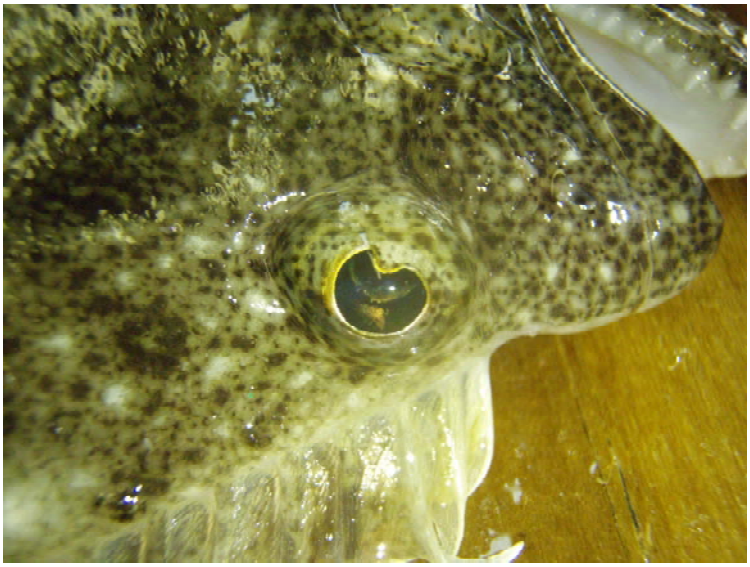
Final Report

Visual Function in Chesapeake Bay Sport and Prey Fishes: Summer Flounder, Bluefish, Cobia, and Atlantic Menhaden

PROJECT RF07-14

July 2007 - Aug 2008

Prepared by



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Submitted to:

Virginia Marine Resources Commission
Marine Recreational Fishing Advisory Board

Funding Total: $ 58,222 ($50,289 VMRC, $ 7,933VIMS)

1 Oct 2008

ACKNOWLEDGEMENTS

We would like to thank Capt. Steve Wray (Long Bay Pointe Bait and Tackle), Jon Lucy (VIMS), Dr. Rob Latour (VIMS), Dr. Mike Oesterling (VIMS), and Joshua Smith (VIMS) for their assistance with animal collection. Capt. Wray and Mr. Lucy's involvement was especially critical to the success of this project.

A number of individuals offered critical assistance with animal husbandry - keeping wild animals in captivity year-round is an arduous and consuming process that is impossible without the support of numerous individuals. Pat Lynch, Andre Buchheister, Kathleen McNamee, Chris Magel, and Leonard Pace gave much of their time to assist with plumbing, feeding, tank setup/maintenance, and troubleshooting. Additionally, Drs. David Gauthier and Wolfgang Vogelbein provided critical assistance with the identification and course of treatment of disease issues in our captive population. Dr. Oesterling provided advice with respect to flow-rates, filtration, and proper diet for long term animal populations.

None of the electrophysiology would have been possible without the efforts of Dr. Eric Warrant (University of Lund, Sweden), who arranged and designed the hardware and software programs that made the controlled, standardized, and synchronized stimuli and analyses possible. Dr. Kerstin Fritsches (University of Queensland, Australia) provided critical advice on electroretinographic methods, interpretation of the analyses, and troubleshooting. Finally, Ms. Lenore Litherland (University of Queensland, Australia) frequently advised regarding electrode creation, maintenance, and placement, data analyses, and hardware-software troubleshooting.

None of this work would have been possible without funding support of the RFAB and the International Women's Fishing Association, and interest from local fishermen and fishing groups.

SUMMARY OF WORK

Electroretinographic data were obtained from four species, including: summer flounder (*Paralichthys dentatus*), bluefish (*Pomatomus saltatrix*), cobia (*Rachycentron canadum*), and Atlantic menhaden (*Brevoortia tyrannus*). Spectral sensitivity (color vision) and Flicker Fusion Frequency (speed of vision) were obtained from averages of the six best day and night recordings to produce the mean response for each species during each diel period. The results for each species are discussed in terms of visual acuity, habitat utilization, and feeding ecology.

INTRODUCTION

General analyses of body shape and structure suggest that vision is an important mechanism affecting predation success in many predatory fishes. In addition, bottom feeding fishes such as Atlantic croaker, spot, and red drum, may use sight along with touch and taste to find prey (Hartman and Brandt, 1995; Chao and Musick, 1977). Color vision, visual acuity, and speed of vision are important adaptations in fishes as they affect the recognition of mates and fellow conspecifics (Guthrie and Muntz, 1993; Kynard et al., 2002), the avoidance of predators (Poling and Fuiman, 1999), and the location and capture of prey (Browman et al., 1994). Predation influences the structure and dynamics of aquatic communities, but little is known about how estuarine predators use visual cues to detect their prey because a complete description of visual function in these fishes is lacking.

