The Journal of Global Underwater Explorers

Quest

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Nohoch Pek: Adventures in Exploration • Equipment Considerations in Deep Post-Siphon Diving • Memorization Techniques: An Unlikely Tool Benefits Diving • Are Rebreathers For You? • Teaching an Old Dog New Tricks

Letter from the Editor

Over the years, GUE instructors have asked me for input on the following challenge confronting them in a class setting. They had students who, though had proven proficient in both the theoretical and practical skills components of the class, displayed character traits that the instructor found disturbing. In one particular case, the instructor found the individual to be argumentative, dismissive, degrading of his classmates, unconscious of his own limitations, and harboring near-future diving goals inconsistent with his training and experience. In other words, in the mind of this experienced diver and instructor, this neophyte was at greater-than-normal risk of injury (or worse) as a result of his *character*. Though the student had seemingly fulfilled what the instructor believed to be the course "objectives," the instructor still did not feel comfortable certifying him for the diving he was about to undertake, believing that his character bode badly for his future safety and that of his teammates. His question to me then was, "Do you think it inappropriate for me not to certify him on the grounds of something as intangible as character? Clearly my assessment of his character is utterly subjective, unlike his ability to maintain good buoyancy and trim, perform decompression, run a reel, navigate a cave, etc." My answer was that it was not, and that evaluations of character, however amorphously constituted, were perhaps even more vital to the cultivation of safe divers than the skill proficiency that we have worked to quantify. I have given this answer to every instructor who has asked me for guidance on an analogous situation.

My reasons for this position follow Aristotle's. Aristotle saw character as the background framing a person's repertoire of actions; for him our characters are a result of habituations: repeated actions that yield the outcomes we desire. If an action fails to produce the outcome we desire (or worse, produces the opposite outcome), it is less likely that it will be repeated, sediment as a habit, and become formative of our character. Conversely, if an action does produce the outcome we seek, and is relied upon often with similar results, it will sediment into habit, and then into character. Once a part of our character, ways of dealing with the world are difficult (if not impossible) to change, as they require a virtual undoing of the self. This is because they are "us;" they are the cemented experience of our engagement in the world and the solutions we have successfully given to the problems we encountered there. To change our character requires a painstaking process of repeated actions that fly in the face of earlier habituation and are continued long (and systematically) enough to become first habits, and then a dimension of character. That is why it is difficult for cheaters to stop cheating, liars to stop lying, the disorganized to become organized, the inconsiderate to be considerate, etc. In large part, each person's character provides the condition of possibility of actions performed by that person.

I recognize that this view of character runs against the view that sees behavior as linked to an act of will—that we can will ourselves to do anything at any time, and as long as our will is firm, then we can change from one day to the next. This view has never made sense to me, theoretically or practically. There is too much empirical research that contradicts it, and I am not at all sure how to even begin to grasp agency unmediated by the world. In any case, this is not the issue here.

Under this conception of personhood, assessing a diver's character is critical when considering whether or not to certify a diver, however intuitive or contextual this assessment may be. This is because whatever skill a given diver possesses will always be set against, and at the service of, a given set of ingrained character-traits that the individual is unlikely to change. If one is of combative, narcissistic or reckless character, no manner how much finesse s/he possesses in the water, chances are that this will not be put to optimal use and thus raise the risk of harm to oneself and others. As a result, it is imperative that the instructor who tacitly testifies to that individual's competency and safety in the water not shy away from making a judgment as to that diver's character, and see this as one of the more important evaluations s/he will make about that individual's suitability for the diving for which s/he is being trained. We should understand that such a judgment, which should be shared freely with the diver in question, will not have the support of the kind of evidence supplied by a video camera; rather, it will be subtly shaped by moral intuition over the course of multiple interactions with the individual in his or her exchanges with the world.

Safe diving,

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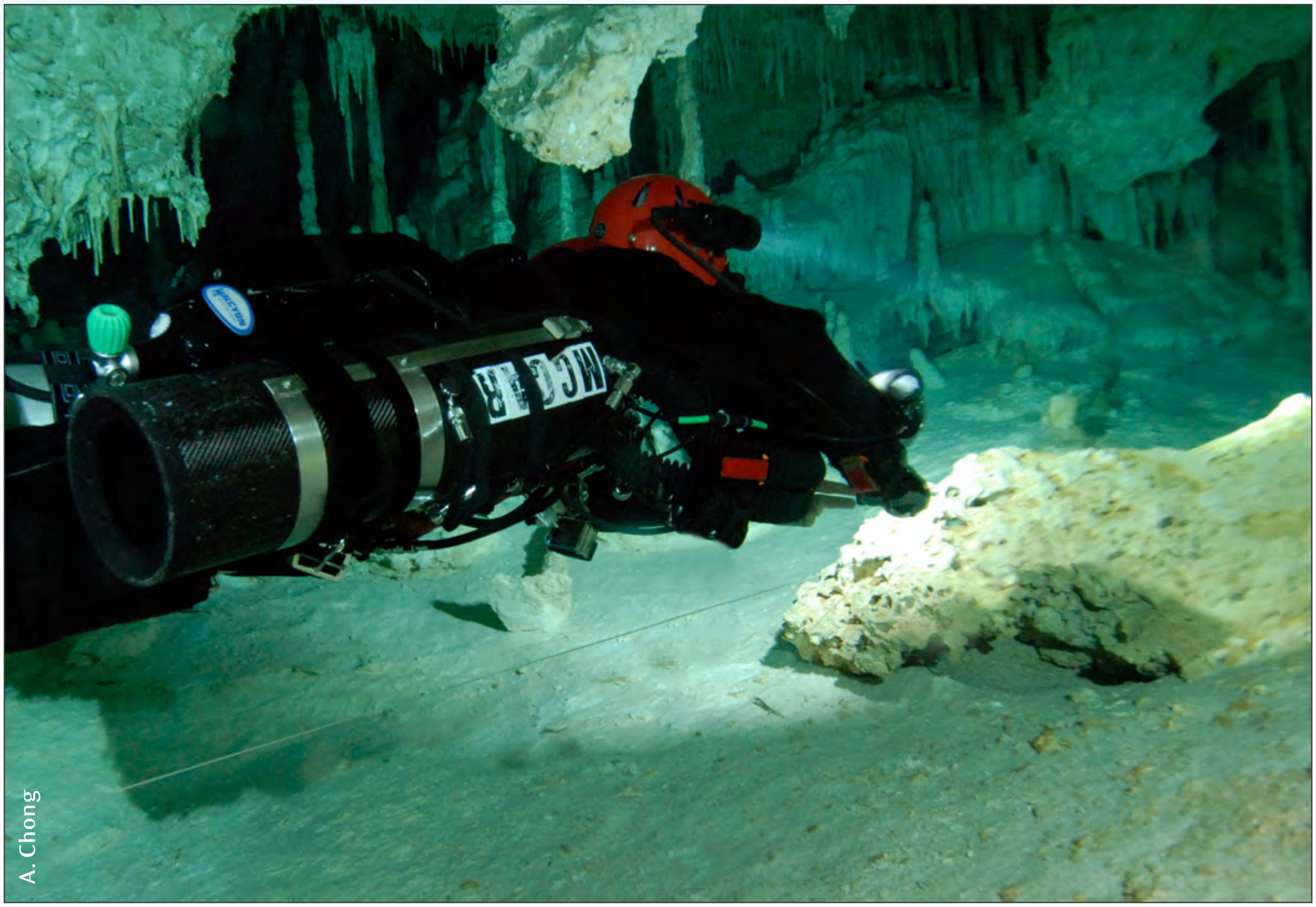
Choosing a Closed-Circuit Rebreather

By Tom McCarthy


A. Chong

Tom McCarthy enjoying a cave dive in a sidemount rebreather

THIS article is intended as a primer for those who are considering diving a rebreather. The decision to dive and potentially purchase a rebreather requires a broad and pragmatic approach. As such, this article is not intended to be your only source of information when making this decision, but rather should be construed as a jumping-off point from which to begin your research.

GENERAL OVERVIEW

What is a rebreather? At its core, a rebreather removes CO_2 and adds oxygen to replace what your body metabolizes in the normal course of diving. A rebreather in its simplest form is a flexible container with a mouthpiece that will allow you to inhale and exhale essentially the same volume of gas. A rebreather must also have a way to move the gas in a constant direction and add more gas to the system (the "loop," in rebreather jargon) as we go deeper and/or metabolize oxygen.

OXYGEN REBREATHERS

Oxygen rebreathers are the simplest rebreather. These units are mainly used for military operations as they are portable and simple to operate.

This unit essentially adds pure oxygen whenever the volume of gas in the loop becomes smaller than the volume required by your lungs. The decrease in loop volume can be primarily attributed to two causes: depth compression and normal metabolism. As such, most oxygen rebreathers have a mechanical function to automatically add oxygen whenever the loop volume hits a certain level.

The one major limitation, however, is that these units cannot be used deeper than 20 feet because the only gas source is pure oxygen. Hence, the oxygen rebreather is all but useless for most divers due to its considerable depth limitations.

SEMI-CLOSED-CIRCUIT REBREATHERS

Since the oxygen depth limit is a limiting factor in an oxygen rebreather, one may ask why we can't simply replace the oxygen bottle with a gas that can be used at deeper depths. Ok, so let's say we pop a bottle of nitrox in an oxygen rebreather.

"First breath, doing great. Few more breaths. The rebreather adds nitrox automatically as loop volume falls. That should be good. Few more, it fired again. Few more, it fired again... Few……… (thud)."

So, what just happened? We blacked out due to a lack of oxygen. The one crucial difference between the oxygen rebreather and this new nitrox rebreather is the nitrogen, which is an inert gas. As our body metabolized the oxygen, the gas volume in the loop fell, which in turn activated the addition of more nitrox (with more nitrogen). This will keep happening as our body burns the oxygen and we exhale the unused nitrogen back into the loop. Eventually, we will reach a point where the loop's oxygen level is too low to sustain consciousness. So, how can we fix this problem? We need to remove some of the nitrogen and replace it with oxygen. The only way to remove an inert gas using nitrox, however, is to forcefully purge it from the loop. This is why we call this a semi-closed-circuit rebreather (SCR).

There are two different ways to purge gas in a SCR. The first option is to continuously flow fresh nitrox through some sort of orifice, much like running a garden hose in a bucket. This causes a small amount of inert gas to continuously overflow from the system. The downside of this method is that this does not adjust to your body's oxygen metabolism rate so we may be wasting gas needlessly.

The second alternative, a passive SCR (PSCR), is a bit more complex but helps reduce this problem. The Halcyon RB80 is an example of this system. The loop, through a system of small bellows (which are shaped like an accordion), vents a small portion of every exhaled breath and adds back the lost loop volume using an automatic valve. This system is very simple to operate, and we now have a wonderful gas extender which is generally around eight times more efficient than normal open-circuit scuba based on the volume of gas that is used. Assuming that we only have gases that are breathable at our current depth plumbed into the system, this gives us the benefit of generally knowing our loop contents and eliminates the need for electronic gas monitoring systems.

However, SCRs present a few drawbacks since they can only extend a predetermined gas mix. As such, they require more complex dive planning, especially when diving in remote areas. SCRs require divers to bring and use multiple gases on complex dives. Thus, divers will need access to filling equipment and large volumes of gas in order to complete the mission at hand. This can be especially difficult when dives are conducted on small vessels at sea or in remote regions with limited access to diving gases or filling equipment. Enter the CCR.

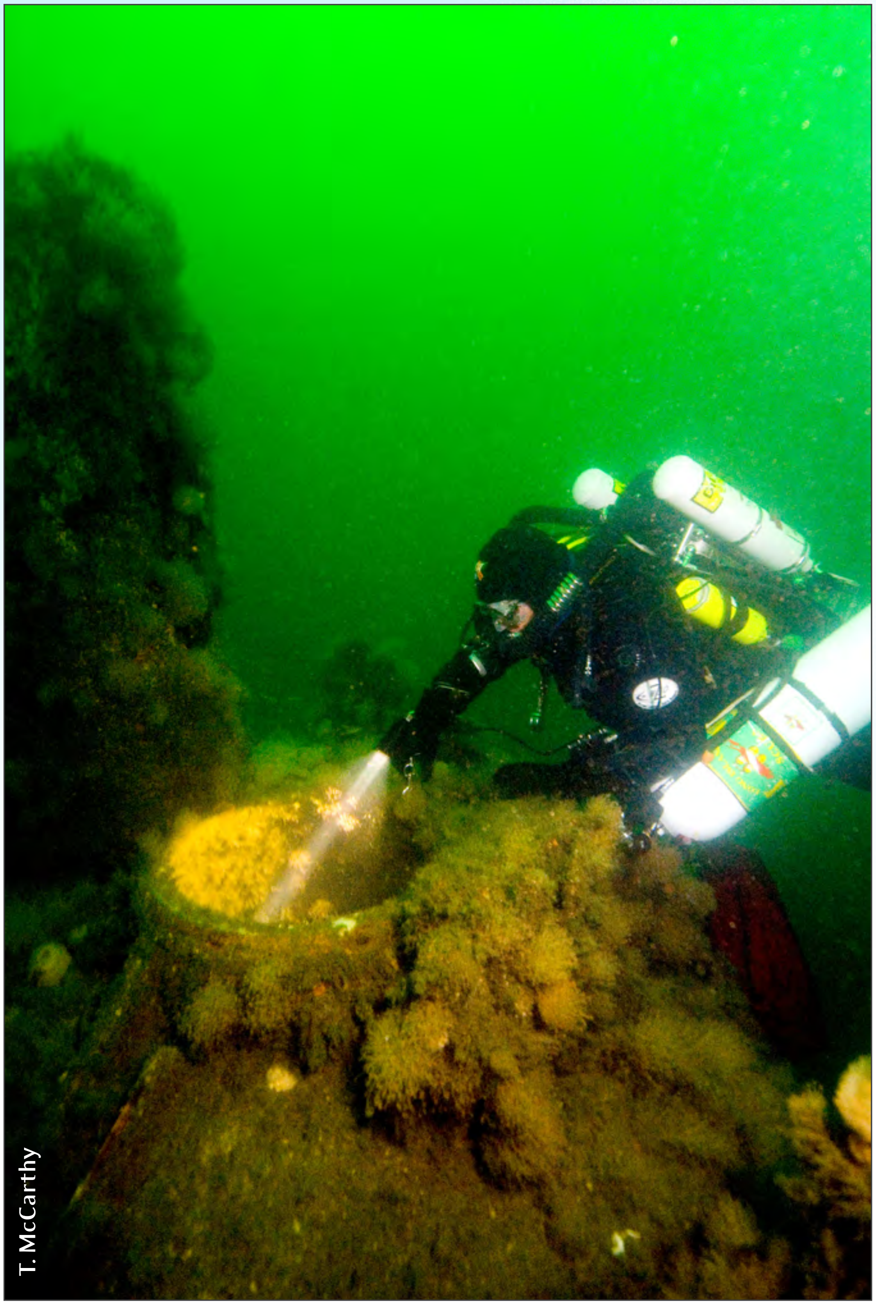
CLOSED-CIRCUIT REBREATHERS

The closed-circuit rebreather (CCR), unlike its semi-closed cousin, has several distinct advantages since this unit is essentially a portable mixing station on your back. In normal dive operations, we may only need to fill two small rebreather cylinders. One cylinder is filled with oxygen and the other cylinder is filled with a bottom mix commonly called a diluent (such as air, trimix, or heliox). This can dramatically simplify logistics, as it reduces the gas needed on all dives, whether they are simple recreational dives or challenging expeditions. The only time we would need to refill large cylinders would be in the event of a rebreather failure where open-circuit bailout gas was used. CCR also provides convenience to divers who may conduct dives to various depths on a regular basis. A CCR diver may have multiple standard bailout gases filled and ready but may rarely need to refill them. It's not unusual for a CCR diver to use the same bailout cylinders for an entire dive season without ever needing to fill it.

So, why is it that we need such little gas with CCRs? This can be attributed to one critical factor: the ability to use pure oxygen. While SCRs must vent a portion of the loop gas in order to raise oxygen levels, CCRs use a designated cylinder filled with 100% oxygen to make up for the amount that is metabolized by the body. In normal operations and at constant depth, no gas is ever vented from the system (hence the name closed-circuit). Every CCR operates under this same principle. However, the way in which the oxygen is delivered into the loop can vary greatly.

ELECTRONICS

In contrast to SCRs, a common concern with all types of CCRs is the possibility for the oxygen levels in the loop to fluctuate to dangerously high or low levels. Therefore, we need the ability to monitor our pO_2 via an electronic monitoring system. These monitoring systems generally function the same way—by utilizing consumable oxygen sensors similar to any nitrox analyzer. Due to constant technological changes, this article will not go into specific models of pO_2 monitors; however, in



Diver on an ECCR exploring the remains of the U-853

short, a pO_2 monitor is simply a voltmeter that displays sensor voltage output, which is then translated into pO_2.

In order to evaluate the various choices for electronics, it is important to select an established and reliable system. The best way to assess the different options is to poll the rebreather diving community at large and collect anecdotal evidence.

Electronics are the most fluid component of the rebreather, and future innovations – from quality CO_2 monitors to significantly improved oxygen sensors – could very well just be around the corner. We've already witnessed fantastic innovations such as real time scrubber prediction systems and early CO_2 sensors. Who knows what the future will hold for rebreathers?

Now, let's take a closer look into the three main functional distinctions of CCRs commonly found in today's market.

MANUAL CLOSED-CIRCUIT REBREATHER (MCCR)

The first and simplest type of CCR is the manual closed-circuit rebreather (MCCR). The MCCR, like all CCRs, has a diluent cylinder and an oxygen cylinder. The oxygen needed to maintain pO_2 is added in two ways: (1) manually, when the user presses a button (similar to a BC inflator), and (2) automatically, through a small orifice where the oxygen is able to trickle in constantly.

Before delving into the second method, it is important to note that the human body generally needs the same number of oxygen molecules regardless of depth. This means that your body will metabolize the same number of oxygen molecules whether you are at the surface or at 300 feet when adjusted for the same amount of activity. The beauty of CCRs is that once you reach your targeted depth, you only need to add a small amount of oxygen to replace what you metabolize; this significantly reduces the volume of gas you would otherwise need when compared to open-circuit scuba or even SCRs.

The constant trickle of gas in a MCCR, otherwise known as constant mass flow (CMF), basically means that the same number of oxygen molecules is allowed to flow into the system rather than the same volume. (The physics behind this are actually quite interesting and worth reading about.) This is achieved by replacing the rubber environmental seal on a first stage regulator with a non-flexible metal disc. This prevents the first stage from compensating for depth and thus the intermediate pressure is kept at a constant pressure. If we were to use a normal regulator which raises the intermediate pressure output at deeper depths, this would result in increasing amounts of oxygen molecules being added into the loop as we descend. However, the modified regulator allows a small trickle of oxygen to flow at a rate that is just slightly lower than the average metabolic rate while at rest. This prevents the pO_2 from creeping up due to too much oxygen. Furthermore, the CMF rate can be manually adjusted by the diver between dives by changing the intermediate pressure of the regulator.

The two oxygen delivery mechanisms in a MCCR provide the diver with complete control over maintaining a given pO_2 but reduce the frequency with which the diver needs to manually inject oxygen throughout the dive. However, the downside of this system is that there is now a depth limit on the rebreather due to the fixed intermediate pressure. Given that the intermediate pressure of the first stage is fixed at about 10 bar, when a diver approaches the equivalent ambient water pressure, the flow of oxygen will decrease. That's not to say that these units cannot be dived deeper. Some have been dived well in excess of 600 feet (185 meters). However, new techniques are needed to safely achieve these depths.

