Going 'Recreational'

Taking the Se7en for Spin

The nascence of recreational rebreathers was just waiting to happen. Spurred on by rapid advances in technical diving, new materials and technology, coupled with cost reductions, the allure of long and quiet dives, with vastly improved non-deco times, had to seep from the technical communities to recreational diving, leading to the design of a new generation of closed circuit rebreathers aimed primarily at recreational divers. But how far have we come to making closed circuit rebreathers a common sight along our shorelines?

Text and photos by Peter Symes

There is probably no point in denying it was with no small measure of boyish anticipation that I showed up at Poseidon's premises on the outskirts of Gothenburg, Sweden, to go through a course on their Se7en closed circuit rebreather, which is an upgraded and meaner looking version of the MkVI they fielded a few years back.

Coming up first on the agenda was taking a closer look at the innards and getting familiar with all the components and how they came together. Looking at the unit as it was laid out gutted on the table, it struck me how compact everything was. The breathing hoses, for example, of which there are four short identical ones, are each just about a foot long. The counterlungs, which detach easily for rinsing, just looked liked a couple of small bladders, but as the manual states, they are "sized to be about half the volume of a full breath for an average individual", and as I should learn later taking it in the water, they had indeed all the volume necessary.

On assembling the unit, nothing felt flimsy or inaccurate; build quality seemed solid, the manufacturing precise, and the design came across as thought through. Not that I expected otherwise, as the Se7en is the improved younger sibling of the MkVI, which already had many years of development, debugging and refinement behind it. It showed in the details and nice finish.

Boot sequence

Once the unit had been assembled and checked, it could be fired up. During start-up, the unit automatically performed a sequence of system checks, the progress of which could be followed on the handset.

During the sequence, there were a few prompts, such as to open or close the mouthpiece, and confirmations to make, such as verifying that a scrubber cartridge had been inserted. In case of any issues or failed tests, an alert would be displayed on the handset along with a diagnostic code number that could be looked up in the manual (which can be downloaded to a smartphone or tablet and thus kept handy.)

It was all fairly straightforward. I won't delve too deeply into the technical specs or the philosophies underlying the design other than to point out that the Poseidon series of rebreathers, in constrast to most other CCR's currently on the market, was conceived as a clean-slate design aimed primarily at the recreational divers from the onset as opposed to a paring down of a pre-existing technical rebreather as a number of other manufacturers have opted to do.

In what has been probably the most radical deviation from the prevailing dogma, Poseidon's engineers opted to use only one oxygen sensor—rather than the usual set of three coupled with a voting logic—to monitor the gas in the breathing loop.

There is a second sensor but this is used, in what Poseidon has dubbed "Active Sensor Validation", only to validate the first and primary sensor raising the alarm if there is a discrepancy in the readings between the two.

As the sensor has direct access to both oxygen and the diluent (i.e. air)—each of which has a known oxygen content—a burst of each of these pure gases will provide a set of data points that can be used to accurately calibrate the primary sensor.

As counter intuitive as it may seem that a system using only one main sensor can be less prone to error than a design that rests on three, the principle does rest on a sound mathematical foundation, as i.e. Nigel Jones, principal at RMB Consulting, demonstrated at Rebreather Forum 3. Leaving any further elaborations of this side of the matter to the geeks, what is the significance of all this to the user?

This design allows for a significant level of automation and reduction of user task load.

It makes for a system that is both capable of precisely calibrating itself, using only a very small volume of gas, without any user input and able to continually monitor sensor performance at depth. As such this design allows for a significant level of automation and reduction of user task load.

Having been originally trained on a technical rebreather, it even came as a relief to me. I would almost compare to the difference of driving a vehicle with a double clutch manual gearbox to one with automatic transmission and cruise control.

Mind you

While rebreathers, also the latest recreational and most automated models, still require a good deal more preparation and diligence when assembling and pre-dive testing the units; the ease of use and reduced task loading felt both more reassuring and safer —a statement that will probably leave me open to flak from the old-school fraction in the CCR-community, but so be it.

High levels of automation don't, however, imply that you are now freed up to go dive more or less mindlessly. Lessening the task and stress loads primarily translates directly into safer diving, and it also means that I can enjoy my subsurface adventures to higher degree, focus on the experience and possibly other tasks, such as photography, which is my main interest and primary cause for diving a CCR.

Training

As with most other courses, training on the Se7en takes you through the familiar sequence of theory, with an exam at the end, followed by practice sessions in confined water before moving on to open water lessons.

In all rebreather diving, using and adhering to checklists becomes a mantra and instilling this mindset permeates the whole course. As tedious as it may seem, it is for good reason such lists are slavishly followed by pilots, highly trained and experienced as they may be. Open circuit gear can more or less be donned and dived after a few and simple tests.

Rebreathers not so. Since something as banale as a dislodged or pinched o-ring may not only compromise your dive but put your life at risk, you would want to go over your kit at least as patiently and meticulously as when you assemble that fancy camera housing of yours.

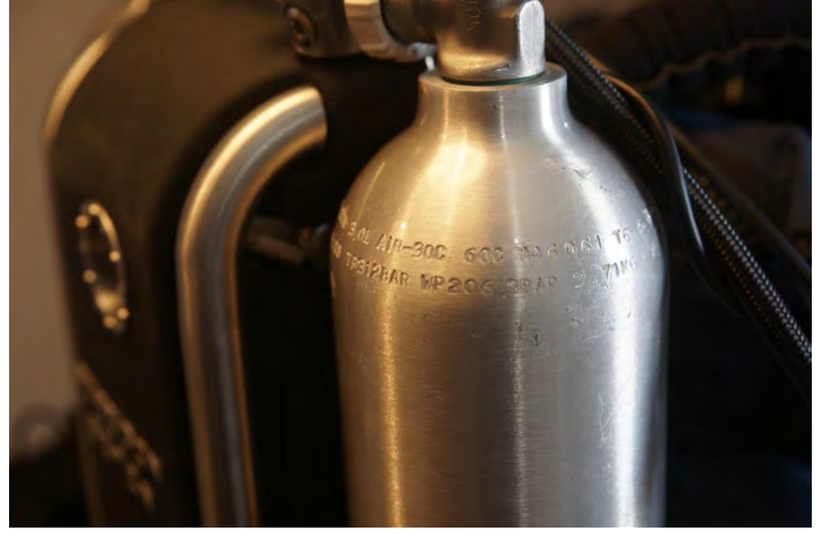
Everything laid bare and ready to be assembled

Consequently, diving rebreathers is not for the impatient. But what is the hurry anyway? Going methodically through the checklists both when assembling the unit and doing the pre-dive checks is of the essence and, in fact, a mindset that all rebreather divers are required to adopt. Students are repeatedly grilled about this aspect and the question will pop up at the exam!

During the in-water training, the primary focus was on buoyancy control, which has to be managed somewhat differently than on open circuit, and on bailout procedures.

On a rebreather one cannot, for example, use a deep breath to slow down a descent or use lung volume to fine tune a hover since the combined volume of the breathing loop and the diver's airways and lungs remains constant. Thus deep exhalations or inhalations make no difference to buoyancy, a habit which many open circuit divers being trained on closed circuit often struggle to break.

Other old habits that die hard but must be killed off include fre-



The standard tanks contain three liters each

Barrel rolling onto my right side, the drysuit valve on my left overarm would vent, and by rolling left, the valve on the right counter-lung would vent. Rock and roll does the trick.

quent mask clearing and exhaling through the nose, both of which are practices that waste gas, counter to the main point of using a rebreather in the first place.

In order to manage buoyancy on a rebreather correctly, the diver must acquire and maintain what is called minimum loop volume. As the attentive reader will have guessed already, that is the amount of gas that just allows for a full inhalation. One should feel just a slight tad of resistance at the top of a deep inhalation. If there is too little gas in the loop, an automatic diluent valve (ADV) should open and add some more. If there is too much gas in the loop from the onset—as is usually the case—this excess needs to be vented.