Very little is known about the color vision of sportfish species despite the importance of vision to the predatory success of recreationally important fishes. Understanding the importance of vision in predator-prey interactions has important consequences for testing community-level trophic interactions and foraging models. Specifically, the visual capabilities of fishes to discriminate and select prey, based on cues such as size and color, are central to estimating prey encounter probabilities required for predator-prey interactions models (Walton et al, 1997). This is especially important considering the interactions of predatory species that feed primarily during the day in brightly lit surface waters (i.e. croaker, spotted seatrout, spot) with those that often feed at night or at depth (i.e., striped bass and weakfish) (Hartman and Brandt, 1995). This suggests differences in color sensitivities, visual acuities, and capacities for effective vision in dim light, and ultimately resulting in different prey detection capacities. An evaluation of the visual abilities of these species is likely to reveal important mechanisms driving the predatory or competitive advantages of some sportfish species over others under different visual conditions (Vogel and Beauchamp, 1999). Moreover, by constructing equations relating the combined effects of light and turbidity on predator reaction distances, the prey detection capabilities of piscivores can be modeled as a function of depth and time in natural environments (Vogel and Beauchamp, 1999).

Research into the link between vision and predation is especially critical in turbid water. The relationship between absolute prey availability (number of prey per unit area) and consumption (number of prey eaten in a given area) is commonly assessed by researchers during predator-prey interaction studies. However, a more accurate operational measure of predation availability would be the visual abundance of prey to a visually-feeding predator – prey that aren't seen by visual feeders aren't really available

to them (Browman, 2005). We know very little about the visual performance of most marine sportfishes, including those in this proposal. Recent work in other ecosystems suggests that increased turbidity should limit the predatory success of piscivorous fishes far more than the feeding success of planktivores. Murky waters may actual serve as a refuge from predation by piscivores because the poor water clarity allows them to escape attack and virtually disappear from the visual field of their piscivore predators (Johnsen, 2005). Turbidity should also favor tactile benthic predators over visual pelagic predators, a particularly interesting concept in light of recent differences in relative abundance among the species in this protocol. Data on the visual performance of Chesapeake Bay's sportfishes will allow us to continually assess the validity of this theoretical work in coming years.

This report summarizes the findings of a project been funded by the Virginia Marine Resources Commission's Recreational Fishing Advisory Aboard to use state-of-the-art electroretinographic (ERG) techniques to assess the color vision, dynamic range, and speed of vision of several important sportfishes in Chesapeake Bay: summer flounder (*Paralichthys dentatus*), bluefish (*Pomatomus saltatrix*), cobia (*Rachycentron canadum*), and Atlantic menhaden (*Brevoortia tyrannus*).

METHODS:

Obtaining specimens: We experienced high levels of success with the following protocol of obtaining, transporting, and keeping these animals in captivity for experiments. Animals were generally caught on natural or artificial baits using medium-light sportfishing tackle (8-12 lb test) during our own sampling or via recreational fishing contacts in collaboration with Jon Lucy (VIMS) and Captain Steve Wray (Long Bay Pointe Bait and Tackle). After capture and dehooking, fishes are placed in 100-300 gallon tanks equipped with aerators and are transported by truck or boat to the VIMS animal holding facilities. Once in our holding facilities at the Eastern Shore Laboratory in Wachapreague, Virginia, or the Marine Culture Facility in Gloucester Point, VA, animals were maintained in 450 gallon flow-through tanks at 25 C (77F) and were fed ad libitum every other day.

We maintained our research specimens on a combination of biomedical-grade fish flake feed, frozen menhaden and tilapia, squid, blue crab, clam, whelk, and live killifish. Marine fishes become limited with respect to B- and C-vitamins in captivity; this only becomes a problem if the fish are kept for more than a few months. The flake food we used is infused with all 20 essential amino acids, a full complement of vitamins, and an ideal protein:fat:carbohydrate ration for animal maintenance. Our fishes feed aggressively, retain their color, and remain healthy and active.

Computer and electrophysiological technology: A schematic summary of the electroretinographic experimental setup for fish color vision, dynamic range, and speed of vision is presented in Figure 1. During ERG experiments, electrodes are placed on the cornea and subdermally in the dorsal musculature to measure retinal response to synchronized light stimuli. Flashes of light of various frequencies (i.e., colors) and amplitudes (i.e., brightness) are presented and responses recorded via a custom designed computer-controlled system.

