Investigating the Effects of Color and Light Perception in Fish Speciation

Spectroscopy is an essential investigatory tool for researchers from across the natural sciences. Biologist, geologists, evolutionary researchers, and climate scientists in particular find extensive use for spectral analysis as we make advances in understanding of light and energy.

Researchers from the University of Leiden, the Netherlands, are using spectroscopy to study the species differentiation of cichlid populations near Makobe Island, Lake Victoria, Tanzania. This type of research requires scientists to study their subjects in their environment. Rugged, travel-ready spectroscopy equipment will be essential for the scientist of the future seeking to advance knowledge of the natural world. Trust Avantes to bring you cutting edge spectroscopy instruments for the laboratory or the field.

Cichlid Bio-diversity

The Cichlid family of fish is one of the most widespread and diverse varieties of freshwater fish. These fish are found throughout the African continent as well as the Americas, parts of the Indian subcontinent, and Southeast Asia. The popular food-fish, Tilapia, is a member of the cichlid family, as are the decorative Oscar and Angelfish, favorites among aquarium enthusiasts.

Cichlids have long been a mystery to evolutionary researchers. There are an estimated 2,500 species of cichlids worldwide, 500 of those species are found in Lake Victoria, and nowhere else in the world. The Cichlid family is known for their rainbow appearance of the males and range from one inch to three feet in length. The female fish, however, are often plainly colored and species is identified only with difficulty. These amazingly diverse fish evolved from a single variety as recently as 10,000-15,000 years ago; this is a stunningly recent event in terms of evolutionary time scale.

The Cichlid Evolutionary Puzzle

Cichlids are an evolutionary curiosity for another reason. Most often species differentiation takes place as a result of geographic isolation, (allopatric speciation) but in the case of the cichlids found in East African lakes, these species differentiated without any physical constraints between populations at all.

Cichlid species have developed highly specialized traits that have allowed the many species to find a unique niche within their environment. Within a small area one variety might evolve to feed one food source, while another variety within the same area might prey on another source. For example, one species of cichlid exists with a jaw developed to open on the right side and they feed on the scales on the left side of their prey, while

another species' mouth opens on the left, and they feed on the scales on the right side of their prey.

This unusual mode of evolutionary differentiation has puzzled researchers. Sensory drive theory may explain sympatric (within the same geographic area) differentiation among cichlids. Researchers Matrine Maan, Kees Hofker, et al, from the Institute of Biology at the University of Leiden, the Netherlands studied two cichlids species, the *Pundamilla pundamilla* and the *Pundamilla nyererei* from near Makobe island in Lake Victoria near the Tanzanian border. Their work is the most compelling evidence to date supporting the theory of divergent sensory drive speciation.

Divergent sensory drive speciation is differentiation of two closely related species driven by differences in sensory perception between the populations. The *P. pundamilla* and *P. nyererei*cichlids is one such species pair that developed divergent speciation while sharing habitat in close proximity.

It is also well documented that cichlid mate selection depends on the female selecting males for their bright coloration. These researchers hypothesize that ecological factors that allow mate selection along a light gradient provide the mechanism for rapid sympatric speciation, supporting the theory of a divergent sensory drive.

Environment and Phenotype

Understanding these cichlid species requires understanding their environment and phenotype. The waters Lake Victoria are turbulent and murky with particulate. Short wavelength light (blue) is scattered and the light intensity and spectra characteristics change very rapidly in this environment. The *P. pundamilla* and *P. nyererei* share habitat that ranges from 0.5 M to 7 M in depth.

Researchers first quantified the spectra of these two micro-environments by calculating orange ratios using the spectral intensity of the 550-700nm (yellow, orange red) range divided by the spectral intensity of the 400-550nm (violet, blue, green) range. The AvaTrek-ABF absorbance spectroscopy field kit with dip probe attachment is the ideal solution for this type of field spectra measurement in the natural environment.

The *P. pundamilla*'s primary habitat ranges from 0.5M to approximately 2M in depth where the short blue wavelengths are scattered. The male of this species is a bright blue color. The orange ratio in this region is 0.57. The *P. nyererei* on the other hand, are more prevalent at 4-7M where the red shift is more pronounced. The orange ration in the 4-7M range was 0.75. The males of this species display a vivid red coloring. Between 2 M and 4 M the two species, which are otherwise very similar, freely intermingle.

Optomotor Response

Researchers caught live *P. pundamilla* and *P. nyererei* near Makobe island. Test subjects were microchipped for identification and placed in tanks illuminated with high-frequency fluorescence (830 nm, 1,100 lux) to acclimatize to a standard 12 hour cycle of light and dark periods.

