What Do Billfish and Tuna See?

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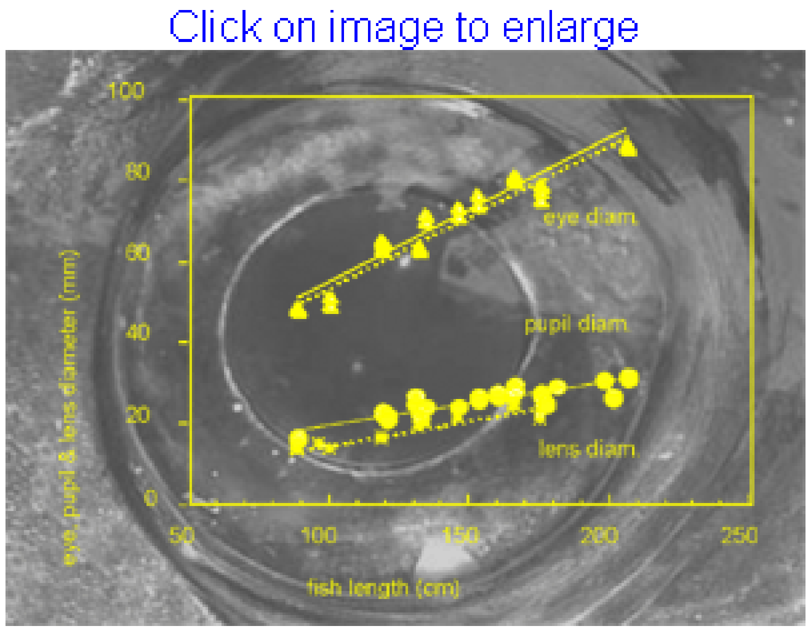
How Important is Vision for Tuna and Billfish?

1. Big Eyes

Click on image to enlarge



Large eyes and a well-developed visual centre in the brain suggest that vision is an important sense for these fish. As in other bony fish the billfish eye grows throughout life (left), thus the ability to capture light and visual acuity is likely to increase throughout the lifetime of the animal.

In absolute size billfish eyes are among the largest in the animal kingdom. From the correlation of eye diameter and body length (left) we predict that the largest swordfish recorded (450cm) had an eye diameter of ca. 19cm.

2. Sensitivity to Dim Light

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Isolated cone photoreceptor of a striped marlin (Tetrapturus audax). Cones are receptors which receive the light information in the retina and turn it into a nervous signal. In marlin the cones are unusually large.

The large photoreceptors (see above) and the large aperture of the billfish eye result in a high optical sensitivity. This allows the billfish to use its vision when the light is dim at depth.

The large eyes of Billfish and Tuna are designed to function well in deeper, darker water. It is very likely that vision is an important sense for feeding at depth.

Our research aims to identify the range of light intensities at which billfish and tuna can still see and hunt effectively. We expect that this information will be useful to identify vertical distribution limits in stock assessments.

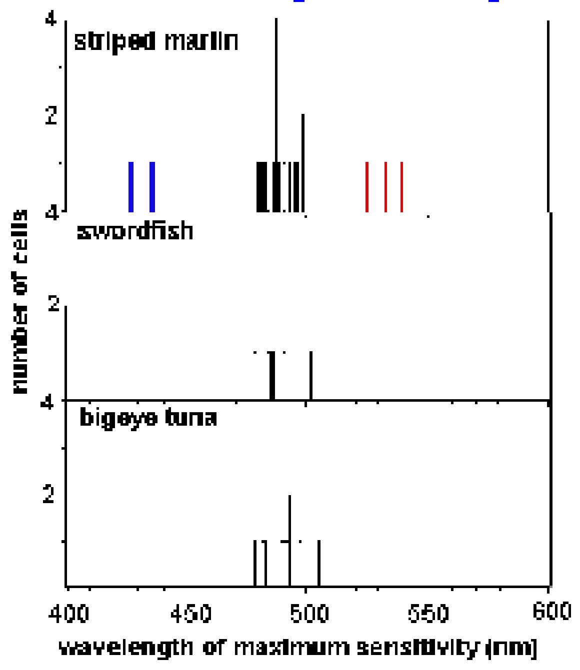
Can They See Colour?