Our visual electroretinography system is portable, which allows experiments to be conducted in multiple facilities, though at the expense of setup and calibration time. We therefore recalibrated the elaborate software programs and repaired hardware attachments to sample both flicker fusion frequency (speed of vision) and spectral sensitivity (color vision) of estuarine fishes *in vivo* (i.e. whole animal) in our winter-spring-fall Byrd Hall research facility in Gloucester Point and in our summer Davis Hall facility in Wachapreague, Virginia. In summer 2008, we permanently moved our Gloucester Point research lab from Byrd Hall to the new Andrews Hall facility. This required similar takedown and setup mechanics and more testing and calibration. The calculations associated with this change in protocol and the sheer volume of software programming were extremely time consuming endeavors. In moving between laboratories, we restructured the hardware-software connections and recalibrated the illuminance of the lamps used in experiments – a very labor-intensive process – to allow for the standardization of quantal energy (number of photons) stimulating the retina at each wavelength. Repeated testing generated fairly accurate and consistent results.

Ten summer research days were lost due to a malfunction of our monochromator, which controls the intensity of our light stimulus, and another ten were lost due to a malfunction of the white LED light used for dynamic range and flicker fusion frequency experiments.. Basically, the unit's UV-grating became worn due to high use, causing contamination of the stimulus light field by UV rays and bright white light. In other words, we temporarily lost the ability to present pure color stimuli during vision trials. The unit was rapidly repaired by the manufacturer and returned to service. We also lost 10 research days This unit was also rapidly repaired by the manufacturer and returned to servic

RESULTS

Overall, about 30% of all recordings failed to produce high-quality data due to low signal-to-noise ratios, biological/individual (subject) variability, or technical difficulties. This value is about 10% higher than in our previous studies because of the more fragile nature (Atlantic menhaden and cobia) or unique morphology (summer flounder) of research subjects in this proposal. Electrical noise and electrode failure were the two most common problems. In extreme cases, whole individuals were rejected from this study due to poor response quality. We obtained high-quality spectral sensitivity (SS: color vision) and flicker fusion frequency (FFF: speed of vision) data from six summer flounder, six cobia, six bluefish, and twelve Atlantic menhaden (six juveniles and six adults). For each specimen, day and night recordings were completed for spectral sensitivity, dynamic range, and flicker fusion frequency experiments.

All species can discriminate green (including chartreuse) – in many cases, the green/yellow border is seen extremely well, which may explain the generally good performance of chartreuse-colored baits. Our results indicate interesting species-specific differences in the spectral sensitivity (color vision) and dynamic range (dim-to-bright light range) and speed of vision (flicker fusion frequency) of the retinas of study animals:

Summer Flounder (Fig. 2): The day spectral sensitivity curve of summer flounder (*Paralichthys dentatus*) suggests a broad response from purple through orange, with peaks in blue and yellow-green. During daylight hours, the bottom spacelight in

Chesapeake Bay appears to be in the green-yellow range of the spectrum, therefore it appears that flounder may be using different pigments to match (yellow-green) and offset (blue) the contrast of objects against the background spacelight. This species exhibits a slight nocturnal blue-shift, meaning that they responded better to blue-green wavelengths of light than yellow-orange at night. Flounder have fairly average flicker fusion frequencies for a coastal fish (~42 Hz), and possess greater light sensitivity than the other species in this study. It therefore appears that flounder visual system has selected reduced resolution and greater sensitivity, thus flounder likely possesses lower acuity thank the other species studied.

Bluefish (Fig. 3): Bluefish (*Pomatomus saltatrix*) have a very narrow spectral range, responding best to blue-green wavelengths. It is therefore likely that their visual pigments have evolved to match the ambient spacelight available in coastal waters. Bluefish are fast-moving predators and possess fairly high flicker fusion frequencies for a coastal fish species (~55 Hz) and are not especially light sensitive. It therefore appears that bluefish visual system has selected resolution over sensitivity, and likely possesses fairly high acuity.

Cobia (Fig. 4): Cobia (*Rachycentron canadum*), like bluefish, appear to have a rather narrow spectral range, responding best from the blue into the green-yellow border. These results appear to be similar to those obtained by other researchers examining vision in mahi-mahi (*Coryphaena hippurus*), a fairly closely-related species. It is therefore likely that their visual pigments have evolved to match to the ambient spacelight available in coastal waters. Cobia possess fairly high flicker fusion frequencies for a coastal fish species (56 Hz) and are not especially light sensitive, likely selecting resolution over sensitivity.

