In 1993, the NOAA Undersea Research Center at the University of North Carolina Wilmington (NURC/UNCW) began exploring the possibility of offering a technical diving program to visiting investigators for scientific research applications. The need for a technical diving capability was realized after a review of the attempts by the NOAA Diving Program (NDP) to support deep, mixed gas diving operations for a team of underwater archaeologists and scientific divers exploring the USS Monitor. The discovery of the wreck of USS Monitor established the first designated National Marine Sanctuary by NOAA and lies at a depth 240 fsw. Access to this site is considered by some beyond the reach of conventional, open-circuit compressed air scuba diving techniques. The review of this initial NOAA tethered, scuba diving effort lead NURC/UNCW to establishing a new diving program to support the scientific community wanting to conduct in-situ research beyond a depth of 130 fsw while safely exceeding the no-decompression limits using specialized techniques and equipment. NURC/UNCW currently possesses an in-house capability of supporting scientific research diving up to 300 fsw using untethered, open-circuit scuba technology. Each year NURC/UNCW supports at least one technical diving operation.

Introduction

The NOAA Undersea Research Center at the University of North Carolina Wilmington (NURC/UNCW) is one of the East Coast Centers funded by a grant from the National Oceanic and Atmospheric Administration’s National Undersea Research Program (NURP) to support undersea research using divers, ROVs, submersibles and an undersea habitat. As a diving technology leader in the scientific diving community, the Center at UNCW constantly strives for ways to make scientific diving safer, more productive, and cost-effective. After an initial attempt by the NOAA Diving Program to conduct in-situ research at the USS Monitor deep-water archaeological site, NURC/UNCW began a planned progression towards developing an in-house capability to
support technical diving operations, with the notion that advanced diving technology could be applied to other forms of marine science investigations.

Prior to 1993, the NOAA Diving Program had limited diving involvement on the USS Monitor. In that same year, NDP attempted to use a Class II, open-bottom bell and position a research vessel overhead in a 4-point moor for staging facilities and a recompression chamber to conduct the planned dives to the Monitor. The concept was that the bell would support two tethered, open circuit scuba divers and allow decompression to be conducted in the water, safely inside the bell. With the ship being held in a fixed, moored position, heavy seas and strong currents prevented dive operations during most of this 17-day expedition. Only three dives were completed. It was reported that divers were hampered by difficulties associated with controlling the bell and umbilicals in unpredictable seas and currents. The conclusion was that the operation was expensive, logistically complex, at times potentially hazardous, and ultimately unproductive. (Dinsmore and Broadwater, 1999). After review of this operation, NURC/UNCW submitted a plan to NDP to obtain a decompression diving capability for visiting investigators. NURC was impressed by its findings of the technical diving community efforts in refining open-circuit, mixed-gas scuba diving techniques, which eventually led both NURC/UNCW and NOAA program divers to request special technical trimix dive training from an outside vendor (Newell, 1995).

Technical Diving

Technical Diving is defined as “the use of advanced and specialized equipment and techniques to enable the diver to gain access to depth, dive time and specific underwater environments more safely than might otherwise be possible” (Palmer, 1994).

Specifically, technical diving occurs beyond a working depth of 130 fsw and incorporates mixed gases, although compressed air is still used operationally up to 150 fsw. The equipment used in technical diving is most always self-contained. Either an open-circuit scuba apparatus or rebreather is worn by the diver. Scuba is preferred by the research community because it is most commonly used for entry-level diving, it is relatively inexpensive, light weight and highly mobile, requires minimal support and maintenance, and is readily available off the shelf (Phoel, 2003).

To view technical diving from the proper perspective, it was developed to avoid having to use air for deep dives (Hamilton and Silverstein, 2000). Helium is added to the breathing mixture to reduce both oxygen percent and nitrogen percent, to help operate within safe oxygen exposure limits, and reduce nitrogen narcosis. This trimix combination, though costly, has numerous advantages for conducting technical diving operations. Dr. Morgan Wells developed a special mix of 18/50 (18% Oxygen/50% Helium – balance nitrogen), which became known as NOAA Trimix I or the “Monitor Mix”. This mix was conceived more for operational flexibility, than for physiological reasons. Filling the cylinder half full of helium and then topping off with Enriched Air Nitrox (NOAA EANx 36), easily prepared the balanced dive gas. Decompression Tables
developed for NOAA by Hamilton Research, Ltd. and were used for subsequent years on NOAA and NURC combined *Monitor* projects (Hamilton, 1993).