This is accomplished by a simple procedure. First, the diver keeps partially exhaling through the nose releasing bubbles around the mask until this sweet spot is acquired. Then, the diver leans onto the left side causing the overpressure relief valve on the right counter lung to open and vent. While in this position, the valve is then slowly tightened until the bubble stream stops, pretty much as one would adjust the shoulder valve on a drysuit. This little exercise usually take some repetitions to get right, but just as well, as it is part of the standard procedures when diving the unit henceforth.

When in doubt, bail out!

Bailing out means going from closed to open circuit and is arguably the most basic and elementary procedure trained on both technical (type t) and recreational (type r) rebreathers. It is essential that performing this procedure becomes second nature and routinely practiced.

"*When in doubt, bail out*" for whatever reason, no questions asked. It applies not only to obvious cases, such as equipment malfunction, but any dodgy feelings or nagging suspicions also qualify.

On a rebreather, having a gas to breathe is not the only concern. Knowing what gas you breathe at any given time is also important. So if you are not sure, better be safe than sorry and switch to open circuit.

One of the aspects that sets recreational rebreathers apart from their technical dittos is a requirement to come pre-equipped with a Bail Out Valve (BOV). Basically, it is just a fancy expression for the open circuit regulator, which has been mounted onto or integrated with closed circuit in such a manner that the diver can switch forth and back from one circuit to the other, without having to remove the mouthpiece.

On some rebreather models, such as AP Diving's Inspiration range for example, this switch is accomplished by twisting and turning the whole mouthpiece 90° with respect to the breathing hose. The Se7en, on the other hand, has this big lever on the mouthpiece housing.

Since this design enables switching using only one hand and without having to let go of i.e. a camera or a downline, I like this better. When the lever is in a vertical position, the closed loop is open (mind you, there is some confusing jargon to observe there), and when it is flipped horizontally and pointing forward and away from the diver, the closed loop is closed, with breathing done off the open circuit from a regulator exhaling bubbles into the water.

During bail-out, the open system draws breathing gas from the diluent tank via a first stage as in any open circuit configuration. Only snag here in this otherwise nice idea is that the said diluent tank only contains a volume of two or three liters, the same as a small pony-bottle.

So even when the tank is still close to full, there is only a quite limited amount of gas available for a safe ascent, and if any significant amounts of gas have been lost due to sloppy technique, matters may even get outright dicey if bailout is required on a deeper dive.

For the same reason, it is a requirement that an additional bailout tank with a regulator must be carried for dives below 18m (60ft) i.e. in the form of a side-mounted tank clasped onto the diver's left side.

Rock 'n' roll

For the Advanced Rebreather Diver course, it is therefore also a requisite to practice bailing out and surfacing while breathing from this separate tank.

This procedure entails closing the loop, a switch to breathing off the bailout tank while being able to maintain correct buoyancy on the ascent. To avoid blowing up and shooting to the surface in an uncontrolled ascent—this is where the minimum loop volume procedure comes in real handy; with the overpressure valves set correctly on the counter-lung as well as the drysuit I had to wear, I just 'wriggled' my way up to the surface in a controlled and orderly manner. Barrel rolling onto my right side, the drysuit valve on my left overarm would vent, and by rolling left, the valve on the right counter-lung would vent. Rock and roll does the trick.

The verdict

Having only gone through a course with some pool-dives and a day of open water dives, this report can only be a reflection of some first impressions and preliminary observations. So while an indepth test where we will take the Se7en thoroughly through its paces is in the works, what can we conclude on the current basis?

Being trained on the Se7en was

How's this for a training site? In early April the Swedish archipelago could still be snowbound but during our open-water training the sun was out and the water smooth as glass. This is Gullmars fjorden at a location called Skår.

a novel but straightforward experience and the machine was always compliant, comfortable and easy to operate in water. Its compactness and snug fit made it easy to dive, and in terms of weight, resistance through water and freedom of movement. it was just as good as my regular open circuit rig. In particular, I fancied the flat and compact assembly of the mouthpiece and BOV, which did not get in the way of getting my eye close enough to the camera.

Holding the Se7en to its apparent design criteria, being primarily designed with recreational rather than technical divers in mind and to let technology do as much monitoring and control as possible, Poseidon has clearly taken huge strides towards eventually making rebreathers somewhat mainstream, or at least not reserved to a privileged few.

I liked its relative ease of use, which however, must not be confused with simplicity, as it clearly packs a lot of technology under the bonnet. Existing rebreather users crossing over to the Se7en may initially not find themselves immediately at ease with not having their usual sort of diagnostic information displayed, such as having the PO_2 readings for three sensors read out and just having dive information displayed along with system integrity. But all others I trust will find the display and operation logical and straightforward. Put technology to good use, I say, like in cars, where I don't really know or worry about oil temperature either.

Type-r rebreathers are required to use prepackaged scrubber cartridges, and if there is a possible Achilles' heel, this may be it. The rules stipulate they only have a lifespan of maximum 24 hours once the seal of the packaging has been broken, or maximimum three hours of diving, whatever comes first.

While I initially had to overcome the reluctance to discard the cartridges every night, even when they have only been used very little and otherwise seemed good for another dive or two, I conceded the expenditure was not a major issue. When bought in bulk, such as in 8-packs, current list prices on the web as this article goes to press are about €30 / $25 / £20 pr. cartridge, which is comparable to the price of air or nitrox fills for the same amount of provided dive time. While a stash of such canisters can surely be stored in an attic or garage, the sticky bit comes when taking the unit on a trip when each cartridge weighs 2.7kg. As this equates to 16 extra kg to carry just for six days of diving, you are either limited to going with operators who stock these cartridges on location, or bite the bullet, pay the extra luggage fee and haul the whole load along.

In all fairness, all makes of rebreathers are somewhat hampered with such issues, but thankfully still more operators are becoming rebreather-friendly and capable of servicing the growing community of recreational rebreather dives so cartridges should just be yet another consumable to be purchased on location.

Poseidon is also addressing the growing issues of luggage restrictions and fees on airlines in other ways; the company is setting up a network of operators where divers can bring just their personalized battery and can have it plugged right into a rental unit on location.

Meanwhile there's no such issues standing in the way of putting your kit in the trunk of your own car and driving off for a leisurely Sunday dive, doing some macro-photography somewhere up the coast. And did I mention it is not a bad looking piece of kit either? □

Scuba Confidential

Don't Let Folk Get Carried Away!

Text and photo by Simon Pridmore

A few weeks ago, a dive centre chartered a boat to take five divers and two instructors out to some islands off the south coast of Bali. It was rainy season and, behind the rainclouds, there would be a full moon that night in an area where currents are notoriously strong and unpredictable. However, water conditions seemed manageable, there were other dive boats out on the water and having done one dive without encountering any difficulties, the divers entered the water again for a second dive that was to be a drift dive.

After about ten minutes underwater, they found that the current was so strong that it was difficult to keep the group together. So they ascended early to find that a storm had swept in, surface conditions were now very rough, and the rain had reduced visibility to a few metres only.

Unaware that the divers had surfaced and expecting that the dive would last an hour or so, the boat crew did not pull up their anchor until about 40 minutes after the divers had entered the water. They moved off to look for them in the area they expected them to be. They did not find them. Then night fell and the divers were gone.

A little over 72 hours later, searchers found four of the divers perched on rocks some 20 kilometres away from their original entry point and one of the instructors in the water nearby. The bodies of the remaining diver and the other instructor washed up on shore in the following days.

This is not a bizarre one-in-a-million accident. Indeed, it is just the latest in a depressingly similar series of such incidents that have taken place in the same area in recent years. Neither is Bali unusual. Similar stories abound everywhere people dive and there are strong currents. Wherever you dive, however, this sort of accident is completely avoidable by adopting some basic procedures and using some very affordable technology.

Doing it properly

Running a safe, successful drift dive, indeed any dive, comes down to preparation and communication.

First, no matter if the boat belongs to the dive operation, or if it is a charter boat, an experienced and professional member of the dive centre's staff should be on board the boat throughout the dive. This person is the surface supervisor for the dive. Before the dive he or she discusses with the in-water guide what route they plan to take and what they will do in an emergency. They have considered all the possible things that might happen and have a plan for each eventuality. Indeed, the dive operation they are working for should have set procedures for all staff to follow so the dive guide and surface supervisor need only review

these and plan for any last minute issues that might have arisen, such as, during rainy season, the likelihood of a sudden rainstorm.

