

Well,  
I'll be  
darned ...

There's a

# Cave Under Ras Muhammad

Text and photos courtesy of Leigh Cunningham

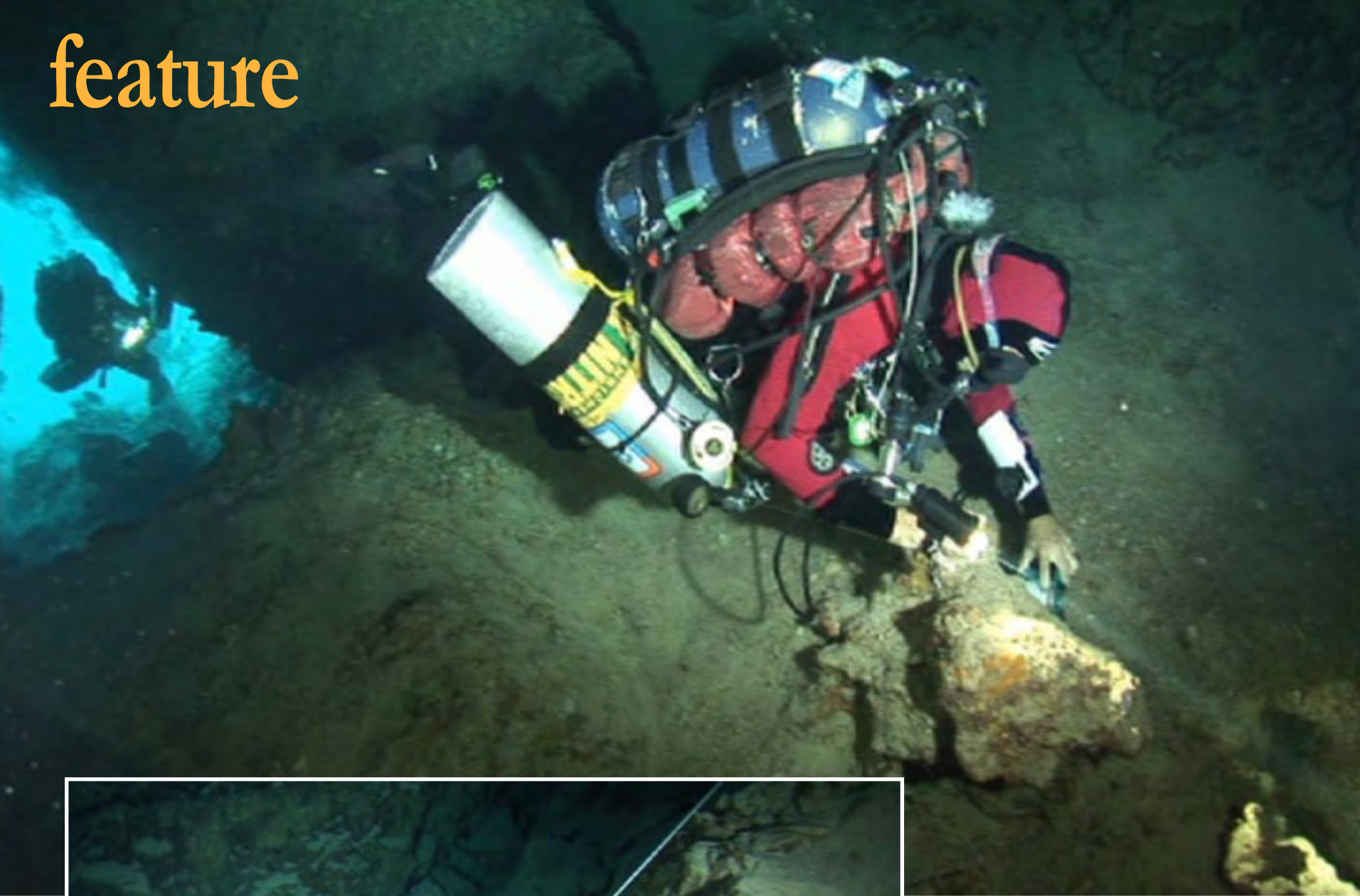
Scores of holiday makers frolic in the waters around Sharm el Sheikh oblivious the cave explorations going on nearby



*The darkness below Ras Mohammed*

Technical divers have discovered an extensive cave system far below the fish and coral at the very tip of the Sinai Peninsula. Leigh Cunningham recounts an ambitious project to dive and survey these mysterious caves, which are already being dubbed "the new Wakullah".





THIS PAGE: Heavily equipped divers investigate the depths of the cave and take measurements

## Ras Muhammed Cave

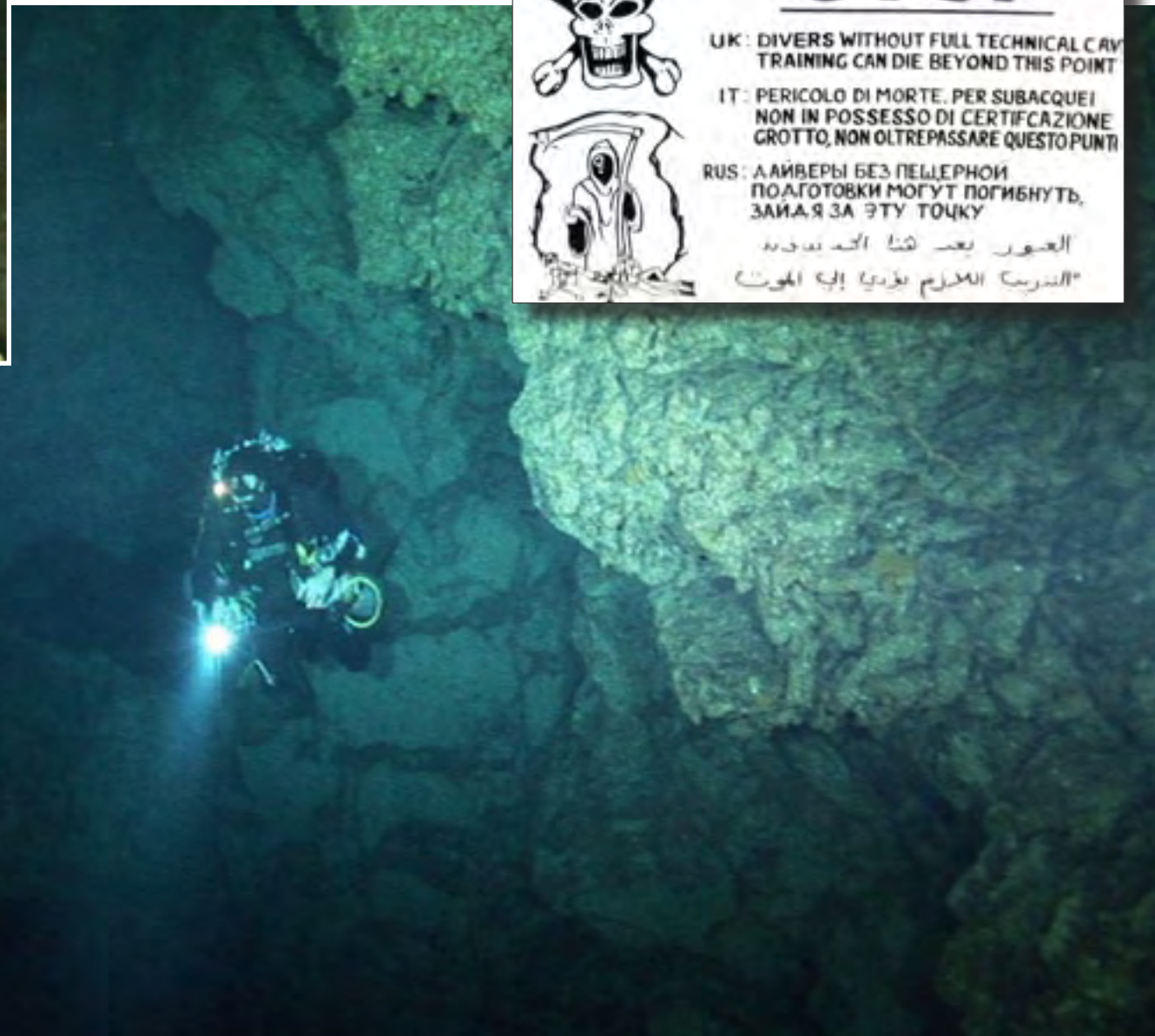
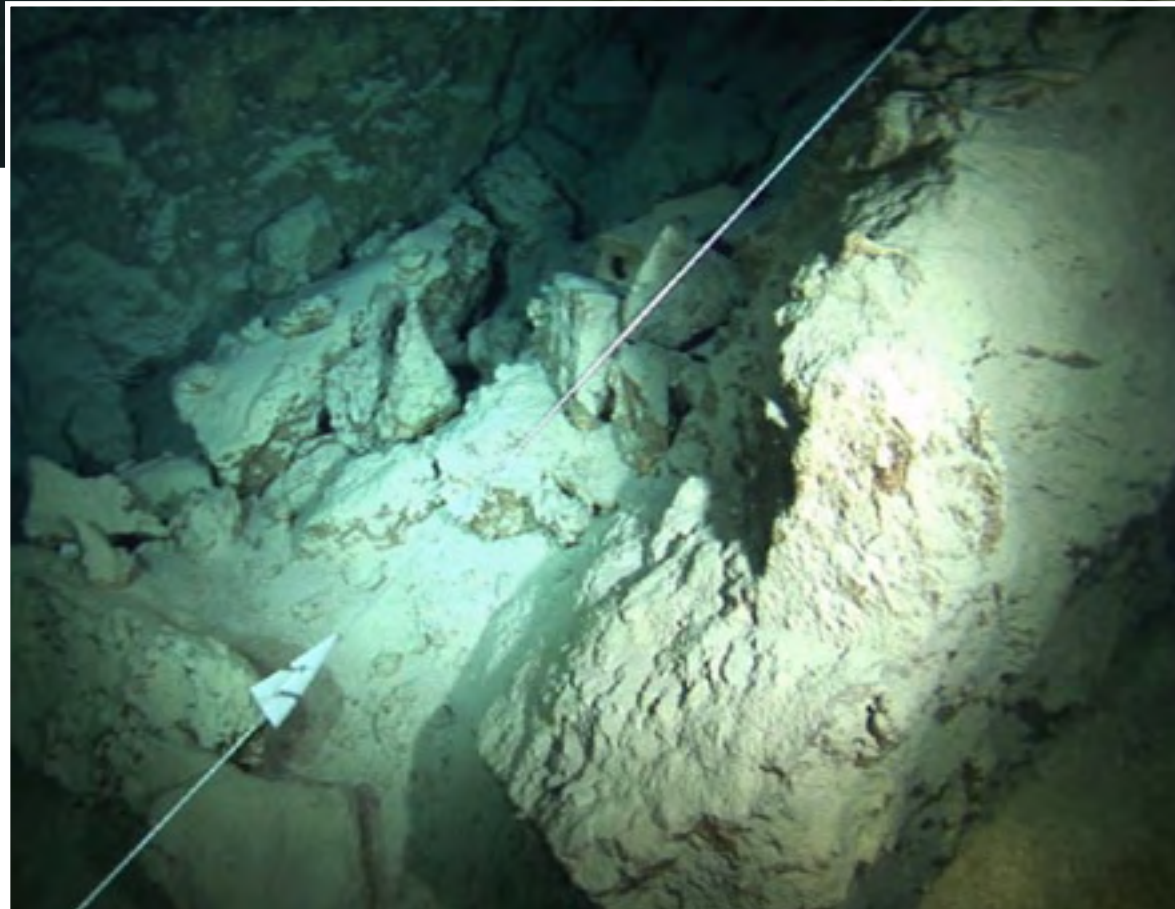
Back in the summer of 2001, I was diving with Francisco Ortigosa, a good friend of mine who had just completed the advanced trimix course with me. Fran is a geophysicist, and we were diving in the Ras Mohammed National Park when he suggested there may be cave systems in deep water in the Jack Fish Alley area on the eastern wall of the famous headland.

