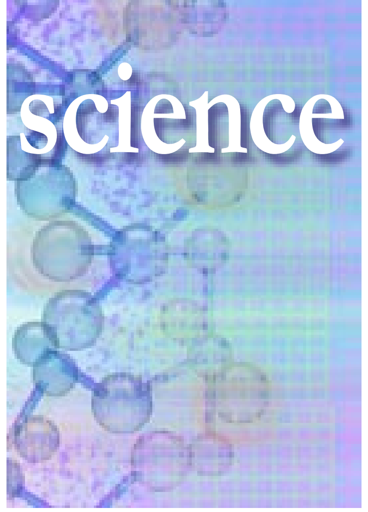

The fishy art of survival

Text by Michael Symes
Photos by Peter Symes

Fish Fashion

Is there any diver who has not been fascinated by the wonderful colours of reef fishes and the reefs of their habitat? Those of us who have been lucky enough to experience at first hand this interaction between these creatures and their environment, cannot fail to have wondered about this rich excess of colour and the reasons for it. In nature there is a reason for everything – if we can but find it.

Humans use colours in many different ways. Normally, we only think of colours when they are being used in a decorative way; we liven up the interiors of our houses with paint and coloured wallpapers, and we brighten our textiles and clothes with many coloured dyes. And at sad events like funerals we also remove colour when we use black clothing.

However, although we are not generally conscious of it, colour plays a much more important part in our lives than this. It can be important for our very survival. For example, we use colours as a diagnostic tool for our health. Not only do we use pale skin to diagnose anaemia and yellow skin as a symptom of liver disease but the bruising from subcutaneous bleeding after a blow can also be observed. Bad teeth can also be diagnosed from their colour.

The use of colour is also important for warning purposes in the case of red traffic signal lights, for example, and the red colour of certain very poisonous toadstools and frogs. We also use colour diagnostically to tell us when our bread is baked, or tell a ripe apple from a unripe one. Colour is very important cosmetically when used both as a sexual signal and as a means of camouflaging bad skin. And colour is very important when used for identification purposes, such as the colour coding of electrical resistors and for product identification, the Kodak yellow film packaging being a typical example. And one could go on, as there are many other important functions of colour for us humans; whole books have, in fact, been written about this subject.