There is also an uncommon type of MCCR worth mentioning. This MCCR uses a normal depth-compensating first stage regulator and an adjustable needle valve in order to control the flow of oxygen into the loop. This requires the user to constantly monitor the rate at which their pO_2 is falling or rising and adjust the valve accordingly. This system, however, removes the depth limitations set by a fixed 1-atmosphere regulator system.

ECCR divers tour the Hydro Atlantic *wreck*

ELECTRONIC CLOSED-CIRCUIT REBREATHER (ECCR)

Next, we have the electronic closed-circuit rebreather (ECCR). The oxygen injection method in ECCRs is a bit more complex than that of MCCRs as it relies on a computer to add oxygen. In other words, the electronics in the rebreather constantly monitor the pO_2 levels of the loop and add oxygen via an oxygen solenoid (which effectively acts like an oxygen dam or gate). The ECCR essentially does the same thing an MCCR does, but it does so hands-free. Think of this as cruise control. Like cruise control, however, we cannot just lean back and take a nap while the system handles everything. An ECCR must be monitored just as closely as any other rebreather. The potential for high or low pO_2 is ever present and the diver must remain diligent. The addition of a solenoid also adds one more potential failure point since it may add too much or too little oxygen into the loop.

HYBRID CLOSED-CIRCUIT REBREATHER (HCCR)

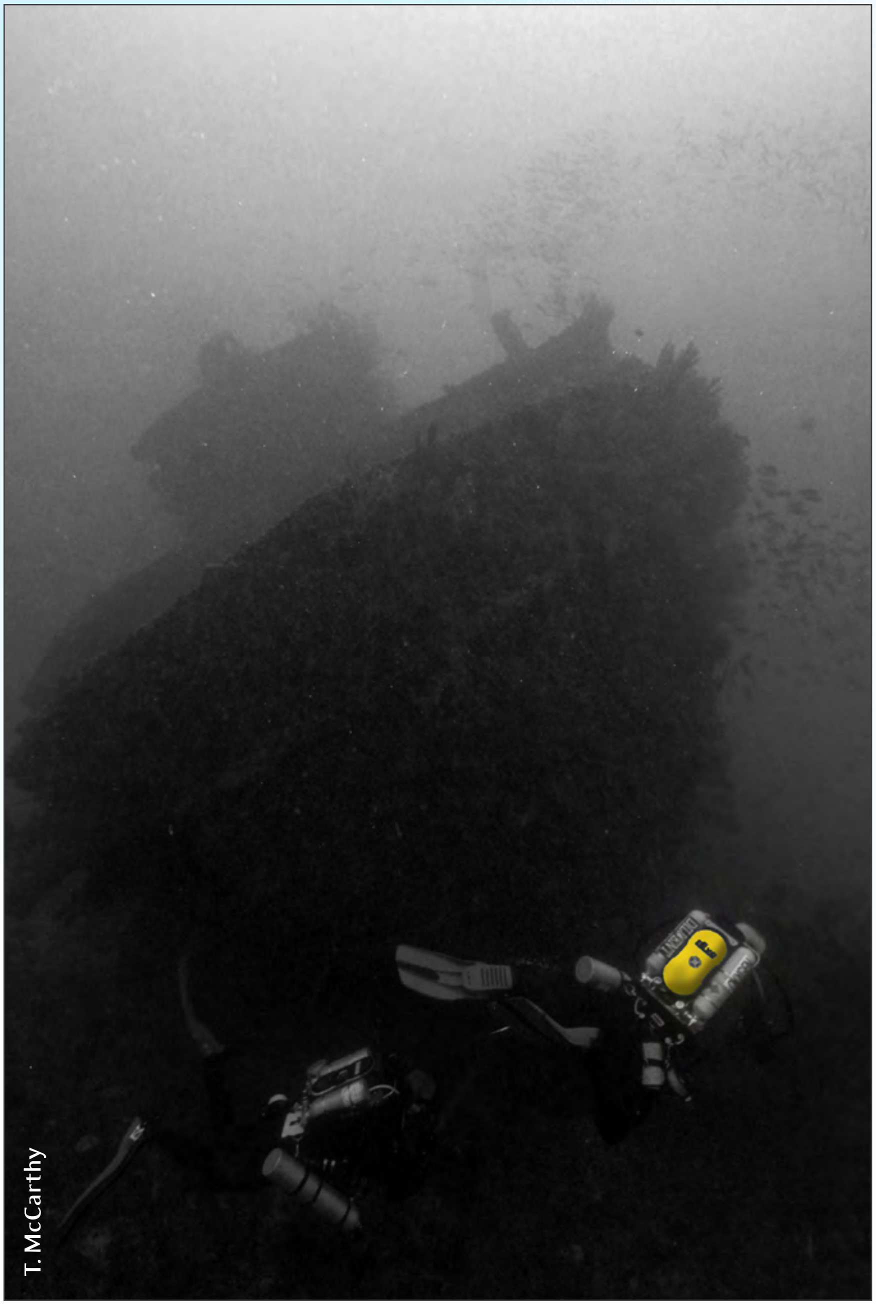
The final type of rebreather is referred to as the hybrid closed-circuit rebreather (HCCR), which is a hybrid between MCCR and ECCR. They utilize both the CMF orifice and the oxygen solenoid to maintain pO_2 levels. Many divers operate these units manually while using the ECCR solenoid as a backup (or parachute) should the diver fail to maintain a sufficiently high pO_2.

COUNTERLUNGS

The next feature to consider when deciding between CCR models is the positioning of the counterlungs. This feature can be highly polarizing for CCR divers, but I'll offer the stated advantages and disadvantages from both sides.

Front-Mounted Counterlungs

The front-mounted counterlung system has been around for a long time. The system has several advantages. The first is flood tolerance. Front-mounted counterlungs, when designed properly,



In bubble-free silence, wrecks take on an even greater atmospheric quality.

will allow a significant amount of water to be trapped within it before water is able to make its way to any of the critical systems of the rebreather (such as the scrubber canister or the oxygen sensors). Most units will have a dump valve located on the counterlung that allows the user to over-pressurize the loop and force water out of the system. This can be a great option in the event that water enters the mouthpiece, or dive/surface valve (DSV). However, some will argue that this is human error and any diver who accidentally lets water in through the DSV (whether it happens before or during the dive) should call the dive and take the unit apart to ensure that water hasn't entered critical areas of the loop. I agree with this view. Any rebreather diver who continues to stay on the loop while having an unknown flooding issue is asking for trouble. A failed O-ring or other sealing system doesn't generally fix itself, and the idea of staying on a sinking ship that is taking on water while you have another option is not advisable.

Another common complaint is that front-mounted counterlungs result in a cluttered chest, which in turn reduces maneuverability and access to chest D-rings. As someone who has trained on and dived a front-mounted counterlung unit for many years, I have to agree with this view. It can, at times, be more difficult.

Let's focus on the positive now. One of the major advantages of front-mounted counterlungs is the work of breathing (WOB), and at one point, this was certainly the case. It is much easier to design a low work of breathing unit with front-mounted counterlungs than it is to achieve the same work of breathing for a back-mounted unit. This is because of hydrostatic pressure. Positioning the counterlungs on the chest means that the diver has an easier time inhaling from the loop but has a more difficult time exhaling from the loop. Human beings are generally better at exhaling than inhaling, which is why musical instruments produce sound through exhalation. However, while it was generally the case that front-mounted counterlungs provided better work of breathing for quite some time, it is no longer the case and it is now more important to look at a manufacturer's work of breathing testing data. Some back-mounted counterlungs units breathe better than some front-mounted counterlung units and vice versa.

Back-Mounted Counterlungs

Back-mounted counterlung rebreathers provide the advantage of an uncluttered chest area which allows for better maneuverability and streamlining. In the past, back-mounted counterlung units had a higher work of breathing when compared to most front-mounted units. However, with improved designs, we cannot unequivocally state this to be true anymore. One of the arguments that some front-mount users will make is that having the counterlung on the back reduces flood tolerance. Some units will make up for this with dump valves located strategically on the counterlungs, and others have small water traps that are intended to collect water before it enters critical areas. Again, while flood tolerance may allow a user to stay on a failed rebreather as a last ditch effort, I believe it is more important to focus on proper bailout gas planning, which allows users of both systems to safely surface from a dive in the event of any doubts produced from flooding.

Top-of-Shoulder Counterlungs

Recently, some manufacturers have started to produce top-of-shoulder counterlungs as a middle ground between the two aforementioned options. They provide an uncluttered chest while keeping some of the flood tolerance and work of breathing properties of front-mounted lungs. I've heard mixed results about these (as with every design). Some people love this feature, while others claim that they greatly restrict head movement. Either way, it's worth mentioning, as it provides one more option to the market.

SIDEMOUNT REBREATHERS

With the ever-growing trend of sidemount diving, the use of sidemount rebreathers should be mentioned. Traditionally, sidemount rebreathers have been a fringe section of the rebreather community, mostly in the form of quasi-homebuilt units. More recently, however, models such as the SF2, Flex, and Sidekick have taken sidemount rebreathers into mainstream production. While sidemount rebreathers can be an excellent tool to accomplish some truly remarkable dives, they are hardly for everyone. They can be notoriously difficult to dive, and they present a slew of new configuration and technique concerns that, in my opinion, should only really be attempted by those who have learned to dive closed-circuit on a backmount unit first. Changes in trim while passing through vertical restrictions can have greater influences on breathing resistance by way of hydrostatic loading—a concern that may cause an inexperienced rebreather diver to panic or handle the situation poorly.

SCRUBBER TYPE: AXIAL VS. RADIAL

Axial Scrubbers

If you had a soup can, removed both the top and bottom, and blew straight through it, you have essentially duplicated the design of an axial scrubber. In an axial scrubber, gas enters through one end of a tube-shaped container and exits the other. The advantage of an axial scrubber is that it is generally easier to pack the scrubber material. Axial scrubbers reduce the chances of CO_2 coming out un-scrubbed, since the exhaled CO_2 needs to travel the full height of the scrubber canister. Furthermore, the probabilities of having empty pockets or channels within the absorbent material that run the entire height of the scrubber are low. While proper scrubber handling procedures will eliminate this issue regardless of the canister, it is still a valid consideration for most. Axial scrubbers are generally considered more than acceptable for the vast majority of diving and have been utilized in some of the most extreme exploration-level projects. That said, axial scrubbers have a limit to how large they can be before breathing resistance becomes an issue due to the long path that the gas needs to travel. This is where radial scrubbers come in.

Radial Scrubbers

Radial style scrubbers are different from axial scrubbers in that gas travels through the sides. Let's go back to the can analogy; instead of the gas traveling from top to bottom in an axial design, a radial design means that the gas will either flow in or out horizontally through small holes in the sides of the can. There is also a hollow tube that runs down the entire center of the scrubber which allows for gas to flow from either the outside to the inside, or from inside to outside (different units use different paths but they essentially function the same way). The advantage and disadvantage of this is that it reduces the cross section of CO_2 absorbent material through which the gas must pass. On one hand, this allows us to use larger scrubbers that have better work of breathing than the same size of an axial scrubber. On the other hand, radial scrubbers are often more difficult to pack correctly, and the reduced cross section of absorbent potentially increases the chance of channeling. Again, through proper scrubber handling and packing this risk is generally minimized.

SCRUBBER MONITORING SYSTEMS

As a side note, some rebreather manufacturers have implemented real-time scrubber monitoring systems into their units. These systems generally operate via temperature probes that are located within the scrubber canister (or canisters, in some units). As we continue to use scrubber material, the absorbent itself produces heat through an exothermic reaction. The temperature probes read this change and determine how long the scrubber material may last based on where the exothermic reaction is taking place within the canister. Some systems simply display an illustration on a dive computer that shows how far this temperature change has progressed within the scrubber material. Other advanced systems actually use several points of data, including the rate of temperature change, depth, water temperature, diver's body weight, and past testing data, to extrapolate the remaining scrubber duration in real time. This generally allows divers to significantly extend dive times versus the standard factory suggested maximum scrubber durations, since the maximum time suggested by the manufacturers are conservative estimates based on very extreme testing scenarios that are generally not reproduced in actual diving situations.

Some manufacturers have multiple scrubber options available. When choosing a scrubber design, it is important to look at the manufacturer durations and compare it against your intended needs. People quite often choose scrubbers much larger than they need and may regret the choice later.

DSV VS. BOV

One more choice commonly found on rebreathers is whether to use a dive/surface valve (DSV) or bailout valve (BOV). When a diver wants to remove the mouthpiece of the rebreather underwater, it is necessary to close the mouthpiece from which we are breathing; otherwise the unit will flood. This generally is done by moving a lever or valve on the assembly itself. On a DSV, closing the mouthpiece seals the rebreather and requires the diver to use an alternate breathing source or open the mouthpiece and get back onto the loop. On a BOV, however, closing the rebreather opening now allows the diver to breathe open-circuit gas from the same mouthpiece without ever having to remove it from your mouth. BOVs can be a wonderful addition to any rebreather by reducing the time it takes to switch to open-circuit gas. However, the downside to a BOV is that additional gas plumbing, if designed poorly, can mean more potential failure points. Moreover, BOVs often have higher work of breathing compared to standard DSVs and traditional open-circuit regulators. Furthermore, BOVs will not help you in the event of a caustic cocktail (the accidental inhalation of highly basic, absorbent-infused water, which will produce chemical burns in your mouth). Just like all other features on a rebreather, we have to weigh the pros and cons against each other.

COMMUNITY

Regardless of which unit you chose, I believe that one of the biggest considerations when choosing a new rebreather is your adjacent diving community. The benefits of having access to team members and mentors who dive the same rebreather model cannot be overstated. They will be there for you when you need help, they will be your spare parts store, and they will be there to teach you the little tricks and tips that can only be gained through experience. Rebreather training is merely a stepping stone towards becoming a truly proficient CCR diver. It is these people who will walk with you on that path.

However, it is also important to note that while most CCRs essentially function the same way, there is very little standardization in the community with regards to gas connections. Thus, this factor should be discussed during the pre-dive briefing before diving with new team members.

MANUFACTURERS

When evaluating various rebreather models, it is also important to choose a unit that is made by an established and reliable rebreather company. Since making a rebreather can be a capital- and intellectually-intensive task, there have been several examples of fly-by-night companies that have stopped offering support for the limited number of rebreathers that they produced.

Additionally, CE certification is considered a great barometer, by some, when assessing rebreathers. The large time and capital expense that is put into completing these tests could prove that a company is committed for the long haul. Furthermore, a CE marking certifies that the unit has met a batch of quality and performance specifications. However, some individuals argue that these tests may actually hinder innovation since the required retesting for every change can be cost-prohibitive.

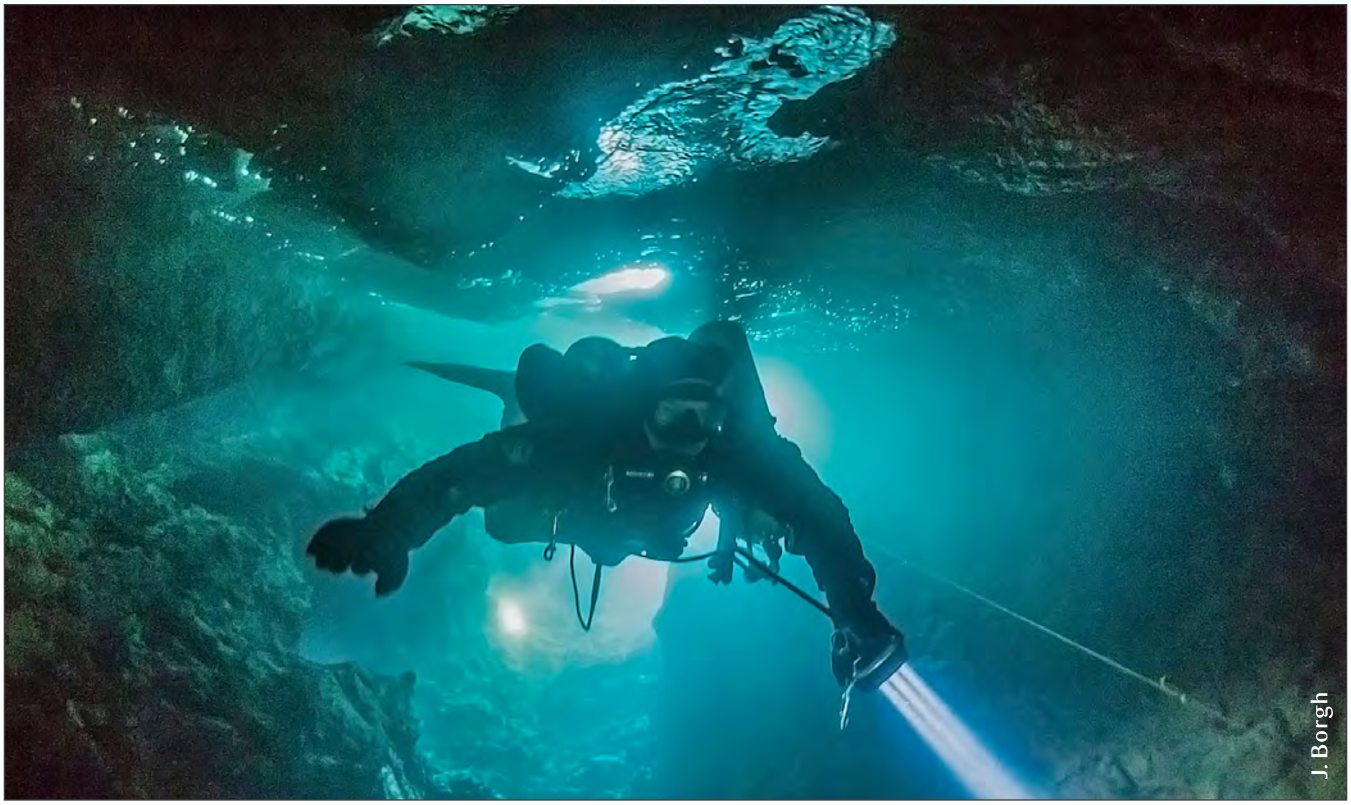
One other consideration when choosing a manufacturer is the proximity of a service center. You should check to make sure that there is at least one domestic or nearby support facility in the event that you ever need repairs. It is both costly and time consuming to ship an entire rebreather overseas to have minor work completed.

CONCLUSION

Overall, it can be quite difficult to choose a new rebreather given the array of factors that need to be taken into consideration. This is particularly amplified when choosing your first rebreather. You don't know what you don't know yet, so you will not be sure of what features you want in a unit until you have developed some experience on one. As such, the best thing you can do is to talk to everyone you can—not only instructors, who are financially invested in a specific unit, but everyday end users as well. Every unit will have its strengths and weaknesses but most will function well for the majority of the diving you will do. Once you have a clear idea of how a rebreather may help you accomplish your diving goals, this will also make the process of choosing a specific unit a bit easier. In the end, no matter which unit you choose, remember to always respect the tool at hand and never allow yourself to become complacent. Safe diving!

Majerovo Vrelo: Following One of the World's Cleanest Rivers to Its Source

By JP Bresser



Project Morpheus diver helping to document the sources and dynamics of Croatia's underground rivers

I'm no stranger to Croatia; I have visited this wonderful country for more than 10 years now, mostly in pursuit of exploring the majestic shipwrecks of the Adriatic and (of lesser priority) the cooking skills of my friend, Maurizio Grbac.