Later, after several exploratory dives, I found a cave close to the old Jack Fish mooring, with an entrance starting at 65m. I explored the cave with Fran and my deep diving buddy, Frenchman Thomas Chabanne. We laid a guide line from the right hand corner of the first chamber leading down a chim-

ney to the second chamber.

After several dives in this cave, we established that there did not appear to be a passable passage leading to any further chambers. Thomas and I continued searching for more entrances close to the original 65m entry, and deeper along the wall, we were rewarded with another cave entrance at 80m.

We planned a deeper and longer dive to explore this cave. When we entered, we found ourselves on a sheer wall, dropping to what appeared to be well in excess of 100m. This was obviously one hell of a cave, and it was very tempt-





THIS PAGE: Scenes from the expedition to the cave under Ras Muhammed

ing to continue exploring, but at that point, I made the decision to halt further deep cave dives altogether until I acquired cave training.

## A case for cave training

For the next five years, I was kept busy with the Yolda Wreck Project and running various various courses. However, in early 2007, my friend, the technical instructor, Gennadiy (Gena) Fursov, asked me for information regarding the exact location of the cave entrances in the Jack Fish Alley area. I gave Gena the information that I had gathered during my dives, and over the next few weeks, I was regularly informed by Gena of his exploits inside the caves.

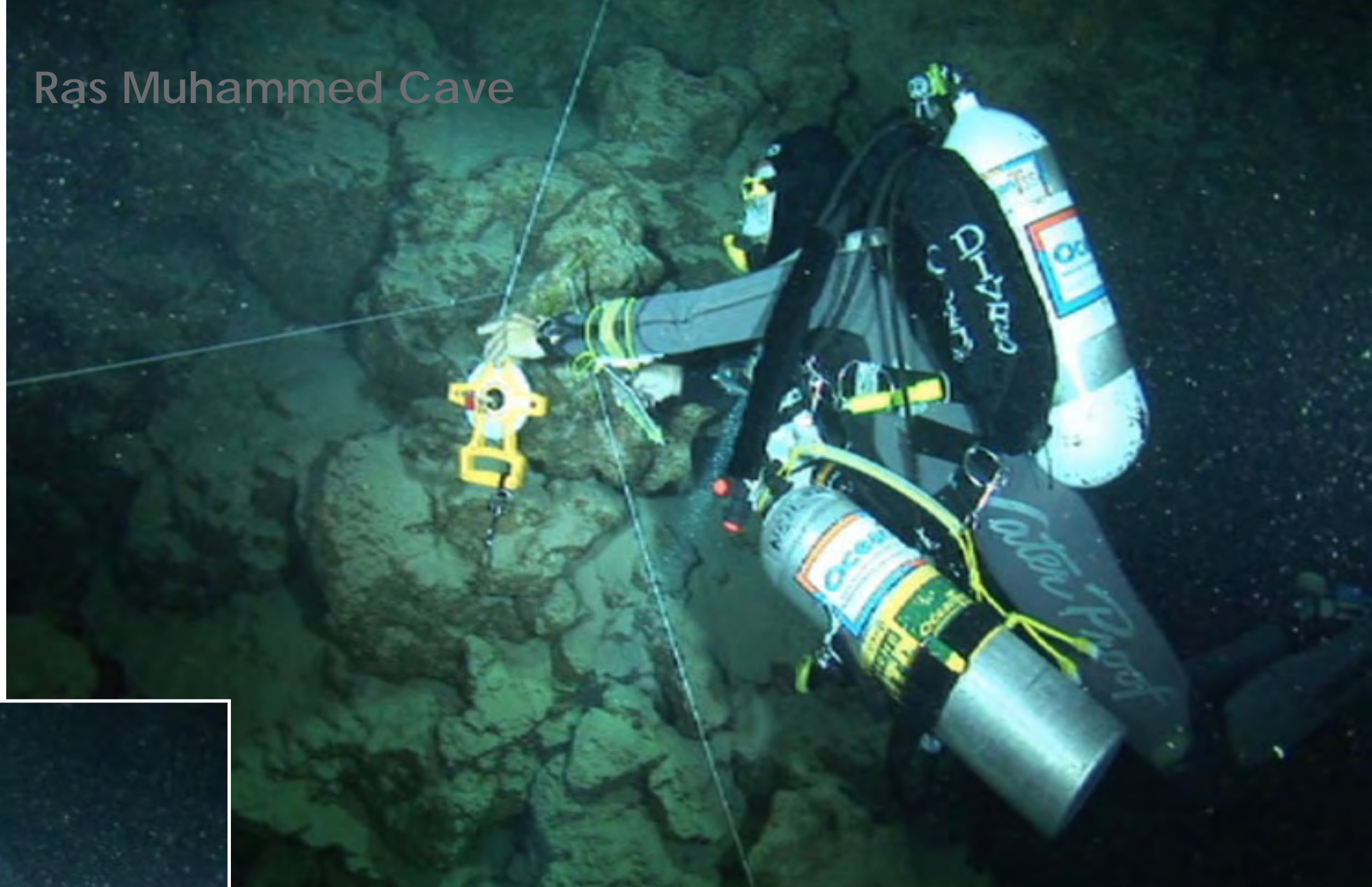
After he had reached 110m in the deeper of two systems, Gena asked me if I would like to put together a team and push deeper into the system.

I agreed at once, but shortly afterwards, I realised I was about to blunder into a highly dangerous situation without the proper preparation.

Six years previously, I made a clear decision to stop diving caves altogether until I completed full cave training. Now, today, with still no cave training, I had given a similarly untrained diver detailed information regarding the exact location of the caves. Even more stupidly, I had agreed to put a team together and lead them into these unknown caves. It was time to get properly cave certified!

I got in touch with Cave Diving Instructor Trainer and Explorer, Andreas Matthes, or Matt to his friends. Matt was responsible for much of the most extensive and logistically complicated cave exploration and surveying in the Yucatan from the early to mid 1990s,

## Ras Muhammed Cave



as well as being an active technical instructor trainer. Matt was an excellent instructor, and after two weeks in Mexico, the team and I felt well prepared for the challenges that lay ahead in Ras Mohammed.

## The project

Once back in Sharm El Sheikh, a plan was formulated for what we named the Jack Fish Alley Cave Exploration Project, the goals of which were:

- To find out if there may be a passable connection between the shallower and deeper known caves, or a passable connection to any other caves

- To explore the deeper cave and conduct a survey of the explored areas

A group of eight cave divers, including Valentina Cucchiara (Deep Cave Videographer), plus five technical support divers made up the dive team. One dive a day was conducted for four days, all using OC scuba. The very experienced dive team was a combination of technical divers instructors and instructor trainers.

## Vital support

Our boat for the project was provided by our main sponsor, Ocean Tec, run by Mr Chad Clark,

who also provided 12 manifolds of Trimix plus intermediate's and hyperoxic Trimix mixes, EANx, O2 as well as a fair few spares each day. Ehab, Ocean Tec's "mix master", kept the blending team busy throughout the night until sunrise each day. Medical support was provided by Dr Adel Taher and Dr Ahmed Sakr from the local Sharm Hyperbaric chamber. Further logistical support was provided by Hamdy Sammy, director the local Search and Rescue (SAR). The cave diving team split into three smaller teams with Valentina, the videographer, swapping teams each day.



## Ras Muhammed Cave

### Day 1: The Reaper's Lair

The team met bright and early at Ocean Tec, where gargantuan amounts of gas, countless dive crates and the deco station were being prepared. Mohammed Salem, director of the Ras Mohammed National Park, had given permission to use the old mooring at Jack Fish Alley; it's not normally allowed, but the proximity to the site made general diving logistics much simpler and safer. Divers kitted up on route and once moored, the floating deco station was deployed with EAN80 and O2 staged.

The support divers, led by Jilly

Healey and Suzy Coombs, laid a guide line from the bottom of the decompression station to the 65m cave entrance (we had called it The Reapers Lair) while the cave teams decide on their goals for the day.

For the first dive, Gena and I were the first team in. We laid a survey line in the Reapers Lair, and conducted a survey to the furthest explored point from the cave entrance. Valentina filmed the first chamber to the connecting passage (Dead Mans Shoot) in the right hand corner of the first chamber, with Thomas and Oxana Istratova in support.

Team 2 (Jim Dowling, Jimmy Jewel and Dave "The Cave" Summerfield) followed an hour later, counting knots on the line and recording depths at key points, all the while drawing the contours of the cave. Team 3, consisting of Paul "Doozer" Close and Neil Black, finished our first day by confirming depths at survey points. They also started measuring distances from survey points to the cave walls, ceiling and floor in the first room.