**Gaining Experience**

Investigation of the training requirements and components for technical diving was obtained directly from a technical diving leader, Captain Billy Deans of Key West Divers, Inc. Deans was contracted by the *Monitor* National Marine Sanctuary to provide initial dive training for the NOAA Divers and to help support the next NOAA field expedition to the *Monitor* conducted in 1995 (Kesling and Shepard, 1997).

After this first NOAA/NURC expedition in 1995, NURC contracted Benthic Technologies, Inc., a technical dive training agency to get additional NURC staff divers trained and qualified for technical diving and to obtain instructor credentials for its leadership staff to conduct in-house technical diver training and certification programs for future visiting investigators requesting this new technology.

**Equipment**

After initial training efforts commenced, it became apparent for NURC to establish a new dive locker with enhanced diving equipment and capabilities. As the Center gained more experience with field operations, the dive locker was expanded with the necessary equipment to support technical diving. One of the benefits of technical diving is that the diving equipment used is similar to what scientific divers are already familiar with. Though packaged in a new configuration, the equipment consists of double scuba cylinders, redundant two stage scuba regulators and wing-style buoyancy compensators, a back plate with harness, mask, fins and either a wet or dry suit for diver thermal protection. Additionally, small cylinders of either steel or aluminum are configured with a two-stage regulator and carried by the divers. Much of this equipment is obtainable off the shelf. Most diving programs have the capability of maintaining the equipment in-house to keep it in good working order. Divers can also utilize this equipment for other routine dives, like those not requiring decompression or mixed gases to maintain proficiency.

There is an up front investment $3,500 to fully outfit one diver with a complete set of technical diving equipment. NURC helps defray the initial cost for this purchase by the visiting investigator by maintaining a dive equipment inventory for six divers to be used on an as-needed basis, or until such time that the research team can acquire their own personal dive equipment. The equipment is configured and standardized for this research diving team training by NURC. Technical dive equipment is relatively compact and is easily transported to the research sites or loaded aboard research vessels.
NURC also owns fixed and portable gas mixing equipment systems, which help to complement the equipment needed for conducting field operations. This ancillary support equipment and gas mixing systems are much smaller and easier to transport to the dive site than those used for other diving technologies.

**Training Programs**

NURC has helped to establish a community standard for operating these new techniques by contributing to the American Academy of Underwater Sciences’ *Standards for Scientific Diving*, which addresses both decompression diving and mixed gas scuba (AAUS, 2003).

Early in the development phase of technical diving for science, NURC/UNCW was asked by its National Undersea Research Program (NURP) sponsor, to establish operating standards and procedures for this new technology entitled, *Standards and Procedures for the use of Technical Diving in Scientific Research* (NURC, 2004). These minimal operational guidelines and training standards cover a 10-day training progression with 13 open-water training dives. This training progression is a relatively short investment of time for the candidate. The training document and outline was modeled after the Standards and Procedures established by IANTD, USA and uses their course materials (IANTD, 2003).

The NURC training program was designed different from that of the recreational training agencies, as a progressive course moving logically from start to finish, with skills building upon themselves and incorporating all aspects of the four IANTD required course modules, thus reducing the repetition of information. Prerequisites for participants considering this training include:

- Certified to dive scuba;
- Current scientific diving medical examination;
- Enriched Air Nitrox certification;
- Authorization to dive through reciprocity or as a temporary diver with current CPR, first aid and oxygen administration certifications;
- Log book with 200 logged dives with a min. of 30 deeper than 90 fsw; and,
- 25 logged dive between 140 fsw and 200 fsw or demonstration of sufficient experience for technical diving.

Training costs are based at roughly $1,500 per diver for the 10-day program. Additional costs incurred by the participants are travel, per diem, lodging, vessel charter, fuel, compressed gases for diving (helium, oxygen and EANx).

NURC has found that once the dive team is trained, technical diving operations become a fairly reliable system. The major key to success is ensuring that the divers maintain proficiency of their newly acquired diving skills. It is relatively easy to
maintain proficiency by using the same diving equipment and configuration for other diving missions. Another key to success is maintaining good physical conditioning by the divers due to the rigors of the extreme environment and the bulk of the diver’s dress.

**Operational Support**

Technical diving allows for greater flexibility when planning dive operations. Once dive team members are identified and training has been completed, then development of a detailed operations plan is formulated outlining both operational and contingency procedures for conducting the mission’s field work. Technical diving can be adapted to many operational scenarios. The content of the operational plan includes an overview of the specific science objectives and lists the cruise participants, roles, and qualifications. The type of diving equipment to be utilized and necessary configuration is identified. Decompression strategies are also proposed. Ancillary support equipment is identified and safety procedures are outlined. Normal dive procedures and contingencies dive plans are covered in specific detail. This plan is peer-reviewed and, once approved, controls the conduct of the overall mission, thus keeping a rigid dive standard. Team selection and diver qualifications are important to overall mission success. There is also a large pool of trained users from the scientific diving community that can be called upon and cross-trained for a variety of science-related task and objectives. Additional training and pre-mission workup dives are conducted for all participants as needed. Drawing upon a pool of trained personnel can help satisfy more operational roles such as topside support, in-water safety diver(s) and standby diver(s) on deck.