But what about the submarine world of

ABOVE: Scalefin Anthias
RIGHT: Coral gardens, Sipadan Island, Malaysia

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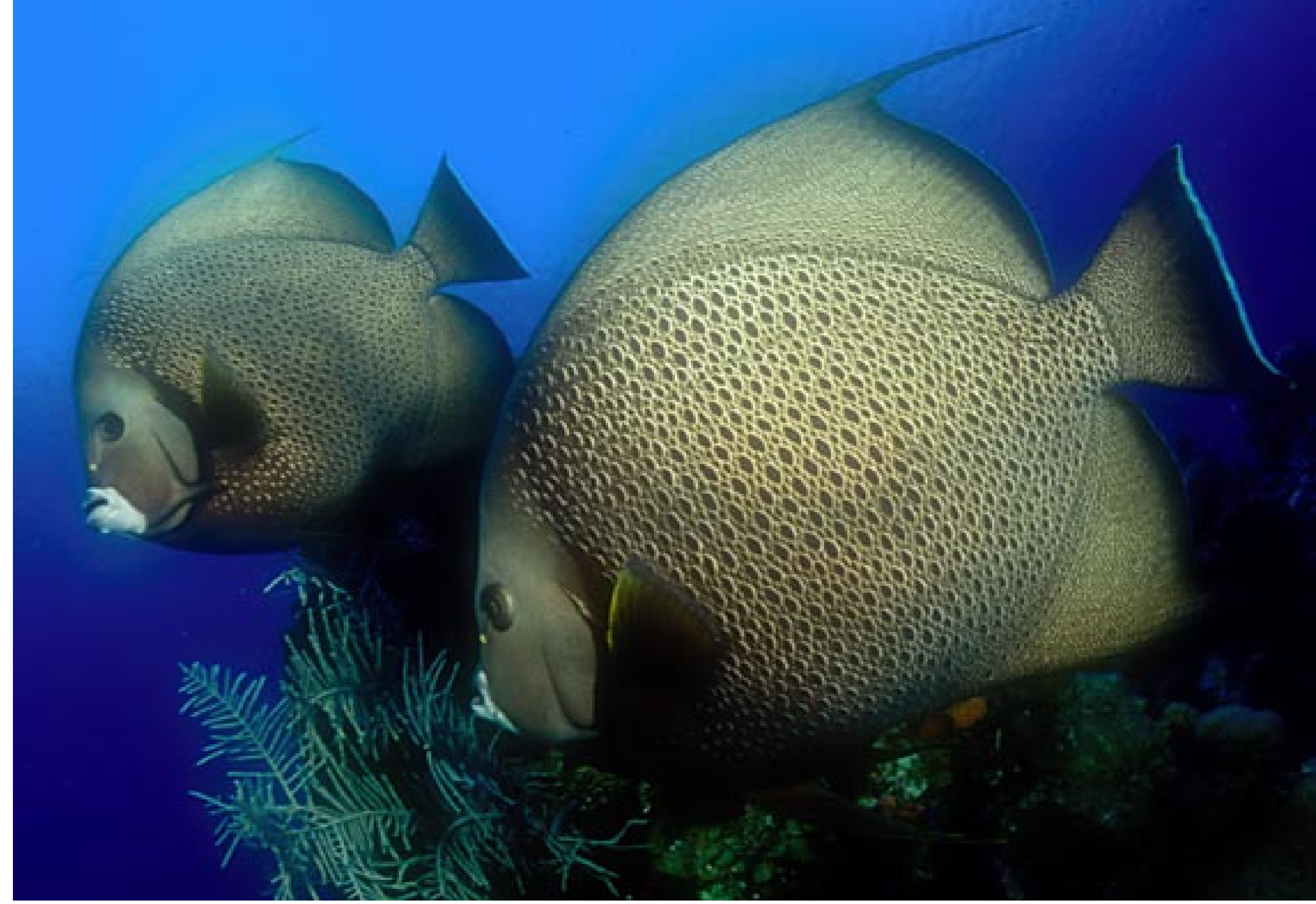

LEFT: Coral gardens
Sipadan Island, Malaysia

RIGHT: French Angelfish,
Cayman Islands

INSET: Pufferfish, Marsa Alam,
Red Sea, Egypt

fishes? Have colours any importance for them? Or are the beautiful colours that divers see in fishes and coral reefs only observed by them and have no function at all for fishes? For there certainly aren't any fish-dentists examining their patients for teeth decay, or fish-bakers making bread.

Several theories have been put forward over the years regarding the wonderful colours of the fishes in and around the reefs.

It was thought that the colours developed through natural selection in order that males will be attracted to females. However, males and females often appear to be the same with regard to colouration.

Perhaps, it was supposed, the colours are warnings that certain fish are toxic or otherwise nasty to eat. This is true for example for the Box fish. However, many brightly coloured fish are excellent eating, not only for other fish but also for us humans.

The gaudy appearance of the box fish reminds predators that poison is secreted through its skin when it is attacked. Predators associate the effects of its venom with the black and yellow com-

bination of warning colours and learn to avoid them.

Konrad Lorentz, the Austrian animal behviourist, proposed that the fish colours might be acting as identifiers of possible mates. For humans this is no problem, as we only form a single species. For reef fishes, however, this could be a real problem as there are so many different species present in the reefs.

Or perhaps the colours are just a byproduct of fish-metabolism and have no real significance, neither at the present time nor over evolutionary time. However, from the point of view of evolution theory this seems unlikely.