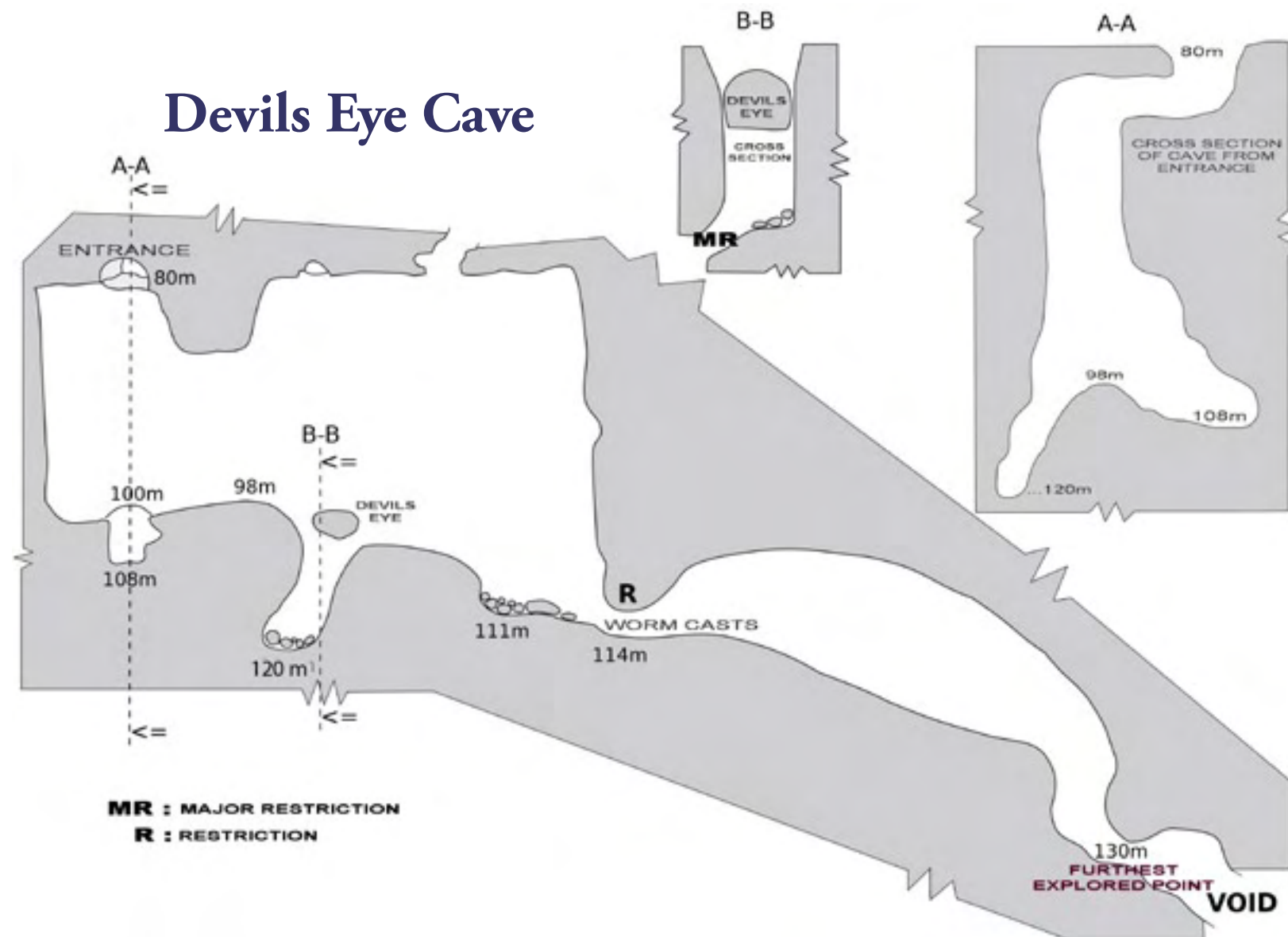
### Day 2: The Devil's Eye

Gena and myself were now focused on exploring the deeper



ABOVE: Preparing for the dive. LEFT: Diagram of Devils Eye cave

## Devils Eye Cave



of the two caves—The Devil's Eye—leaving the other two cave teams to continue work on the Reapers Lair, working towards a comprehensive Grade 3 survey. Gena was using twin 20's, and I had twin 18's on the back, plus another five 12-litre cylinders required to complete the relatively long bottom time and the required four hours of decompression.

This was very much the day of the cylinders—we needed loads to cover the 25-minute bottom time to explore between the cave entrance at 80m and 130m, and the idea was to use our large

twin sets solely for cave gas. We travelled to the cave entrance with an intermediate Trimix, staging this mix and another mix of hyperoxic Trimix at the cave entrance. We laid 45m of survey line from the cave light zone vertically, to a little over 100m, before veering off to the left and following a passage leading to a major restriction in 108m. I tied the line off and followed Gena back up the main line to 95m, then turning right over the Devils Eye, explored another passage to a max depth of 113m.

When it was time to head back to the main line, we approached

a secondary tie off at 100m. On the way out, we noted the main vein of the cave appeared to run of to the right, (facing line) bearing North. Our torch beams disappeared into a narrow, seemingly endless void. More to explore tomorrow!

As we exited the cave, our support divers, Nina and Oxana, were waiting with fresh gas to exchange for our intermediate mixes en route along the guide line system to reach the pure O<sub>2</sub> cylinders staged on the decompression station.

The second team completed a 20-25 minute bottom time



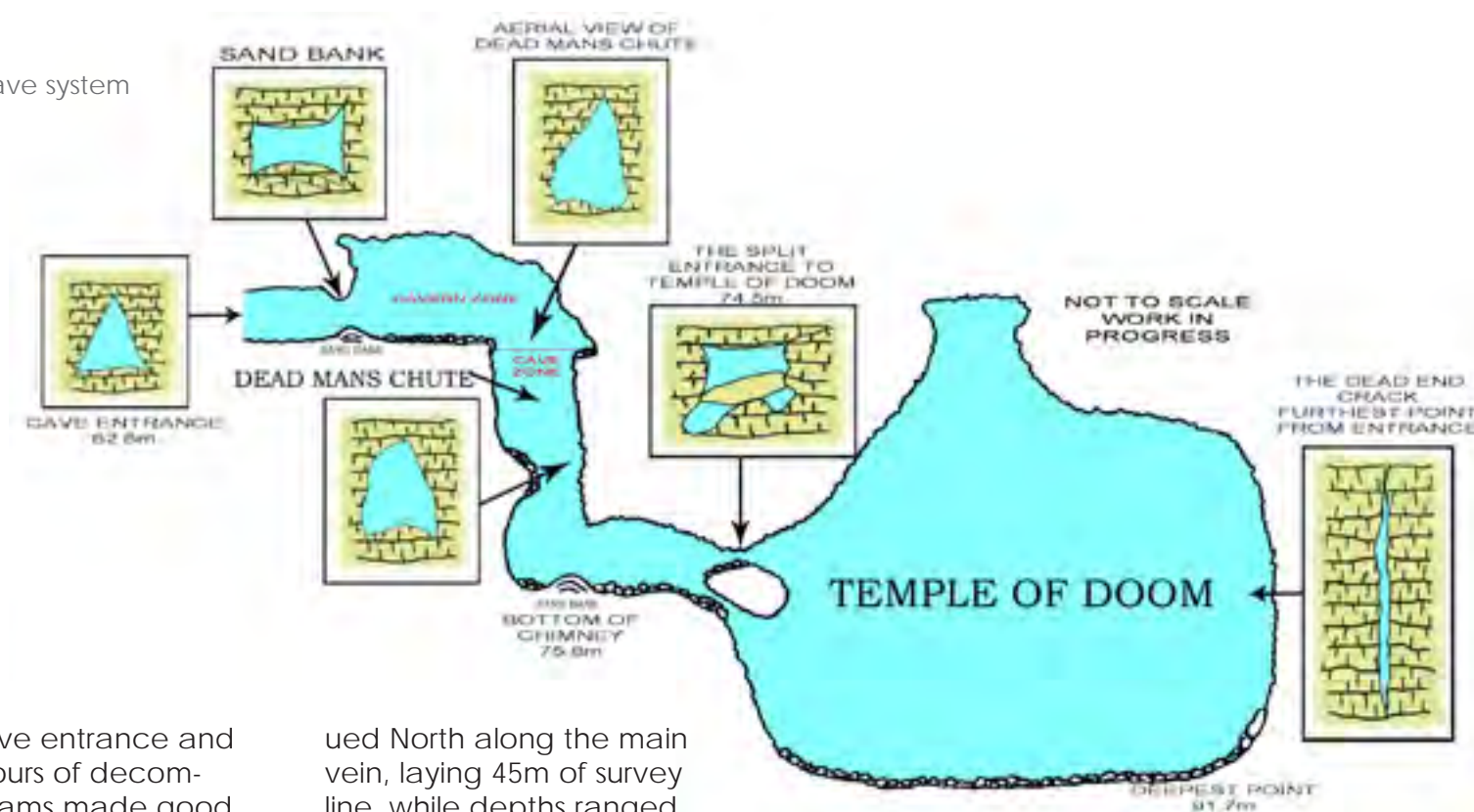
# 4<sup>ème</sup> CONGRÈS INTERNATIONAL DE PLONGÉE SOUTERRAINE

## 4<sup>TH</sup> INTERNATIONAL CAVE DIVING CONGRESS

31 MAI - 1<sup>ER</sup> JUIN 2008 SAINT NAZAIRE EN ROYANS ( DROME )



Diagram of the cave system



between the cave entrance and 90m, with two hours of decompression. Both teams made good progress pushing further with the Grade 3 survey, obtaining compass bearings from survey points, plus measurements from the survey line. Meanwhile, Dave and Val, teamed up to get footage inside the Reaper's Lair as well as removing the old guide line, which had been laid six years earlier.

### Day 3: Temple of Doom

Dave and Neil were the first team in, taking measurements in the deeper chamber of the Reapers Lair, which we had named the Temple of Doom. Whilst there, they discovered a small, round, orange sponge-like organism. Val was shooting video from the cave entrance to the bottom of this chamber.

Gena and myself entered the water next, heading for the Devil's Eye cave. We had the same mixes as the day before, and our plan was to follow the main line to the secondary tie off in 10m. Then, we wanted to make a jump and explore what appeared to be the main vein, running north. After passing over the Devil's Eye boulder, we explored the same passage as we had the day before to a major restriction in 121m. We then reeled back out and contin-

ued North along the main vein, laying 45m of survey line, while depths ranged between 100m and 110m. We reached the end of the line with the open maw of the cave passage still demanding further exploration. When I looked for a place to tie off the line, I saw some bizarre worm casts in the cave. There was life in the cave!

### Day 4: Infinity beckons

The already outrageous quantity of gas ordered over the last three days doubled on day four due to all cave teams planning an exploratory dive in the Devil's Eye cave. Mr Chad, of course, never even broke a sweat, as Ocean Tec pumped dozens of manifolds and cylinders with an increasingly complicated order of gas.

Dave entered first with Thomas in support and Val filming. Both used a twin 12-litre manifold, plus another 12-litre single of bottom mix. They followed the main line to the 100m tie off, then made the jump left and followed the line for another 45 metres, before turning at the worm cast tie off and starting the journey back to the light zone.

Gena and I entered the water an hour later, using the same volume of gas and mixes as the previous two days. Our plan was to waste no time

travelling back to the Karst Worms tie off. Once there, we tied into the line with another 45m of survey line and laid 25m of line horizontally along a winding passage. After a while, the passage narrowed, but when I looked down, I noticed the cave widening, so we dropped down to 130m before our safety line finally ran out.

I shone my torch down into the black void; there was no cave floor in sight. With no time for sketching or taking notes, we made our turn, eager to match our entry speed on the way out to stay within our one third reserve gas management rule. Due to the increase in depth, we had reached the absolute maximum safe gas reserve limit. For exploration beyond this point with open circuit, we would need to carry more cave gas and/or stages within the cave, or consider the option of rebreathers.