The sole function of surface supervisors is to monitor the dive. Their role is as crucial as that of the guide. They watch the bubbles initially to see if the guide is following the plan, and once the divers are en route, they instruct the boat crew to move and accompany the divers from a distance.

If difficult water or weather conditions arise, they ask the captain to bring the boat closer. They remain alert and ready to assist if there is a problem, for example if anyone makes an early ascent, and stay on watch until the whole dive team is safely back in the boat.

Dive operators must look at the way they handle dives, especially in locations that are known diving black spots. Divers can play a role in improving standards too by asking the right questions and making sure that they dive with operators that are properly prepared and equipped.

A little bit of kit

In scuba diving, we carry safety sausages and noisemakers to help a dive boat find us if we are lost at sea. These are essential pieces of equipment and everyone should have them on every dive. However, it is sadly futile to deploy a safety sausage or blow a whistle if nobody is there. In the incident described above, the divers might have had safety sausages raised, but for at least the first 30 minutes that they drifted, nobody even knew that they had surfaced. Then when the boat did start looking, it is likely that the surface conditions had swept the divers away, and the boat was searching in the wrong place. Then it got dark and the divers were gone.

In remote backcountry skiing, where avalanches are a risk, everyone is equipped with an avalanche beacon, a device that constantly emits a signal. In the event the skier is buried, the signal helps a rescue team find them. Now, wonderful as it may be to imagine a world in which every diver is required to carry an emergency signalling beacon in the event that they become lost at sea, this is unlikely to happen any time soon.

However, there are simpler and more practical alternatives available right now. Last year, a Singapore technical diving instructor found himself drifting alone in the South China Sea after a series of unusual events. He looked around, saw where he was in relation to the land, pulled out his hand-held GPS radio that he carries on every dive in a dedicated pressure resistant box and called the boat to come and pick him up — no drama!

The cost of a radio like this is under US$300. So a US$600 investment pays for a unit for a dive guide and another for the surface supervisor. As long as the guide maintains contact with his team and the radios are well maintained, the risk of loss at sea becomes tiny.

Improving standards

With a little forethought regarding procedures, better staff assignment and a little cheap technology, the seven divers would not have been lost that day. It would not have taken three days to find them. They would not have needed the miracle chance that the sea carried them towards some rocks to survive and two would not have lost their lives.

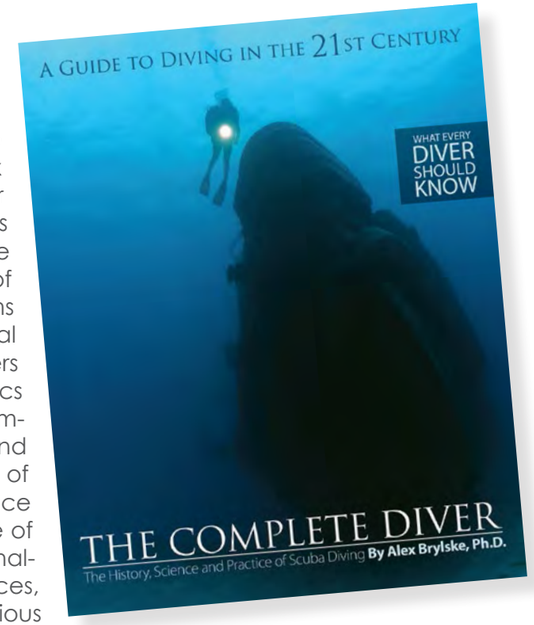
Dive operators must look at the way they handle dives, especially in locations that are known diving black spots. Divers can play a role in improving standards, too, by asking the right questions and making sure that they dive with operators that are properly prepared and equipped. □

Simon Pridmore has been around the scuba diving industry in Asia, Europe and the USA (well, Guam) for the past 20 years. His latest book, also called Scuba Confidential, *was published in September and is available on Amazon.*

Divemaster game

This fun game from independent developer, Gyula Somogyi, has both iOS and Android versions for the iPad found on iTunes and Amazon. *Divemaster* is a casual simulator game of real diving from a divemaster's point of view. An avid underwater filmmaker himself, Somogyi saw there was a lack of realistic diving games for mobile devices, so he created a diver-friendly game with simple game mechanics coupled with real diving physics. Players are in control of an 8-person dive group and work the simulated job of a divemaster on a dive boat visiting tropical underwater reefs. Players can live out their dream job in this simulation in which they guide divers underwater to show them coral reefs and creatures and connect divers to animals they want to photograph. The more photos taken, the greater the rewards and tips to the player. There's no violence in the game, no animals are shot, and responsible behavior of divers is promoted. But divemasters beware: You must take care of your divers. If the divers run out of air, they perish and it's gameover.

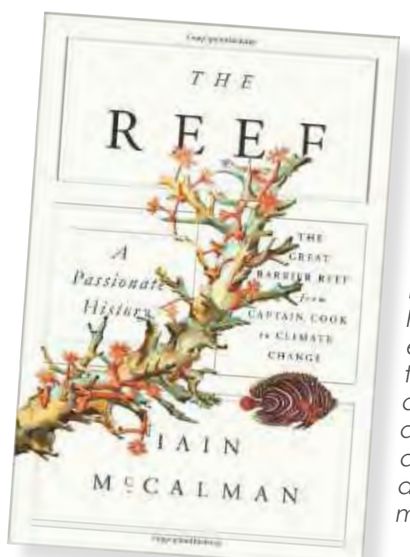
Guide to Diving



The Complete Diver: The History, Science and Practice of Scuba Diving, by Alex Bryske. The author, 20-year senior editor for Dive Training magazine, Alex Bryske brings his formidable expertise and experience in teaching diving and develping many of today's most popular dive training programs to this comprehensive book on recreational diving. In the book's 42 chapters, he covers the most important and most common topics and aspects of diving, as well as less common topics such as undersea exploration and innovation. In the content and approach of the book, the author has found a balance between the overly dumbed-down tone of many diving textbooks and the overly challenging content of highly technical sources, presenting a knowledge base every serious diver will want to acquire.

Paperback: 346 pages
Publisher: Dive Training LLC
Date: 29 October 2012
ISBN-10: 0615721338
ISBN-13: 978-0615721330

Great Barrier Reef



Visible from space, the Great Barrier Reef stretches for 1,400 miles along the coast of Australia and is home to thousands of marine species on 3,000 individual reefs and over 900 islands. Explorer and historian, Iain McCalman reveals in his new book, The Reef: A Passionate History: The Great Barrier Reef from Captain Cook to Climate Change, how human impact over two centuries has affected this extraordinary ocean ecosystem. The book discusses the relationship that people have had with the reef as well as the changing perceptions of the reef as a dangerous maze to a resource of economic gain to a frontier for scientific discovery, ultimately to raise awareness of this fragile World Heritage site and humanity's desire to save it for future generations.

Hardcover: 352 pages
Publisher: Scientific American
Date: 20 May 2014
ISBN-10: 0374248192
ISBN-13: 978-0374248192

Underwater Museum

In his new book, *The Underwater Museum: The Submerged Sculptures of Jason deCaires Taylor*, the U.K. artist and sculptor, with contributors Carlo McCormick and Helen Scales, takes us on a dive to visit the underwater sculpture parks where marine life grows over time on the unique and compelling life-size statues he has created, installations of special cement anchored on the sea floor to become living reefs. The science behind the art is explained, as coral, fish and algae are attracted to these statues transforming the installations, as well as the efforts these underwater sculpture parks aim to facilitate.