The last couple of years Maurizio has drawn me inland, away from the ocean, where a different Croatia unfolded. The coastal region is known for its clear water and Mediterranean lifestyle—an appealing family tourist attraction. Inland Croatia is a different story: the locals by nature and history keep a polite distance from strangers, and the impact of the war is still noticeable, like a healing scar. Landscapes range from rough and mountainous to lush, green settings blossoming around huge lakes and waterfalls. I quickly learned to appreciate this different side of Croatia, and specifically what the inland has to offer: fresh water, and tons of it.

Diving conditions during the project were challenging, but project divers were up to the task.

Because of the success of the project I organized together with Maurizio in the Cetina region under the umbrella of the Project Morpheus Initiative in 2014, I jumped to the occasion when Maurizio talked about a new location where multiple springs create one of the cleanest rivers in the world, a river called Gacka.

My idea was to use this opportunity to fulfill the many requests I receive from GUE divers eager to take their first steps in the world of project diving but finding it hard to kick start their dreams, as most global projects prefer some kind of experience. Why not use this project as an occasion for development and to coach participants while working together as a team to reach a set of common objectives?

In the fall of 2015, a European team consisting of GUE divers from the Netherlands, Croatia, Sweden, Germany, Belgium, Czech Republic, Switzerland, and Italy traveled to the beautiful region around Otočac, Croatia, where we all met in our hotel. Together with Maurizio, I began the first briefing, emphasizing the importance of clear and simple objectives, while dictating the flow and structure of the project. Our objectives were simple: create a highly detailed map of the first area of the cave, produce a video documentary on the project and region, clean up garbage in open-water and cave environments, produce a high-resolution panorama photo, collect sediment samples, and film deeper parts of the cave using rebreather technology.

After the initial briefing, small teams formed, each with a team leader. The beauty of working with small teams within a larger group of people is that it streamlines logistics and oversight and creates a clear leadership structure. This system would make my life as a project manager much easier, as each team leader would be responsible for data gathered and the report at the end of every day.

Project Morpheus is not only about cave diving, documenting, surveying, and laying line, but also about grasping the bigger picture of the importance of understanding and preserving the fresh water reserves in Croatia. As the water quality from the springs is generally very good, whole regions rely on them for drinking water. By documenting the sources and dynamics of these underground rivers, we can arm local authorities with priceless data that can help them more efficiently manage and preserve the quality of the water.

Towards that end, members of the team went to Otočac to meet with Marina Legčević, the director of the Water and Sewerage Company, to film an interview with her and get a better understanding about the importance of fresh water in this region.

She explains: *We are located at the most important spring of the river Gacka, called Tonković Vrilo. The company provides water to the Otočac area, Vrhovina county, and parts of the town Senj.*

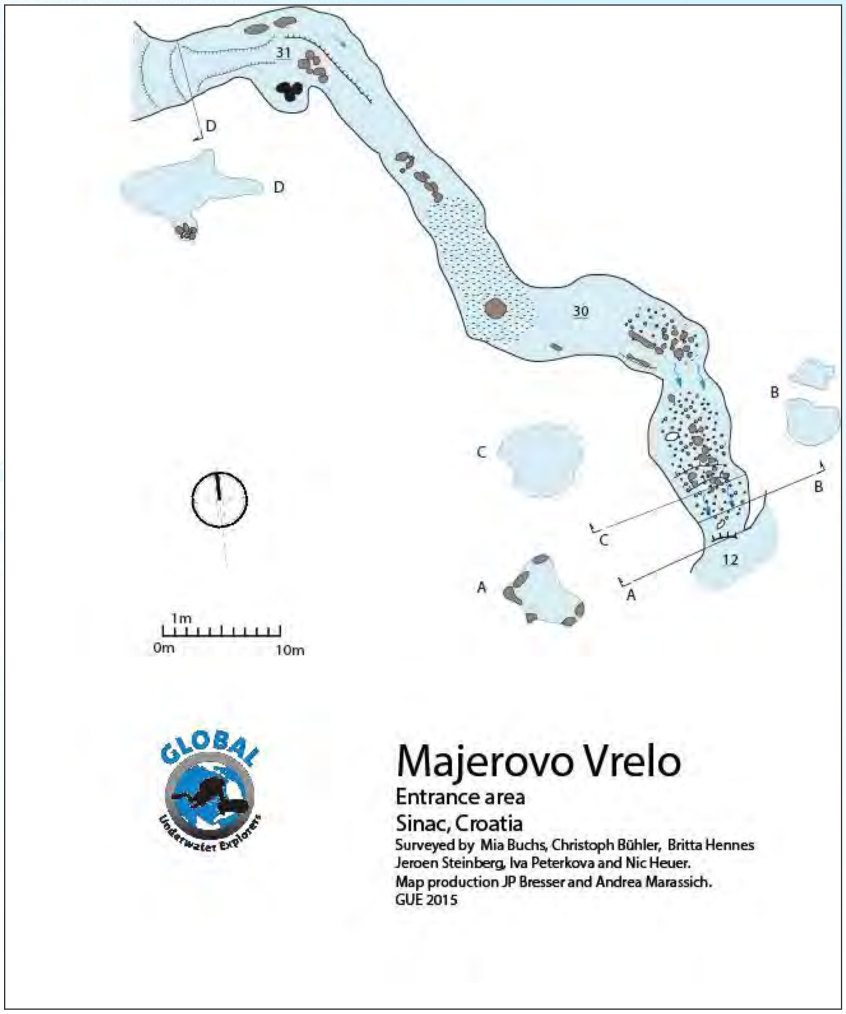
The capacity of Tonković Vrilo is 400 liters per second. With this capacity, Tonković Vrilo can provide water to the whole Lika-Senj county, which consists of more than 50,000 people. Besides Tonković Vrilo, other famous springs here include Majerovo Vrilo and Klanac

Vrilo. There are several other springs in the area, such as Kostelka, Knjapovac, Begovac, and Sinačka Pučina.

The water running through the Gacka River is important for this entire area; the river provides drinking water from the springs I just mentioned.

The Gacka River is the second-cleanest river in Europe, and the third-cleanest river in the world. Because of this, the river is rich in important flora and fauna. The Gacka has many different species of fish—the most important is the autochthonous (indigenous) river trout. Besides the trout, there are also some grayling, northern pike, and the famous white-clawed river crayfish. Proteus anguinus, *also known as olm or the cave salamander, can also be found in the deepest parts of the river.*

We also visited the Croatian Center for Indigenous Karst Water Fish and Crawfish Species. The main function of the center is to conduct scientific research on indigenous karst water fish and crayfish species, with emphasis on their genetic profile and spawning behavior. The center has its own foundation stock of the indigenous river trout, and they run a successful fish restocking program in the Gacka River to improve the fishing tourism in the area. In addition to the river trout, the center also farms a type of river crayfish, the European crayfish (also known as the noble crayfish, broad-fingered crayfish, or by its genus and species name, *Astacus astacus*), which is used for restocking other karst rivers in Croatia and elsewhere.



Map of the first section of Majerovo Vrelo (Courtesy of JP Bresser)

Diving conditions at Majerovo Vrelo proved quite challenging due to considerable flow at the entrance and limited visibility in the beginning. This was handled well by the teams, who adjusted rapidly and began efficiently gathering data. Every day ended with a general debriefing, during which logistics and results were discussed. I strongly believe that sharing experiences and recorded data on a daily basis benefited not only the teams, but made the entire project run smoothly.

TESTIMONIALS

Nils Gilles, Germany

It was my first time participating in a project like this, and I was eager to see how the different GUE divers from several countries would successfully operate together.

From day one, it went efficiently and everyone was on the same page. In the evenings, results were reviewed and the team discussed what could be done to improve data collection. I think one should highlight that such a project is not limited to the days of diving at the local site—it also means preparation and research beforehand (e.g., how to achieve specific goals, like "creating panorama pictures in underwater caves" in my case), as well as processing data afterwards to get presentable results.

It was a great experience to participate in a project that involved working with people I had never met before and whom I now consider friends—thanks for this experience!

Bart Hoogeveen, The Netherlands

When traveling to Croatia for the Morpheus project, I wondered if my nine cave dives after cave 1 certification were enough to contribute to the project.

Now that the project is finished, I think it was a good decision to join the project with only nine cave dives. It was just awesome to be part of a project. I'm convinced I learned a lot more in a week of project diving than a week of plain cave diving.

Jimmy Borgh, Sweden

Day one started with a detailed briefing about the project itself and what was expected of us as a team. We were broken down into smaller teams with different tasks. I was very happy to find out that I got a spot in the video documentation team.

The first dive of the project was a scouting dive with a small team, in which I was included. Its goal was to scout the cave and assess what conditions to expect during the coming week and to see that the line was intact. JP also shot some video for which I helped as a light diver.

On our return, JP explained that it was up to us to get good video footage, and he communicated the project's different objectives for a planned television documentary. That put pressure on us, but also helped us to focus and to improve our work.

The total experience of my first project was positive and gave me tons of experience to bring to the next project as I continue my journey in project diving.

Jens Olberts, Germany

One of our goals for this year's cave Project Morpheus at Majerovo Vrelo was to clean up the pool and further parts of the cave. During one of our first dives into the right-hand tunnel, we noticed a very confusing line situation. In some passages up to four different lines crossed each other; some of the lines were even broken. Therefore, we decided to install a new line and remove all the old lines from this passage.

While laying a new line on the way into the cave, we had to work against noticeable flow. On the way back, the flow made our efforts of removing and collecting the old lines quite demanding.

All went well and resulted in a clean and clearly-laid-out side passage.

RESULTS OF PROJECT MORPHEUS 2015:

- Video documentary: https://vimeo.com/156668638
- A detailed map of the first section of the cave
- Lines cleaned and repaired
- Cleaned up trash from spring and cave
- Sediment samples taken

The Team: Josef Chroust, Nils Gilles, Flip Vernooij, Geert Allaert, Jeroen Wilms, Jeroen Steinberg, Dijana Stupar, Huub Martens, Bart Hoogeveen, Serge Pellikaan, Jens Olberts, Ramona Olberts, Roger Hovind, Jimmy Borgh, Iva Peterková, Nic Heuer, Britta Hennes, Mia Buchs, Christoph Bühler, Anne-Marie Bresser, JP Bresser, Maurizio Grbac, Andrea Marassich

Divers gear up for a project dive

Reflections on Climate Change

By Thomas Sawicki, Ph.D.

Left unabated, rising global temperatures caused by anthropogenic factors can only spell disaster for the human species. (Courtesy of epa.gov)

In January 2016, the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) announced that 2015 was the warmest year since global records began in 1880. Based on independent analyses of the data, both agencies reported that 2015 was 0.90°C above the 20th century global annual average of 12.2°C.[1] In itself, this fact is not alarming. One year does not make a trend; climate and weather naturally fluctuate. Furthermore, a strong El Niño dominated the central and eastern Pacific in 2015, resulting in warm water typically restricted to the western Pacific spreading across this large region.

[1] For those distrustful of government data, one should be aware that in 2012, a self-described climate skeptic, UC Berkley physicist Richard Muller, announced that the temperature data being recorded by government agencies was accurate and best explained by anthropogenic release of carbon dioxide by the burning of fossil fuel. His research was reportedly funded, in part, by $150,000 from the Charles G. Koch Charitable Foundation.

Since 2015 does not exist in isolation, when placing these results within decadal temperature averages to smooth out annual anomalies important insights emerge. Not only was 2015 the warmest year on record, but the twenty-teens are, to this point, the warmest decade on record, beating out the 2000s, which were the previous decadal record holders. The 2000s took the record from the 1990s, which had beaten out the 1980s, as the warmest decade (Figure 1). The trend is unmistakable, and by looking at the decadal data, it is clear that the warm temperatures the globe is now experiencing are part of a longer trend.

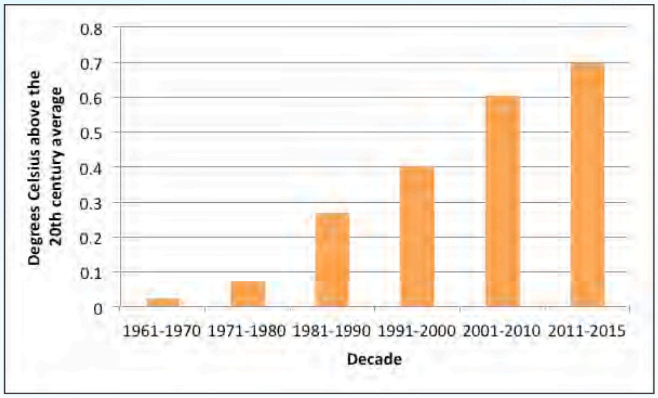


Figure 1. Average decadal temperature anomalies from the 20th century average (data from NOAA.gov)

The data also conclusively disproves the idea that there was a hiatus in global warming during the late 1990s through the first decade of the 21st century. The origin of that statistical lie is easy to ascertain when the data is separated out, the smoothing effect of decadal averages is removed, and specific annual anomalies are considered. The last time there was an El Niño as strong as the one experienced in 2015 was in 1998. Like 2015, 1998 set an all-time temperature record for the time. At 0.63°C above the 20th century average, 1998 eclipsed 1997 at 0.51°C above the 20th century average, and was a full 0.19°C warmer than 1999, which came in at 0.44°C above the 20th century average—1998 was an anomalously warm year *for the time.*

Global warming did not push the average background temperature up to of the El Niño-fueled year of 1998 for approximately a decade.[2] This fact has been used disingenuously by individuals who attempt to discredit global warming science by saying that there was no warming during this time period. They misrepresent the data from the late 1990s through the first decade of the 21st century by drawing a straight line from 1998 to 2010 or by simply dropping 2010 from the graph (Figure 2).[3]

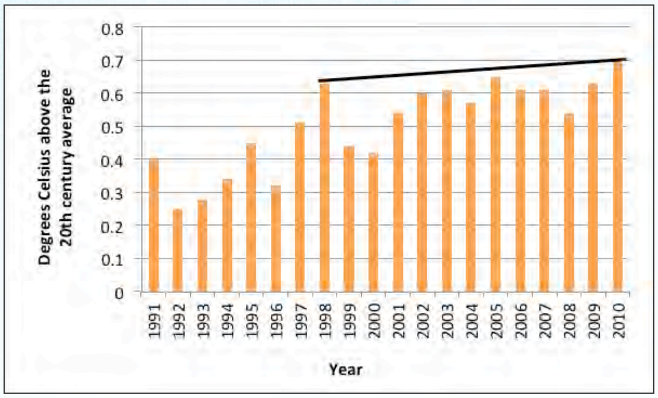


Figure 2. Annual temperature anomalies from the 20th century average from 1991 to 2010, with a line drawn from 1998 to 2010 (data from NOAA.gov)

A better way to examine the data would be to add a trend line that takes into account annual temperature variations, by creating a best fit average over time (Figure 3).

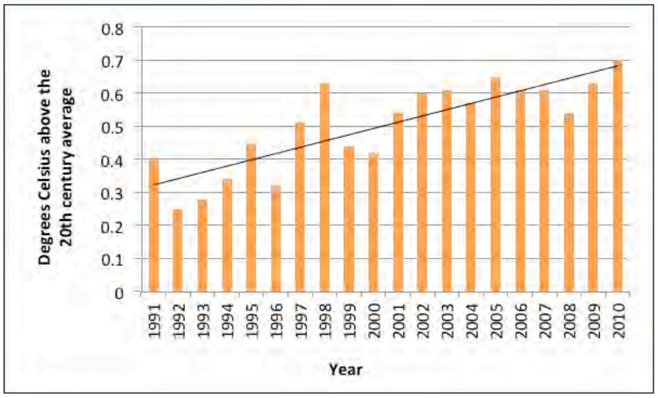


Figure 3. Annual temperature anomalies from the 20th century average from 1991 to 2010 with a best fit trend line (data from NOAA.gov)

The positive slope of the line in Figure 3 clearly shows the increase in warming over this two-decade period. Additionally, it shows just how anomalous 1998 was relative to the background temperatures at the time. Examining decadal averages makes it even clearer that there was no pause in warming during this period (Figure 4).

To be fair, after a large jump in temperature from the late 1990s to the early 2000s, the rate of warming during the 2000s did appear to slow down (the five-year mean for 2001 to 2005 was 0.59°C above the 20th century average, and the five-year mean for 2006-2010 was 0.62°C above the 20th century average). However, though it is true that warming slowed down, there was no "hiatus." The five-year mean for 2011-2015 saw another large jump in temperature to 0.69°C above the 20th century average (Figure 5).

[2] *Background temperature* here means annual temperatures that are not affected by a strong El Niño.

[3] 1998 was 0.63°C above the 20th century average. The average global background temperature from 2006 to 2010 was 0.62°C above the 20th century average. In effect what this means is that it took about a decade for average background temperatures to catch up to the El Niño-fueled year of 1998.

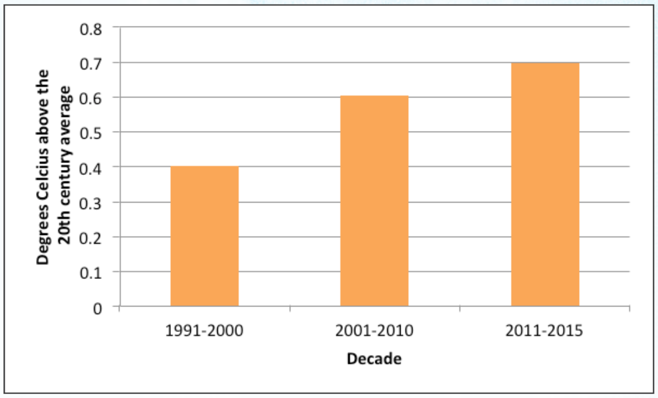


Figure 4. Average decadal temperature anomalies for the 1990s, 2000s, and the first five years of the 2010s, from the 20th century average (data from NOAA.gov)

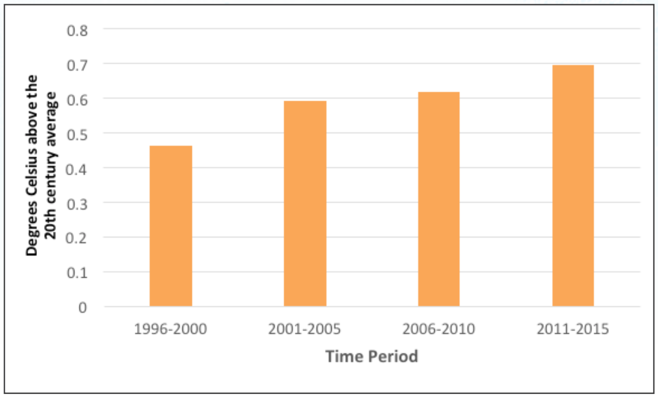


Figure 5. Average half-decade temperature anomalies for the late 1990s to the early 2010s, from the 20th century average (data from NOAA.gov)

In 2015, another significant El Niño pushed up global temperatures well beyond background temperatures. The average temperature anomaly for 2011 to 2015 was 0.69ºC; if one chooses to exclude 2015, the average temperature anomaly was 0.64 ºC. This compares to the 1996 to 2000 average temperature anomaly of 0.46ºC. So, even including 1998 in the 1996-2000 average, and excluding 2015, the early twenty-teens were 0.18ºC warmer than the 1996 to 2000 time period (Figure 6).

Just as in 1998, the El Niño-fueled year of 2015 blew away records. And as the current El Niño eventually subsides, the next few years may not be as warm as 2015 (though El Niño persists in 2016, and 2016 may be close to another record). Nevertheless, as long as the burning of fossil fuels continues unabated, releasing waste heat and heat-trapping gases into the atmosphere, background temperatures will continue to rise. Eventually, background temperatures will catch up to 2015s' El Niño influenced temperatures.