The importance of the caves is evident. I can only speculate about just what could lie below our recent route. The cave will surely continue to provide further challenges for Sharm's technical divers and the wider caving community. ■

in





Edited by  
Michael Symes

We have previously looked at the various properties of water which have an effect on aquatic fauna, some of them a bit out of the ordinary, such as surface tension. However, one of the **most important properties influencing the marine environment is one we perhaps notice first of all, the temperature of the water, especially when we go swimming or diving.**

The increase in world temperatures due to the rise in atmospheric CO<sub>2</sub> levels is currently much in the news, with the many references to warmer summers, droughts and rising sea levels. Most of the information available concerns the effect of rising global temperatures on terrestrial environment i.e. desertification, flooding, etc. Yet the global warming also has important impacts on the marine environments. Not only do increasing temperatures affect the physical properties of water such as its density, and its ability to dissolve salts and gases; it has a also great effect on marine biological processes. Fish populations and other aquatic resources are likely to be seriously affected by higher water temperatures.



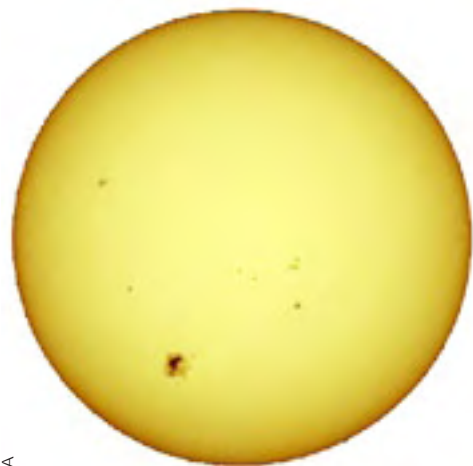
# T *How aquatic animals will cope – or not – with changing water temperatures* Temperature

By Michael Symes

As pure water is only a liquid between 0°C and 100°C, it is not surprising that life, at least as we know it, which depends on water, is to be found on earth where this condition obtains, though most life on Earth lives at temperatures of less than about 50°C. Yet, the so-called hyperthermophiles can live in extremely hot environments i.e. hotter than about 60°C, with an optimal temperature above 80°C. The most heat-tolerant hyperthermophile is the recently discovered Strain 121, which can exist at temperatures of up to 121°C. The toughest hyperthermophiles live on the superheated walls of hydrothermal vents, and require temperatures of at least 90°C to enable them to survive.







NASA

The present temperature of the oceans

The oceans store vast amounts of energy in the form of heat, which has the sun as its primary source. Infrared radiation from the sun plays an important role in that ultimately all the forms of energy in the oceans, such as the long-term circulation and the evaporation at the surface of the sea, depend on input from the sun. There are only two sources of energy that do not depend on solar heating. These are tidal energy derived from the gravitational pull of the sun, moon and—to a small extent—the planets; and geothermal heating through the seafloor from the molten core of the Earth.

The net heat input to oceanic heating is given by the direct solar input and geothermal heating. These are estimated at 150 watts/m² and 0.01 watt/m² respectively. So, it is obvious that the geothermal heating is negligible compared with the solar heating. The net heat loss is given by black body radiation (50 watt/m²), the conductive heat loss to the atmosphere (10 watts/m²), and the loss due to evaporation (90 watts/m²).

The amount of sunlight arriving at the sea surface varies, of course, according to the time of day, season, and weather.

Global average surface temperature has increased over the 20th century by about 0.6°C

The temperature of the oceans is thus given by a dynamic balance between incoming heat and outgoing heat. There are naturally great differences, though, in the temperature of the water between, say, equatorial waters and polar waters, at least for the surface waters. These surface water temperatures range from some 40°C in shallow tropical lagoons to -1.9°C (the typical freezing point of sea water) in polar regions. Apart from the Mediterranean and Red Seas, any warm water in the open ocean is restricted to an upper mixed surface layer of about 100 – 200 meters depth.

However, whatever the surface temperatures are, the temperature falls to about 5°C at about 1000 m depth and thereaf-

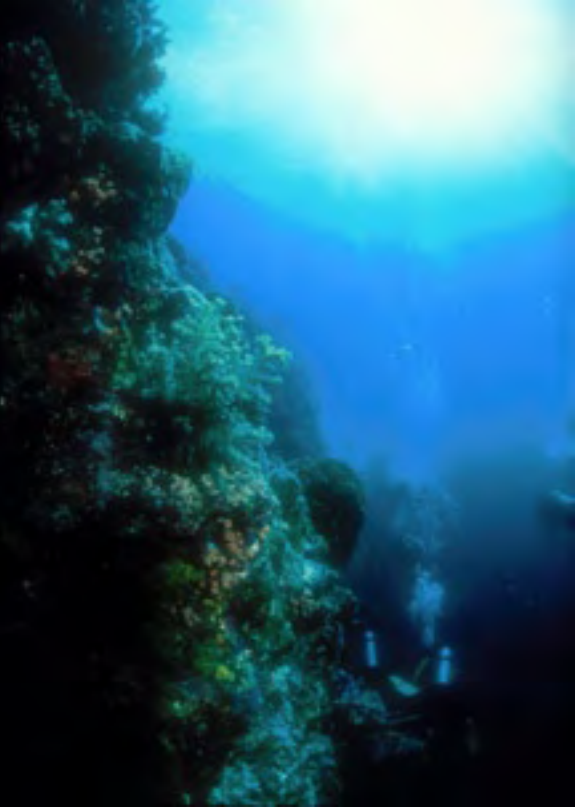
ter declines slowly to between about 0°C and 3°C at greater depths. Even below the hottest tropical regions, the water at a depth of 2000 to 3000 m hardly ever rises above 4°C. There are, of course, some few exceptions to this, for example the water close to hydrothermal vents where the water can emerge at temperatures of up to 400°C, although it rapidly cools to the surrounding water temperature of 3 – 4°C. (See X-RAY MAG issue 5, 2005)

Increasing ocean temperatures

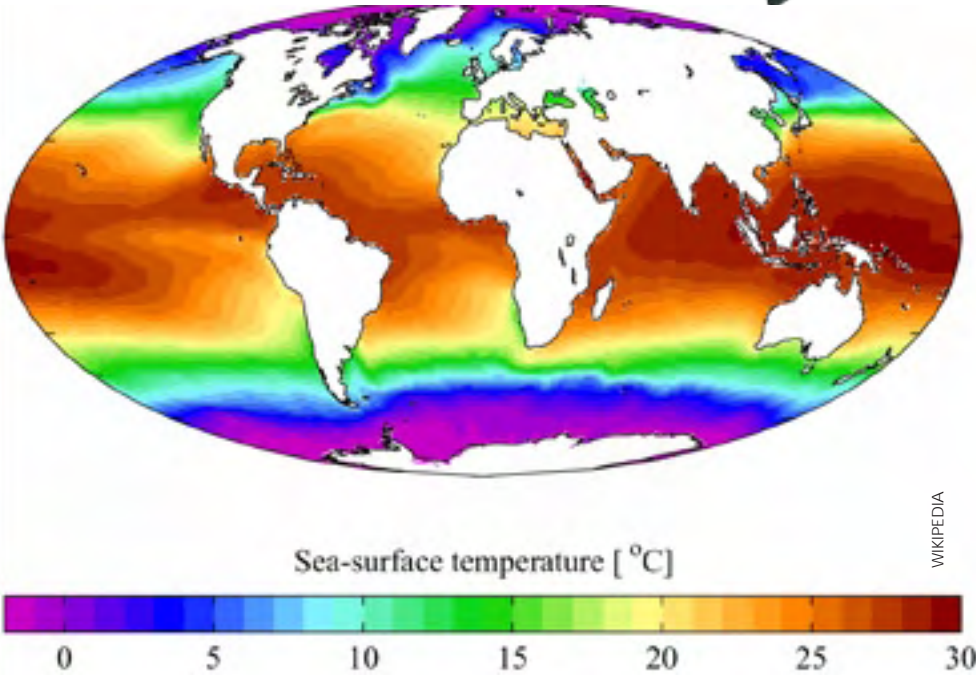
There are various opinions about the magnitude of the temperature changes

occurring due to global warming. However, the Intergovernmental Panel on Climate Change, based on a consensus of many hundreds of scientists from many countries, state that the global average surface temperature has increased over the 20th century by about 0.6°C ± 0.2°C. It should be noted, though, that this warming has not been globally uniform. The most recent warming has been greatest between the latitudes 40°N and 70°N, while the North Atlantic Ocean, for example, has cooled in recent decades.

These temperature changes are, however, still mostly confined to the upper water



STEIN JOHSEN



WIKIPEDIA

Annual mean sea surface temperature from the World Ocean Atlas 2001. Temperature here is in degrees Celsius

levels. Work by the Scripps Institution of Oceanography has modelled the time variation of heat content for the various ocean basins. In both the simulations and observations, the heat content in most of the oceans increased only slowly with depth, consistent with a diffusion process. The water had been warmed below about 1000 meters only in the north and south Atlantic, reflecting strong vertical convection there.

The mean daily variation in surface temperature in the open ocean is, however, very small, being gener-

ally less than 0.3°C. Below ten meters depth, there are practically no variations in temperature. Unlike for creatures living in inter-tidal waters, which can be subjected to great differences between day and night-time temperatures, plankton and fish are unaffected by temperature changes over 24-hour periods.

Not only are there vertical changes in temperature, there are also the oceanic currents, which circulate the warm waters and the cold waters. Whilst most marine life has evolved as a function of the environments brought about

Even below the hottest tropical regions, the water at a depth of 2000 to 3000 m hardly ever rises above 4°C

by these regular currents, irregular currents such as El Niño can cause biological and physical functioning to change quickly over both small and large areas. It can disrupt the whole marine food chain

The following table shows the average temperature for the various thermal ocean layers at the Equator.

| Thermal layer         | Depth in meters | Average temperature °C |
|-----------------------|-----------------|------------------------|
| Mixed surface layer   | 0 – 150         | 26                     |
| Permanent thermocline | 150 – 750       | 7.5                    |
| Deep layer            | 750 – 2000      | 4.5                    |
| Bottom waters         | >2000           | 3.3                    |