3. Can They or Can't They See Colour?

We find that there is a difference between species of both tuna and billfish with respect to colour vision. We test for colour vision by searching for different colour receptors in the eye. If there is only one receptor the animal can only distinguish light from darkness. If we find a combination of receptors reacting to different colours we can assume that the animal has some form of colour vision.

The striped marlin has three receptors which are sensitive to different wavelengths (see right) - the basis for a trichromatic colour system. In the swordfish and bigeye tuna we have only found one receptor, suggesting that they are probably colour-blind.

Click on image to enlarge

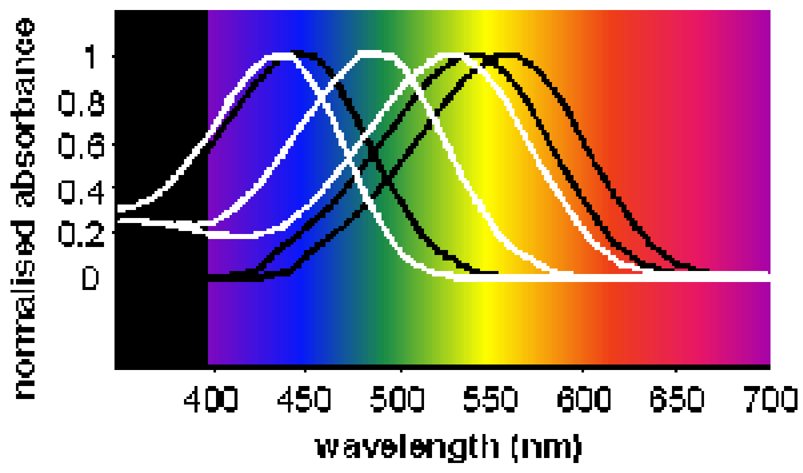


Using microspectrophotometry (MSP) we shine light through individual receptors and identify which colour (or wavelength) the receptor is sensitive to. We repeat this procedure until we find groups of receptors which are sensitive to different wavelengths. Here the striped marlin has three groups of receptors while swordfish and bigeye tuna have only one.

4. Why Judging by Our Own Eyes Doesn't Work with Fish

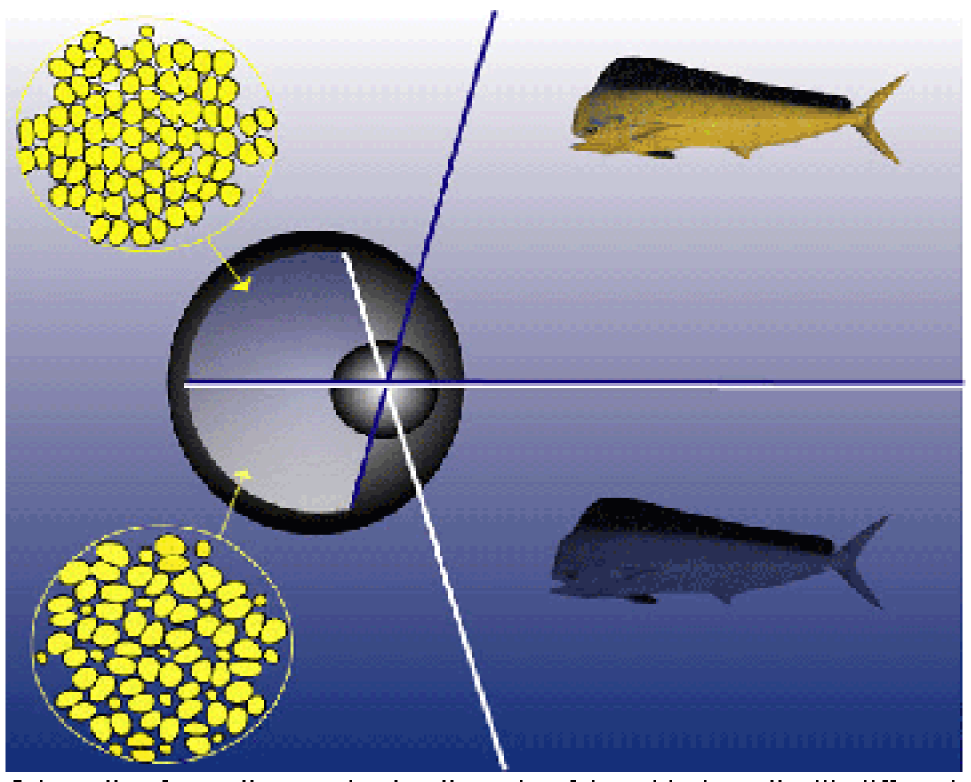
Does a yellow lure look yellow to a fish too? Not necessarily! Human eyes are good at distinguishing yellows and reds from greens. This is an adaptation from our past where we needed to find ripe fruit in a green forest - a very different task to that undertaken by billfish and tuna in their blue world. We therefore need to look at the fishes' world with fish eyes and all their unique capabilities, which is what we are aiming to do in this study.