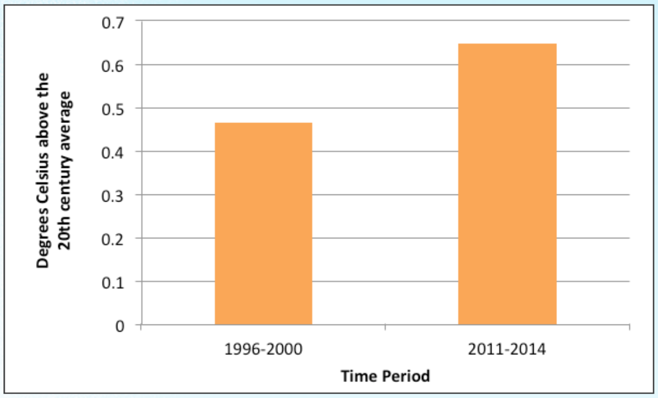


Figure 6. Average temperature anomalies for the time periods 1996-2000 (including the El Niño year of 1998) and 2011-2014 (i.e., excluding the El Niño year of 2015), from the 20th-century average. The background temperatures of the early twenty-teens were 0.18 ºC warmer than the 1996-to-2000 time period. (data from NOAA.gov)

Based on these facts, I will make two predictions. First, as the current El Niño subsides, and temperatures go back to "baseline," those who seek to disprove global warming will once again proclaim a "hiatus" in warming. Second, when the next 1998/2015 magnitude El Niño strikes the central and eastern Pacific, it will be against a background temperature that is warmer than today's, and in that year, an annual global temperature will once again smash the record books.

The slowdown in warming in the early 20th century does seem strange to some. After all, if we are releasing heat trapping gases into the atmosphere, shouldn't there appear to be a linear increase in global temperatures? First, according to Figure 1, it is clear that temperatures are rising quite rapidly. It may seem slow on a human time scale, but these are massive changes on a geologic time scale.

Even so, I believe it is worth examining this question in some detail. First, it is important to understand that the Earth has a natural buffering system. This buffering system helps to maintain temperatures within what could be called a "metastable state." That is to say, although there may be wildly different and random temperature fluctuations at any given time (random weather), these variations approach a relatively stable trend over time.

To understand this buffering system, we must first realize that the Earth's atmosphere has a limited ability to absorb and store heat. One major reason for this is that the atmosphere is thin. Carl Sagan provided an easy way to visualize just how thin:

…the thickness of the Earth's atmosphere, compared with the size of the Earth, is in about the same ratio as the thickness of a coat of shellac on a schoolroom globe is to the diameter of the globe.

Additionally, and very importantly, air has a very low density, and so is not a good substance to store heat energy. Water, on the other hand, due to its much higher density and chemical nature, is an excellent heat storage medium relative to the same volume of air—water is thus said to have a high specific heat. It is noteworthy that water in its different phases has even more heat storage capacity. It takes three thousand times the energy to heat a given volume of water relative to the same volume of air, more energy to turn the same volume of ice into liquid water and even more energy to convert the same volume of liquid water into vapor.

What does all this mean? It means that it is absolutely remarkable that the Earth is warming as quickly as it is. Over 70% of the Earth's surface is covered by water, and oceans are very deep. Because of their great depths, most of the ocean's water is very cold, only a few degrees above freezing. This means that as heat is transferred from the atmosphere (the air) to the ocean's surface water, there is an enormous capacity for that heat to be absorbed. It takes even more energy to convert solid water (ice) into liquid water—a process called a phase transition. When that happens, the heat energy is used to create a phase transition, i.e., the heat is not used to cause the water's temperature to rise, but to change from one physical state to another. We know that glaciers are melting from satellite data (NASA 2012), and thus, an enormous amount of energy is being absorbed by the biosphere that has no immediate impact on temperature rise.

I sometimes demonstrate water's capacity to absorb heat energy to my students with a very simple, but powerful demonstration. I place a paper cup over a Bunsen burner. Of course heat is transferred from the flame to the cup and the temperature quickly rises until the paper cup hits the ignition point, and the cup suddenly catches on fire. This is precisely what many people expect of global warming—a linear and constant increase in temperature as we absorb more heat energy from the Sun.

I then surreptitiously place water into a second paper cup, and place it over the same flame—to the student's surprise the cup does not catch fire. Seconds turn into many minutes, and yet the cup simply sits there. How can this be? It is because water has an enormous capacity to absorb heat. By absorbing the heat energy from the Bunsen burner, the water prevents the paper cup from reaching its ignition point. Likewise, our oceans and glaciers are absorbing huge amounts of heat energy, acting as a buffer to help stabilize our climate. Water in its various phases is the primary reason why we are not experiencing a linear increase in atmospheric temperature on an annual basis.

Given these insights we can rethink the original question. How is it then, with the buffering effect of the huge quantities of water found on the Earth's surface, that our biosphere is still warming? The answer is due to the sheer magnitude of the changes that we are effecting. Coal is a fossil fuel that mainly consists of plant material that accumulated over tens of millions of years in ancient swampy forests, especially during the late Carboniferous period. Oil mainly consists of the organic remains of phytoplankton that accumulated over tens of millions of years as it died and drifted down to the bottom of ancient tropical and subtropical seas. Plants and phytoplankton both conduct photosynthesis, absorbing the energy of the sun to convert carbon dioxide and water into chemical energy (organic molecules such as carbohydrates, lipids, and proteins). Time, heat, and pressure converted this ancient organic chemical energy into coal, oil, and natural gas. Our civilization has dug up or drilled into massive amounts of these ancient organic chemicals; we have brought them to the surface and burned them, thereby releasing an immense amount of energy and carbon dioxide once captured by those ancient organisms.[4] This goes on day after day, year after year. We are burning tens of millions of years of organic matter, and doing so in only a few hundred years. Humanity will *release tens of millions of years of captured solar energy into the biosphere in only a few centuries*. The magnitude of the changes we are inflicting on Earth is truly epochal in nature.

Based on what are primitive modeling techniques by today's standards, Machta (1973) predicted that in the early 21st century, the Arctic would warm faster than the rest of the Earth. This forecast has come true and was in full effect in 2015—although the global temperature anomaly for 2015 was 0.90°C above the 20th century average, *the Arctic was over 3°C above the average*. Warming in the Arctic is particularly worrisome because of the potential positive feedbacks that could greatly increase the rate of warming.[5]

We are conducting a massive, uncontrolled experiment on Earth's biosphere—on the only habitable planet that we know to exist in the whole universe. Many people in power, and in the populace at large, use the excuse of economic growth, or the comfort of political ideology to refuse to accept the reality of climate science. If we are to solve the environmental issues of our time, we must incorporate the laws of physics into our economic models—there is nothing scientific about any economic model that ignores the Second Law of Thermodynamics—and we must abjure political opinion that makes claims not consistent with physical reality. Physical laws are indifferent to our deeply held beliefs, economic models bend to their will, and political affiliation is inconsequential—the laws of physics are immutable. As Richard Feynman, said, "For a successful technology, reality must take precedence over public relations, for Nature cannot be fooled."

LITERATURE CITED

EIA International Energy Statistics [Internet]. 2014. United State Energy Information Administration; [cited March, 2016]. Available from https://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=3&pid=26&aid=2

Machta, L. 1973. Prediction of CO_2 in the atmosphere. Brookhaven Symposia in Biology, (30): 21-31.

Muller, R. 2012 July 30. Conversion of a Climate-Change Skeptic. New York Times; Sect A.19.

[4] As context for these amounts, in 2012, we burned over 22 million tons of coal every day; in 2013, we burned over 91 million barrels of oil every day; in 2013, we burned 332 billion cubic feet of dry natural gas every day (latest available annual data from the United States Energy Information Administration, EIA).

[5] See the selected citations at the end of the article to learn more.

NASA Mission Takes Stock of Earth's Melting Land Ice [Internet]. 2012. National Aeronautics and Space Administration Jet Propulsion Lab; [cited March, 2016] Available from http://www.jpl.nasa.gov/news/news.php?release=2012-036

Climate at a Glance [Internet]. 2016. NOAA National Centers for Environmental Information; [cited March, 2016] Available from http://www.ncdc.noaa.gov/cag/time-series/global/globe/ocean/ytd/12/1880-2015

Sagan, C. 1995. Wonder and Skepticism. Skeptical Inquirer, 19 (1): 24-30.

FURTHER READING:

All About Arctic Climatology and Meteorology; Climate Change in the Arctic [Internet]. 2016. National Snow and Ice Date Center; [cited March, 2016]. Available from https://nsidc.org/cryosphere/arctic-meteorology/climate_change.html

Durack, P. J., S. E. Wijffels, and R. J. Matear. 2012. Ocean Salinities Reveal Strong Global Water Cycle Intensification during 1950-2000. Science, 336(6080): 455-458.

NASA Global Climate Change; The Earth as an Integrated System [Internet]. 2016. National Aeronautics and Space Administration Earth System Science; [cited March, 2016] Available from http://climate.nasa.gov/nasa_role/science/

A winter sunset from the Pensacola Beach fishing pier (Photo by Jim Edds. Courtesy of National Oceanic and Atmospheric Administration/Department of Commerce)

A New Generation of Cathedral Canyon Exploration

By Jonathan Bernot

Despite its notoriety in the North Florida cave diving community, Cathedral Canyon has been largely untouched over the past decade.

INTRODUCTION

Cathedral Canyon, the site of Sheck Exley's record cave penetration in the 1990s, is well-known to anyone who has read Exley's *Caverns Measureless to Man* and to those active in the North Florida cave diving community. With as much notoriety as the cave has received, and as much controversy as it has garnered recently, very few people have set eyes on it over the last ten years, and most would not even be able to find it without the address and their GPS. For a site so rich in history, and with an end of line (EOL) wide open and waiting for exploration, it is remarkable that it lay largely untouched until recently (ignoring, naturally, that visibility has been between 5 to 10 feet over the last decade). With the exploration potential made possible, however, by new advances in equipment, a group of us decided that it was time to return to Cathedral Canyon and see what we could do.

I don't think we are better explorers now than we were thirty years ago. I also don't think the dives are any less difficult now than they were thirty years ago. The easy pickings that allowed a larger number of people to explore thirty years ago have by and large disappeared, but the extended dives done at the top end of cave exploration are just as difficult now as they were back then. However, logistics and equipment have evolved dramatically in recent years to allow divers to do a lot more with a lot less (e.g., scooter burn times). If Sheck Exley had a top-of-the-line rebreather and SUEX scooters in 1991, there would be fewer caves to explore.

THE DIVES

In the early fall of 2015, a few of us in North Florida started hearing rumors that Falmouth Spring was flowing and that the water was clearer than it had been in recent memory. This cave had barely been dived by this generation of cave divers. Visibility was poor, and aside from the 17,119-foot EOL that Todd Leonard and Bjarne Knudsen had explored to in 2005, there was no known considerable open exploration potential. Charlie Roberson and I, after hearing that Brett Hemphill and Joel Clark had had a successful dive in Falmouth up to Aquarius Sink, decided we wanted to take a look. We received permission from the NSS-CDS to enter at Cathedral Sink to attempt to repair the line and start the process for the potential reopening of the site to divers. We arrived early and could barely get the gate open due to the site being so overgrown. Once we reached the water, we were greeted by a site with inches of visibility, a slight smell, and no apparent start of a line. We were concerned we would not even be able to find the line and would have to call the dive before we even had a chance to accomplish any of our objectives.

As we began gearing up, we said screw it, let's drive down and get in at Falmouth. We had XK1 scooters and it was only a 2,500-foot run to Cathedral. Entering at Falmouth, we ended up patching the line from Aquarius to Cathedral when we ran out of replacement line. It was a good dive; we learned that the site did in fact have 20-30 feet of visibility and that the cavern was clear below 20 ffw. Over the next few weeks a group including ourselves, Ted McCoy, Derek Ferguson, Jeff Frank, Ken Sallot, Kristi Bernot, and several others relined the system using silt stakes all the way to 4,000 feet past Cathedral. Now it was time to start doing some real dives. Imagine my surprise when I showed up to do the first dive from the Cathedral, a long-range setup dive to drop bottles at 8,000 feet, and found that the cold snap had turned the murky, nasty basin over. We now had a nice 30 feet of visibility. I immediately texted the team a picture, "Guys, grab your gear, we have vis."

Several more setup dives ensued until we had safety bottles placed all the way out to 10,000 feet. Now, it was time to consider a push to the EOL. Charlie Roberson and I spent hours discussing scooter duration, scooter stage points, bailout distances for safety gas, and other logistics. We accepted that our planned 10- to 12-hour dive may yield nothing but line repair and further setup. Instead, we were amazed to find the line in relatively good condition beyond 10,000 feet; in fact, we made the trip to 17,119 feet in remarkable time with few navigational issues. I was ecstatic when I spotted an end to the line; instead of broken frayed line, there was a loop. We had made it.

After taking a minute to check ourselves and tie-in, we laid just less than 600 feet before we ended in a slot canyon with no obvious way forward.

Then the problem occurred. A battery can read just fine at the surface but after three hours of diving, we had a primary rebreather display failure. From then on, we made it protocol to start all exploration dives with new batteries even if readings were good. At almost 18,000 feet, we decided to survey on the next dive and headed for the door. Redundancy is an important facet of exploration, but it's just as important to realize when it is time to take that redundancy and use it to exit. We had the EOL at Cathedral, but 600 feet of unsurveyed line was nothing to brag about. We knew we had to return.

Just a few weeks later we did just that. This time a support team consisting of Ted McCoy and Ken Sallot dropped off two XK1s at 8,000 feet. This dive went remarkably smoothly. Upon reaching Todd and Bjarne's EOL, I began to survey our previous line while Charlie scouted the walls, searching for an ongoing lead. We were a little concerned when we got to our tie-off and had yet to find anything. We eventually saw a small duck-under which turned out to be the way forward.

Charlie Roberson joined Jonathan Bernot in a renewed effort to explore Cathedral Canyon.

Orientation of Cathedral Canyon shows exploration nearing a dairy farm. (Courtesy of Charlie Roberson/Google Earth)

Our mantra for most of this journey was to follow the flow. For nearly 1,200 feet we meandered through small, twisting passages; with each turn around a corner, we were convinced that the cave would end. Instead, it kept going. Just as Charlie ran out of line on his 1,200-foot exploration reel, we were in a room bigger than anywhere else in Cathedral. It took us a good five minutes to find a tie-off. The rock we eventually found was so soft that the first tie-off—over twelve inches thick—broke, taking the line and reel with it into the silt.

This rock spoke to the evolution of the cave: tannic acid is dissolving the cave, leaving us with impressive passage, even if the visibility—or the lack thereof—hides it. Almost fourteen hours after descending, we surfaced with 1,800 feet of survey data. We felt vindicated, but wished we hadn't turned as early. Again, we immediately planned for the next dive.

Before undertaking another exploration dive, we decided that some hard science was needed. The Suwannee River Water Management District, which had granted us a permit to dive from Falmouth Spring, wanted a datasonde water quality reading out as far as possible. In addition, Dr. Thomas Sawicki wanted water samples from various points in the cave. The dive team also wanted to confirm previous exploration survey data. One of the things Dr. Andrew Pitkin realized early on was that many survey maps had not accounted for the forty years of magnetic differences in the earth's gravitational field. Once this was adjusted, we decided to perform cave radio locates at 6,000 feet and 10,000 feet of penetration. In a similar manner as was found in radio locates performed at Manatee Springs, the original Sheck Exley data was found to be extremely accurate with less than a one percent deviation over 10,000 feet. This both impressed and humbled us. This technology is invaluable as it allows us to validate past and future survey results.

Our third dive took place on the morning of January 9, 2016. This time we were prepared and the cave set up properly. On our previous dive, we still had to carry multiple bailout bottles into the far reaches of the cave, a process that had been both time-consuming and exhausting. On our third dive, previously placed bottles allowed us to focus on our specific tasks.

We reached our previous EOL in around 140 minutes. We dropped the first reel quickly into virgin passage, and then the second one came out. A few hundred feet into it Charlie flashed me and signaled "arrow." I reached into my right pocket and pulled out a special arrow Dive Rite had cut for us, and at 20,000 feet, we installed it and shook hands before continuing on towards another duck-under with broken slots in the rock.

During the dive, however, I was encumbered by my mask, which had been fogging for three hours. With 10 to 20 feet of visibility as it was, the mask was a real nuisance. I lost the going passage so reeled back a bit and turned around. While I knew the passage went, I couldn't see well enough to scout. I love laying line as much as anyone else, but I handed my reel to Charlie as I fixed my mask. He found the going passage and we laid the rest of my reel and his first reel before turning the dive and surveying out. This process moved smoothly as I recorded depths and distance and Charlie passed the compass back to me. We finished this dive having extended the line by 2,747 feet. All in all, our third dive had been a good one.

The data revealed we were headed straight for a dairy farm. Only the next dive would tell us if the limited visibility in the system is a result of pollution. If it is, logic would dictate that once we get past these farming operations, the cave health will improve. During our background research, we gleaned data that indicated that nitrate levels do vary, but tend to decrease the further into the system one gets. Though we enjoy the sport for its recreational value, this type of data is the true gain, not just for us as a dive team, but for everyone in the area. The information gathered on these dives can help understand pollution in the area and determine its potential sources.

DIVE LOGISTICS

When it came to long-range exploration logistics, Charlie and I drew heavily from the WKPP. Casey McKinlay gave us some numbers on scooter duration that proved to be invaluable. Most people never experience the draw a fully loaded diver, with

CCR, LP121s for bailout, a safety bottle, and three scooters has on your batteries. This is completely different from a basic dive to the Henkel with a set of 104s. A 14,000-foot penetration scooter can easily become an 8,000-foot penetration scooter. One team member learned quickly that his high end brushless motor chewed through batteries infinitely faster than ever anticipated when running fully loaded. We chose SUEX XK1s for all of our push dives for several reasons. Scenarios that were once hypothetical now became critical. Overheating motors when running fully loaded for an hour between scooter drops was an issue with previous models. The ability to clear a prop of entanglement in the low visibility by removal and replacement was critical (and yes, this happened at 15,000 feet).

This type of exploration involves loose and broken line as well as low visibility, so we needed rebreathers capable of twelve-plus hours on the loop in addition to open circuit oxygen in the habitat. Charlie used a Megalodon with an 8-pound radial scrubber, while I used a JJ-CCR with a 7-pound radial scrubber. Both have held up so far, but we are very conscious that we are nearing the breakthrough point (even with limited exertion, as most of the dive is scootering or at decompression). We used escorts from decompression up to the surface because the extended times on oxygen drove our CNS limit through the roof.

We learned quickly that equipment compatibility within the team was critical. While every diver may not have exactly the same equipment, we ensure all bottles can be used by all divers. Charlie and I dive different rebreathers, but they are both fed by our off-board bailout cylinders via QC6 connectors. All gas in the system is suitable for breathing at 190 ffw, the maximum depth of the cave. Although there are shallower sections, we chose to use one standard gas for all safety gas staged or taken into the system to prevent confusion or to prevent gas from not being useable at certain points on the dive.

None of this could be done without a good team and support. There is room on these teams for anyone who is a safe diver and willing to help. Some support divers never venture beyond the cavern, but they are some of the most critical members of the team – without them, we could not execute the dive. There is no comfortable deco trying to manage seven scooters between two divers. This project has allowed a number of divers to fine-tune their long-range diving in one of only a few sites that offer the opportunity. The equipment manufacturers and shops that have donated, lent, or helped to subsidize equipment have also played a vital role in making this exploration possible. To everyone who had a part in this project, this is your project as much as it is the divers who install the last bit of line. The logistics required for this level of exploration are staggering, and every piece is important.