STEIN JOHSEN - WWW.LIVFOTO.NO





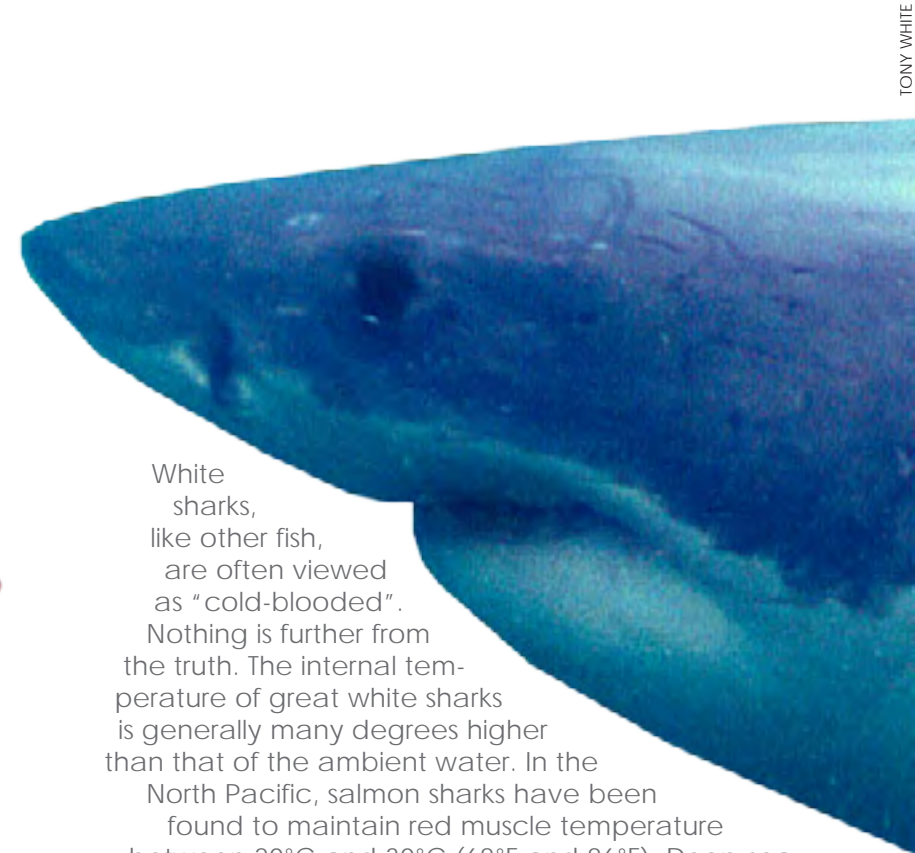
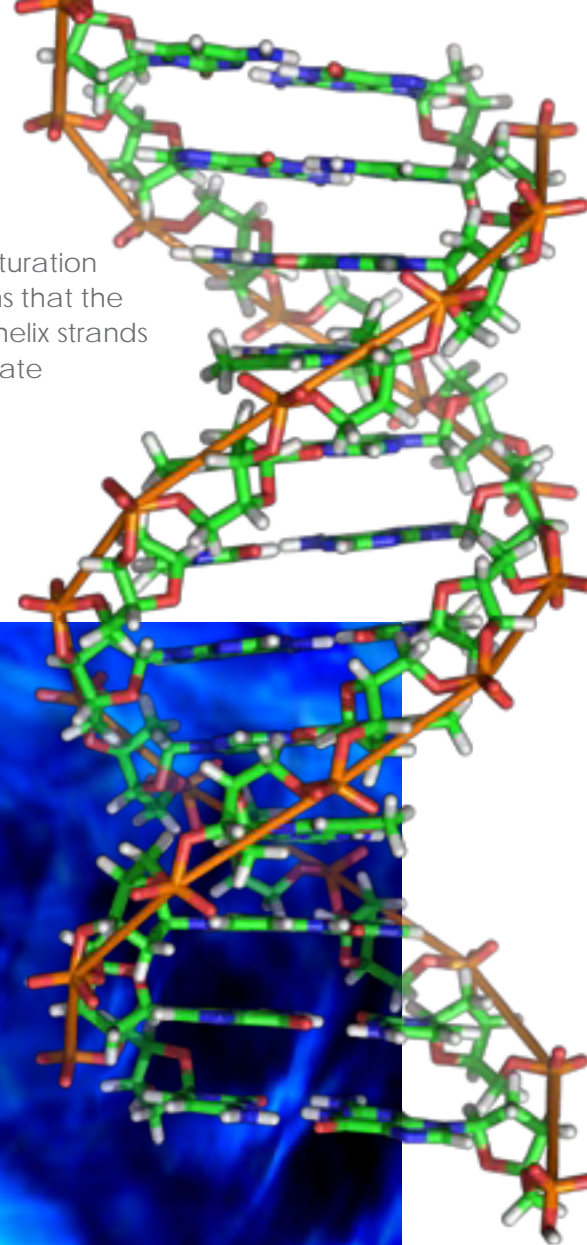


BEV SYKES VIA FLICKR

A boiled egg has a different consistency because the proteins takes shape by being heated

the proteins become irreversibly changed during the four minutes or so at 100°C. To counter the effect of high temperatures in nature, the thermophiles, for example, mentioned above, have had to evolve special proteins, as DNA will normally be denatured above 60°C. Denatured means that the DNA helix strands separate. When

Denaturation means that the DNA helix strands separate



TONY WHITE

White sharks, like other fish, are often viewed as "cold-blooded". Nothing is further from the truth. The internal temperature of great white sharks is generally many degrees higher than that of the ambient water. In the North Pacific, salmon sharks have been found to maintain red muscle temperature between 20°C and 30°C (68°F and 86°F). Deep-sea predators such as swordfish, tuna and sharks also warm their eyes and brain to give them superior vision when hunting

and can be catastrophic for some species such as the Peruvian anchovy.

these factors will effect life in the oceans.

Although there might be some disagreement about the magnitude of the increase in oceanic temperatures, one thing is certain: even small changes in sea surface temperature can have drastic effects. There will be changes in oceanic circulation patterns, the polar ice will melt (it is already starting to doing so) giving a rising sea level, and giving fresh cold water which, being more dense, tends to sink. These variations in temperature and salinity will control vertical ocean currents. Water temperature also partially determines the concentration of dissolved gases, such as oxygen and carbon dioxide, in sea water. These gases are fundamentally linked to biological processes. All

### Effect of increasing temperature on biological processes

Biological processes, like all other chemical processes, are rate-dependent on temperature, and biological molecules are generally very sensitive to increased temperature levels. The rate of reaction increases with increasing temperature up to a certain point, where either the reaction reaches an equilibrium or the reactants/products decompose. An exaggerated example, perhaps, but just think of a boiled egg where

double stranded DNA is heated up to between 60 to 80°C, the two strands unbind into single strands. They will recombine if allowed to cool slowly. Such organisms will probably be totally unaffected by any possible increase in the Earth's temperature.

### The temperature dependence of the rate of

### chemical reactions

A rule of thumb is that for most simple chemical reactions the rate approximately doubles for every 10°C increase in temperature. Thus a reaction at 35°C will go about twice as fast as at 25°C. However, biological reactions are far from being simple from the chemical-kinetics point of view. The rate of metabolism, as

measured by oxygen consumption, of all poikilothermic organisms is greatly increased with rise of temperature.

According to van't

Hoff's rule, the increase is two to three times for each 10°C rise in temperature within favourable limits. This can be of great consequence for life on earth in the years to come.

### Effect of temperature on marine animals

Marine animals, like their terrestrial counterparts, can be divided into four main types with regard to their thermal behaviour.

Firstly, there are the animals whose body temperature varies with the temperature of the surroundings. They are the **poikilothermic** animals, the so-called cold-blooded animals, (from Greek, *poikilos*, various), these

being the invertebrates and fish. It is well known that different poikilothermic animals differ greatly in their ability to tolerate high temperatures although the time of exposure is also very relevant. This is in part due to the effect of temperature on nerve velocities in peripheral nerves, which can have sharp upper and lower limits. For example, in some Antarctic poikilotherms heat-block was found to occur at around 31°C. Poikilothermic animals generally have more complex metabolisms than the homoiotherms (warm-blooded

**Poikilothermy** – This refers to creatures whose internal temperatures vary, often matching the ambient temperature of the immediate environment (Greek: "poikilos" ποικίλος = "varied," "thermia" θερμία = "heat"). (In medicine, loss of normal thermoregulation in humans is referred to as poikilothermia.)







PETER SYMES

Bald rock cod are so well adapted to very low temperatures that there is a possibility of developing commercial antifreeze products from them

Greek, *stenos*, narrow) which are restricted to narrow temperature limits. These include the reef-building corals, for example, which require a minimum temperature of 20°C and a maximum temperature of not much more than 30°C.

Species, which are cold-stenothermic, have a wide geographical range, being found in the shallow waters of the Arctic as well as at depths of 2000 – 3000 m where the temperatures are about 4°C. An example is the bald rock cod, *Pagothenia*

To mingle with the in-crowds below, humans need an attire that preserves body heat



NOAA

in a previous issue, that have sophisticated mechanisms for maintaining body core temperatures, which are close to that of humans, 37°C. For example, the Humpback whale has a body temperature of 36°C, with the av-

*borchgrevinki*, a common fish which lives under sea ice at temperatures of -0.5°C to -1.8°C, and which dies at temperatures over 6°C (this is the lowest known temperature to kill an animal). However, in the long term this may not be true, see below.

Thirdly, there are the animals that can exist in environments with a wide temperature range; they



BERNARDO SAMBRA

Marine mammals must maintain a core temperature almost identical to that of humans—about 37° C

are known as **eurythermic** (from Greek, *eurus*, wide). These species tend to have wide distributional ranges, or they live in regions of considerable temperature fluctuations, such as temperate inter-tidal zones. Such animals are, for example, the periwinkle (*Littorina litorea*), the common mussel (*Mytilus edulis*) and the common cockle (*Cardium edule*).

Finally, there are the aquatic mammals that are **homoiothermic** (from Greek, *homos*, same) i.e. they maintain a constant body temperature, and are usually referred to as warm-blooded. These are the cetacea, discussed

erage body temperature of Cetaceans being ca 35.5°C, which is low for a mammal. In comparison, the elephant seal has a body temperature of 36.7°C and the Weddell seal 37°C.

Periwinkle (*Littorina litorea*)



Tropical corals only thrive between 20° and 30° C

creatures), having four to ten enzyme systems that operate at different temperatures.

In general, poikilotherms do not use their metabolisms to heat or cool themselves although the swimming muscles of the Tuna fish are warmed by a heat exchanger, with a network of fine veins, the rete mirabile, providing a thermal barrier against loss of heat. One obvious means of temperature control for poikilotherms such as fish is to change depth in the water column to find a suitable temperature.

Secondly, there are the **stenothermic** species (from



JASON HELLER





## Control of temperature in aquatic mammals

In terrestrial mammals, temperature is controlled by a number of mechanisms. The central organ for temperature control is situated in the hypothalamus, which contains the control mechanisms as well as the key temperature sensors. The body core temperature is detected by these sensors, which change their rate of nerve impulse generation according to the temperature. At the normal

body temperature, these cells generate pulses at a certain rate which indicates the pulse set point of the system. If, for example, the core body temperature falls below 37°C, then the nerve impulse rate slows down, and a message is sent to the hypothalamus. The body will then initiate a number of positive responses to conserve heat in the body and to increase heat production, and with immediate cessation of sweating. Flow of heat to the skin will be reduced

by vasoconstriction of the capillaries, shivering will be induced to increase heat in the muscles, and there will be secretion of the hormones norepinephrine, epinephrine, and thyroxine to increase heat production. There may also be 'goosepimpling' of the skin, which raises the hairs on the body. This is a residual effect from our evolutionary ancestors who were covered in hair or fur, and erected the hairs of the fur to increase insulation.