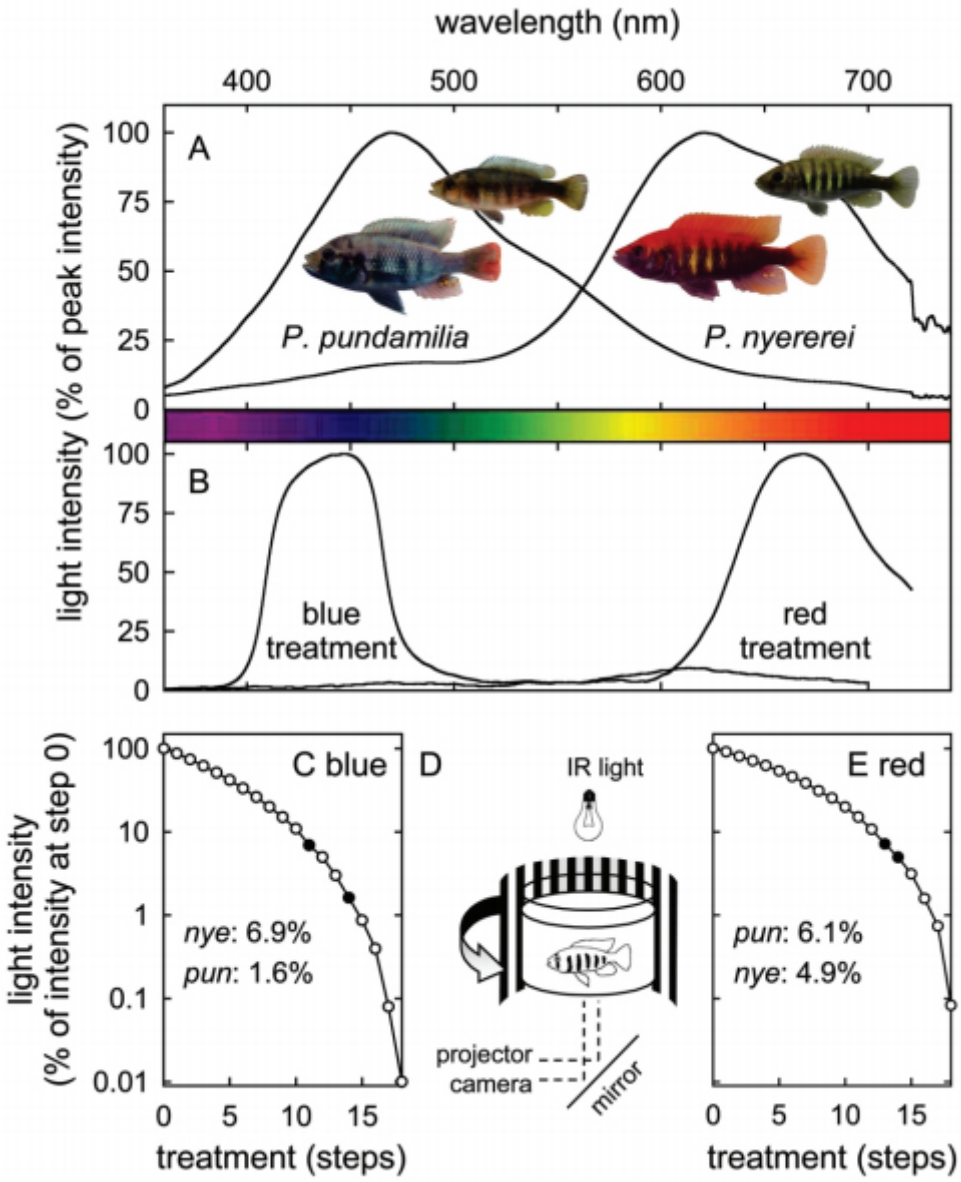
After the acclimatization period, researchers placed female fish in a circular tank surrounded by a rotating screen of vertical white and black bars. They used the optokinetic response of fish to follow a moving light to determine spectra sensitivity thresholds, the lowest light intensity at which the fish responded to the moving light stimulus. The same test was repeated using light filtered for blue (436 nm) and red (656 nm).

There was significant difference in response between the two species. The *P. pundamilla* females displayed a lower sensitivity threshold in blue light, while the *P. nyererei* performed better in red light. Between the two tests, 23 of 25 individuals (92%) were characterized into two non-overlapping groups based on visual response.

Because mate selection appears dependent on color display, the photo responsiveness of female cichlids is a likely factor in the rapid speciation evident in cichlid biodiversity.

Spectroscopy in the field

Spectroscopy is a powerful tool for researchers, allowing fast, non-destructive analysis, and capable of providing data for many lines of scientific inquiry. Modular equipment and rugged designs now make it easier than ever to use spectra analysis for irradiance, absorbance, reflectance, and fluorescence in the field. Contact an Avantes sales engineer to learn more about the new AvaTrek field spectrometer kits, available only in North America.



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