Although there might be some truth in all of these theories the current consensus seems to be that fish use their colourings mostly for camouflage purposes. At first sight this would seem to be paradoxical, for the fish appear to us to be clearly observable against the uniform blue-grey background of the water or even against the many bright colours of the coral reefs. The critical words here, though, are "appear to us", for fish are

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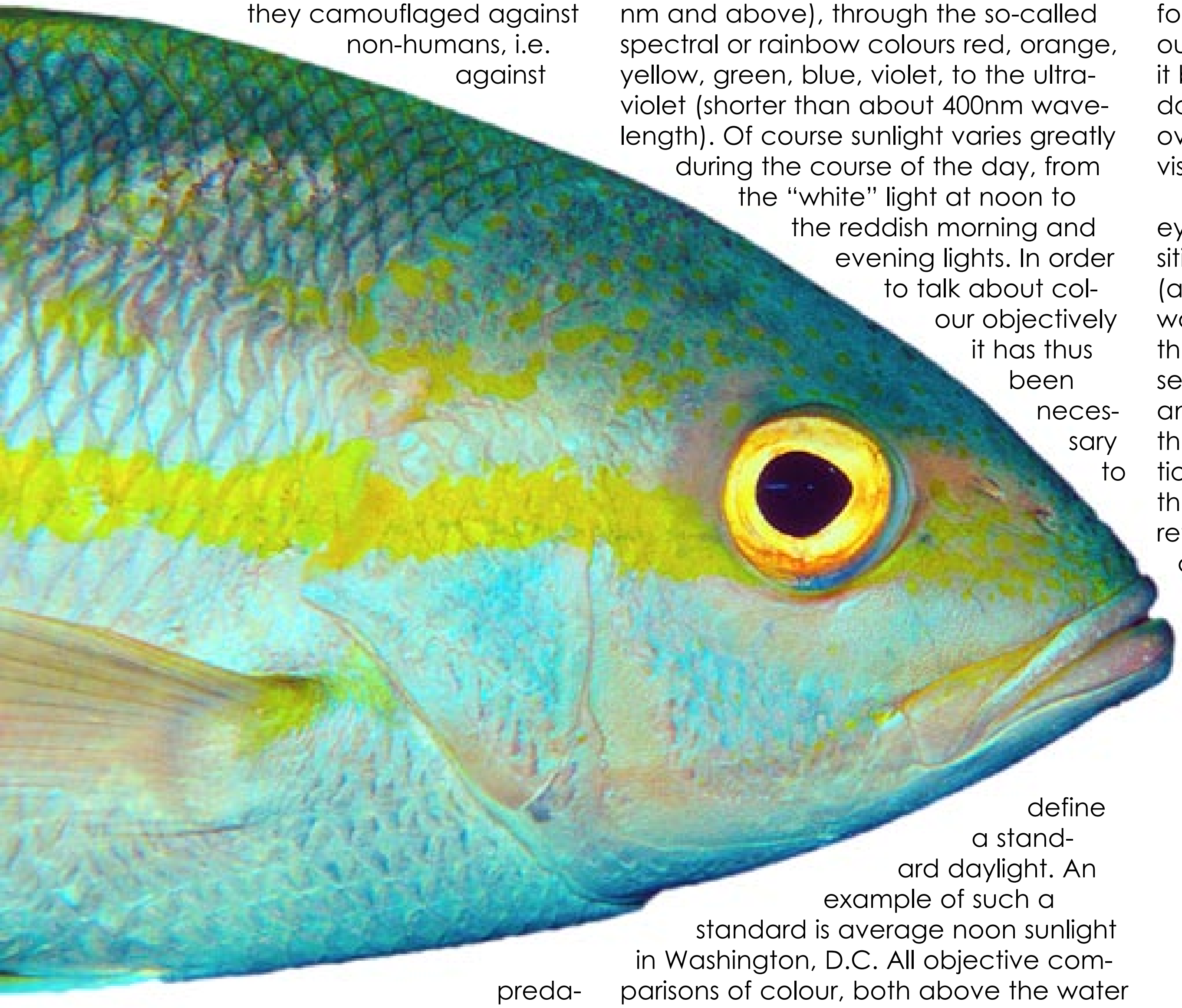


clearly not camouflaged against human sight. So, we can ask ourselves, are they camouflaged against non-humans, i.e. against predatory fish species? What do predatory fish actually see when they look at their prey? To attempt an answer these questions we must first look at some of the factors involved in the perception of colour.