Like in their terrestrial relatives, the aquatic mammals, too, have a very sophisticated temperature control system. Although very similar, it is obvious that some of the mechanisms used by the human body cannot be used by the aquatic mammals. Sweating, for example, has no function in controlling the temperature of these creatures.



MARCELO MAMMANA

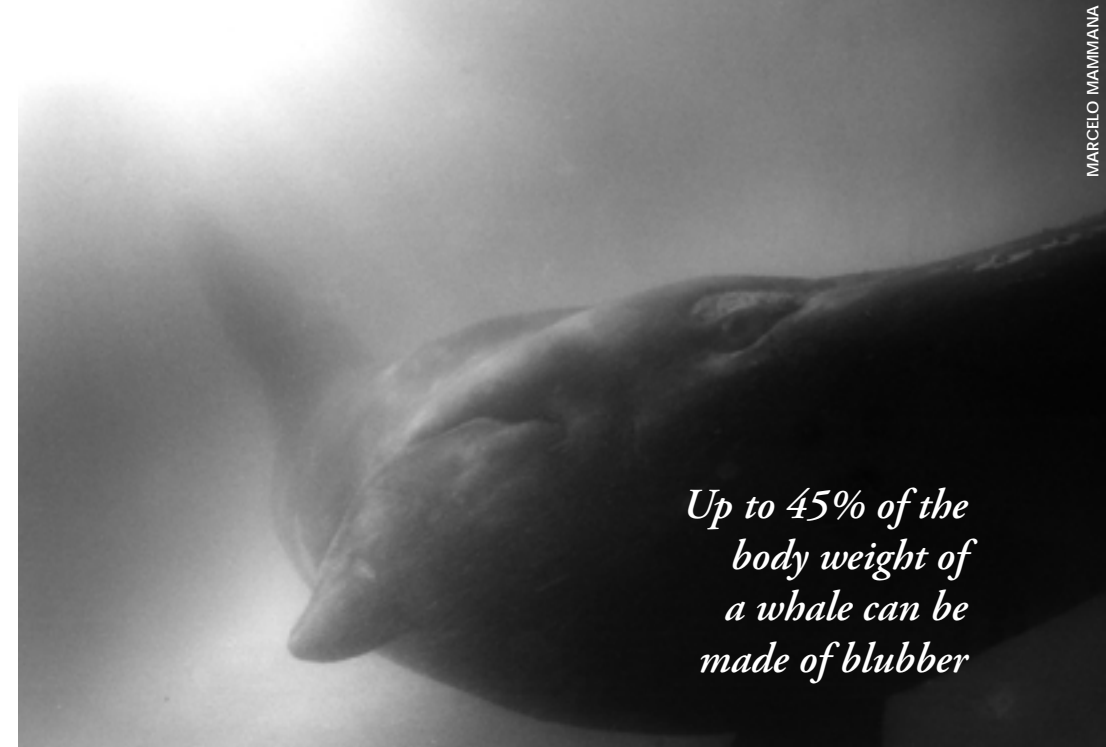


Aquatic mammals too have a very sophisticated temperature control system but cannot use perspiration to cool themselves

If the body temperature is too high, it can be cooled by radiation, conduction, convection, and evaporation of sweat. The first three factors are not under control by the body; they are purely physical effects that depend only on the actual temperature of the body and the ambient surroundings. Naturally, we humans can increase their effect by removing clothing, to improve radiation, or fanning our bodies to increase conduction and convection. However, the body itself can actively induce sweating, so that if the skin temperature increases above 37°C, sweating will begin almost immediately.

Whales require a thick layer of blubber to maintain their body temperature in water because heat is transmitted much more easily by water than by air. Up to 45 percent of the body weight of a whale can be made of blubber, which serves not only as an insulator but also as an energy reserve. Ocean water is relatively cold in contrast to body temperature, but a fast swimming whale does produce a lot of heat, which has to be removed. This is carried out by means of blood vessels leading to an extensive network of capillaries in the flippers, tail flukes and dorsal

There is nothing like a good layer of blubber to make you all comfy



*Up to 45% of the body weight of a whale can be made of blubber*

Whales require a thick layer of blubber to maintain their body temperature in water

fin. Concurrent circulation, on the other hand, minimises heat lost from the arteries to the surroundings. In some ways, temperature control may be easier for the cetacea, for it is easy to get rid of heat in cold water—if the water is cool enough.

## Adverse effects of increasing oceanic temperatures

It has been discovered that global warming caused marine mass extinction at the end of the Permian period 251 million years ago. It is estimated that 95 percent of marine species were killed off.

This mass extinction, although the worst, was but one of five that have occurred over the past 550 million years. The temperatures are estimated to have been about 6°C higher than today. The most recent event was the Cretaceous-Tertiary, which occurred 65 million years ago, when temperatures were about 4°C higher than today.

The mass extinction 251 million years ago appears to have happened because of the slow decline and death of deep sea creatures, which were the first to



MARCELO MAMMANA





*Dolichorhynchops osborni*, a plesiosaur from the Late Cretaceous when temperatures were about 4°C higher than today

go, followed by the shallow water inhabitants. It indicates that something was arising from the deep oceans which possibly was the very toxic hydrogen sulphide produced by deep-ocean anaerobic bacteria i.e. those that don't use oxygen in their metabolism. These bacteria were favoured by the fact that the warming of the surface water had decreased the ability of the oceans to absorb oxygen. However, whatever mechanism it was that caused the mass extinction, it was probably tied to the ocean circulation processes. The emission of hydrogen sulphide from the oceans could also account for the great demise, 65 percent of the terrestrial species, which occurred at the same time.

**Will a rise in temperature lead to a new mass extinction?** Whether or not a mass extinction is soon to occur, it is believed by some climatologists that a rise of 1.5°C to 2.5°C is likely to take place before the middle of the century. If this is true, then between 20 percent and 30 percent of animal and plant species could die. Sea water temperature affects faunal distribution and, as we have seen, water temperatures can vary both horizontally in the surface and vertically down into the depths. So, these temperature changes have a great significance for the faunal—and floral—distributions. Faunal distribution depends to a large extent on a given organism's ability to adjust to the ambient conditions. If they cannot adjust, they must either move or die. For example, the eelpout, *Zoarces viviparus*,

*Whether or not a mass extinction is soon to occur, it is believed by some climatologists that a rise of 1.5°C to 2.5°C is likely to take place before the middle of the century*

is near the top of its local food chain in the shallow waters of the southern North Sea. Research carried out at the Alfred Wegener Institute in Bremerhaven, Germany, appears to show that the fish face an oxygen constraint because as the water warms up, it contains less dissolved oxygen. With less oxygen available, the eelpout gives birth to fewer young, so their population declines. This also appears to be the case with cod in the North Sea, which are finding it hard to maintain high reproducibility. A permanent increase in water temperature will probably not mean that these fish will become extinct, but that they will move from their ancient homes to new, cooler aquatic pastures to the north.

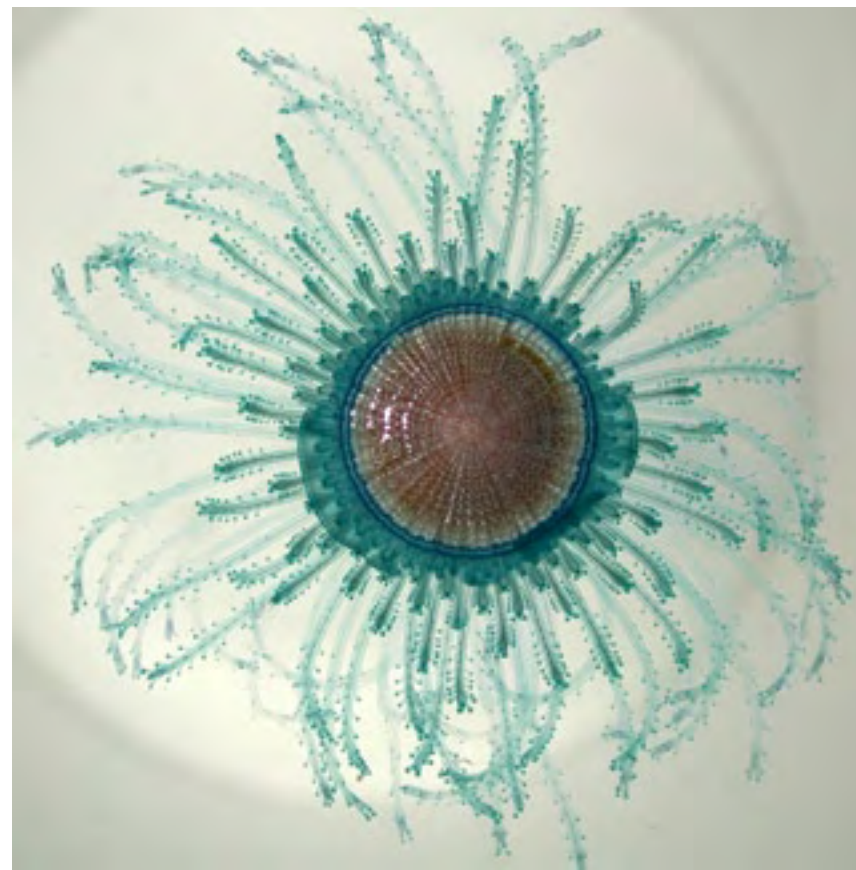
### The invasion of jellyfish

A typical example of what happens ecologically when the sea temperature changes even slightly is given by the mauve stinger jellyfish. Recently, millions of these creatures drifted into a salmon farm in the Irish Sea, killing more than 100,000 fish. Several more swarms of these jellyfish, a Medi-

terranean species, have been observed around Britain, even as far north as the Shetland Islands. Apparently, warmer sea waters in the Mediterranean is boosting the jellyfish numbers by increasing winter survival and lengthening the breeding season. The increasing water temperatures then allows them to move north. Generally speaking, most jellyfish are posi-

Because they have positive control over their body temperatures, the homoiothermic animals will probably be the least affected by temperature increases, at least initially. Those best suited to survive will therefore probably be the aquatic mammals which, like humans, have a large measure of control over their body temperatures thus making them, to a large degree, independent of increasing water temperatures.

The first type of aquatic animal to be really effected are those who are restricted to narrow temperature limits i.e. the stenothermic



Jellyfish swarms are becoming more commonplace

tively affected by global warming, not only by the increasing water temperatures, but by the fact that the increased concentration of carbon dioxide affects creatures with acid-soluble shells which compete with jellyfish.

animals such as the corals. There is already evidence that this is occurring with the bleaching of corals.

Freshwater pearl mussel (*Margaritifera margaritifera*). Mussels have a wide temperature tolerance but may be affected by change in predation

The eurythermic animals, which have evolved to survive in environments with a wide temperature range, will probably have little difficulty in adapting to increased temperatures.