Atlantic menhaden (Fig. 5): Atlantic menhaden (*Brevoortia tyrannus*) have a very broad spectral response that appears to change with age. Juvenile menhaden are sensitive from the UV-A range into orange wavelengths, with peaks in the blue and yellow. This spectral curve shifts left at night, as juvenile menhaden become more short-wavelength sensitive. Interestingly, UV-sensitivity roughly doubles at night. In contrast, adult menhaden do not appear to be UV- sensitive. Adult menhaden lack such a diurnal shift and appear to resolve wavelengths from the purple to the orange-red border, with peaks in the blue, green, yellow, and orange. This species possesses fairly high flicker fusion frequencies for a coastal fish species in both life stages (~42 Hz). Menhaden do not have especially large light sensitivity, apparently selecting resolution over sensitivity.

Public Outreach and Media

We have made the preliminary results of this study and previous work available to the Virginia Angling community by presenting at local fishing organization meetings. A. Horodysky presented the results of vision studies at the following public forums:

Virginia Beach Angler's club (Oct 2005, April 2008)

Peninsula Salt Water Sport Fisherman's Association (Dec 2005, Sept 2008),
VIMS Eastern Shore Laboratory Evening Public Seminar Series (June 2006)
Boater's World (August 2006),
Big Island Fly Angler's Club (Dec 2006, Apr 2007, Apr 2008)
Virginia Coastal Fly Anglers Club (Oct 2007)
VIMS Fisheries Science Lunch Seminar Series (Apr 2006, Mar 2008)

This research has been featured articles in the following print media:
Daily Press (May 2006, and numerous internet blogs thereafter)
Daily Press (July 2007, and numerous internet blogs thereafter)
IGFA Book of World Records (coming Jan 2009)
Salt Water Sportsman (upcoming late 2008 or 2009)

This research was featured on the Dr. Bogus radio show in 2007

Our work was presented in the summer 2006 edition of The Crest, a VIMS research publication (available at: http://www.vims.edu/newsmedia/pdfs/fish_vision82.pdf) that was subsequently picked up by dozens of blogs and online fishing chatboards from 2006 through the present. We continue to welcome any such invitations to present results at meetings of local fishing organizations, and have fielded numerous public and media phonecalls in the last month regarding this work.

Scientific Presentations

Mr. Horodysky presented this research at the 8th International Congress on the Biology of Fish (July 2008) and the 137th Annual Meeting of the American Fisheries Society in San Francisco (2007). The latter talk was part of a special symposium entitled "Visual Ecology in Fisheries" he co-organized with Dr. Brill. The data were very well received. This talk stimulated much discussion regarding how little is known about estuarine fish vision in general and especially within related groups, and several researchers commented that the involvement of the recreational fishing community both as a funding source and for providing subjects was a wonderful example of cooperative research. These results were also presented at the), the 136th Annual Meeting of the American Fisheries Society in Lake Placid, NY (September 2006), and the 7th International Congress on the Biology of Fish (July 2006).

Scientific manuscripts

Fish vision research from RF 05-14 was recently accepted for publication by the Journal of Experimental Biology and should appear in late 2008. Although this journal maintains a 6-month subscription-only access exclusivity, papers published therein become "open access" 6 months after the publication date. In other words, 6 months after the article is published, anglers with internet connections can obtain a pdf for free.

We intend to submit the research from RF06-08/RF07-14 to peer reviewed journals in 2009-2010, and will strongly consider journals with open-access formats so that recreational anglers can obtain copies of this work for free.