We are doing more with what we have today. Scooters are longer-range and more reliable. Our rebreathers are more streamlined and reliable than ever and allow for limited setup dives versus doing repeated pushes on open-circuit. My primary dive light burned for thirteen hours and twenty minutes on one dive before dying at decompression. If previous generations of divers had had our equipment, they would have been where we are going. We are at an exciting time in cave diving. We are at a point of technological advancement due to battery technologies and electronic design. Who knows where we will end up?

Jonathan Bernot prepares for a dive into Cathedral Canyon

DIVE TEAM

Charlie Roberson, Jonathan Bernot, Ted McCoy, Ken Sallot, Kristi Bernot, Derek Ferguson, Jeff Frank, Howard Smith, Alan Pelstring, Casey McKinlay, Steve Cox, Blake Wilson, AJ Gonzales, Brian Richardson, Meredith Tanguay, James Draker, Bob Beckner, David Doolette

EQUIPMENT AND MATERIAL SUPPORT PROVIDED BY

- SUEX/D3 Diving
- Dive Rite
- Diving Unlimited International
- Cave Country Dive Shop

New Area of Exploration Surfaces in Mexico's Yucatan

Nohoch Pek: Adventures in Exploration

By Mauro Bordignon

Mauro looks up the "tube," the rear entrance into Nohoch Pek (Courtesy of Mauro Bordignon)

In May 2013, Phillip Lehman arrived from the Dominican Republic for one of his regular cave trips. Phillip has been coming down since 2009 to dive with me, during which we have divided our time equally between exploration and filming. This time the plan was to investigate the area around Chikeen, a few kilometers south of Tulum, and to explore Cenotes Doggi and Caterpillar, two caves in the Muyil area.

On June 3, we woke up to a horrible thunderstorm, and because we already had seven days of non-stop exploration completed, we decided to take a day off from diving. After devoting the morning to preparing a stick map of Chikeen—which is now displayed in the cave—Phillip and I were joined by Patrick Widmann to go cave-hunting in Muyil. After some time wandering an area not far from the highway, we eventually discovered a little dry cave with a nice tube just 10 meters away.

With my skinsuit, mask, fins, and an S30, I jumped into the small pool inside. After some time poking around, I was about to give up when I suddenly noticed a spot where roots disappeared

Kim and Mauro hike to the back entrance of Nohoch Pek (Courtesy of Mauro Bordignon)

into a small crack between the rock wall and the calcite flakes in the floor. I moved a bit of the sediment away, and the material was immediately sucked down.

With Patrick and Phillip impatiently waiting in the rain and repeatedly asking, "Does it go? Does it go?" I moved a couple of rocks to create a space large enough to push my body through. I then returned to the surface to report, "Yes, it looks like it might go!"

Behind this newfound restriction—which we named "The Filter"—a white inviting passage seemed to lie before us, promising wonders. But it was late in the day, and we only had our "scouting" gear, so we headed back to Tulum. Excited to return the next day, we endured Phillip's non-stop whining of "I'm not going to sleep tonight!" the entire drive back.

Day 1 was, as they say in the DR, "epic." Four of us (Patrick, Phillip, Kim Davidsson, and me) entered a virgin cave and lay roughly 4,000 feet of line. Once we passed the Filter, and after a couple of minutes of restricted passage accessible only by sidemount, we found ourselves in a large, white super-cave with passages veering off in all directions. We were able to explore as a team of four for almost a whole week, which gave a significant start to this new amazing cave.

As we contemplated what to name this new cave, we joked about how it was growing larger than nearby Doggi—which it would eventually absorb. Thus, the cave became Nohoch Pek, or "Big Dog."

After a few days, we realized that the cave was pushing us everywhere but east. This was not necessarily a bad thing given that Mukkin was to the north of us, Doggi to the south, and nothing but uncharted passages to the west. As we moved west, we found uncharted cave, with every apparent dead end yielding a crack that took us to a new section.

We decided to focus on moving south towards Doggi. Nohoch Pek was growing so fast that connecting to Doggi was no longer a dream, but a real possibility. At this point, we were joined by Alvaro Roldan and Tristan Termat; the more the better as we always say!

We got very close to making the connection; in fact, we made it to less than 200 feet from Doggi's north section. But our dream of connecting the two systems disintegrated when we met a big collapse and a gas pocket area, very similar to what I had left on the Doggi side almost two years before. We managed to reduce the gap to a hundred feet, but after trying every single crack, with sidemount and no-mount, we decided that the connection was unattainable and to leave it for a while. This ended up being a good call because, again, the cave gifted us with a new section with wide bedding planes and westbound tunnels. Despite this new find, come mid-June, we all had to return to our daily lives: work for us, surfing for Phillip.

I managed to go back to Nohoch Pek at the beginning of July for a few days and then again for a few more days around the end of the month, when I was joined by Alvaro, Jason Renoux, and Harry Gust. By then we were armed with scooters and stages, and after a few of these dives, we got lucky and found a beautiful little entrance that we later named Cenote "Second Look."

We recruited Phil's crew to cut a trail to Second Look, and dove into exploring right from the end of the line. From the new cenote, we attempted another southward movement, still with the hope of connecting Doggi and Nohoch Pek. Once more, we were greeted with breakdowns, and the beautiful cave shrank smaller and smaller. So, we turned our efforts west and were rewarded with probably the biggest tunnel of the whole cave, which was similar to the Crystal Tunnel past Doggi's Tripline.

By around mid-August, we had explored more than 10 kilometers of cave, and for the third time it turned south. The distance was also growing, which again required the use of a scooter. It was a pain to carry the scooter through the jungle, lower it down into Second Look, and then squeeze it through the tiny entrance that only offered one precise spot through which to get it through. But it was a pleasure to push it for five minutes and then ride it all the way to the new EOL, enjoying the beautiful scenery.

August 29 was the last long dive from Second Look. On this dive I managed to get within 250 feet of Doggi. The cave was getting too complex, and I only had three days before flying to Italy for a month, so I decided to leave the next attempt for when Phillip came back from the DR at the end of October. Next time, we would begin from Cenote Style, Sistema Doggi's second entrance, a 1.5-kilometer hike. But before leaving, there was one more thing that was worth trying. On August 30, I went back to Nohoch Pek's main entrance and managed to push a northbound line that we had laid the first week.

The end of the line was in front of a little collapse, with organic material and little bird bones attesting to a no-longer-existing-opening into the cave. To the right of it were flow ripples on the floor and what looked like a very small tunnel with clear flow

Main entrance of Nohoch Pek (Courtesy of Mauro Bordignon)

Diver making his way into Nohoch Pek (Courtesy of Mauro Bordignon)

moving north. The more I pushed myself into the narrowing passage, the stronger the current would become. I followed the compass on my reel in the right direction, due north, but the flow from behind made it difficult to continue. Really annoyed, I cut my line with plenty of gas left and decided to go back. After a couple of meters in zero visibility, however, the water was crystal clear again.

I experienced an adrenaline rush when I realized that all the silt disappeared into a little hole left of my line. Deciding to pursue this lead, I removed my sidemount wing and other accessories, and after clipping everything to the line, I passed the restriction with a tank in front and one clipped behind me wearing the harness, the reel, and a safety. Five or six shots later, I found myself right at the entrance of Cenote Mukkin.

With this connection, and thanks also to the work of Vincent Rouquette-Cathala, Natalie Gibb, and Anders Knudsen in Muukin, Nohoch Pek became the eighth-longest cave in Quintana Roo, measuring 21,396 meters.

Exploration of the cave is still active, and as of 2015, it measures 25 kilometers. However, connecting to Doggi has proved pretty difficult; every time the two caves get close, a breakdown shuts the door.

Until we discovered Doggi in 2010, Muyil was considered an area without any caves. However, in a little over five years, more than 100 kilometers of passages have been found and mapped. It is now time for everyone involved in cave exploration in this area to get together and share their data so that we can try to form a general picture of our underwater resources – especially before development begins in earnest in the Muyil area.

Dangers and Remedies Associated with Negotiating Dry Sections During a Cave Dive

Equipment Considerations in Deep Post-Siphon Diving

By Anton van Rosmalen

The beauty of post-siphon diving at Oliero Italy

THE high carbon dioxide, low oxygen conditions in the gigantic Ressel Dome made me gasp for breath. Every step felt like an uphill sprint. Fatigue took over as I crossed the eighty-meter-long chamber for the sixth time, and my legs began to wobble. Walking across the steep, loose, and slippery rocks started to feel more and more like stumbling, like I was continuously falling. Sander and I both sat down to take a short break. Trying to catch my breath, I gasped: "There has got to be a better way to do this."

The small, uninviting opening of Source de Marchepieds in southern France contains some of the clearest water in the Lot region before flowing into the muddy Célé River. The first part of the cave was supposedly a bit tight, but we decided to give it a try anyway. In true GUE fashion, we used two backmounted steel 12L cylinders, an AL80 stage, and PRO14 lights. After what seemed like an eternity of wiggling and pushing rocks and equipment ahead, we made our way through the first thirty meters of submerged passage and were then able to fully admire

Post-siphon progression at Grotte di Oliero

this beautiful cave. On a subsequent dive we decided to give sidemounted tanks a try, and what had previously taken us half an hour (and substantial gas) to navigate just took five minutes, saving the bulk of our gas for exploring the cave. Applying a flexible approach towards gear configuration not only took us much further, it also made this dive much safer.

Applying sidemount techniques vastly expanded our possibilities for cave diving in Europe. Shortly thereafter we were faced with our next big challenge, which, strangely enough, did not involve diving at all. Because Archimedes' law doesn't apply to much of anything outside the water, getting in and out of the water inside a cave can be quite a challenge. When the chances of receiving any sort of help, let alone rescue, are virtually absent, the dry caving part that comes after a sump is generally much more dangerous than the diving itself.

RISK ANALYSIS OF POST-SIPHON DIVING

Post-siphon diving is a combination of dry caving and cave diving and presents a number of unique challenges and risks:

- When exiting the water past a sump, light is required. To a certain extent, a primary dive light can be used while still wearing dive equipment. However, make sure it is a LED light; other kinds of lights can quickly overheat (they need water for cooling the bulb). We managed to damage quite a few HID lights this way. Even so, given that both hands are often needed to traverse a dry section of cave, a wildly swinging clipped-off primary light turns out to be impractical. Backup lights can be used, but we discovered that these are easily damaged when dropped or banged against the rocks. Furthermore, though they provide more than enough light, they are impractical (as handhelds) while climbing, crossing uneven terrain, or carrying gear. Lastly, backup lights are intended as an emergency backup for getting you out of the cave in case the primary light fails, not as a primary light source to be used for getting you farther in the cave.

- Having to decompress on the way in requires divers to take their deco gases past their MOD all the way in. This tends to slow the diver down, leading to more even decompression. The possibility of getting DCS inside a cave is very real; decompression at the end of a sump may not go well and the exertion required to traverse the dry section may trigger a hit. The latter we found out the hard way, luckily on the exit side of the cave, as getting back into the water for further recompression would have been virtually impossible.

- Scrambling across slippery terrain or even climbing with equipment can result in falling, injury, and/or damaged equipment.

- A high carbon dioxide, low oxygen atmosphere, as can be found in many caves, makes you feel like you have to do the aforementioned scrambling and climbing while running an

- Rescue is nearly impossible. The Ressel Dome, to stick with the opening example of this article, is located at roughly three kilometers from the cave entrance. In order to get there, a diver has to pass an eighty-meter-deep siphon followed by the first dry chamber, then another one kilometer siphon—a shallow one this time. Having to extract an injured diver from the Ressel Dome would easily be the riskiest, biggest, and most expensive cave rescue operation this world has ever seen. It would probably also lead to the local government closing the most famous European cave diving location forever.

Cave diving is all about managing risks. Looking at the risks I just outlined above we have been in the process of experimenting with different approaches towards gear configuration. Below I would like to discuss equipment considerations in order to provide solutions for deep post-siphon diving. The basic principles of simple, streamlined, and redundant gear also apply here.

Difficult access at Cascade de Bellegarde, Switzerland

uphill marathon with a backpack while wearing airtight, thickly insulated clothing.

- Be careful of extensive equipment wear or even malfunctioning equipment—including drysuits—because of mud, impact with rocks, and repeatedly having to disassemble and reassemble gear for transportation.

PSCR VS CCR

An RB80 setup easily weighs 50 kilos, which makes it extremely hard to carry across uneven terrain. It isn't only challenging; it's also dangerous for both the diver and their equipment to move this heavy setup across the loose rocks. In order to move an RB80 across any sort of terrain it usually has to be taken apart, moving bottles and the rest of the setup separately. We found using a combination of Lola valves on both backmounted tanks, with its flexible manifold and Scubapro tank straps, accommodates this in the least amount of time. However, taking the set apart usually means the diver has to cross the same difficult terrain three to five times, going back and forth to move the backmounted gear alone. Also, taking the whole configuration apart is not without risk of damaging equipment. The next major drawback of using the RB80 is the need to always carry decompression bottles, which cause significant drag, leading to additional bottom times and inert gas absorption.

A GUE-configured JJCCR isn't that much lighter and, moreover, depends on electronics to function. Looking for a lightweight, streamlined solution, I ended up with a KISS CCR in its original setup with one small bottle of diluent and a small bottle of oxygen. When squeezed out of every gram, the weight of the whole set can be brought down to just over eighteen kilos. The advantage gained using a smaller setup is quite dramatic: a trip to the end of Ressel and back took us twenty-four hours using the RB80, while Swiss cave divers using a lightweight approach did it in nine, without cutting corners as far as bailout reserves are concerned.

Post-siphon diving can be rough on gear.

HELMETS

Let me start by saying I really don't like wearing helmets when diving. They make wearing a mask annoying (let alone replacing one), they rarely fit nicely over a thick neoprene hood, they are bulky, and they make you look silly. Also, helmets generally don't benefit you much underwater, with the exception of sidemount diving through no-mount restrictions, in which case you need a place to temporarily park your primary light while still being able to see what's going on in front of you. Out of the water, however, they serve two vital purposes: protection and light. A fall on slippery, sharp rocks in a dry cave can easily result in a nasty head injury, and you simply want a helmet to protect you against that possibility. Getting a head injury in a place where any sort of aid puts many lives at risk because you didn't want to wear a helmet is more than a bit irresponsible. Also, a helmet with a proper, waterproof caving light gives you the opportunity to climb or scramble with your hands free once you step out of the water while still being able to see where you are going. Dry caving is much nicer with a high-end caving light. Who would have thought caves are beautiful to look at even when not fully submerged?

If taking a helmet is too big of a violation of rule #6 (always look good), at least consider taking a decent head light. A small head light like a Petzl Tikka can easily be brought along in your undergarment, but it is not easily accessible without undressing. A small light canister can also be used as a miniature dry tube holding a headlight. The canister can be attached to the waist belt or backplate using argon straps, which provides for a more readily accessible solution.

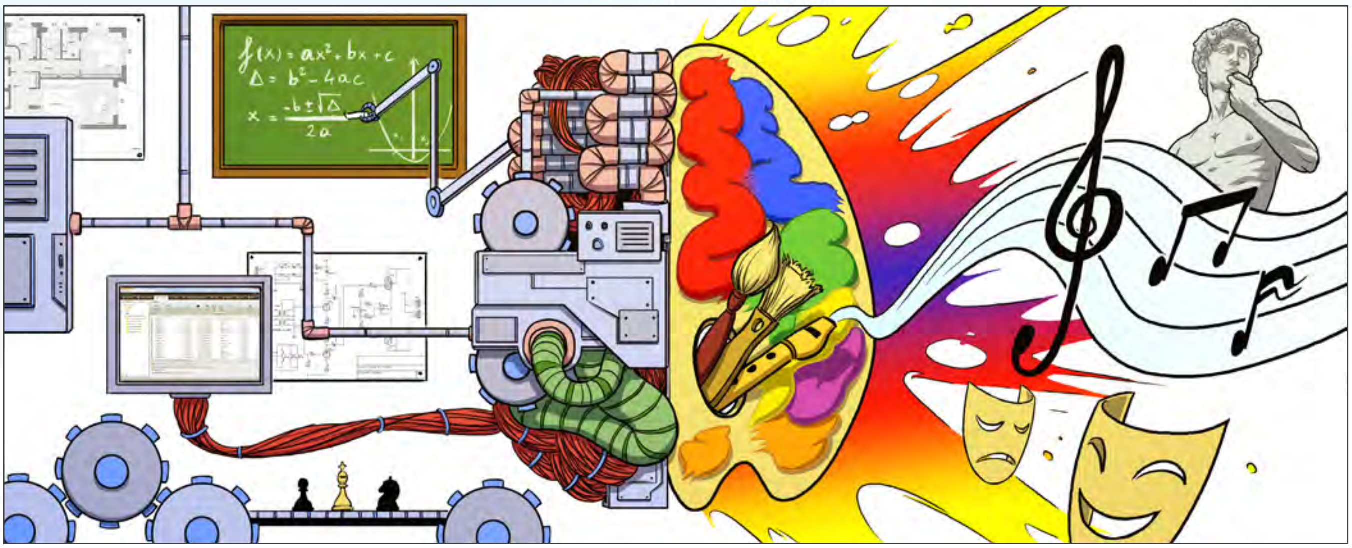
DRYSUITS

While ferrying equipment, it is prudent to take off one's drysuit in order to avoid damaging it and to make carrying gear more comfortable. Rock boots are ideal for two reasons: the likelihood of damaging your turbo soles is significantly reduced, and they can be used while dry caving so you only have to bring neoprene socks for your socks to stay dry. Donning and doffing a drysuit are the moments the suit is most likely to incur a catastrophic failure like a torn seal or broken zipper. Behind a deep and long siphon, this is really a bad thing. When tearing off the wrist seal from my drysuit in the Bivouac chamber in Ressel with more than two kilometers of cold water diving between me and the exit of the cave, I was glad we brought a spare drysuit in the dry tube. Other items you might want to consider taking along are spare catheters.

When I came across GUE and DIR for the first time, I found the standardization of the equipment configuration to be well thought out, down to the smallest detail, and one of the most powerful concepts I had ever encountered in diving. The standardized equipment configuration GUE divers use has tremendously boosted diver safety and efficiency. I love it for its rugged no-nonsense and streamlined setup, providing security through redundancy at the same time. As our diving progressed, however, we encountered more and more places in Europe where the shape of the cave simply made it impossible for us to continue underwater or dive it at all using our beloved setup. Also, I found the overtly dogmatic "there are plenty of other places to dive" answer I got when I tried to address this problem quite unsatisfactory. Why should my equipment configuration dictate where I can and cannot dive? Besides education and conservation, GUE is about exploration so I won't accept the fact that this same GUE approach is now preventing me from exploring some very interesting places. In the end I think flexibility takes you farther than rigidity and dogmas, and contrary to popular belief among GUE divers, it can even make things safer, much safer in fact.

Memorization Techniques: An Unlikely Tool Benefits Diving

By Ivan Wagner



Mnemonic techniques can be useful for divers on land and in the water. (Courtesy of Ivan Wagner)

DURING spring 2015, I had the opportunity to take a course called "The Magister." The course was split into modules that included public speaking, mnemonic techniques, mind map creation, and fast reading. In this essay I would like to concentrate on the memorization techniques that I was able to successfully apply to diving. During my years in academics, no one really taught us practical ways to study. Each student had more or less his or her approach, and when it came to memorizing concepts, it was more a matter of repeating arguments continuously until they were acquired. Mnemonic techniques can be applied in the most challenging of subjects including math, chemistry, history, learning a new language (vocabulary), and so on. While I took this course I thought of where I could apply these techniques, so I decided to experiment with the methods underwater. To my surprise, it is astonishing how well it works. Obviously, the more the technique is exercised on dry land, the more benefits are discovered while underwater.