The greatest effect of changing temperatures will obviously be on those creatures that have no, or little, control over their temperature, because this is a function of the ambient water temperature. These are the poikilothermic animals and to a lesser degree the stenothermic species. As heat is required for many chemical changes to take place, including those needed for muscle activity, the activity of poikilothermic animals depends greatly on the temperature of the surrounding water. Therefore, these animals mostly flourish where the water is warm, near tropical coral reefs, for example, where there is an abundance of fish species to be seen. On the other hand, there are relatively few fish and invertebrates to be found in the cold depths of the oceans.

A clear example of what can happen to an ecological system in delicate balance when temperature changes occur is given by starfish and mussels in the tidal waters of Oregon, USA. It was found by Eric Sanford of Oregon State University that a 5°F (ca 2.8°C) change is enough to change dramatically the feeding habits of the starfish. This creature feeds mainly on mussels along the US Pacific coast.

He found that a drop of the same magnitude caused the starfish to virtually stop feeding on the mussels, which then allowed a rapid expansion in the mussel population. They can then crowd out algae, barnacles and other organisms. On the other hand, an equivalent increase in temperature caused the starfish to go on a feeding binge, which caused the mussel population to drop drastically. The consequent collapse of the mussel communities then affects the crab, sea cucumbers and worms, which are part of the ecosystem.

*A temperature drop of the 2.8°C caused the starfish along the US Pacific coast to virtually stop feeding on the mussels, which then allowed a rapid expansion in the mussel population.*





His study thus suggests that if a key species in an ecological system is sensitive to temperature, a slight warming or cooling can trigger a cascade of rapid changes that will affect every animal within that system.

Some cold-stenothermic fish, however, may be able to adjust to increasing water temperatures. For example, in the case of the bald rock cod mentioned above, it has been found that when these fish were exposed to long-term changes, they could compensate for those changes. Dr Frank Seebacher of the University of Sydney has found that they could adjust their cardiovascular system and metabolism to survive in warmer waters. The cod were first acclimatised in 4°C water for four weeks and then transferred to water with temperatures of up to 10°C. The fish appeared to live as happily in the warmer water as they did at -1°C.

However, temperature affects many life history parameters such as fecundity and the development time with the development time from egg to adult being accelerated under increasing temperatures. Increased temperatures can also affect the sex ratios. It has also been found that this accelerating effect of increased temperature has a life-shortening effect corresponding to the rate of reaction increase with increasing temperature. For these creatures, it appears to be a case of 'Live fast, die young'.

If the changes in temperature occur very slowly, then the species can adapt. The fact that an Antarctic fish, the bald rock cod, has the capacity to compensate for chronic changes in temperature means that we must be careful in our predictions regarding the catastrophic consequences of global warming. Unfortunately, the current increasing changes in



*Aspergilliosis* is caused by the terrestrial fungus *Aspergillus sydowii*. The gorgonia counteract the disease by encapsulating fungal hyphae in purple pigmented galls

bright blue coral, found in Caribbean and Florida Keys, has been dying in some places at a rate of over 20 percent. The sea whips have also been found to be dying of the bacterium *Scytonema* in the Florida Keys. The optimal temperature for many of these pathogens to flourish is about 32°C, the temperature at which bleaching is prevalent.

There are also the secondary effects of warming such as predator-prey interactions. These again will have a feedback effect on other plant and animal species, with the bleaching of corals due to increasing water temperatures being a well-known phenomenon.

### Coral bleaching

As described in a previous issue, corals are a symbiosis between small polyps and a type of algae called zooxanthellae, which are packed into the cells of the polyp tissue. The algae use the photosynthetic process to produce energy-rich compounds. The corals can utilise some of these products in their own metabolism and, in return, give protection to the zooxanthellae.

Corals and zooxanthellae, like all biological life, live within a preferred range of temperatures. Summer sea temperatures that are 2 – 3°C above normal can kill corals. At these temperatures, the symbiotic relationship will eventually collapse and, as the corals cannot escape to more suitable environmental conditions, being attached to the reefs, the corals will die. As it is the algae that give colour to the corals, the loss of them from the coral will cause the corals to become pale or bleached. Many corals appear to be living close to their upper temperature limit, and transient temperature increases

of only a few degrees above the usual maximum can kill corals. However, there is a great variation in susceptibility to changing temperatures between different coral species, so that some corals may survive an increasing oceanic temperature—if not too great. There is also the effect of the increasing solubility of carbon dioxide in the warming surface waters of the oceans, resulting in the reduction of the amount of dissolved calcium carbonate available to reef-building corals.

### Apocalypse soon?

Many climatologists today feel like Cassandra of Greek mythology who was thought to be endowed with the power of prophecy but fated never to be believed. So, are we facing another mass extinction event? Not immediately, perhaps, but all the realistic prognoses indicate that there will be a great loss of species by the end of this century. And the great tragedy is that with the bulk of marine species still undiscovered, we will lose species before we even know of them. And it is not just species we will lose, it is whole ecological systems.

In the short-term, it is possible that corals, for example, can adapt to the rising temperatures either by acclimatisation, with changes in their physiology, or by natural selection. However, it may not be the relatively simple effect of an increase in water temperature that is the most important effect. It has been suggested that great changes in the oceanic currents can occur, both horizontally and, especially, vertically. Such changes could drastically change the environments for all marine species, both the bottom dwellers and those who live in the surface waters. Most species would be quite incapable of coping with such changes and would therefore be wiped out.

*More relevant for the diving community, regarding the relatively near future, we may see a total loss of our beautiful coral reefs. So divers, visit the reefs while you can, for many of the more susceptible may not exist for many more years. ■*

water temperatures are happening too fast for many of the current species to adapt, and they will therefore disappear. Of course, evolution will ensure that species will appear that can survive—and flourish—under the new conditions.

Although the oceanic temperature changes are, as yet, small, they can still have some significant effects. Climatic-related pressures can act directly on aquatic animal life through physiological effects such as changes in food demands, in growth rates, and in abilities to reproduce and survive. It has also been shown that increasing temperatures can be favourable for disease-causing pathogens in corals.

For example, it has been shown that a fungus, *Aspergillus sydowii*, is a pathogen for the sea fan, *Gorgonia ventalina*. This

Deep sea mussel beds are likely to be least affected by temperature change







Edited by  
Michael Arvedlund, PhD  
& Peter Symes, M.Sc.

# *They are all* Transsexuals

The popular anemone fishes are mostly known for their symbiosis with giant sea anemones, their interesting behaviour, and beautiful colours. But they also have another lesser known but interesting side to their lives: Their life cycles includes transsexual 'stunts'

Anemone fishes are hermaphrodites. They have both male and female gonads. However, once hatched, the female gonads are suppressed, thus turning them all into male when juvenile. Among young fish, it's all boys, no girls.

In the early part of their life cycles, after some days out in the blue as pelagic larvae, anemone fishes settle on the coral reef once they find a suitable host sea anemone. Usually, there are a small group of anemone fishes in one large sea anemone. The first one in the pecking order in a sea anemone turns into a female and mates with number two, which will remain a male. The rest of the fishes in the pecking order also remain males. They are not allowed to mate with the female. Only the number one male in the pecking order, the alpha male, can mate with the female.

The phenomenon of sex reversal is a fascinating part of anemone fish life history. Sex change occurs in many fishes. For example, it is now well established that most wrasses (*Labridae*) and parrot-

A reared batch of anemone fishes of the species *Amphiprion melanopus*, and they are all boys!

Michael Arvedlund and Peter Symes





## Boys, girls or what?

fishes (*Scaridae*) begin adult life as females and later assume the more colourful male phase. Similar changes are widespread among groupers (*Serranidae*).

### A leader with no balls

What sets the anemone fishes apart in this respect, however, is that the sex change goes

from male to female. As mentioned above, the largest and most socially dominant fish in a particular anemone is generally the female whose

gonads are functioning ovaries with remnants of degenerated testicular tissue. The smaller male, which in species such as *A. frenatus* and *P. biaculeatus* may be less than half the size of the female, has gonads that are functioning testes but also possess non-

functioning or latent ovarian cells. If the dominant female dies or is experimentally removed, the male's gonads cease to function as testes, and the egg-producing cells become active. Simultaneously, the largest of the non-breeding individuals becomes the functioning male.

This adaptation allows continuous reproduction; without it, an adult would ►

The clownfish, or anemonefish, are the subfamily *Amphiprioninae* of the family *Pomacentridae*. Currently 27 species exist, of which one is in the genus *Premnas*, and the rest are in the subfamily's type genus *Amphiprion*. The other pomacentrids are called damselfish.

Clownfish and damselfish are the only species of fish that can avoid the potent stings of an anemone. There are several theories for how this avoidance is accomplished.

In a study published in the journal *Nature*, evolutionary biologist Peter Buston and colleagues report that clownfish in Papua New Guinea reefs can change their sex at will for social reasons. ■

The humphead wrasse (*Cheilinus undulatus*) is a wrasse that is mainly found in coral reefs. It is also known by the name "Napoleon wrasse", "Maori wrasse", or "Napoleonfish", or "So Mei" (in Cantonese, or "Mameng" (in Philippines).

Some males grow very large, with one unconfirmed report of a Humphead Wrasse that was 229cm long and weighed 190.5 kg