Hardcover: 128 pages
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Date: 11 March 2014
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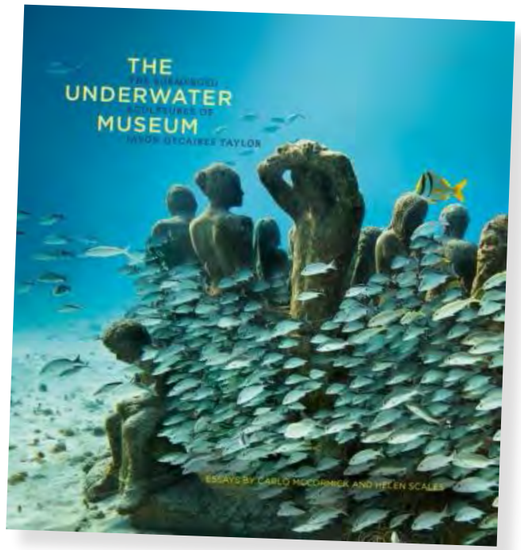
ISBN-13: 978-1452118871



Why you should never go diving with an idiot

—and how to avoid that happening to you

Text and photos by Steve Lewis

Being swept along on this technical diving thing, has been a long, somewhat twisted, but definitely entertaining journey. If you and I had met when the whole affair started, we could not possibly have envisioned how directly and pervasively, what were then radical activities, like cave diving, trimix diving and rebreather diving, would influence the mainstream dive community. Watching the evolution of technical diving, and being able to observe the changes it's wrought on all aspects of recreational scuba, has been a true privilege—and great fun.

But perhaps, evolution is too soft a word to describe what's happened. So many things have changed. Gear, training, the places we visit to dive, how we exchange information, even what form dive magazines and textbooks take: case in point with *X-RAY MAG* for example. I'm not particularly nerdy or wired but "traditionally printed" magazines and books no longer figure very prominently in my professional or personal life. I still do carry a notebook and pen in my backpack, but there's an iPad, iPad mini, and two smart phones in there, too. I really have more than the proverbial "1000 songs in my pocket". And I am typical rather than an exception.

However, some things have not changed. Especially good advice.

A while back when the tech diving revolution was first building up a head of steam, one piece of advice that created some controversy came from the politically incorrect keyboard and mouth of a character called George Irvine III. He told anyone who would listen, not to dive with "strokes." The shortest possible explanation or definition of Stoke is someone who is unsafe and unaware. "Don't dive with strokes" was Irvine's corruption of much earlier advice from cave dive training manuals to not dive with folks whose skills and mindset were unknown. And that little gem—as light its impact was compared to Irvine's version—had its Genesis in the caution from open-water training to be mindful when diving with an "insta-buddy".

Personally, I opt for the middle ground: You should never go diving with an idiot.

Let's explore that statement.

What is a stoke?

One of the most controversial things about Irvine's don't dive with strokes advice, was the definition of a stroke itself. The actual guidelines describing where strokery began and ended varied depending on who was supplying the definition—the most radical being a form of tribalism that I found reminiscent of the gang mentality I saw as a kid on the terraces of football grounds in London's East End—a sort of modified, "We're Millwall. Nobody Likes Us and We Don't Care!"

My definition of the sort of idiot who should be avoided when diving is easier to draw a box around… and I believe

Self-assessment [can] help an experienced diver avoid the Siren-call of complacency

less tribal… but perhaps no easier for some of us to accept.

Complacency, for me at least and in the context of defining a diving idiot, is a solid starting point. If I wanted to build a monument to diving idiocy, complacency would be my cornerstone.

Complacency is sneaky, and the more skilled we become, the sneakier it gets. Regardless of how detailed and comprehensive our dive plan, it will be completely negated by complacency. Moreover, rather like a virus, once complacency gets a foothold in one's pre-dive process, it can spread and infect others. I believe it is a strong contender for top-spot in the list of things to avoid if we don't want to dive with an idiot.

So, a simple technique that can help us side-step complacency is what I'd like to make a case for.

Again, back when the tech diving revolution was tearing down limits imposed by the PADIs and NAUIs of the dive industry, a pretty smart guy with more than a few dives in his logbook and a political incorrectness all his own, told me that complacency kills experienced divers.

His was not a quick and cursory sidebar conversation, but a week-long rationalisation that was part my first technical instructor program. It was Bret Gilliam, founder of TDI (Technical Diving International) who formalised for me the essential process of self-assessment, and reinforced for me the value of self-assessment as part of the prelim for each and every technical dive. It was, he insisted, self-assessment that could help an experienced diver avoid the Siren-call of complacency. Therefore, self-assessment was held up as a good habit to cultivate, and not a bad barrier to raise between you and a huge mistake.

Complacency kills experienced divers.

The self-assessment process

Self-assessment begins with the quiet and reflexive process of providing oneself with honest answers to a series of simple questions.

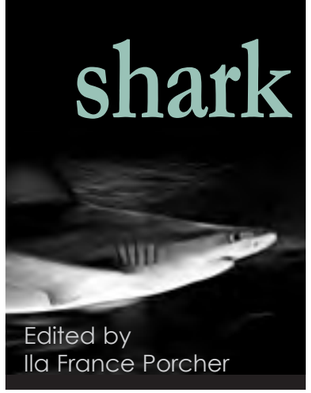
- Does my training and experience match the needs of the team on this dive?
- Do I understand what's meant by the phrase "most skills are perishable" and have I recently practiced the skills needed to perform this dive?
- Do I have fluency in the distinct and particular skills needed to get me and my mates back to the surface in one piece should the crap hit the fan during this dive?
- Are the other team members ready for this dive, and in the event of a catastrophe, can they save themselves and me without submitted themselves to an unacceptable risk of injury or death?
- Is the gear my team and I are using appropriate and does it meet or exceed the requirements of this dive, and is it fit for purpose?
- Is there more than enough gas for everyone, and is it the right flavour or flavours?
- Do I feel confident, comfortable and capable to complete this dive safely, today?
- Does our dive plan cover our arses and our assets?
- Are the environmental conditions here at the dive site less challenging, as challenging or more challenging than we planned for and how does that affect the answer to the next question?
- Is there is ANYTHING at all about the plan and intended execution of this dive that is outside the security of best practice? If so, has every one of us and our loved ones signed on it?

A lot has been said and written about the promotion and use of checklists in diving—especially rebreather diving—of late, but I believe that the self-assessment checklist needs to be adopted as part of the pre-dive protocols for ALL divers.

Actually, I feel strongly enough about the point to tell you that if you and your buddy do not engage in any form of structured self-assessment as part of your pre-dive routine, you are diving with not one, but two idiots… and so is your buddy.

And just to be clear, diving with an idiot can get you killed.

Steve Lewis is a diver, instructor, dive-industry consultant and author. He teaches and lectures at home and abroad. His main focus is to increase safety and point out ways to make us all better divers than we are now. His latest book, Staying Alive: Risk Management Techniques for Advanced Scuba Diving, *is a best-seller, available at Amazon. For more information visit:* ***Techdivertraining.org****. This article is based on a presentation first made by Lewis at Beneath the Sea in 2013 and 2014.*



Cognition in Sharks

Text by Ila France Porcher. Images by Ila France Porcher, Wolfgang Leander

A difficulty in obtaining information about wild animal behaviour is that detailed observations of different individuals is necessary over long periods of time, and this is especially hard to achieve with sharks. But in the shallow lagoons of French Polynesia, such observation was possible without the encumbrance of scuba gear, and without the problem of the shark disappearing into the depths. Over a period of 15 years, I searched out and observed reef sharks in the different locations where I lived there, and for seven years, studied them intensively.

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As I learned where and how to look for the local sharks, I focused on blackfin reef sharks (*Carcharhinus melanopterus*), because they were so easy to find patrolling the shores. But other species, including whitetip reef sharks (*Triaenodon obesus*), grey reef sharks (*Carcharhinus amblyrhynchos*), sharptooth lemon sharks (*Negaprion acutidens*) and nurse sharks (*Ginglymostoma cirratum*) were present and often observable for long periods, too.

As time passed, I learned to put them at ease with me, they became accustomed to my presence, and accepted me into their community. By recording the actions of the various individuals, I was able to access a dimension of their lives that had not previously been documented.

Individual differences

Individual differences marked each shark's behaviour. Each one had a unique pattern of roaming, under the dual influences of the lunar phase and the reproductive cycle. Some were nearly always present in their home ranges, while others travelled for months at a time. Individual sharks demonstrated different rates of learning, and they varied greatly in their responses to different situations. They had complex social lives, and their behaviour showed a flexible intelligence.

