to enhance nitrogen de-gassing. It is not being advocated for sports diving or for therapy. Provided that the bar depth is stable at 3 m, as in this case, and that divers on the stop are closely monitored, by the divers in the next team in this instant, using oxygen in this manner is a safe procedure.
4. The use of reduced bottom times when heavy work was expected e.g. strong currents.
5. Strict dive timing and close observation of the stop with extension of stop times when arrival to the decompression bar was late. This occurred on one occasion only.
6. Five hour surface intervals between repetitive dives and more conservative bottom times than allowed by the USN tables. I used an Aladin Pro Dive Computer to compare with our profiles. This unit uses the Buhlmann Tables for its basis and on this limited trial, matched our chosen profiles closely. These tables use shorter NDLs for rectangular dive profiles, a slower ascent rate 10 m/min, and compulsory stops. A dive to 36 m for 15 minutes using this table requires a 3 min stop at 3 m compared with our more conservative 5 mins[12]. The repetitive dive system of the Buhlmann tables includes a large safety margin to allow for the problem of reduced desaturation during the surface interval, caused by bubbles in the lungs. Further evaluation of this and other dive computers is warranted and is to be accompanied by Doppler ultrasound studies on future expeditions.
7. Adequate pre and post dive fluid intake was actively encouraged. The risk of DCS from diuresis and dehydration was thus minimised.

The 15 divers completed 160 dives on the Pandora with a combined dive time of 60 hours 36 minutes with no detectable decompression sickness. The safe exposure of the 9 trainees to working in one specific underwater environment was accomplished. Further experience in other situations, e.g. in shallow surf, poor visibility etc. will round off their training.

<u>Scientific Diving Techniques</u>

While some skills needed by different disciplines (biologist, oceanographer, archaeologist etc.) differ widely, others are similar. Aspects covered in this course were:

The use of basic scientific equipment such as tapes and ropes.

Underwater bottom and reef searches of the areas adjacent to the initial site of the grounding of the Pandora.
Setting up a grid reference system.
Close plot magnetometer survey to ascertain the extent of material beneath the substrate surface.
Surface communications using a hand-held signalling device.
Underwater photography.

All of the above were well handled by the group. Other skills such as sampling techniques could be added to broaden the course base.

The Role of the Diving Physician

On an expedition these duties primarily consist of general health care of all participants, diving clearance of divers, prevention and treatment of diving related problems, and involvement in lectures and practical sessions.

General Health Care

Prevention or early treatment of ailments is vital on an extended expedition and a comprehensive medical kit is essential to meet all contingencies. Problems encountered were minor cuts and abrasions, minor sprains and many upper respiratory tract infections on the last few days. These were not diving related and may have been influenced by the prolonged work schedule. Sea sickness occurred in 5 members of the team, mostly in the first 48 hours and responded well to the use of “Acubands”, and/or “Scop” transdermal scopolamine patches. Minor skin rashes from heat, salt water and wetsuit, occurred towards the end and were minimised by adequate fresh water for showers. Three cases of neck or lower back pains responded well to acupuncture.

Diving Clearance of Divers

This consisted of pre-dive assessment initially and then daily with respect to specific dive profiles, underwater tasks and repetitive dive limitations. Working in harmony with the expedition leader and divemaster, as occurred on this occasion, the diving doctor can greatly enhance accident prevention.

Prevention and Treatment of Diving Related Problems

Regular ear checks were performed. All divers did ear toilet using “Aqua-ear” or a mixture of 95% methylated spirits to 5% vinegar. Three divers had problems early on with slow middle ear equalising, but no episodes of barotrauma occurred. The use of “Spraytish” nasal spray prior to steam inhalation in a hot shower at night is a potent remedy. No significant marine injury occurred on this trip.

The one significant incident was a case of decompression sickness that occurred on Day 4 of Phase I, two days before starting work on the Pandora. This occurred in a diver who was not subject to the course requirements, fitness assessment, acclimatising to deep dives etc., undertaken by all other divers.

Case Report

DH the deckhand of the vessel, asked to accompany two of our divers on a dive to free the vessel’s anchor while at Martha Ridgeway Reef. The depth according to the depth sounder was 33 m. Aged 27, DH is a qualified divemaster with 500 previous dives. The dive profile was:

depth	37 m
bottom time	6 mins (NDL 10 mins)
slow ascent	6 mins
safety stop at 5 m for	3 mins

Within 5 minutes of surfacing, the 3 divers were breathing 100% oxygen on the surface for 6 minutes. The divers slowed their ascent because of the extra work involved in clearing the fouled anchor chain and the surface oxygen was added as a further precaution. Two hours after surfacing DH presented with left elbow pain, parathesiae and weakness of the left hand. He was anxious and hyperventilating. Examination revealed ill defined deep joint pain of the left elbow, and a glove and stocking distribution of reduced light touch sensation to the left forearm and hand. No actual weakness was demonstrated and full examination revealed no other abnormality.

He had three risk factors for DCS. He was more than 10 kg overweight. He smoked more than 20 cigarettes a day. He was short of sleep from being anchor watch the previous night. A diagnosis of DCS involving the left elbow with a possible spinal bend.

He was treated with 100% oxygen on the surface via a scuba demand valve using a cycle of 25 mins on oxygen followed by a 5 minute air break. He drank 500 ml immediately, then 1000 ml per hour.

Adequate re-hydration was demonstrated by a good urine output.

Reassurance and slowed diaphragmatic breathing while on oxygen was followed by complete resolution of the parathesiae and full return of sensation over 60 minutes. The elbow pain responded more slowly but after 2 1/2 hours of treatment, DH was asymptomatic apart from slight fatigue. He rested for 24 hours and has been well since. No diving was allowed for 5 days. On his return to diving more conservative dive profiles were adopted and no repetitive dives allowed.

DH was the only diver over whom full control was not exercised from the outset. Such control is essential to ensure safety. An on-board recompression facility is obviously desirable in remote locations.

Lectures and Practical Sessions

The presence of a competent diving doctor is undoubtedly reassuring on isolated work expeditions. The psychological benefits are enhanced by an active role in relevant theoretical and practical sessions.

Future Directions in Scientific Diving Training

The requirement for careful diver selection and training in scientific diving is established. Efforts by the Working Group on Scientific Diving and standards such as the UNESCO Code of Practice for Scientific Diving support this. Standardised training courses will further improve safety standards and working ability, with the training procedures themselves exerting a strong selective force on candidates. Apart from medical aspects the principal disqualifying factors on candidates on an intensive course such as that conducted by Sci Dive, are psychological and physical. Only through experiencing what it is like to work in the subsea environment at first hand can the potential scientific diver be ultimately and correctly selected. On this pioneering course, all of the candidates completed the theoretical and practical assessments to a high standard. From advanced divers they have progressed to a level that would make each of them a valuable asset to future scientific diving expeditions. Application has been made to CMAS in the real hope that appropriate recognition of their achievement can follow, i.e. the CMAS Scientific Diver Qualification. The course itself was a model from which others may develop.

As no program can cover all situations, it is important that all scientific divers maintain a detailed, validated, up-to-date log book. This should include data concerning the divers training and qualifications, dives and medical checks, details of equipment used, environments worked in and techniques performed. This would facilitate diver selection by expedition leaders and divemasters.

Australian divers are at the forefront in many areas of underwater scientific endeavour. With further education and acceptance of a valid set of standards, we can build on these beginnings. Future training courses, such as this one, will further promote diver safety and productivity. For the diving doctor, this arena provides a unique and rewarding opportunity to be actively involved in the field with many research possibilities.

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