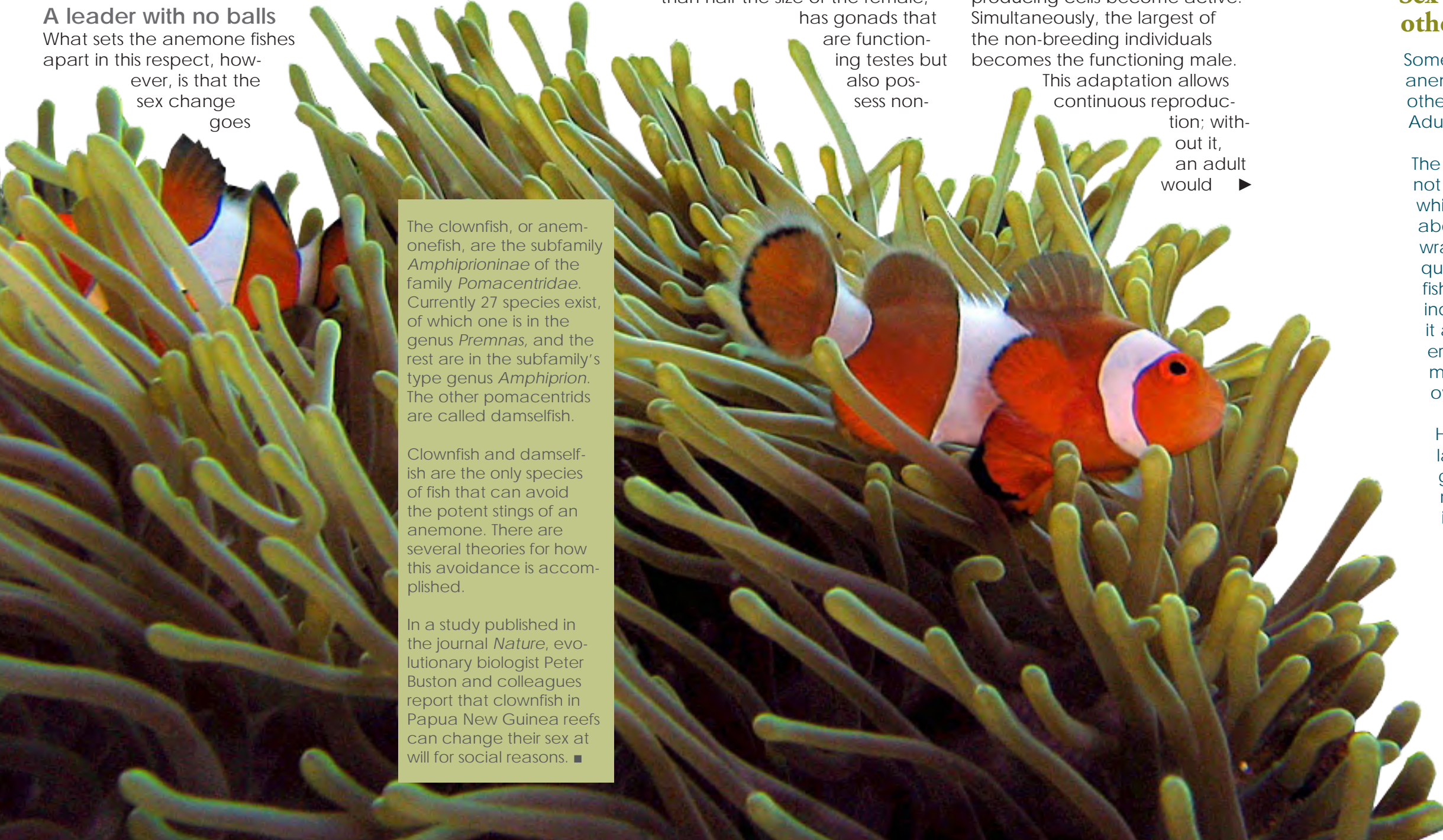
### Sex change the other way around

Some fish change sex from males to females, like the anemone fishes. In different species, it may be the other way around, such as in humphead wrasses. Adult females are known to change into adult males.

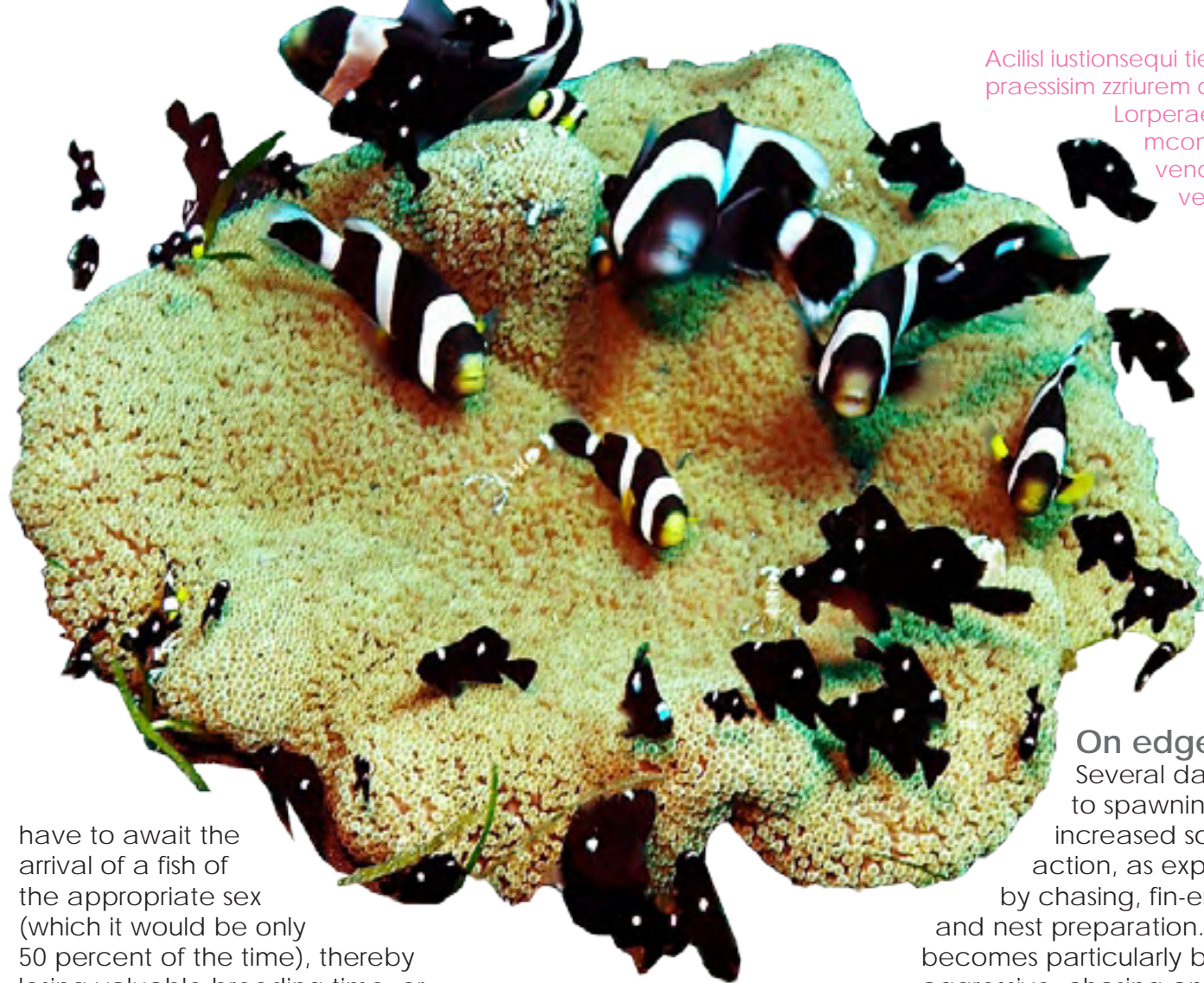
The factors that control the timing of sex change are not yet known, nor how 'decisions' are made about which fish changes sex. We still have much to learn about the biology of this species. The humphead wrasse is long lived, but breeds very slowly. It takes quite a long time, possibly up to five years, with the fish reaching about 35-50 cm in total length before individuals reach sexual maturation. This has made it an endangered species, as it is not being regenerated fast enough to compensate for fishing. Its meat is in high demand Southeast Asia, selling at over US\$100 per kilogram.

Humphead wrasse mate in pairs formed within larger social groups that form temporary aggregations. Sometimes spawning aggregations can number several hundred fish in areas with no fishing pressure. Planktonic eggs are released into the water column and drift away from the spawning site.

After hatching, the larvae stay in the water until they settle on the substrate. Population sizes and structures are not yet known for this species. Juveniles occur in coral-rich areas of lagoon reefs, among live thickets of staghorn *Acropora* sp. corals, in seagrass beds, murky outer river areas with patch reefs, shallow sandy areas adjacent to coral reef lagoons and in mangrove and seagrass areas inshore. They tend to move into somewhat deeper waters as they grow older and larger. ■







have to await the arrival of a fish of the appropriate sex (which it would be only 50 percent of the time), thereby losing valuable breeding time, or it would have to seek out a mate, leaving its anemone and thereby risking predation both on itself and on its symbiont.

Within the tropics, spawning occurs throughout most of the year, although there may be seasonal peaks of activity. In subtropical or warm temperate seas, as, for example, in southern Japan, reproductive activity is generally restricted to spring and summer when water temperatures are at their highest. At Enewetak Atoll (located at about 11°N in the central Pacific), spawning is strongly correlated with the lunar cycle: most nesting occurs when the moon is full or nearly so. Moonlight may serve to maintain a high level of alertness in the male, which assumes most of the nest guarding duties. Moreover,

because newly hatched larvae are attracted to light, moonlight may draw them towards the surface, thereby facilitating their subsequent dispersal by waves and currents.

Anemone fishes are unique among damselfishes in forming permanent pair bonds that sometimes last for years. In other damsels, one male may mate with several females during a single spawning episode, and different sets of females are often involved in subsequent spawnings. However, pair-bonding in most species of anemone fishes is very strong and is correlated by the small size of their territories (centered on their sea anemone) which is, in turn, correlated with the unusual social hierarchy that exists in each "family" group.

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#### On edge

Several days prior to spawning, there is increased social interaction, as expressed by chasing, fin-erection, and nest preparation. The male becomes particularly bold and aggressive, chasing and nipping his mate. He also displays by fully extending his dorsal, anal, and pelvic fins, while remaining stationary in front of or beside her.

During the nuptial period, he selects a nest site, usually on bare rock adjacent to the anemone. Initially, the male spends considerable time clearing algae and debris from the site with his mouth; he is eventually joined in these activities by his mate.

Spawning, which occurs most often during morning hours, generally lasts from about 30 minutes to more than

two hours. Once it commences, the tiny, conical ovipositor of the female is clearly visible. A number of eggs are extruded through this structure on each spawning pass, when the female swims slowly and deliberately in a zig-zag path with her belly just brushing the nest surface. She is followed closely by her mate, who fertilizes the eggs as they are laid. Numerous passes occur during each spawning session. The number of eggs deposited ranges from about 100 to over 1000, depending on the size of the fish and on previous experience. In general, older, more experienced pairs produce more eggs than do recently formed pairs.

Anemonefish eggs are elliptical or capsule-shaped, are about 3-4 mm in length, and adhere to the nest surface by a tuft of short filaments. They incubate six to seven days. Just prior to hatching, the embryo, which has undergone rapid development, is clearly visible through the transparent parent egg membrane: the most noticeable features are the large eyes with their silvery pupils, and the red-orange yolk



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#### How to determine the sex on a fish

Often you cannot determine the sex of a fish just by looking at it. Determination of the sex and gonadal maturity of a fish is often necessary to determine the sex. A typical sex identification problem is facing biologists in groupers. A newly developed method by the fish sex change expert, Alam Mohamed at Sesoko Station, Japan, is an accurate and reliable determinate of the sex of live groupers using 5-10 mg gonadal tissue samples, harvested using non-lethal gonadal biopsy. Alam's fish survive the operation and there is no serious infections resulting from the surgery. Alam's method is therefore quickly spreading around the world. ■

sac that is responsible for the general colour of the entire egg mass when viewed from a short distance. Throughout incubation, the nest is guarded and cared for by the male. He chases other fishes from its neighbourhood, especially potential egg-eaters (e.g. wrasses). The male frequently visits the nest to fan the eggs with his pectoral fins and to remove dead eggs and debris with his mouth. The female is mainly occupied with feeding during this time, but occasionally assists the male with his duties.

The embryos hatch one night after about a week (dependent on the species) and the tiny embryos swim to the surface guided by the moonlight and out on the open ocean, away from predators, and to a life as pelagic larvae for one or two weeks (also dependent on the species). Out on the blue the larvae grows by feeding on zooplankton, and returns another night to settle on the reef, detecting a suitable host sea anemone, and the life cycle has once again made on full round. ■