In time I concluded that they were using cognition rather than reacting automatically to stimuli. This was the reason that I spent so much time observing them, and following the precepts of cognitive ethology, tried to learn what they were like as animals and individuals.

Cognition is the term used for thinking in non-human animals—the process of knowing through thinking. An animal shows that it is using cognition, rather than trial and error, when it must have referred to a mental representation in order to act as it did. Many life forms, including invertebrates, are increasingly found to be using cognition in their daily lives, and cognition in fish has been well studied.


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Knowing others as individuals

The sharks recognized each other as individuals, which is the prerequisite for the complex social lives in which cognition is most evident. They tended to travel with preferred companions, and these sets of friends joined with wider groups of sharks at times. Due to the circular paths in which they move, they repeatedly crossed each others' scent trails, and thus remained in loose contact as they roamed, together, yet not usually within visual range.

Companions were individuals of the same gender, and usually the same age as well. Some sharks usually travelled alone, some always with the same companion, and others changed companions relatively frequently. Often, travellers were temporarily joined by sharks residing in the regions through which they moved. There was always excitement when travellers and residents met. They would follow each other around and swim side by side for long periods, before the companions moved on together.

As far as I was able to determine, such friends came from the same region. The reef sharks were acquainted with the other individuals whose home ranges overlapped theirs; travelling companions were usually neighbours at home.

Bonnethead sharks, too, have been shown to recognize each other as individuals, and it has been documented that at least some species of sharks and rays choose their mates, providing further evidence that individuals know each other.

Memory and learning

Learning plays an important role in the lives of sharks, as has been well documented. Learning is closely involved with memory, and the sharks I had under observation frequently showed their ability to remember events far back in time. Familiar sharks recognized me in the lagoon as much as two years after their last meeting with me, and their behaviour, of greeting and swimming with me, was unchanged.

Like people, different sharks had different rates of learning. For example, among those who accompanied me most often, one of them never learned to take a treat I threw for her, while only a few caught on immediately without practice.

Vigilance

Wild animals are always vigilant, always on the look-out for danger, and sharks are no different. Whenever anything was different about my visit, whether it was in a different place or at a different time, the sharks' behaviour became more cautious.

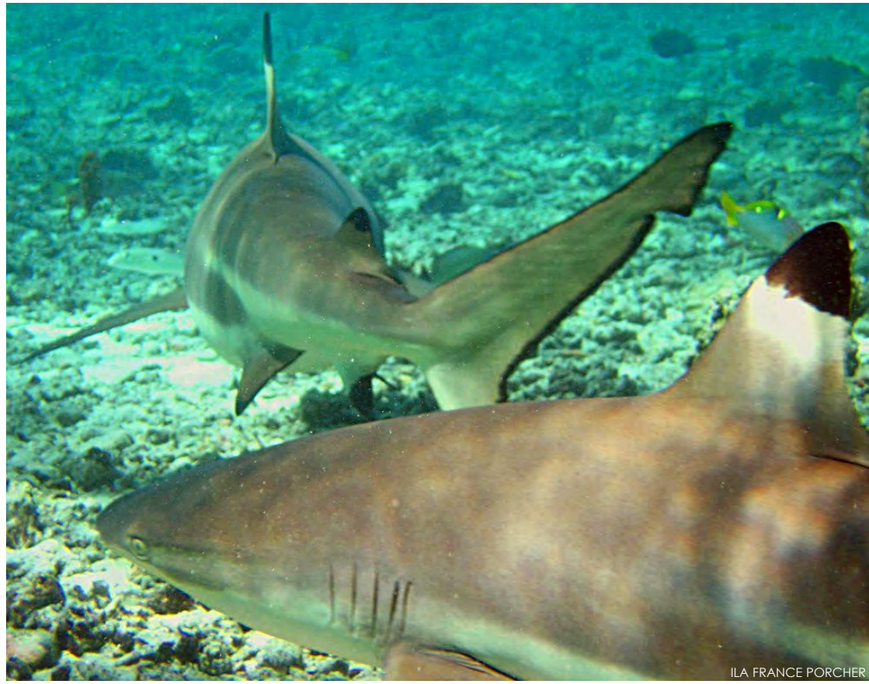
When I brought a second person with me, which happened very rarely, they initially vanished beyond visual range after a swift approach when I first appeared underwater. Many minutes passed before they reappeared, usually approaching the stranger first, in long lines led by the boldest among them. This initial disappearance never happened when I was alone, and demonstrated their alertness to changes, and their ability to make quick decisions based on unexpected findings.

Those who complain that shark feeding dives cause sharks to harass spear fishermen, have failed to understand this crucial point—sharks easily discern the difference between a shark feeding event and a spear fisherman. It is the fishermen themselves who attract sharks, by holding dying fish underwater and trailing scent.

Approaches

All of the species of reef sharks I observed habitually used the veiling light to conceal themselves. Once out of sight, they often continued to pay attention to events from beyond visual range, by listening and through their lateral line sense. Sometimes they passed into view for a brief look just at the visual limit, then vanished again beyond their curtain of blue.

The diagram (above) shows the general pattern of approach of a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THIS PAGE: Blacktip reef sharks

Medication of shark

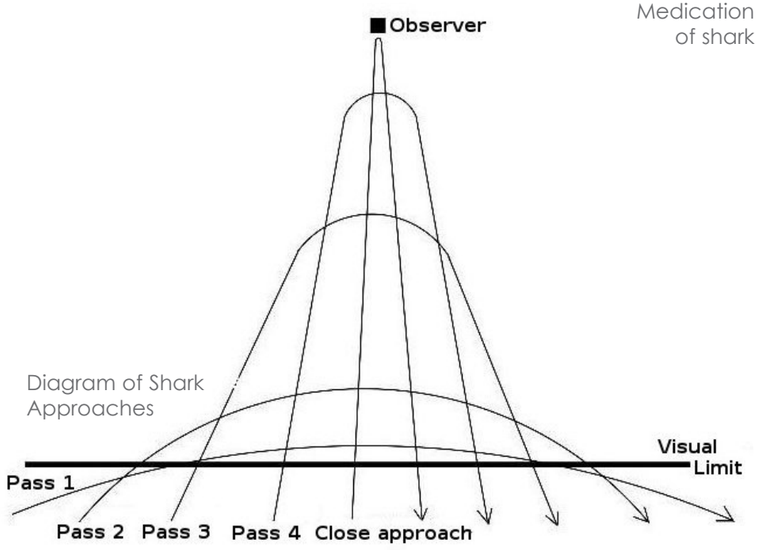

Diagram of Shark Approaches

blackfin reef shark.

Initially, the shark curves briefly into visual range, then out. A few minutes later, it appears again for a closer look. With each repetition, the arc becomes more acute until, if the shark is very interested, it approaches nearly head on.

Any variation on this pattern could occur. Shy older females often lingered out of visual range before making one or two passes into view, but never came close, while males coming into the lagoon in exited bands to mate after sunset, often omitted the 'cautious passes' phase, and zoomed straight up to me.

Other species showed a similar general pattern of approaching, but their closest approach came more from the side than head-on.

Hiding

Often a shy shark who appeared briefly in visual range would suddenly pass close behind me, but dart away if I turned and saw her—she had come to look without being seen. Sharks had no trouble recognizing frontal views, and they understood the direction in which a person was looking. In other ways, too, they showed that they were aware of whether or not they could be seen. When I was with another person, for example, they always swiftly approached if we raised our heads above the surface to talk.

Once I was swimming with my step-son, and he climbed on a dead coral structure to look around above the surface. The shark who was accompanying us swam over to sniff his legs, and with his head above the surface, the boy never saw her. Sharks even surprised me by swimming between my face and hands when I was drawing, which never happened when I was paying attention to them. One unusual shark passed me nearly every time I went to the lagoon, drifting by from left to right, always and only when I was looking the other way. She did this for eight months before relaxing her vigilance and moving around me more freely.

Always on the alert, the sharks used their awareness of whether or not a person could see them to their advantage. Therefore, it is not surprising that it is said that you never see the shark who bites you. As with other predators, it is best to face them, and pay attention to them when you are with them. But, that said, shark bites are very rare, and sharks were the only wild animal with which I was in intimate contact for many years—which never did bite me, either through accident or irritation. My conclusion in the end was that an inhibition against biting companions was at play.