The perception of colour

Firstly, there must obviously be light present, without light nothing can be seen. Human beings have evolved their colour vision under sunlight. Sunlight consists of electromagnetic radiation ranging from the infra-red (wavlengths 700 nm and above), through the so-called spectral or rainbow colours red, orange, yellow, green, blue, violet, to the ultra-violet (shorter than about 400nm wavelength). Of course sunlight varies greatly during the course of the day, from the "white" light at noon to the reddish morning and evening lights. In order to talk about colour objectively it has thus been necessary to define a standard daylight. An example of such a standard is average noon sunlight in Washington, D.C. All objective comparisons of colour, both above the water and in it, are then made using such standards.

Secondly, there must be cells in the eye to detect this radiation. Most vertebrates, including humans, use two systems of light-sensitive cells in their eyes. Two or more types of so-called cone cells (three in humans) produce a sensation of colour in abundant light, and a single type of rod cell detects light much more sensitively, but achromatically, under reduced lighting conditions. Thus, as a survival strategy, humans forgo their colour vision when it begins to get dark and switch over to their rod vision.

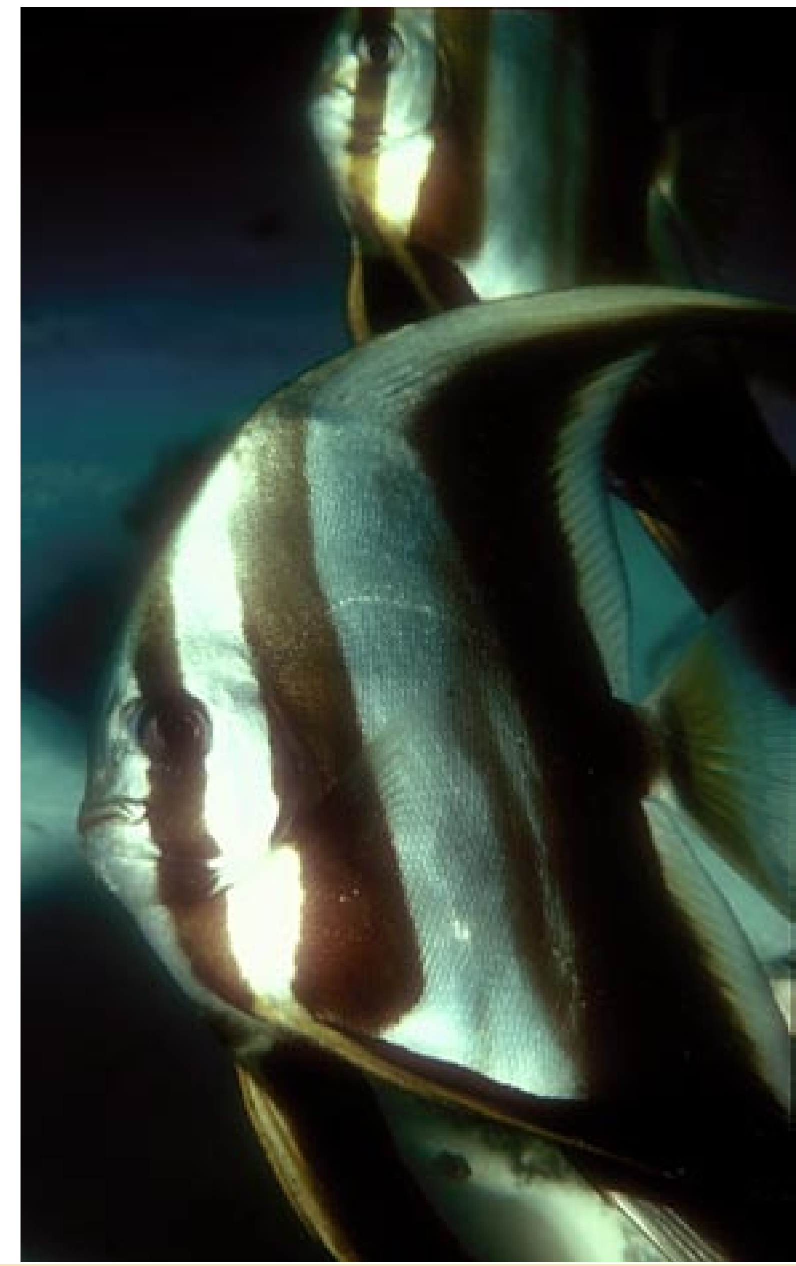
The human eye is most sensitive to green (about 550 nm wavelength) in the middle of the spectrum, with the sensitivity falling to zero in the infra-red and ultra-violet i.e. we can detect neither ultra-violet light nor infra-red radiation. To enable us to perceive colour, the three types of cell in the human retina, are sensitive to the blue, green and red spectral regions respectively. The relative amount of different light radiation falling on these three types of cell give rise to the perception of colour. For example, if there is relatively a lot of light of, say, 600nm wavelength and above, and little of the shorter wavelengths, we will perceive an orange/red colour.