Our brain absorbs a great deal of information as it memorizes consciously and unconsciously; thus, the issue is not memorizing things but rather having a way to recall this information. This essay provides just a brief explanation of how to practice recalling information. As a caveat: a class devoted to this subject normally takes two to three days before you will be able to master these memorization techniques. If you do it on your own, it usually requires much more time.

DAILY LIFE APPLICATION

Memorization techniques can be applied anywhere. For a trip to the grocery story, I will memorize the list of ten to thirty items I may need rather than writing them down. I also use them for presentations (e.g., when I'm teaching dive classes). I use memorization techniques in conjunction with mind maps: maps that sum up all the topics and sub-topics I want to speak about. All the branches in the mind map have an index (the number) with which I associate it. All in all, I find that there

People tend to rely on one sensory type when observing the world around them.

are several aspects of my life that benefit by my having efficient information recall. Each of us will have our own area that will benefit from memorization techniques

UNDERWATER APPLICATION

There are a number of different situations underwater in which memorization is useful. During a cave diving class we were asked to memorize time, depth, consumed gas, and environmental characteristics at key junctures and memorization techniques aid in this. But these skills are not limited to cave diving; they can be used in all types of diving, including recreational. Once we're familiar with a dive site, experience overtakes the memory technique. In fact, it's not necessary to use the technique once experience yields the requisite knowledge. The technique is there as a support tool, like any other piece of diving equipment.

THE TECHNIQUE

The memorization technique is built on three blocks:

1. PEG system: this system is used to associate numbers with phonetic sounds;

2. Senses: to better understand our predominant channel of information input and retainment (visual, auditory or kinesthetic); and

3. PAV: used to create an easy-to-recall story as a foundation for memorization.

PEG SYSTEM

The PEG system is used as a foundation for the phonetic conversions between numbers and words. The following table is an English version of the associations between numbers and the letters.

#	Letters	Phonetic examples
1	t, d	**T**ea, **D**ay, **D**ye, **D**oe
2	n	**N**oah,
3	m	A**m**y, Ha**m**
4	r	**R**ay, Hai**r**
5	l	**L**eo, Oi**l**, Ho**l**e
6	ch, j, sh	**Ch**in, **J**ane, **Sh**oe
7	k, g	**K**ey, **G**uy, **C**ow
8	f, v	U**f**o, **F**oe, **V**an
9	p, b	**B**oa, **P**en, **P**an, **B**ee, **B**oy, ...
0	s, z	**Z**oo, **S**ea, **S**un, **S**oy, ...

Other letters (nouns or vowel) are not considered within our indexing system. Beginning with number 10 on, it's just a matter of combining elements. For instance, the number 30 can be associated with the word *mouse*—i.e., the number 3 represents the letter "M," and 0 represents either "S" or "Z" (though in this case, its represents the letter "S"). There is a list of 100 associations (from number 1 to 100) to study, and each number is linked with something (this list is given during the course). It is best to practice in a relaxed environment without distractions. In our case we were given a DVD with some background music and pictures of all 100 associations, which would be played in sequence. After devoting 20 minutes a day for about a week, it is possible to memorize all 100 items on the list. The trick lies in training your brain to fluidly convert between the letters and numbers.

SENSES

We use all five of our senses to perceive the world around us. To demonstrate how we use sight, hearing, touch, smell, and taste to become better acquainted with our surroundings, let's use the image of the landscape on the prevoius page as an example.

People tend to primarily rely upon one sensory type. These include:

- **Visual:** Individuals who primarily rely on vision to interpret their surroundings. They will often notice colors, shapes, sizes, etc.; they are more likely to recall the blue sky, the vivid green grass, and the contrast between different shapes and sizes.

- **Auditory:** "Auditory people" rely on the sounds of the environment. While looking at the image, they would likely recall the sounds of waves, birds, and even the blowing wind.

- **Kinesthetic:** Kinesthetic individuals rely on touching something or the act of physically moving to interpret their surroundings. These individuals would likely recall the feel of touching the grass or the feel of the wind blowing on their face.

The more familiar we are with our own sensory preferences, the more successful we are likely to be with memorization techniques (PAVs). Based on what sense we rely on to interpret our surroundings, we may need to incorporate a visual, auditory, or kinesthetic element for assistance.

PAV (PARADOX, ACTION, AND VIVID)

PAV, or Paradox, Action and Vivid, is one technique that can be used to assist with memorization. With this technique, we can use our creativity to develop stories. These stories need to be absurd (paradoxical); they need to contain some sort of action; and they must be vivid. The more absurd the story, the more it will remain glued together in your mind, ensuring it will be easily recalled when needed. When first starting with PAV, it's common to close your eyes while creating the associations so that you aren't influenced by what you see around you. Once this technique is fully mastered, you'll realize that you can accomplish this with open eyes.

A PAV EXAMPLE

Let's consider applying this technique to cave diving. First, we need to have a set of rules to avoid mixing up the various pieces of information we want to memorize. My scheme is the following (pick or decide whatever makes sense to you):

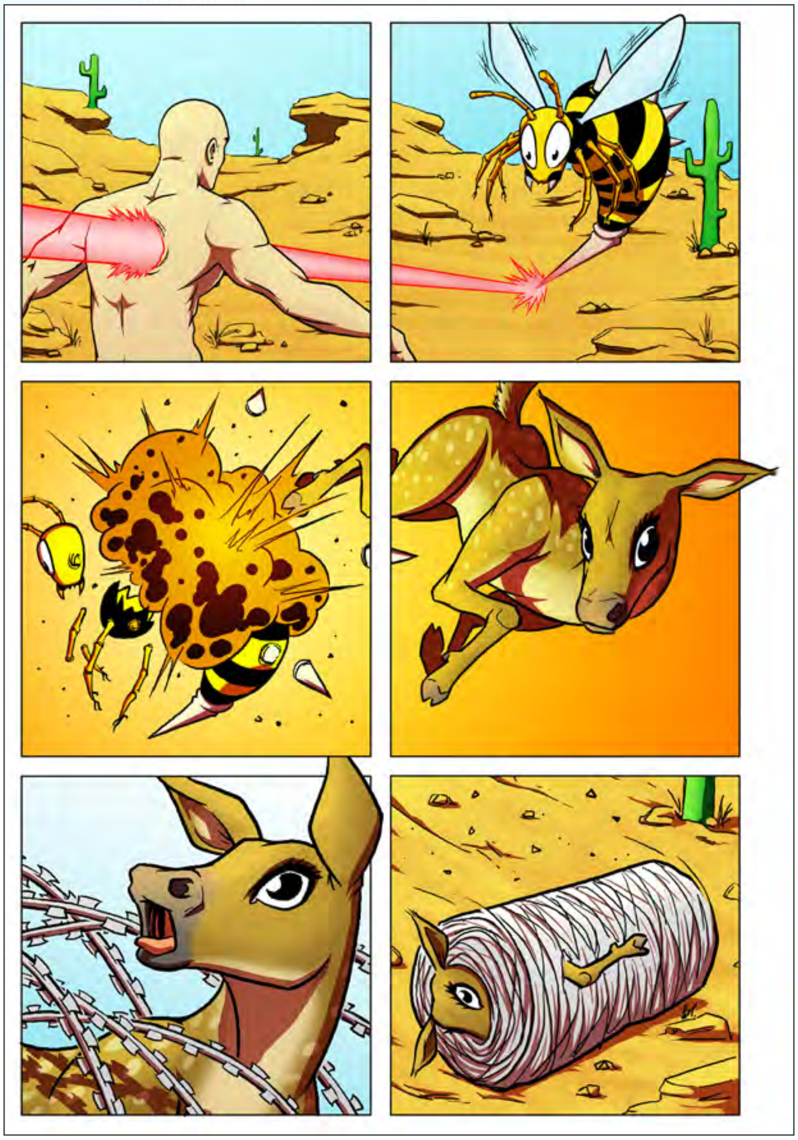
1. First object refers to **time**;

2. Second object refers to **depth**;

3. Third object refers to **consumed gas**; and

4. The fourth real-life object refers to the **environment** associated with the previous information. For this I usually select an object I set as a reference in the environment (or something that reminds me of the environment, e.g., column, large room, T, animal bones, etc.).

Let's consider the following mental snapshots taken during the course of a dive:



The more absurd the story, the easier to remember. (Courtesy of Ivan Wagner)

1. Time: 4 minutes, depth: 9 meters, gas: 200 bar, environment: reel to mainline connection.

2. Time: 20 minutes, depth: 12 meters, gas: 190 bar, environment: first T.

3. Time: 25 minutes, depth: 11 meters, gas: 180 bar, environment: huge room.

4. Time: 31 minutes, depth: 14 meters, gas: 170 bar, environment: second T.

5. Time: 46 minutes, depth: 20 meters, gas: 150 bar, environment: calling the dive.

Here is the story I will use for memorization of the first snapshot:

- *I'm walking on a desert road and suddenly, I feel a laser **RAY** (time: 4 minutes) burning on my chest. I notice it comes out from a huge angry **BEE** (9 meters) tail until it overheats and explodes. A **DOE** (consumed gas: 10 bar) pops out in mid-air from the bee's remains. She falls on the floor, entangled in a barbed wire forming a big coil that reminds me of a **diving reel** (environment: reel – mainline connection).*

You may think it is complicated to construct such a story, but remember that you already will have mastered the PEG system; the words (RAY, BEE, and DOE) would immediately recall your parameters. Secondly, this story only occupies a few lines of text. Our brain takes far less time (a matter of seconds) to create it. If we don't build a personal and exaggerated story, it's difficult to recall it. The strategy here is to be creative.

Snapshot 2:

- *I keep walking on the road and suddenly, I see a huge red bleeding **NOSE** (time: 20 minutes). Desperate to stop the bleeding, it sniffs a large sand **DUNE** (depth: 12 meters). The previous wet, stinky **DOE** (consumed gas: 10 bar) reaches up and brands the nose with the "**T**" letter (environment: our first T). The doe starts riding the nose until I lose them from sight.*

Snapshot 3

- *I keep walking and I free fall down a hole to a room filled with rusted hanging **NAILS** (time: 25 minutes). All the nails start to shake and from the ground a huge **TWEETY** (depth: 11 meters) bird emerges with the bleeding **TOES** (gas consumption: 10 bar) wrapped in its huge claws. I realize that the bird is flying high. The room I'm in is **HUGE** (environment: huge room) and I can barely see the hole from which I fell.*

Snapshot 4

- *Moving away from the large room I suddenly step on brown and sticky **MUD** (time: 31 minutes.) As I try to remove my stuck foot, a huge rotten **TIRE** (depth: 14 meters) comes out. Inside I see human **TOES** (consumed gas: 10 bar) and other remains. I pick up all the bones and realize one finger has two wooden ancient rings, each with a "**T**" (environment: second T).*

Snapshot 5

- *I move a bit forward because I see something shining, and I realize that it is a treasure which makes me a happy and **RICH** (time: 46 minutes) person. I hear something fall behind me, and just as I turn my back I realize it is the huge and bleeding **NOSE** (depth: 20 meters). It is scared—just as a protective parent would be—as it takes out its child from its nostril. All of a sudden the child takes out a phone, asking **NOSE** (consumed gas: 20 bar) to **call** (environment: calling the dive) her father to pick her up.*

The details you include in your story are personal, and you need to ascertain if you're able to recall everything with just a few details. If you realize it's too challenging to recall the associations, it usually means that your PAV is not strong enough. If that is the case, usually including more details and/or exaggerating the story even more does the trick. Remember that you also have to consider your preferred sensory channel. Add colors and shapes if you're visual; add sound if you're auditory; include touch if you're more kinesthetic. The more you practice the easier the story creation becomes. The good news is that you can practice it out of water, in the office, or even while driving - as you memorize car tags while driving to the Lot region in France, for example.[1]

FINAL THOUGHTS

There are a variety of approaches to assist you with your memorization skills. You can easily start with simple parameters like time and depth, and once you feel comfortable, you can incorporate more details. Don't become discouraged; you will not be perfect at the start. Do keep in mind that there are courses led by professionals that can help you master the method in two to three days. I strongly suggest taking a class if this topic interests you. From personal experience, I know it has helped my diving.

REFERENCES

Your Trainers Group: http://yourtrainersgroup.us

Wikipedia:
https://en.wikipedia.org/wiki/Mnemonic_peg_system

[1] To keep multiple stories straight, select an aspect that can change with different dive conditions, for example, night vs. day, cloudy vs. sunny, overhead vs. open water. Another approach is to use the same letter-number associations, but select a different word (e.g., "7" can mean "KEY," but it can also mean "GUY.") In the previous story example, the storyline consisted of me walking in a desert and encountering various scenarios. If I were to perform a second dive, I could change the story to have me flying across the sky like Iron Man, visiting different far away locales. The course teachers are adept at applying various methods across diverse scenarios and can be a great resource.

Factoring One's Own Psychology into Whether Or Not to Pursue Rebreather Diving

Are Rebreathers For You?

By Gareth Lock


T. St. George

Though they may not be suitable for all divers, rebreathers are ubiquitous in sport diving.

REBREATHERS have long been used in diving. Though the early models didn't have complicated oxygen addition systems or elaborate scrubbing mechanisms for the removal of carbon dioxide (CO_2), this has changed; today, rebreather technology is both reliable and sophisticated and the use of rebreathers is now commonplace in sport diving. Though some might argue this is for the wrong reasons, what is clear is that they are here to stay. Given the price of helium, their use will likely overtake open-circuit on dives where helium is recommended for safety reasons.

This article has been written under the assumption that closed-circuit rebreathers can be an asset to a diver and his or her team, while concurrently underscoring why they aren't suitable for all divers and to examine the significant, but latent, risks that are present when undertaking rebreather diving.

REBREATHER HISTORY

Going as far back as 1726, rebreathing equipment was used to help miners survive disasters by using a flannel liner soaked in salt water and tartar to scrub impurities from their breathing gas. In 1878, the first oxygen (O_2) rebreather was patented, followed soon thereafter (1881) by the use of barium hydroxide as a carbon dioxide scrubbing material for a rebreather built by Achilles, Khotinsky, & Lake. However, rebreathers really came to the fore during World War II when the Italian Navy used O_2 rebreathers in combat operations, and the Royal Navy used nitrox rebreathers for the same purpose. The use of nitrox extended the Royal Navy's operational depth range which then gave them a significant advantage.

Designing systems that reliably and consistently address the physiological requirements of the human body has been the key challenge in developing a safe rebreather. Hyperoxia, hypoxia, hypercapnia, and decompression sickness all pose significant risks to divers, especially as we have no consistently reliable way of internally monitoring the physiological development of these outcomes until it is typically too late.

Since World War II, rebreathers have developed from specialized military and commercial life support systems to the sport diving equipment we now see. I have intentionally used the terms *system* and *equipment* for a reason and I will come back to this point later, as it is fundamental to enhancing the performance and safety of rebreather divers.

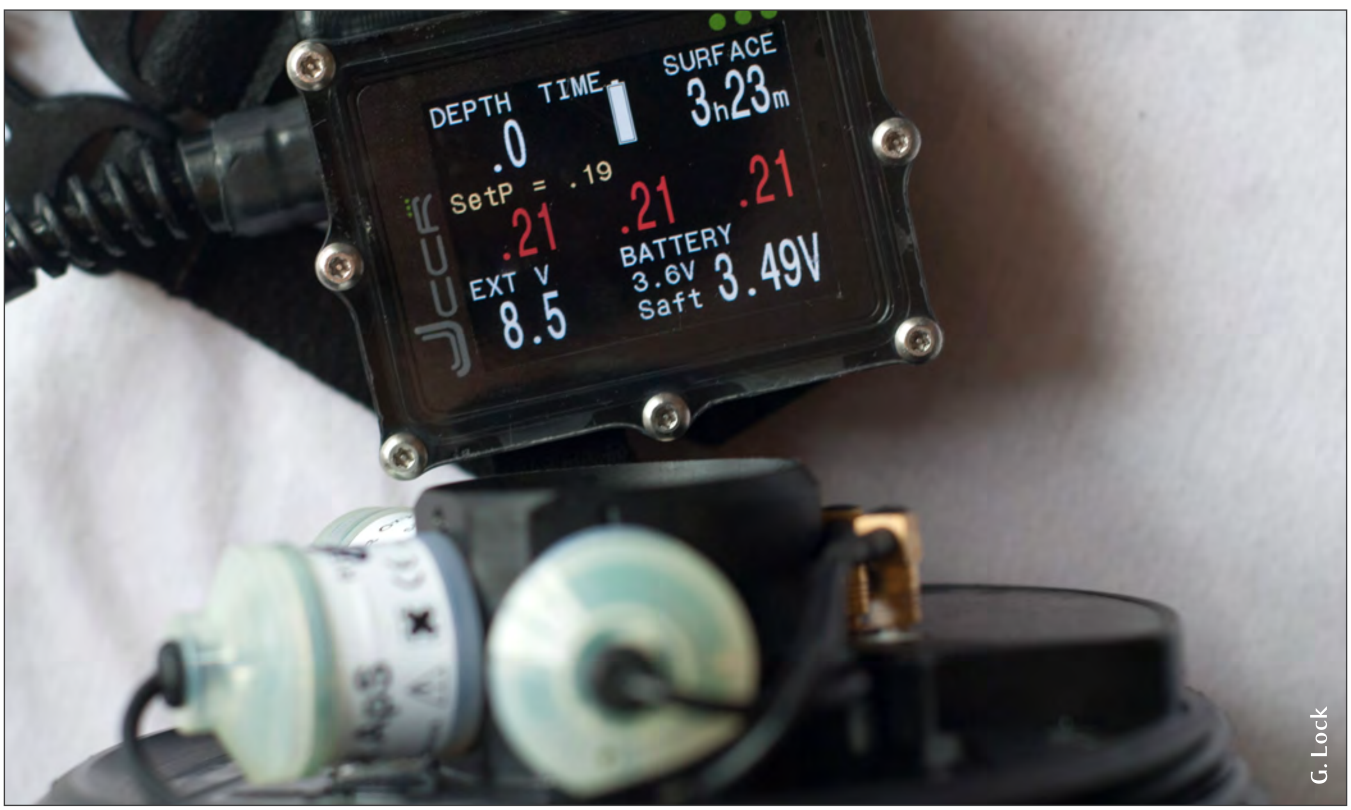
REBREATHER UNIT DESIGN

Some rebreathers are far more complicated than others, but fundamentally, a rebreather is a pretty simple piece of equipment. It needs a source of breathable gas, a way of replacing metabolized oxygen, a scrubber, a breathing loop consisting of a mouthpiece and hoses, and finally, a means of controlling gas volume and pressure when ascending or descending and breathing in and out. The complicated part is how to consistently and reliably manage the composition of the breathing gas so that it is breathable at variable depths within acceptable pO_2 parameters, taking into account ascents and descents, which change the volume of the gas in the breathing loop and therefore the pO_2.

In closed-circuit rebreathers, the loop's pO_2 is monitored by O_2 sensors, and the oxygen metabolized during a dive is replaced by a number of different methods: manually, continuously, manually and continuously, or through the use of a solenoid and a manual addition system.

Nonetheless, sensors were not designed to be used in moist, hyperbaric environments (precisely the environment for which they are used in diving), an orifice on a mass flow unit can clog, and a solenoid can fail open or closed. This means that the closed-circuit rebreather diver must be super vigilant with respect to what is going on in the loop.

Equally critical is making certain that CO_2 is eliminated from inhalation. Proper maintenance, scrubber packing, and assembly checks can go a long way to reducing the likelihood of a CO_2 hit, which if not dealt with can easily lead to disorientation and death. Nonetheless, other factors may contribute to a CO_2 hit



As part of build checks, divers should ensure that there is enough power in the batteries for the electronics and solenoid.

so CO_2 loading needs to be carefully monitored, and if any of its signs manifest themselves, divers should bailout.