Attention, curiosity and observation

The sharks were very curious, and investigated anything new. If a coconut floated across the surface, one would notice and rise to sniff it, followed by the others. They would often follow me for long distances, sometimes for hours, while remaining hidden beyond visual range. From time to time, I checked to see who was with me by suddenly stopping, whereon they came into view. It was surprising that they would remain concentrated on one thing for so long.

Sometimes unexpected events revealed patterns I might not otherwise have seen. When one of the sharks became ill, each evening I tried a different tactic to give him a piece of food in which I had inserted antibiotics. The other sharks seemed to anticipate each of my attempts, and their actions made it very difficult for me to medicate him.

One of the tactics they used after several nights of missing out on the food, was to wait beyond visual range. When the time came, and I went to the kayak and threw the food into the water, seven sharks whom I thought had left an hour earlier, soared in, and the fastest one snatched the treat in mid-water.

Since they had been out of sight, they had based their decision to act on a signal they had heard. They had understood the sounds of me getting the treat and throwing it, and their actions were effective, because one of them did get the food! This example shows their ability to predict something that might occur in the future, and to concentrate on it. Cognition is indicated because they must have held a mental representation of food coming under such circumstances, the signal that would trigger its imminent arrival, and what they planned to do when it came.

It often seemed that the sharks tried to be one step ahead of me. In long-evolved predators who catch swift and evasive fish for a living, the strategy of watching and waiting, and trying to predict from past experience what the prey would do next, could well have been selected for.

Self-awareness

Cognitive ethologist Donald R. Griffin pointed out that when

Close approach by a shark

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Sharks passing into view

an animal hid itself from view, it was demonstrating self-awareness. He described how Lance A. Olsen had reported that grizzly bears sought places from which they could watch hunters while remaining hidden. Other observers had reported too, that bears tried to avoid leaving tracks. The researchers concluded that these bears were aware of being present and observable, as well as creating effects their tracks through their movements, which could be seen by others.

The sharks' habitual way of remaining concealed behind the veiling light until an opportunistic moment, or approaching from behind to avoid being seen, is in the same category of behaviour, and indicates that they are aware of being present and observable. This is the reason why the so called 'shark counts' divers are asked to participate in, have no scientific validity. Since sharks are either attracted to divers, or avoid them, the numbers of sharks seen by divers are not representative of the true numbers on the reef.

Where sharks are habituated to divers and come to see them, such counts may give the impression that there are many sharks, when actually, their numbers are few. Shark finners are attracted when the information is publicized, and the dive site is fished out.

Decision making

Occasionally, reef sharks would flip on their backs to wriggle in the sand, presumably to scratch or to free themselves of parasites. On other occasions, a shark would turn to whip the side of its body against a sand bank. The floor of the lagoon was made up of sand interspersed with reef flats and coral, and the sharks invariably chose only sandy places for such manoeuvres.

Sometimes a shark carefully positioned himself to use a smooth, flat surface of dead coral on which to rub himself. Apparently, he had intentionally surveyed the environment and chosen a suitable structure to use. He must have held a mental image in mind of what he wanted, and referred to it while looking for a formation of the right shape.

Though this may not seem to be very impressive in terms of thinking in sharks, the availability of surfaces to use in this way doesn't mean that the animal will realize how they can be of benefit.

For example, mynah birds (*Acridotheres tristis*), and junglefowl (*Gallus gallus*), the wild ancestor of domestic chickens, both spend much of their time foraging for insects on the ground, and both have strong feet for walking. However, mynah birds haven't discovered that they can use their feet to help them uncover these insects, while junglefowl do so instinctively.

I was lucky to witness a clear decision made by two sharks, between two possible choices. One day near my study area, the fins of several blackfins were slicing through the surface, and underwater, fish were spawning, and sharks were gliding among them, occasionally snapping

one up.

Two came over when they saw me, and returned from time to time to circle me over a 15-minute period. When I left and travelled another half a kilometre into the lagoon, these two sharks followed from the spawning site.

They decided to follow me even though they had not seen me for several months, and they made the choice that was based on a mental reference, a thought or memory, that sometimes I brought food. Yet, they were in a situation in which they could see, hear and smell food, moving in a stimulating way, and I had not fed them in that location before.

Such memories of events that can be called upon for decision-making, are called declarative memories. It is now thought that they cannot be used in the absence of consciousness.

Communication

I could not see evidence of communication between sharks except through body language. If you have ever met an aggressive shark, you will know how well body language communicates at a physical level. The response arises deep within us without any interference from the frontal lobes of the mammalian brain!

Occasionally, companions acted in concert, leaving the other sharks, and swimming in formation to perform a specific act together. How they communicated the decision to do this was not clear, but likely body language played a role.

In his book, *The Secret Life of Sharks*, Professor Peter Klimley described how great white sharks ritualize their conflict when a seal, which one of them has killed, comes under dispute. Each slaps the water at an angle with its tail, and the shark who raises the most water and blasts it farthest wins the prey. For this ritual to be effective, each shark must view its opponent's gesture as a communication, and understand it, since the winner gets the seal without a fight, which could badly hurt both sharks.

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Scheduling

Sharks often passed the same place at the same time on consecutive occasions. One young visiting male passed by my observation post about five meters to the right, between ten and 15 minutes after sunset each night for several weeks. Each time, he saw me and came for a closer look, then turned and went on his way. Another rare visitor's first four visits, though months apart, occurred precisely at the moment that the sun touched the horizon, four days before the dark of the moon.

Intrigued, when one of the residents who had habitually met me on my arrival in the lagoon, began coming instead at the end of the feeding session, and missing out on the food, I kept careful track of the time of her return. For reasons known only to her, she had suddenly begun to spend her days in the ocean. Over a period of many months, she returned about ten minutes before sunset, night after night. Sometimes, she still met me when I arrived, yet other times, I saw her return from the sea when it was nearly dark, passing in the distance, and not coming to the feeding session.

Besides illustrating a remarkable ability to follow a daily schedule, and yet be flexible about it, her actions indicated that she had not become dependant on my weekly feeding sessions, though she had known about them since she had been a juvenile.

The sharks seemed to have no trouble catching a fish when they wished to, and often came to the feeding sessions only to socialize. Resident sharks routinely left for months at a time, and visitors did not remain in the area because of the food. Though many came to my feeding site at the proper time, their long-term schedules were unaffected by the few scraps I provided weekly to facilitate my observations.

Social learning

The resident sharks learned, in time, that the fish-scraps I brought to the feeding sessions were in the back of my kayak. Though this species has not been documented breaching the surface to eat or to look around, these sharks found that the food could be accessed by leaping from the water and leaning towards the boat, while snapping at whatever they could locate. The sound of their jaws snapping shut made loud clapping sounds, and some of the kayak's straps were cut, punctured and sliced by their sharp little teeth.

This behaviour pattern, which was a new foraging technique, was initiated by one or two sharks and instantaneously copied by the others present. Later it was repeated by the sharks in that group. This discovery occurred twice, in different locations, under different circumstances, with different groups of sharks, and is an example of social learning, which is basic to the development of culture.

Under normal circumstances, the space above the surface is not something that these sharks

Lemon shark

WOLFGANG LEANDER

would have reason to consider. But they were presented with an artificial situation in which I came from above the surface and returned there, and so did the food in which they were interested.

They would doubtless have stored memories about the surface from the occasions, particularly when they were small, when they swam through it or up against it while chasing a fish, though it is unlikely they could have formed more than a vague impression that there was a space above, from such brief events. Yet, their behaviour suggested that they were aware of a volume above the surface in which things could exist, and from which I came and went.

A question in cognition is whether an animal knows that something continues to exist when he or she can no longer see it. An object apparently ceases to exist for dogs, for example, when it goes out of sight. So few people would agree that sharks could understand that I was in the boat, even when I had just left their company and climbed into it. Yet they were aware.