So, when we humans perceive coloured objects we are using a specialised set of light sensitive cells under an illumination which preferably contains all the wavelengths to be found in sunlight at sea-level. Of course, we do observe coloured objects under quite different illuminations such as the strong yellow sodium light of some street lamps. But as we have all experienced, this form of lighting disturbs our normal colour perception, and the colours of a given object seen under such lighting will generally be much different to that seen under normal daylight. To take an example, an object that looks a pure bright blue under ordinary daylight can appear to be quite black under yellow light. The perception of the colour of an object therefore depends critically upon the type of illumination.

CLOCKWISE FROM LEFT: Snapper, Yellow Shrimpgobies, Batfish, Red Bigeye (Malaysia)

Light

Now, to any diver it is obvious that the light penetrating below the surface of the seas is somewhat different to that of daylight above the surface. Although water is apparently quite transparent it does absorb red light weakly, and has a bluish colour – a white object under the surface looks bluish-green. In 15m of



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water
red light
is reduced to a
quarter of its intensity.

Sunlight is not always available, especially in the ocean depths, so some animals produce their own illumination. Glow worms, fireflies and several species of fish produce their own light by a chemical reaction, chemiluminescence, which is a by-product of their metabolism rather than the more usual heat.

Furthermore, it seems that fish do not have the same type of cells in their eyes as we do to enable them to see colours – at least in the way we do.

We then arrive at the core of the problem. How do fish perceive other fish?

To get some idea of this, we need to understand how the eyes of fish are constructed and how they react to the light entering them. We thus have to study the visual biology of coral reef fishes.