COMPLICATED VS. COMPLEX

Rebreathers are sometimes termed "complex," and while the following might appear to be a matter of semantics, there is an important distinction between "complex" and "complicated," especially when it comes to managing risk. In safety management terms, "complicated" means that the system consists of a large number of parts which all behave in an expected manner, including how they interact. As such, they can be accurately and reliably modeled. Because the limitations of the system are known, these can be mitigated or controlled.

In contrast, "complex" means that while individual system component behaviors are understood and can also be modeled fairly reliably, their interactions are not always understood and emergent behaviors are possible. Fundamentally, this means that recreating events or systems from the decomposed individual components or parts doesn't always yield the same event or outcome.

Adding a human into any system where decision-making is required certainly adds complexity because we are unable to reliably model system outcomes, especially when the outcome might be greater than the sum of the parts or, indeed, novel.

The analogy of raising a child could be used here. Formulae have limited application. Raising one child provides experience but no assurance of success with the next. Expertise can contribute but is neither necessary nor sufficient to assure success. Every child is unique and must be understood as an individual. A number of interventions can be expected to fail as a matter of course. Uncertainty of the outcome still remains.

CCR divers need to properly monitor the state of their O_2 cells both during calibration and diving.

Given the above, complexity poses problems when trying to mitigate potential risks as it is not possible to think about every possibility. To manage the unknown, the most useful and successful outcomes usually emerge from discussions within team or system users/designers and wider sources of information or knowledge.

SYSTEM VS. EQUIPMENT

A system consists of a set of components, the capability of which is greater than the sum of its parts. There are a number of ways of thinking about systems, and one simplified model is known as the SHEL model. The acronym stands for:

- *Software*: the rules, procedures, written documents, etc., that are part of standard operating procedures or accepted practice.
- *Hardware*: the equipment, displays, controls, and functional systems that are interacted with.
- *Environment*: the physical, social, and economic contexts within which the software, hardware and liveware operate.
- *Liveware*: the human beings within a system (e.g., divers, dive center staff, skippers, servicing and manufacturing personnel, agency staff, etc.).

For any system to be effective, it needs to take all of these elements into consideration. You cannot have a brilliant system if you don't consider the variability of human performance when it is liveware that is operating the equipment, or what the training requirements need to be to operate the system (rather than just pass the training course), or what procedures/checklists need to be developed to use it—both in normal and emergency situations given the cognitive limitations (whether they be social, physical, or economic) of the user in all of the environments in which it is likely to be used.

Therefore, one of the challenges faced in getting divers to operate a rebreather safely is convincing the 'liveware' that a rebreather is not just a piece of diving equipment, but rather an component in a system comprised of the aforementioned elements.

REBREATHERS ARE MORE LIKELY TO KILL YOU THAN OPEN-CIRCUIT

If this means that rebreathers provide more hazards that need to be mitigated than open-circuit: definitely. However, the reasons for these failures are not normally undetected technical failures, but rather human performance variability leading to the system failing.

Fock, in his 2013 paper[1], highlighted that there is "a 25-fold increased risk of component failure compared to a manifolded twin-cylinder open-circuit system" and the risk of fatality was "between four and ten times higher than open-circuit diving." He goes on to say that 21% of fatalities are due to hypoxia or hyperoxia and 9% are due to hypercapnia. However, Fock does recognize that the data for fatalities is not reliable and that better reporting and research are required.

Research conducted by Cranfield University graduate student Hardy in his thesis "Risk Based Design Considerations for the Cranfield 'Home Build' Closed-Circuit Rebreather"[2] and work by Tetlow and Jenkins in their paper[3] "The use of fault tree analysis to visualize the importance of human factors for safe diving with closed-circuit rebreathers (CCR)" identified that the majority of failure modes were not due to hardware, but rather the human interacting with the system (Table 1).

Table 1. Frequency of occurrence of specific end events for the full fault tree

End Event	Total Number of Occurrences
Poor Training	180
Poor Pre-Dive Checks	147
Stress	78
Poor Maintenance	52
Incapacitated	42
"It Will Do" Approach	32
Poor Dive Planning	29
Mechanical Failure	24
Other	16
Total	600

As one will note from the above table, effective training, pre-dive preparedness, and stress reduction cover 67.5% of end events in the failure tree and therefore should be the key focus areas to improve safety in rebreathing diving. Note that mechanical failure only relates to 4% of failure modes. This links back to the system-based thinking portion earlier.

UNDERSTANDING THE LIMITATIONS OF A SYSTEM

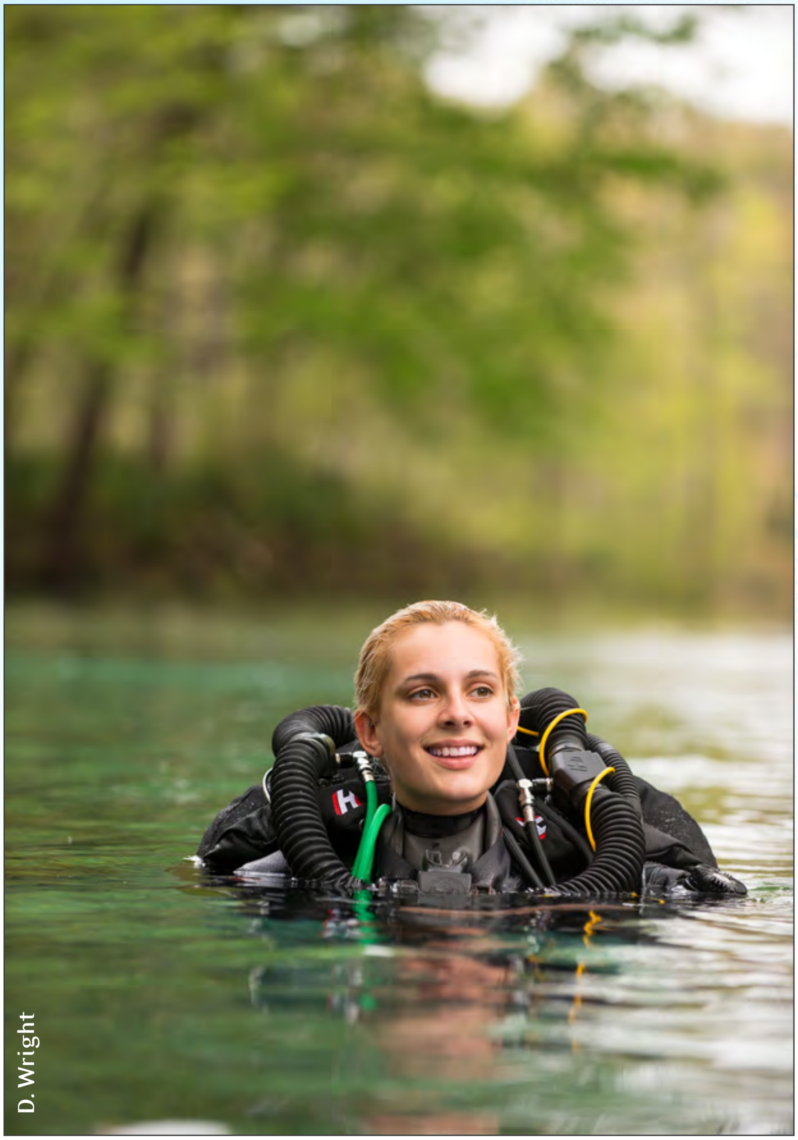
Prior to 2014, there was much focus on the 5-minute pre-breathe as a means of ensuring that the scrubber had been packed correctly and worked to specification. However, in 2014, Mitchell and his team conducted research[4] to test this theory and showed that in a significant number of divers it was not possible to detect CO_2 breakthrough, even when a specific component which would allow CO_2 to bypass the scrubber was missing. (This particular component had been implicated in a number of near misses because it was overlooked – could be considered sub-optimal hardware design). Some consider the use of a pre-breathe as an essential part of pre-dive preparation because it can demonstrate that solenoids and controllers are working correctly in a 1 bar atmosphere; however, humans are unable to reliably and consistently show responses to excessive CO_2 in the breathing loop. Therefore, there is a need to understand why processes and procedures are in place and their associated limitations.

The human in the loop (no pun intended) is a key system component and we need to understand our own cognitive, physical, and physiological limitations, and how these limitations vary from person to person and over time when relating to one person.

CHECKLISTS: NOT THE BE-ALL AND END-ALL OF SAFETY

Much has been made about the effectiveness of checklists to reduce accidents and incidents in aviation and healthcare; specifically in the surgical environment, the use of standardized check lists reduced fatalities by more than half according to a global study led by Dr Atul Gawande. As a result, members of the diving community have embraced the view that checklists should be used by all rebreather divers. There has been some resistance to checklists, partly because they involve change and humans don't normally like change, but also because there isn't a consistent definition of *checklist* across the diving community. Even so, GUE has adopted a number of hard-copy checklists within their CCR diving operations to minimize the risks involved. These take into account the unit build, pre-dive preparation at the dive site, and the final pre-breathe.

Looking beyond GUE, ongoing research aims to identify whether or not checklists are effective and why. What is clear from other areas is that by having a communications structure that is coherent, easy to use, and is consistently used by the team to cross-check important information, accidents and incidents will be reduced. However, as Catchpole says in his paper[5], "…a checklist reliant on teamwork for success may fail despite all the items being followed because those team skills were insufficient." He also says (when referring to the successes gained in aviation through the use of checklists), "The failure to replicate results in healthcare demonstrates that at the very least, where success has been observed, it was not only a checklist that created the effect."



Despite its added complexity, rebreather diving can be a great source of enjoyment.

MINDSET IS KING

As implied throughout this piece, it is essential that the correct mindset is applied by divers and dive teams to rebreather diving. GUE has a history of developing thinking divers who understand team diving and have the ability to look out for each other, contribute to joint needs and outcomes, and discuss positive and negative events in an open and reflective manner. However, not everyone has this mindset even when they have been certified as a GUE diver. Many of the risks of rebreather diving are predominantly managed at the individual level and require divers to be honest with themselves before they can be honest with their team. For example, the Advanced Rebreather Preparation Checks (ARPC) requires that parameters and tests are completed and signed for so that the team can simply validate that these have been done (in the same way a gas analysis tape is used). However, there is nothing to stop these being forged other than personal integrity.

SUMMARY

Is rebreather diving dangerous? That depends on where your risk perception and acceptance thresholds lie. If you have the mindset that recognizes a high level of skill, regular practice with reflective feedback, and a considerable and ongoing financial investment are essential to safe diving, then you are likely to consider rebreathers safe. However, if you treat a rebreather as just another piece of dive equipment that you can throw on and jump in the water with, conducting the minimum amount of pre-dive preparation and inconsistent equipment assembly, and with no real teamwork present, then using rebreathers may prove risky, as they are likely to end up putting you in danger at some point given the numerous and insidious ways in which failures can happen. The main concern about rebreather failures is that they often result in symptoms that are not easily detected—such as hypoxia and hyperoxia—until it is potentially too late.

As with any type of diving, it can be safe; you just need to remember that things can go wrong in the blink of an eye, and without the proper training, experience, and mindset while diving, these situations can prove dangerous.

Rebreathers may be just the gear for you—or they may not be. Either way, dive with what you're comfortable with and always stay smart.

REFERENCES

1. Fock, A. W. (2013). Analysis of recreational closed-circuit rebreather deaths 1998--2010. Diving and Hyperbaric Medicine, 43(2), 78–85.
2. Hardy, S. (2001). Risk Based Design Considerations for the Cranfield "Home Build" Closed-Circuit Rebreather.
3. Tetlow, S., & Jenkins, S. (2005). The use of fault tree analysis to visualise the importance of human factors for safe diving with closed-circuit rebreathers (CCR). Underwater Technology: The International Journal of the Society for Underwater Technology, 26(3), 105–113. http://doi.org/10.3723/175605405784426619
4. Deng, C., Pollock, N. W., Gant, N., Hannam, J. A., Dooley, A., Mesley, P., and Mitchell, S. J. (2015). The five-minute pre-breathe in evaluating carbon dioxide absorption in a closed-circuit rebreather : A randomised single-blind study in a closed-circuit rebreather: a randomized single-blind study. Journal of the South Pacific Underwater Medicine Society, 45(1), 16–24
5. Catchpole, K. R., & Russ, S. (2015). The problem with Checklists. BMJ Quality & Safety. http://doi.org/10.1136/bmjqs-2015- 004431

Seasoned Technical Diver Discusses the Benefits of GUE's Fundamentals Class

Teaching an Old Dog New Tricks

By Leigh Bishop

Instructor Rich Walker briefs Leigh Bishop

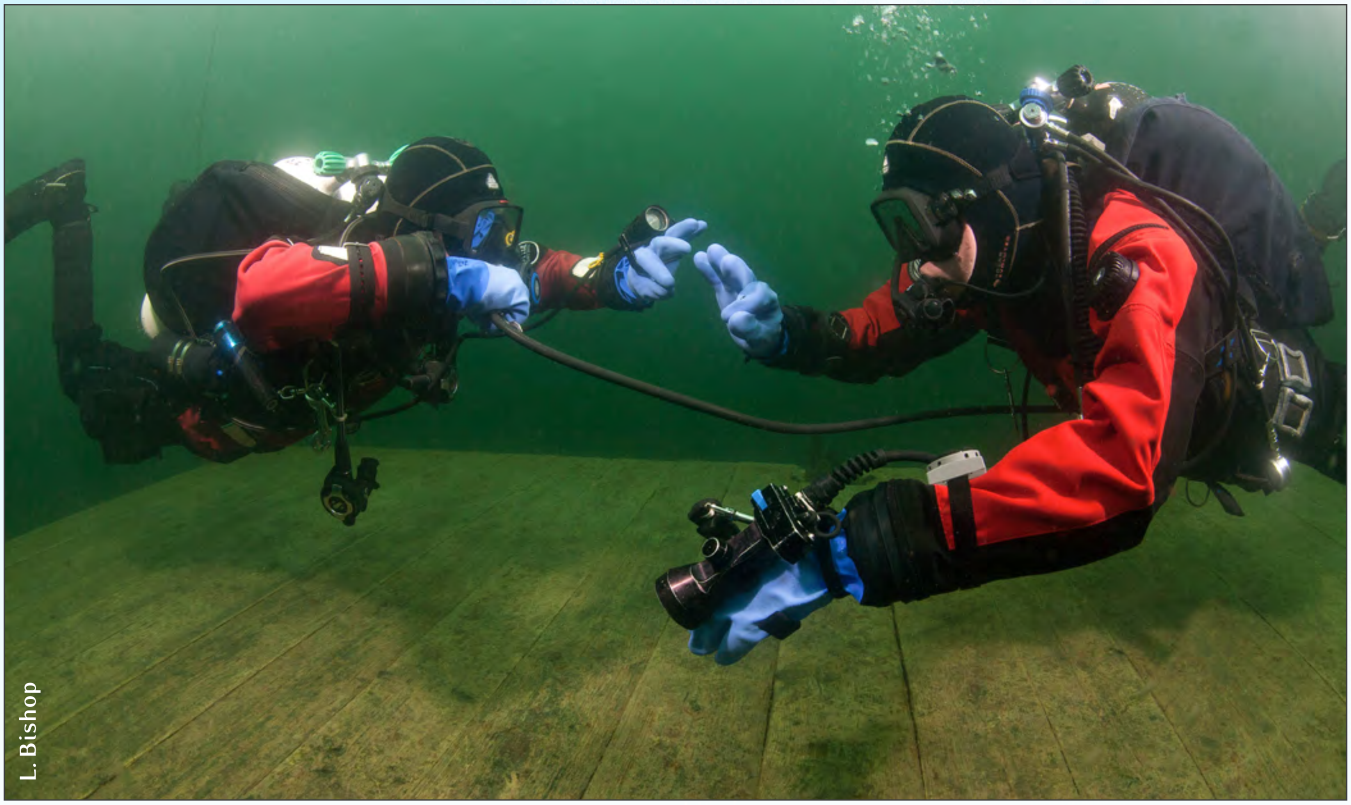
CAN *an old dog learn new tricks? Internationally renowned deep wreck diver Leigh Bishop enrolled in a GUE Fundamentals course to find out. His quest was simply to improve his existing underwater survival skills. Set in his ways and not having taken a technical diving class for over 20 years, the big question was: would he actually pass?*

"Tell me again, exactly, why are you booked on a GUE Fundamentals course?" A question repeatedly asked with the odd frown thrown my way.

My instructor-to-be, UK-based Richard Walker asked a similar question:

"What exactly am I going to teach you?" he asked.

There was reason to question. I was, after all, an established diver who could be described as someone with "a lot of experience." I had been there at the onset of technical diving, been a rebreather development diver, as well as a member of many significant deep shipwreck projects. Back in the heyday of mixed gas exploration, I had dived an estimated 400 virgin wrecks. Every weekend of the 90s I had lived for deep wreck exploration. Some of today's leading instructors have admitted how my writing and photography had inspired them into technical diving themselves. I even founded my own technical diving conference, Eurotek.



A student undertakes an out-of-gas S-drill

So, why exactly was I signing up for a basic level scuba course? It was time to be honest. I openly admitted my confidence for the deep had dwindled in recent years. I had lost close friends; others were bound to wheelchairs from decompression illness. I'd been working on a book and interviewing old friends I hadn't seen in a long time, including friends who had been seriously disabled from diving incidents. Seeing how their lives had changed made me seriously consider my reasoning for wanting to go deep. Did the advantages outweigh the disadvantages? The more people I interviewed, the more it seems they didn't. The psychology of it all was getting the better of me. Older and wiser, I began to appreciate everything around me. My mind told me I had two options: either hang my fins up, or do something about it.

In my professional life as a firefighter, barely a month passes where I'm not dragged away on another training course to be updated on developments of something I was taught only the year before. It's called "continuous professional development." Indeed, the fire service is a different job in terms of safety than when I first started 25 years ago. I began to wonder if the same was true in diving. The only difference was that in my job I was mandated to do it. The late legendary diver Rob Palmer taught me to use mixed gas well over 20 years ago. I was a member of the British Cave Diving Group in the 1980s, and I had known Rob for some time, which made him an easy choice as my instructor. It was his first UK TDI Trimix course one-on-one; in fact, it was so new there wasn't even any course material, let alone a smart online registration system like GUE has today.

Plenty of water had passed under the bridge since. If I went back to the drawing board could I learn something new, maybe new concepts or techniques, or perhaps some ingenious safety protocols that could have saved a friend or two? Would it help bring my confidence back? Was there another deep project still left in the old dog yet? My dilemma wasn't helped when I discovered the sheer volume of courses and agencies available. Back in the day, the options were nitrox and trimix, either taught by Rob or a new guy on the scene named Kevin Gurr, or travel to the USA for a Sheck Exley course, and that was it. Normoxic! Jeez, who would have ever believed that back in those days!

The joking and laughs took a backseat as my dive buddies absorbed the crux of my thought process. I'd made up my mind; from now on I would periodically enroll in a course in order to continually improve my underwater skills. But I wanted quality, so where would I start? My last deep wreck project had been on *Mars*, the 450-year-old warship in the Baltic Sea. It was of course a GUE project, but I wasn't a GUE diver—in fact, far from it. I did, however, share a close friendship with two of the men who founded and shaped GUE into what it is today, Richard Lundgren and Jarrod Jablonski. I respected both of them, and along with Richard's brother Ingemar, they would always be on my list for potential shipwreck projects.