Click on image to enlarge



Position of the visual pigments in the colour receptors of the eye of striped marlin (white curves) and humans (black curves). The colours of the spectrum (as they appear to us) are displayed in the background. The difference in position and spacing between pigments in marlin and human illustrate that colours will appear different to marlin.

5. A Split World



Schematic of a marlin eye viewing the colourful world above it with different colour receptors while the blue depth below is seen with a blue receptor.

We have shown from our anatomical work that the marlin has optimised its eye to the environment around it. **The part of the eye which looks up into the bright and colourful world above the fish is capable of distinguishing colours. The part of the eye which looks down into the dark blue colour can only see this blue and no other colour.** A fascinating example of how to optimise vision!

6. Screening for Colour Vision

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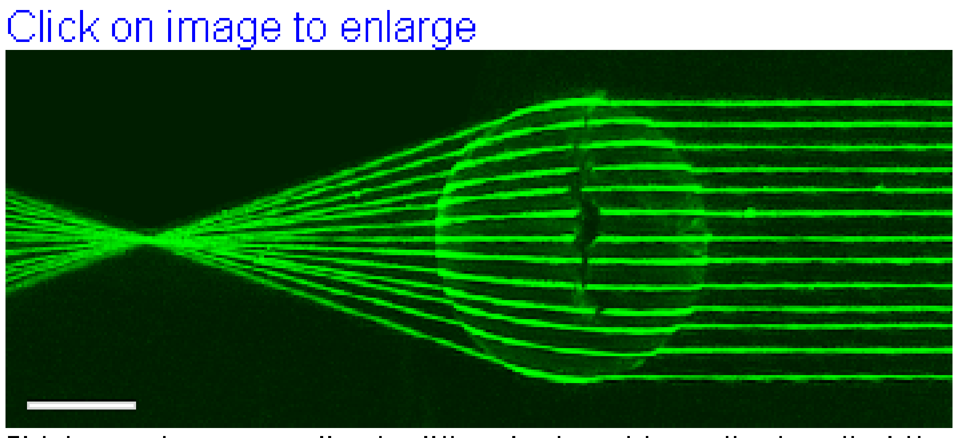

Fish lenses show a correction for different colours (chromatic aberration) if the fish can see colours. The swordfish lens shown above does not have this correction, indicating that colour is not perceived by this fish. We use this lens tracing technique as a screening test to identify which fish are likely to have colour vision (scale bar 1cm).

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These are just some examples from our work on the vision in tuna and billfish. We also study how good these fish are at detecting movements, how their vision changes between day and night and how the presence of a specially adapted heater organ in the eye helps vision. Thanks to additional funding by the National Marine Fisheries Service we will expand these studies to include marine turtles. If you would like to know more please contact:

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