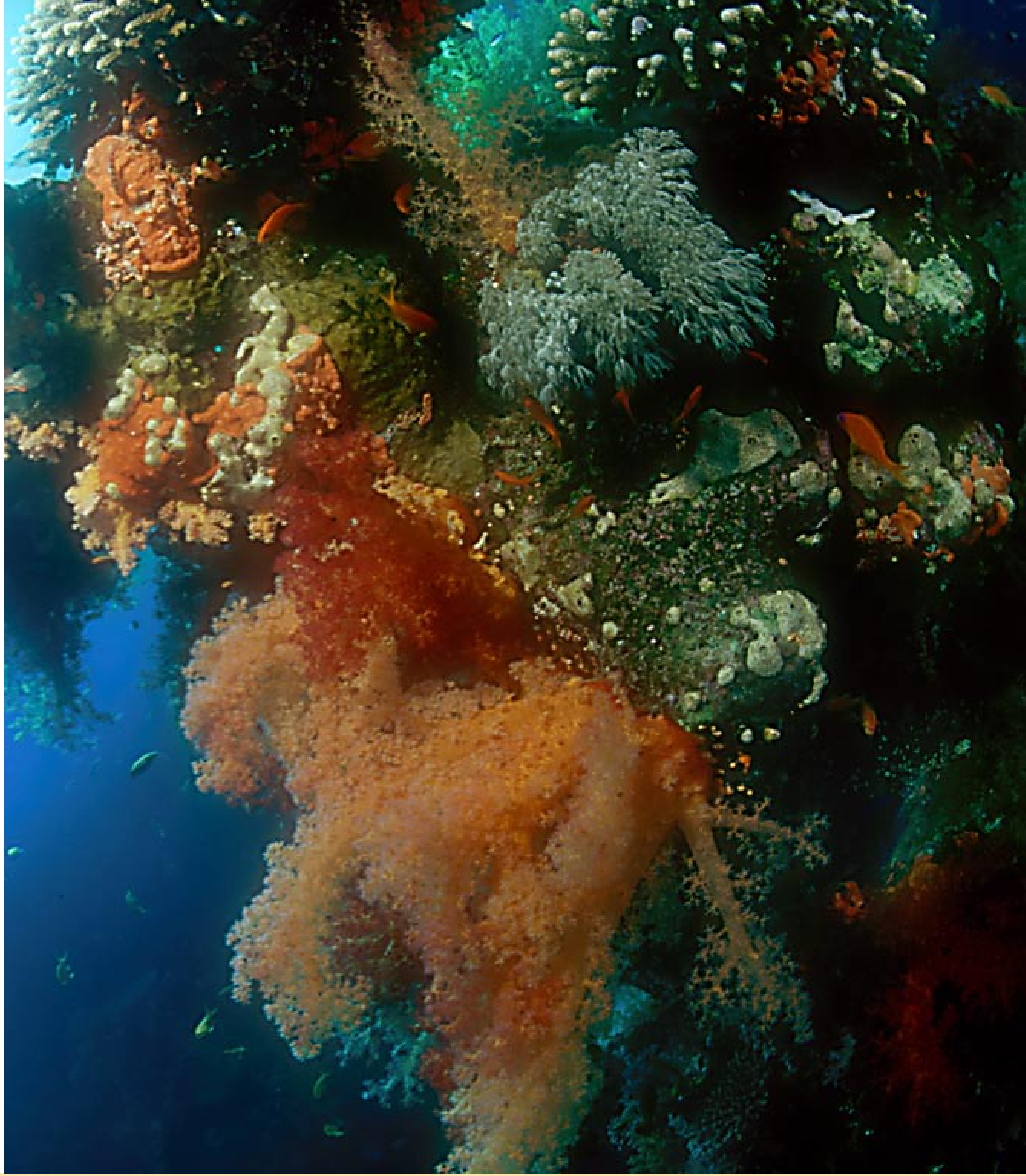
Visual biology of coral reef fishes

There has been a lot of research done on the vision of fishes, some of the most interesting that being carried out on coral reef fishes by, among others, G.S. Losey at the Hawai'i Institute of Marine Biology, University of Hawai'i ,and N.J. Marshall at the Vision, Touch and Hearing Research Centre, University of Queensland, Australia. In three very interesting articles published in Copeia, vol 2003, No. 3 they discuss the visual pigments of Hawaiian reef fishes, the colours of Hawaiian coral reef fishes, and the environmental light in the ecology of reef fish vision.

Visual pigments in reef fishes

The eyes of Hawaiian reef fish were examined for the spectral sensitivity of the visual pigments in the retina. The spectral absorption curves for the visual pigments of 38 species of Hawaiian fish were recorded using microspectrophotometry. The visual pigments of single cone-cells of the fish eyes had their maximum absorptions were at 347-376 nm (ultraviolet), 398-431 nm (violet) and 439-498 nm (blue). For humans the cone cells have maximum sensitivities at about 460 nm (blue), 540 nm (green) and 580 nm (orange). Thus, unlike humans, they had no visual pigments covering the green-yellow-red part of the spectrum. Generally speaking, there appear to be three types of short-wavelength vision in fishes: UV-sensitive, UV-specialized and violet-specialized. Some species, like the marine stickle back, in fact have four types of cone cells. At least some of the species examined could therefore possess true UV-colour vision and hue discrimination, although this would only be in a reduced part of the spectrum perceived by humans. This means that fishes cannot have the same perception of colour as humans.

UV-sensitive eyes are found throughout the fishes from at least two species of sharks to modern bony fishes. Eyes with specialized short-wavelength sensitivity (in the ultra-violet region of the spectrum) are common in tropical reef fishes. Water itself is fairly transparent to UV, with a more than 80% transmittance at wavelengths down to 300 nm. In research in which the visual perception of



ABOVE: Grouper
RIGHT: Soft and hard corals, Malaysia

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Wall corals with Anthias

fishes is concerned, because most glass and plastics are UV-opaque, it might be necessary to ensure that aquarium dividers, specimen holding containers, etc., are UV-transparent. Op. Cit.