Likewise, Richard had invited me to dive with them. But this trip wouldn't be my finest hour. A layoff meant I wasn't seasoned and my mind and heart were just not with it. I was a mess. During the trip I saw what I thought were some of the best divers I had ever seen in the world. Upon jumping in the ocean, I soon discovered part of my rig was not set right, so I returned to the boat. Ingemar climbed down the ladder to help, but as he was not familiar with my equipment he struggled to understand what I wanted, let alone help, leaving me no option other than to abort the dive. I was embarrassed, and as I removed my equipment, anger raged inside me over my performance. It was not Ingemar's fault; it was mine. Had I been standardized, he would have solved the problem blindfolded. I'd been inspired by these divers—not only by their safe, team-based approach, but their solid diver style and mind-set. If I was going back to basics, why not make it a GUE Fundamentals course. In the dictionary I looked up "fundamentals:" foundational and basic. The course would be a perfect start!

My instructor-to-be, Rich Walker, understood and applauded my openness. Despite who I was, I wasn't going to sneak through the net to achieve any standard of qualification without having to work hard and stick strictly to the required standards.

Honestly, I had no idea what I signed up for. I would soon discover it wouldn't be a walk in the park; my brain would have to engage both above and below the water to achieve any kind of worthy award on completion.

My intentions were not to become a full-on GUE diver. My focus was to learn precision skills, methods of configuration, and integrate them into my existing practices. A hybrid I suppose, or so I told myself. If I were honest, an end goal as a GUE CCR diver would be nice.

The big question was, after 25 years of deep wreck diving at the highest level, was I too set in my ways to accept change? This concern was equally shared by my instructor. A four-day fundamentals course would surely provide the answers.

I liked the philosophy, especially the fact that GUE never set out to do training for the sake of just training; I knew it was far more complex than that and the approach appealed to me. I had watched it evolve from a group of skilled U.S. cave divers to one of the world's most respected organizations today. I saw the aquatic activity of the three specific areas—education, conservation, and exploration—as the main objectives of what diving is entirely about.

Something many don't know is that I'd actually been a member of GUE for almost eight years. Being a GUE member, however, does not entail that one is trained by GUE; one can support GUE through membership without ever taking a GUE class. Nevertheless, instructors from other agencies had told me that a GUE qualification is accepted everywhere and highly regarded. Those holding one are regarded as having had the very highest level of training available. I had made up my mind; it had just taken me eight years.

Over four days I would have to complete a theory exam as well as six dives, demonstrating propulsion techniques, buoyancy, trim, S-drills, shut-down drills, a no-mask swim, and, of course, the Basic Five, all the while familiarizing myself with new terminology. I would also learn to move an unconscious diver from one place to another before making an ascent, something

Students demonstrate that their long hose is deployable.

G. Lock

The students participated in hours of diving theory lectures.

I can't for the life of me remember ever being taught in previous dive training courses.

DAY 1—8 A.M.

Rich Walker introduced himself to the class; the students did likewise. Rich had chosen the bleak British midwinter and a freezing inland quarry for our Fundamentals course; what was he thinking?

I expected a full class of students and was confused when only one other guy, Nigel, joined us. I asked when the others were arriving and discovered that the Fundamentals course maxes out at three students. This allows the instructor to devote the necessary time and attention to each student's progress.

I knew of Rich, a long-time GUE Instructor and an accomplished technical diver in his own right. He had been a speaker at the Eurotek conference. He began with an informative explanation of the organization and its benefits without sounding like an obvious 1980s car salesman. Something I found really appealing about GUE was that qualified GUE divers could join any GUE project around the world. With more exciting projects cropping up by the year, I could hire or borrow exactly the same equipment I was familiar with and dive with any GUE diver anywhere. In fact, standardization of equipment and training meant I could dive with a total stranger, but feel as if they had been my regular buddy for years. I began to think about the times that I had transported all my gear around the world; in those situations, I had to take everything with me, as there was no other option. I also considered previous expeditions and the concern I had of whom I would pair up with. By GUE standards, these were two elements I would no longer need to worry about.

Our first assessment was the swim test with a pre-set distance both above and below the water. Although I had forgotten my very European Speedos, I wasn't getting away with it. I improvised with padded cycling shorts, as I'd thrown my mountain bike in the back of my van thinking that if there was any spare time I would hit the local trails. How naïve was I to think any spare time whatsoever was factored into a GUE course. The pool session also incorporated basic body positioning; a nice, arched back and clenched buttocks would bring the knees into a nicely trimmed position. I was told these were essential for the precision required for techniques that would follow when fully kitted.

Back in the classroom, Rich discussed the advantages and disadvantages of equipment, including the things to avoid and the logical reasoning behind GUE's equipment choices. I knew GUE had a reputation for being prescriptive with what the diver could use and how it's set up. Thinking old school GUE and the days of the DIR militants, I was ready to attack him for telling me what I could or could not do in my life. However, at no time did Rich steer us to a particular brand. He was reasonable, methodical, and I liked his approach straight away.

He covered everything, from wings to suit inflators, from reels to lift bags; there was reasoning supporting everything, even down to the correct hose lengths. It was all starting to make sense. For example, a 60cm hose was perfect for a back-up regulator; not too short as to restrict your head movement, not too long as to cause a potential snagging hazard. I learned it all comes back to one basic principle: if you don't need it, don't take it. I began to understand what GUE does is based on simplicity. It was all about consistency across varied environments. Depending on what your diving style or choice is, it was all logical and appeared to work just fine.

The other aspect of the GUE configuration that attracted me was that wherever I chose to dive globally, the kit was the same. It hadn't struck me before that I could rent the exact set-up I dived at home from Extreme Exposure in Florida or borrow it from a likeminded GUE diver if I joined a project in Australia, not to mention the obvious advantage of weight saving on airlines. It also appeared to be very adaptable; I could dive the same harness set-up on a GUE deep project in Greece to 120 meters that I would use the following week looking at fish in 3 meters of water in the Red Sea.

Nigel and I went through a simulated dry run in the classroom wearing the standard GUE configuration. We were taught about left post roll off, why the pressure gauge feeds from the same post, and all sorts of clever reasoning and accident preventative measures. I knew a GUE configuration had evolved from those who had learned lessons from being at the sharp end. All the elements coalesced logically and could be applied in any environment.

DAY 2—8 A.M.

Day Two was all about getting into the water and working on basic skills, including buoyancy, trim, and propulsion. Future skills would all be based on those foundations.

Rich kindly loaned some equipment for the duration of the class. I thought this was a good idea; if I were totally new to the sport and was unsure what to purchase, or if GUE wasn't my way forward, I had not spent unnecessary funds. Then, just when I thought I couldn't cope with any more mnemonics in life, Rich gave me another: GUE EDGE.

When it came to buoyancy, gas distribution interested me: where it should and shouldn't be in relation to trim and how to control it. I wondered why so much emphasis was placed at the onset on buoyancy and trim. The skills that followed answered my question.

While diving *Mars*, if I swam around or held the anchor line during decompression, I noticed the others staying perfectly still in the water, eyeballs rolling left to right as they followed me under a frowning eyebrow. It was time for me to learn where I may have been going wrong.

When it came to propulsion techniques, I won't say I didn't have a reasonable technique; it just needed fine-tuning. Helicopter

Leigh Bishop demonstrates S-drill gas donation kicks I had used often, but, hang on, fin backwards? Keep trim absolutely perfect? Was he joking? At first I thought this was a waste of time. Why would I ever need to fin backwards? This was stupid! However, the more I thought about it the more I realized the skill could be quite useful. Take for example, while diving on a restricted wreck, my curiosity gets the better of me. The only way to exit is the direction from which I have come, but due to the limited space, I have no option but to implement the backwards fin kick.

The goals of the afternoon dive were focused around the Basic Five and the S-drill, skills most people can do or have at least done in a class. Though I had experience using my long hose, the S-drill was more about being the donor, with both divers remaining calm and safe.

The day ended, as would each of the four days, with a brainstorming session in the classroom. I was exhausted, but I was learning, and most certainly improving my in-water skills. I was also beginning to think a GUE class was more than just a class. It was an investment in my future.

DAY 3—8 A.M.

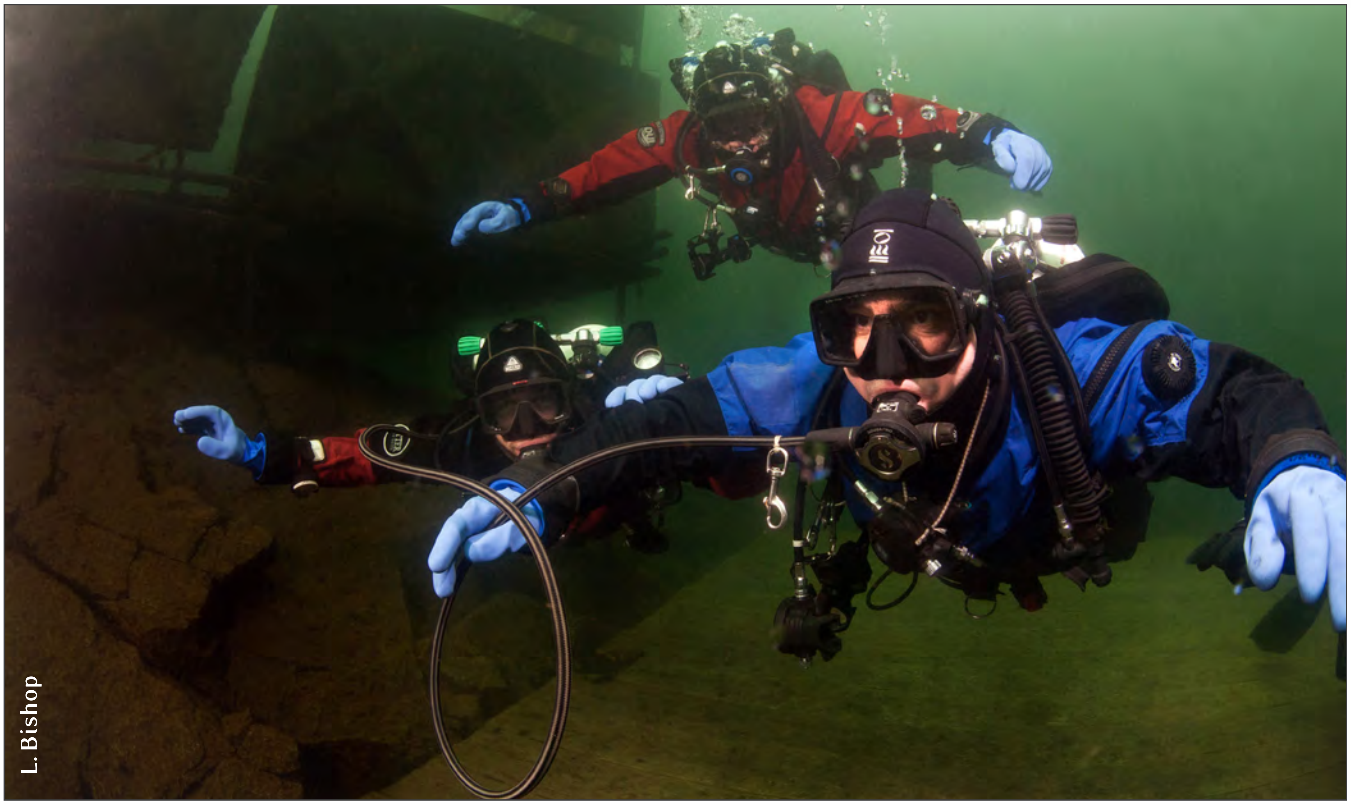
Emphasis was placed on gas management and particularly on gas analysis. Near to my own heart, this subject addressed the cause of how I lost my best friend. I liked the GUE method of contents labelling; in fact, I own a roll myself. While I was never a believer during GUE's early days, there had been little things over the years, such as the gas labelling system, that once they caught my attention, I thought clever and ingenious.

The morning's dive was focused on gas shutdown drills, something I don't do as a CCR diver. I soon understood the reasoning behind a correctly cut drysuit for reaching the valves. Luckily for me, my perfectly-cut Santi Elite was fine and allowed me to undertake the isolation process, but it did take a few attempts to get it right. GUE diving is all about teamwork, thus the importance of learning the skill correctly was more than emphasized.

Never in all the years I've been diving had I lost or swam around without a mask. The afternoon dive was one I hadn't been looking forward to and one where I would do just that: swim with no mask. I passed the skill, but the thought of doing so did not sit well with me at first. Now, if I were to accidently lose my mask on dive, no matter how challenging the environment, I felt confident that with this training in hand, I could control the situation, reach for the spare mask in my cargo pocket, and continue to safety.

DAY 4—8:30 A.M.

The regime of gas analysis set in and I began to think how a day of diving would feel odd if it wasn't the first priority. The final day's dives incorporated some new skills while brushing up and fine-tuning others we had learned.



Students perform a long hose gas-sharing drill.

Leigh Bishop's first GUE certification

The first dive incorporated additional practice with S-drills, shutdown drills, and other skills we had learned previously. I also learned how to maneuver an unconscious diver from one point to another, something I hadn't done for years and certainly not in this way. Most mainstream scuba rescue drills typically entail grabbing the diver, inflating the BC, and immediately ascending to the surface. GUE's course taught me that oftentimes the environment does not allow for this technique. I liked the method, one I figured I would practice every so often.

Richards's description of the last dive made me laugh, as he called it his "flexible dustbin dive." The dive focused on repeating drills until they were spot on.

Finally, after six dives, Nigel and I had individually demonstrated our capabilities of each and every skill. A possible certification award now sat in the hands of my instructor. For me to continue through the GUE structure, he would need to be confident I was ready to progress and award me a Tech pass.

Admittedly, modifying habits I'd developed over two decades wasn't going to happen overnight. I was set in my ways and Rich knew that. Skills I'd avoided over the years simply had to be demonstrated. They gave me the boost I needed. I carefully dissected each one and thought long as to how I would integrate each into my existing practices, from weight to buoyancy distribution to what I really did and didn't need on a dive.

I didn't find GUE Fundamentals cheap. However, I relate it to my Mac computer theory: people may avoid them because they're more expensive than a PC, but they last three times longer.

You pay for quality, and I can honestly say that's what I got from my GUE Fundamentals class.

Thankfully, I passed the class, and I can now consider becoming a GUE technical diver.

I guess this old dog can learn new tricks.


S. del Curto

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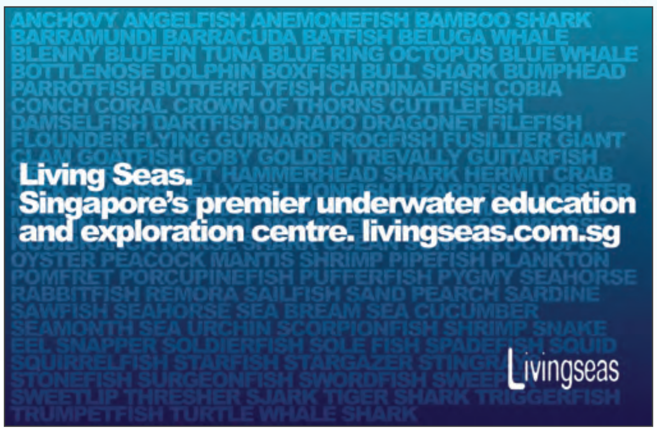

This Issue's Contributors

Jon Bernot started diving in the lakes in Oklahoma as a teenager and became a scuba instructor in 2005 while attending the University of Oklahoma. After serving as an officer in the United States Marine Corps, he purchased his first dive operation in coastal North Carolina and later moved to North Florida. With a strong background in wreck and cave diving, he is currently the owner and training director of Cave Country Dive Shop in High Springs, Florida. Before that, he was a service and product manager for Dive Rite. His experiences have allowed him to learn about the industry from the unique perspectives of an instructor, owner of a retail facility, and as part of a major manufacturer. He has certified nearly a thousand students from the open water through technical instructor levels and is an IT with IANTD. In addition to a B.A. in Political Science, he holds a Master's Degree in Environmental Management. He currently teaches courses on the O2ptima, KISS, Fathom, and JJ CCRs. He still loves teaching after ten years as an instructor, but is also an avid explorer, and his favorite type of dive is always a deep cave dive.

Leigh Bishop is a British shipwreck explorer and pioneer of deep wreck mixed gas diving. He specializes in deep wreck photography, and his research has led to the discovery and identification of hundreds of shipwrecks. He has been a member of many significant deep shipwreck expeditions as well as scientific projects that have carried the Explorer's Club flag. Leigh has been featured on many television shipwreck documentaries, and has worked as a deep-water cameraman for National Geographic, History Channel, ITV, Channel 4, and other global networks. He lectures frequently on the subject of shipwrecks, and his photographs and articles have appeared in countless magazines, books, and major newspapers over the last two decades. Leigh is also the founder of the advanced diving conference Eurotek. He was taught mixed gas diving by the late Rob Palmer, is a qualified CC mixed gas diver, and recently began GUE coursework.

Mauro Bordignon was born in Italy in 1975, began diving in 1997, and in 2001, he began cave diving. He became a professional diving instructor in 2002 and a cave diving instructor in 2009. Mauro lives in Akumal, Quintana Roo, Mexico.

JP Bresser is a GUE Cave 2 and Tech 1 Instructor based in the Netherlands. As an editor, photographer, and filmmaker, JP has traveled to exciting dive locations all over the world. He is famous for his underwater photography and film work that has featured cave and deep wreck exploration in remote and hard-to-reach locations. JP is also a member of several cave exploration teams and has worked with many projects around the world to support and manage underwater documentation, including MCEP in Mexico and Karst Odyssey and Morpheus in the Balkans. As a member of the USS *Atlanta* team, JP travelled to the Solomon Islands to document the impressive wreck at a depth of 130 meters.

Gareth Lock is passionate about improving diver safety. In 2011, he formed a research company whose aim was to transfer established safety management system practices from aviation to sport diving, cognizant that a straight path would not be possible given the nature of sport diving. In 2012, he began his Ph.D. which examines the role of human factors in scuba diving accidents and incidents. He has presented at a number of national and international diving conferences, promoting a "just culture" and reporting in the sport diving community to breaking down barriers, thereby making diving safer. He has recently been appointed as Director for Risk Management for GUE to strengthen the organization and further develop a "just culture" within GUE. He has also launched a number of online and classroom-based courses to improve divers' personal and team performance.

Tom McCarthy is the owner and operator of East Coast Wreck Diving and the Long Island dive boat *Tempest,* based in Freeport, New York. He is also the founder of the dive retailer StoneRust.com. He is a technical diving instructor, holding ratings as a Trimix Instructor as well as a SF-2 and rEvo Rebreather instructor ratings. Tom is an active wreck diver, cave diver, and underwater photographer in the northeast United States.

Dr. Thomas R. Sawicki is an Assistant Professor of Biology at Florida A&M University. His research focuses on the ecology of anchialine and freshwater caves and the systematics of macrocrustaceans that live in these environments, particularly amphipod crustaceans.

Anton van Rosmalen is a business consultant specializing in risk management in the Netherlands. Outside of the office, he takes his RB80 into as many caves and wrecks as possible. Always looking for possibilities to combine challenging dive projects with scientific research, he has been involved in Project *Mars* Makalös, MCEP, EKPP, and the Project Baseline Mediterranean Expedition (the one with the submarines!). He is one of very few divers to reach the end of Emergence du Ressel, Europe's most famous underwater cave.

Ivan Wagner is an embedded software engineer and co-founder of a consulting and development company based in Switzerland. He was first dive certified in 2002, and received his GUE Fundamentals certification in 2010. Ivan is passionate about the underwater environment, diving primarily in the lakes of Switzerland and the wrecks of the Mediterranean.

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Photo by Gemma Smith