Could they see me through the surface? It often appeared that they could, and when they raised their heads from the water, they raised them straight towards my face as if they could see it from beneath. Once their faces were in the air, they could certainly see me there in the mysterious volume above the surface—great white sharks are known to deliberately look around above the surface.

The electro-sense works at close range, and possibly continued to inform them that my living body was just beyond the plastic hull when I vanished. Further, they could hear the sounds of my movements in the hollow craft with their lateral line sense and sense of hearing, a way of perceiving the environment that appears to be dominant in sharks.

If the sight of me underwater was replaced by the sound of my movements in the hollow plastic kayak as I got in, these perceptions could well continue to inform them that I was still present, even though their view of me was blocked, just as it was blocked whenever they listened to me underwater, from beyond visual range.

WOLFGANG LEANDER

Lemon and tiger sharks

Indeed, the many ways that sharks took advantage of the opportunity to hide behind the veiling light, and to approach when they were not visible, such as when a person's face was above the surface, strongly suggests that they are quite comfortable with the idea that something continues to exist, in spite of being out of sight.

Sharks have exquisitely coordinated senses, and their behaviour indicated that they used this sensory input alertly to make moment-to-moment decisions, and respond flexibly and appropriately to changing circumstances. They remembered the events in their lives, and referred to these memories to make decisions.

They were curious, but cautious, and learned quickly. Their versatile behaviour, individual differences, and different ways of handling various circumstances, were not indicative of a set of stimulus or response reactions. Yet, distanced so far from us in evolutionary time, the motives and true states of subjectivity experienced by sharks must remain mysterious.

I have observed other species, including bull sharks and tiger sharks, for shorter periods, and found that their behaviour was remarkably similar to the behaviour of the requiem sharks, far off, but not too distantly related, whom I had known in Polynesia. This is to be expected since sharks have been evolving for approximately 420 million years, and many species travel widely and are found around the globe.

The essential qualities that sharks evolved to be so successful would already have developed in the ancestral forms, before they evolved into modern species occupying the ecological niches we know today. There is no reason to assume that the Polynesian sharks were different. It is more probable that they were ordinary sharks, quite representative of their kind.

Though fish may seem primitive when looking down on them from the altitude of Homo sapiens, in fact they are highly complex and evolved life forms. And no brain is simple, as anyone who has observed the activities of a spider will appreciate. □

Ila France Porcher, author of My Sunset Rendezvous: Crisis in Tahiti, *is an ethologist who focused on the study of reef sharks after she moved to Tahiti in 1995. Her observations, which are the first of their kind, have yielded valuable details about their lives, including their reproductive cycle, social biology, population structure, daily behaviour patterns, roaming tendencies, and cognitive abilities. Her next book,* On the Ethology of Reef Sharks, *will soon be released.*

Edited by
Michael Menduno

The Art of Bailing Out

Bail out with Inspiration rebreather, Tahiti

Text by Pascal Bernabe
Photos by François Brun

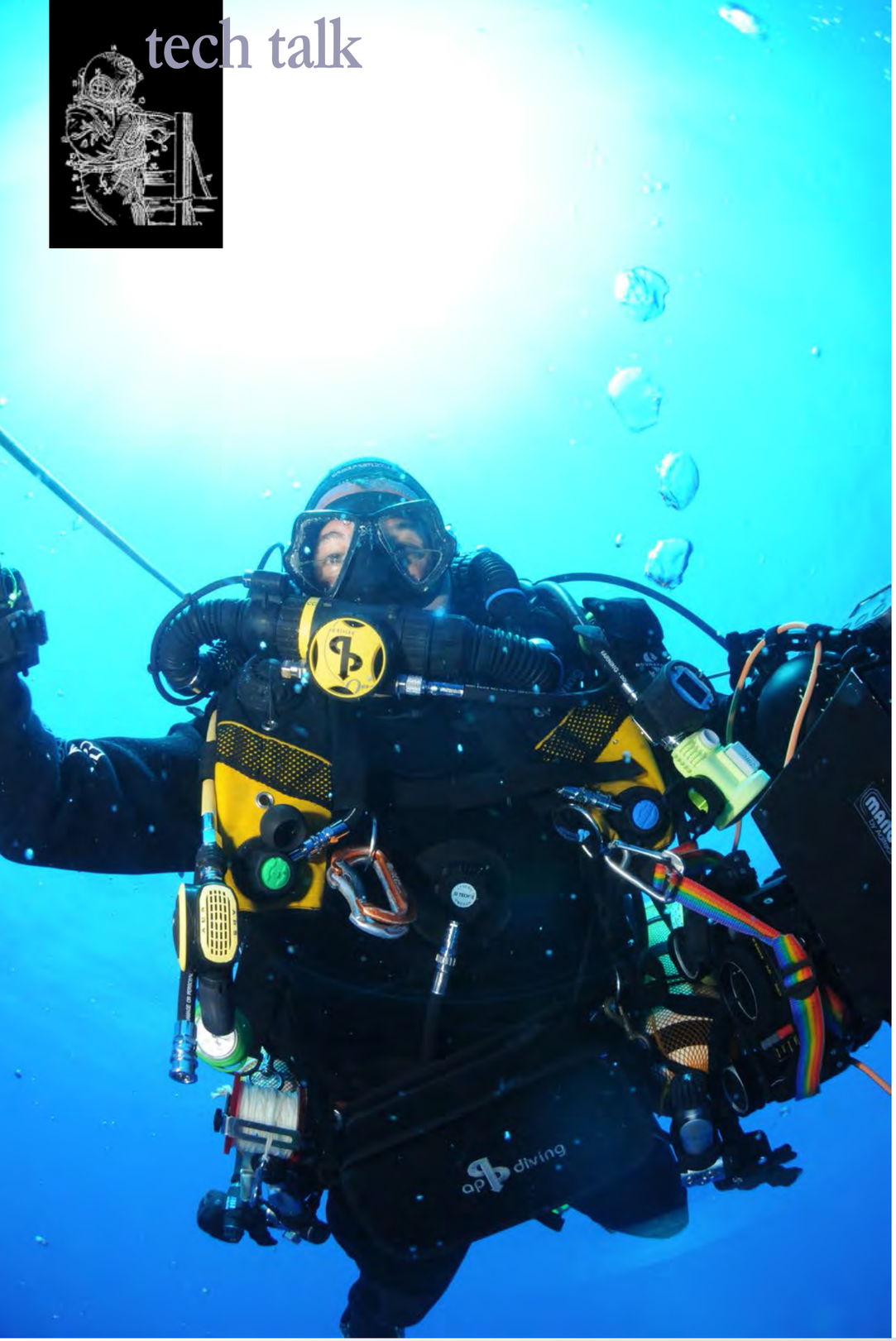
Rebreather diving is currently one of the fastest growing activities in the diving universe. Divers' motivations for getting a rebreather vary. Some derive enjoyment from "piloting" a sophisticated machine like a cosmonaut journeying through (inner) space. Others find pleasure in possessing a powerful tool for exploring caves, wrecks, canyons and reef walls, and being able to silently approach and photograph marine life without any bubbles.

However, despite their increased capabilities, rebreathers can be subject to serious failures. Accordingly, one of the primary objectives of good rebreather training is to learn how to react correctly and quickly to a problem and perform the emergency procedure appropriate to the situation or the failure.

There are a number of rebreather failure modes that require the diver to get off the breathing loop immediately and switch to a reliable back-up system, typically open circuit scuba, which is currently the most reliable and inexpensive form of back-up. Rebreather divers refer to this as switching to "bailout"—in other words, an alternate gas source appropriate for the dive in the event of problems with the rebreather. The general rule taught in rebreather classes is, "If you are in doubt, switch to bailout."