The colours of coral reef fishes

The colours of 51 species of Hawiian reef fish were measured objectively using a spectrometer. Such measurements record, independently of any human eye, the different wavelengths of the ambient light that are reflected by the fishes. It is this reflected light that enters the eye of a human or a fish to be perceived as what humans call a colour. In common with other known reef fish populations Hawaiian reef fish reflect light in the spectral wavelength region of 300-800 nm. This is an illustration of the fact that we see reef fishes in all the colours of the rainbow. Yellow or orange with blue, yellow with black, and black with white are the most frequently combined colours.

The authors state that "trends in fish colours seem to indicate that there are both visually driven selection pressures and chemical or physical restraints on the design of colours. UV-reflecting colours can function as semi-private communication signals. White or yellow with black form highly contrasting patterns that transmit well through clear water."

But as we have seen, fish cannot perceive yellow as such, due to lack of the necessary visual pigments, and will thus only see it achromatically, i.e. non-coloured, as a lighter or darker grey. Therefore, the patterns perceived on fishes by other fish is not due to colour but only to an achromatic contrast between the reflecting white or partially reflecting yellow areas, and the almost totally non-reflecting black areas. Fishes see other fishes, not in colour, but only as patterns of non-coloured grey stripes or areas, and black. If these achromatic patterns are similar to those arising in the coral reef environment (for these highly colured reefs will also be seen achromatically) then they will be camouflaged against predators.

We may conclude, then, that one of the main functions of the colours of reef fishes is for camouflage against their natural predators and not against we colour-perceiving humans who delight in their colours.

Camouflage

Although achromatic colour difference is probably the most important factor in successful fish camouflage it is interesting to take just a very short look at the other types of camouflage strategies used by fish.

Humans were very late compared with the fishes in discovering the survival advantages of camouflage on the battlefield, and it was not until the middle of the nineteenth century that khaki uniforms were introduced in the fighting in Afghanistan.

The uniforms of modern soldiers are now nearly always basically khaki coloured to match with the earth colours of sand and soil, or khaki/green to match with foliage, depending on the battlefield. But this is not the only, or even main factor in camouflage.

Kahki as camouflage

Khaki, Urdu for dust-coloured, was first used for the uniforms of the English regiment of Sir Harry Burnett Lumsden in 1848 when he was fighting against the Afghans. All British trops in India adopted khahi in 1885. The Boers used khaki clothing as camouflage in the first Boer War; in the second Boer War the British did as well.

The French suffered heavy losses during the first World War, because the troops wore red trousers as part of their uniform rather than, say, khaki, thus learning a bitter lesson about the need for camouflage.

TOP TO BOTTOM: Common Sand Goby (Denmark) Sculpine (Denmark) Crockodilefish (Borneo)

INSET: Plaice (Denmark)

Movement, sound, silhouette, shine, shape and shadow can all betray the presence of a soldier to the enemy on the battlefield. For fishes the enemy are the predators, the sharks and killer whales, and the battlefield is the submarine environment in and around the coral reefs.

Plaice, turbot brill and flounder can match patterns of mud, gravel and sand so carefully that they can even mimic a chess-board.

Movement

One useful strategy is to keep still and hope that your enemy won't see you. This is a stratscience

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LEFT: Angler fish (Malaysia)

Which came first, fish color or reef color?

Decorator Crab, Puget Sound (USA)

egy used by, for example, goby and sculpine.

Silhouette and shadow

These may be avoided by keeping away from light sources by hiding under an overhanging coral.

Shape

The problem here is to break up the familiar fish outline and make it less recognisable. Like the soldiers uniforms which are coloured in broken patterns to look like leaves, so can fish camouflage themselves. At the approach of a diver an angelfish will try to hide itself among the coral branches, where its stripes serve to confuse its outline.

Also, as soldiers attach leaves and grass to their helmets to camouflage their shape, so spider crabs attach pieces of algae to their carapaces.

We see, then, that fishes have evolved quite complex camouflage strategies for survival in and against the background of the coloured reefs. But quite another question is, of course, why the reefs themselves are so vividly coloured. What role do colours play for the reefs themselves? Are they camouflaging themselves against something? And if so, what? ■