When using self-contained, untethered scuba for diving there are more deployment platform options to select from. Small dive boats to oceanographic research vessels can be utilized. Since technical diving is usually conducted by free-drop diver deployments under “live boating” conditions, vessels are not restricted in their ability to maneuver. Divers can be deployed up-current, descend, and drift into the study sites, which makes the research sites more attainable, since maximizing bottom time is the greatest priority. The piloting skills of the research vessel captain are critical to this type of deployment and overall success of the mission. Because this type of deployment technique is preferred, diving operations can be conducted under a wide variety of surface and bottom conditions. Depending on team size, a large number of man-hours or divers can be supported. Mobility for the on-bottom divers has been the hallmark of technical diving operations for science.

Ancillary support equipment that may be required is smaller and highly portable (compressors, mixing equipment, DDCs). Breathing gases can be mixed on-site or delivered as “premix” in storage cylinders. Small hyperbaric chambers can be used in lieu of large, multi-place chamber systems. The *Hyperlite*, hyperbaric stretcher, is now a minimum requirement for all NOAA Diving Program decompression dives operating outside of a thirty-minute evacuation time to a facility. (NOAA, 2004).

The key to implementing a technical trimix dive is the ability to perform an efficient and reliable decompression that does not pose a substantial risk of oxygen toxicity.
Decompression planning and contingencies are handled by either consulting printed dive tables, dive planning software programs, or the use of diver-worn dive computers. Decompression procedures are planned ahead of time and primary and secondary decompression schedules are prepared and carried by the diver. The use of multi-gas, multi-mode decompression computers has provided far greater flexibility for conducting diving operations than printed schedules.

Field Operations

Before commencing a dive, the entire field operations team is briefed. Divers are dropped on the research site and begin the bottom phase of the dive. After the bottom phase of the dive, the team remains together and begins an ascent incorporating deep stops into the dive schedule either from published table or the use of a diver-worn decompression computer. In-water safety diver(s) are deployed and escort the team throughout the remaining decompression with gas switches to intermediate or primary hyperoxic breathing mixes, depending on depth. The in-water safety diver(s) are prepared to respond to contingencies of the dive team like low, or loss of, decompression gases. When reaching the 20 fsw stop divers switch to 100% oxygen and are monitored for oxygen toxicity by the in-water safety diver(s). In some cases, oxygen is delivered via a surface-supplied regulator system. Once all required decompression is completed, divers surface and are recovered from the water. Back on deck, the diver team is thoroughly debriefed and alternate plans or improvements to the dive operations are discussed.

Statistics

Table 1 lists NURC/UNCW supported decompression/technical dives from August 24, 1994 to November 10, 2005.

| Total Dives | 2,376 |
| Max. Depth | 283 feet |
| Average Depth | 173 feet |
| Max. Deco Duration | 162 mins. |
| Average Deco Duration | 51 mins. |
| Max. Bottom Time | 40 mins. |
| Average Bottom Time | 23 mins. |

From this exposure dataset there have been three reported cases of decompression illness. One case incurring lymphatic bends and the other two cases involving Type II decompression sickness with vestibular involvement. One DCS II case developed as a result of using published decompression schedules while the other occurred from a diver-
worn decompression computer real-time profile. All three cases were eventually treated with recompression therapy.

Summary

Today, a technical diving capability is available to the marine science community from NURC/UNCW. The NURC Diving Program has established itself as a leader in technical diving for marine science research applications. NURC has the ability to support extended field diving operations and maintains an in-house infrastructure to handle gas mixing and cylinder filling, vessel operations, and personnel accommodations. It has a dive staff with expertise in technical diving that can serve as vessel captains, diving medical support, research divers, and dive station supervisors. Essentially, NURC offers a turn-key advanced diving operation to visiting investigators. The NURC model for safe conduct of technical diving can be applied to most marine science research projects where extended depth ranges and prolonged decompression is a consideration. The use of untethered, open-circuit mixed gas scuba diving operations has proven to be a productive tool for enabling scientists to reach depth ranges from 130 fsw up to 300 fsw.

Acknowledgements

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References