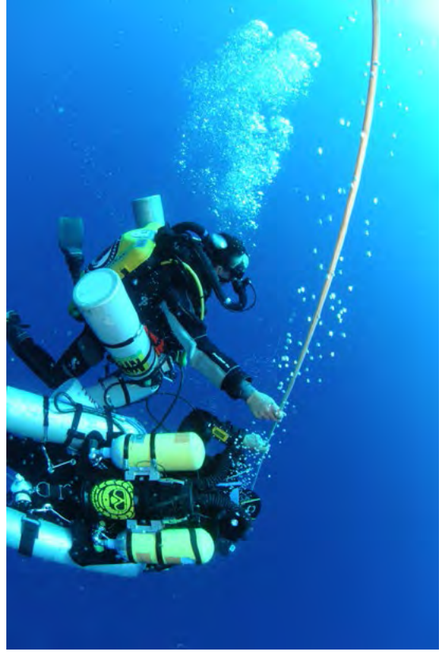
There are a number of situations that would prompt a diver to bailout. These include:

- A completely flooded loop that has become un-breathable, for example, due to a rupture in the breathing hose or counterlung.
- An excessively high partial pressure of oxygen (PO_2) in the breathing loop creating an immediate risk of hyperoxia particularly at deep depths and where the PO_2 exceeds 1.6 bar. (Note: the solenoid is an electric value that injects oxygen into the breathing loop in order to maintain a constant oxygen partial pressure, usually between 0.7 and 1.3 bar.)
- A low PO_2 below 0.16 bar in the breathing loop, resulting in the immediate risk of hypoxia.
- Shortness of breath and/or a carbon dioxide (CO_2) hit caused by strenuous effort for example swimming against a strong current, panic or the failure of the CO_2 scrubber system to remove carbon dioxide from the breathing loop. This can occur if the diver exceeds the scrubber duration, there's an error in assembling the unit, particularly the absorbent canister, or there's a failure in the mushroom valve.



Bail out and BOV with Inspiration rebreather

Bail out with rebreather, Tunesia



- A complete failure of the electronics (PO_2 display and heads up display) making it impossible for the diver to know the PO_2 in the loop.
- Running out of onboard oxygen and/or diluent.
- The failure of two or more oxygen sensors. In this case, the diver can no longer be sure of his or her PO_2 (when three cell voting logic is used).

The general rule for bailout is that there should be enough of the appropriate gas to ascend to the surface while allowing for a safety margin. For example, the rule used in cave rebreather diving, that is also applicable for decompression diving, is to calculate one's consumption rate based on 30 l/minute (1.1 ft^3/min) multiplied by 1.5 for a safety margin or 45 l/min. (1.6 ft^3/min. Experience shows that in the case of getting short of breath or CO_2 intoxication, the gas consumption may rise to as much as 70 l/min (2.5 ft^3/min) during the first minute and to lower to some 25 l/min (0.9 ft^3/min.) during the following minutes.

Bailout options and configurations

A. Open circuit bailout (tanks)

The first question divers have to ask is whether to have an integrated bailout valve (BOV) on their rig or not. A BOV is a regulator integrated into the rebreather's mouthpiece that allows the diver to immediately switch from the closed circuit to the open circuit by moving or turning (depending on the design) a special lever.

Ideally the BOV should be connected via a quick-release and waterproof Swage Lock type fitting to a tank with gas breathable at the maximum dive depth, and provide means of reconnecting it to other tanks according to the depth during the ascent, for example, to manage the

Bail out and BOV with Inspiration rebreather, Tahiti

Bailing Out

A SHORT GLOSSARY FOR REBREATHER NOVICES

PO_2: Oxygen partial pressure, which should ideally lie between 0.7 and 1.3 bar according to the dive phase: 0.7 during the descent and at shallow depths and 1.2-1.3 bar at the bottom. PO_2s are sometimes boosted to 1.4 during decompression.

Diluent: An air, nitrox, or trimix/heliox, which is contained in the left tank of the rebreather and is blended with oxygen to give the diver the best mix for a given depth.

Solenoid: An electric valve that adds oxygen at the right time to maintain a constant PO_2.

Onboard Gas: Gas inside the rebreather system.

Off Board Gas: A gas source outside the rebreather system (stage/bailout tanks).

HUD: A heads-up display that shows the PO_2 and is positioned on the loop next to the mouthpiece and is very easy to see.

mCCR: A closed-circuit rebreather with manual controls (if the diver needs more oxygen he or she injects oxygen, if the diver wants to lower oxygen he or she adds diluent, simple, no electronics).

eCCR: closed-circuit rebreather with electronic controls. Constant PO_2 is maintained with the help of solenoid.

Bail out with two rebreathers

Bail out with lateral rebreather (below)

Bailing Out

decompression.

It is not recommended that divers connect the BOV to the small onboard diluent tank that often has only 3-liter (15-21 ft³) capacity tank, which offers too little gas in the case of emergency.

The arguments for a BOV? It is the quickest means of switching from the closed to the open circuit, which is essential in case of emergency.

The arguments against a BOV? It is a fragile and also a costly piece that requires regular maintenance and may free flow on occasion. Moreover, it may represent a risk for a diver if a hypoxic mix is connected to the BOV at the time of switching to the open circuit, for example near the surface.

Bail out with Megaladon rebreather, Tahiti

Some other things to note:

1. Bailout tanks can be carried as stages, or may be attached at the back of a rebreather at both sides with or without manifold, as in some DIR configurations. Such configurations are typically used by divers equipped with semi-closed passive rebreathers such as the RB80, but are becoming more common with closed-circuit rebreathers with manual (mCCR) or electronic (eCCR) controls. Typically the cylinder on the right has a regulator with a long hose of 2m (7ft) in order to share gas with a buddy in the event of an emergency. The cylinder on the left side has a regulator with a short hose that goes under the neck attached by a neck ring in addition to a pressure gauge or manometer. This configuration is an adapted deviation of the Hogarthian configuration, so dear to the heart of DIR divers. It allows them to carry huge amounts of bailout gas.

2. Usually bailout tanks are carried as stages, and are attached with the spring hooks at the sides of a diver. Sometimes they can be carried in sidemount configuration where the neck of the stage cylinder is attached under the arms with the help of a rubber band to get them close to the body, and the bottom is attached at the sides or to the butt-plate fixed beneath the rebreather at the buttocks level. This is much more hydrodynamic!

3. In any case, the golden rule is to not connect the Automatic Diluent Valve (ADV), a regulator system that adds diluent to the loop on demand to compensate for ambient pressure to the same tank as the BOV, wings, dry suit, and or hose for the manual diluent supply to the same tank!

Connecting the rebreather and buoyancy devices to the same small onboard 3-liter tank is a receipt for disaster. If the tank is empty there will be no gas for the rebreather or for maintaining buoyancy!

Instead these connections are typically evenly allocated among different tanks. For example:

- Connect the ADV and the wing to the rebreather's onboard diluent tank if the dive is not deep. Connect the wing to one of the stages if the dive is deep or it is a

Bailout with semi-closed rebreather, Lot, France

cave dive with a saw-tooth profile.

Connect the back-up manually injected diluent to one of the off board bailout tanks and the dry suit to another tank, if there is one, containing air or nitrox (helium mixes create thermal problems) or to a small suit inflation bottle mounted on the side of the rig.

B. Rebreather bailout

A bailout rebreather can be carried on the back creating a double back-mounted rebreather. Two rebreathers are heavy and their buoyancy is hard to manage. The drysuit, wing and two full loops make at least four gas spaces to manage and vent during the ascent. No easy task! A back-up rebreather can also be mounted at the side (like a stage cylinder) or in front of the body—for example, an M3S Triton a White Arrow Sweet Deco.

In general, using a secondary rebreather for bailout is much more expensive and difficult to manage in comparison with an open circuit back-up.

Moreover, a bailout rebreather does not allow the diver to recover as quickly in the case of a CO_2 hit i.e. shortness of breath. Finally, the diver does not necessarily know whether the bailout rebreather, which was not breathed during the descent, is full of water or has an appropriate PO_2 when the diver is in urgent need of it (This problem has already happened!) In that case, you completely lose your operational capacity!

The real benefit to a bailout rebreather system is the huge run time (3 to 5 hours) it affords in the event of an emergency. Hence, it's the option of choice for the divers engaged in exploration who want to achieve the best balance between the run time and bulk important in Alpine technique.

Pascal Bernabé of France holds the world record depth on a deep dive using self-contained breathing apparatus. He dived to 330m on trimix in 2005 off Propriano, Corsica. See; ***Pascalbenabe.com***

Pascal Bernabé with semi-closed rebreather