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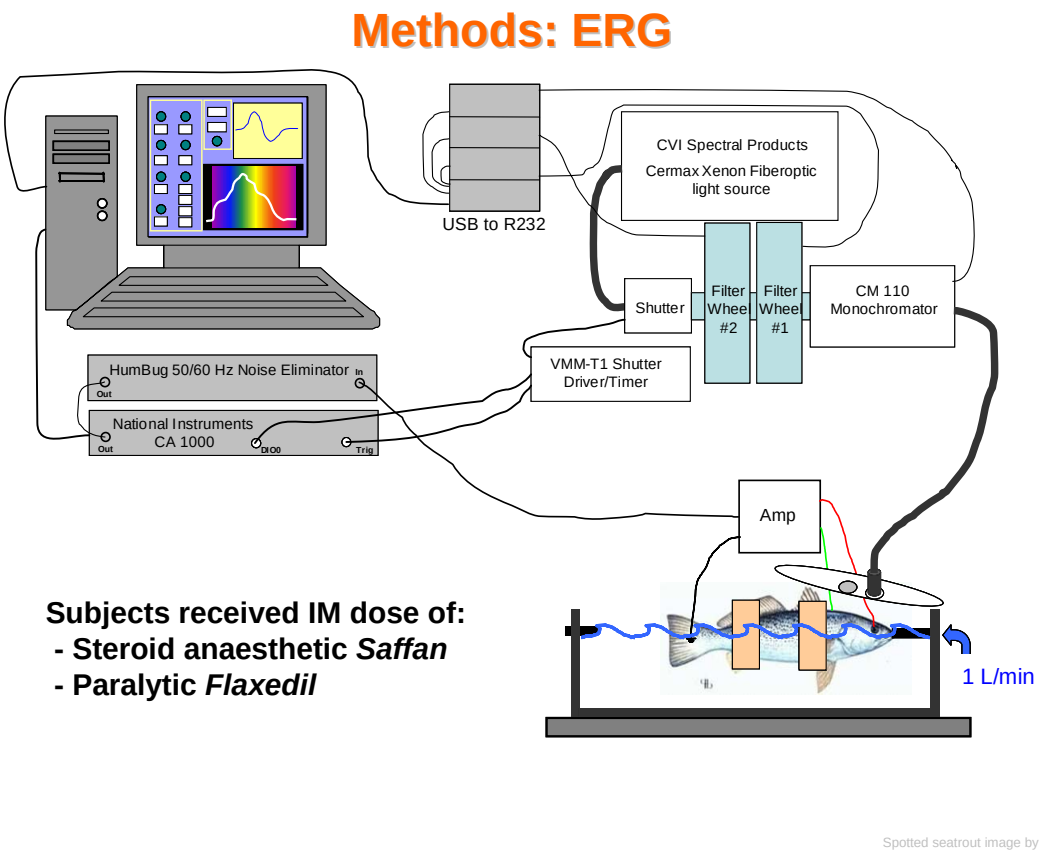
Fig 1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USB to R232
CVI Spectral Products
Cermax Xenon Fiberoptic light source
Shutter
Filter Whee #2
Filter Wheel #1
CM 110 Monochromator
VMM-T1 Shutter Driver/Timer
HumBug 50/60 Hz Noise Eliminator
In
Out
National Instruments CA 1000
Out
Trig
Amp
1 L/min
Subjects received IM dose of:
- Steroid anaesthetic Saffan
- Paralytic Flaxedil
Spotted seatrout image by D. Peebles

Fig. 2

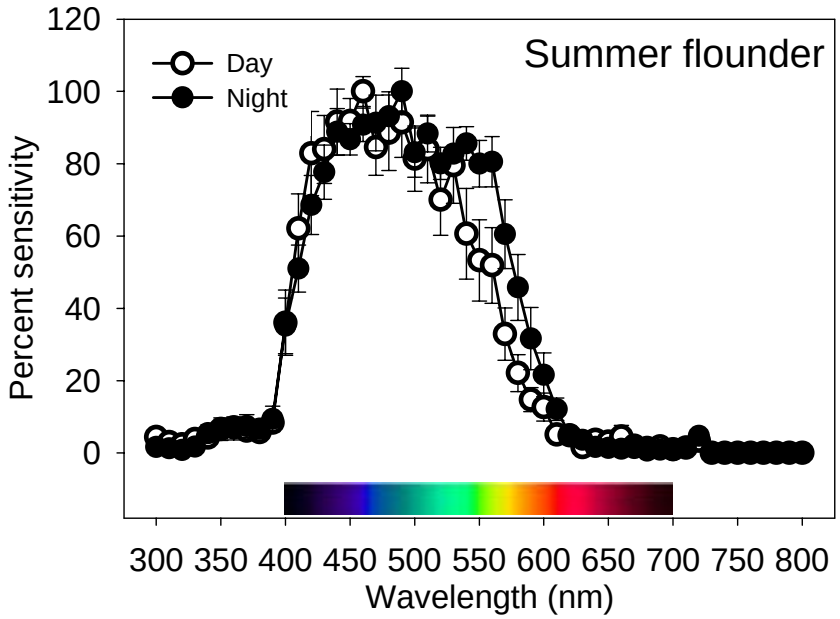

Summer flounder
Day
Night
Percent sensitivity
120
100
80
60
40
20
0
300 350 400 450 500 550 600 650 700 750 800
Wavelength (nm)

Fig 3

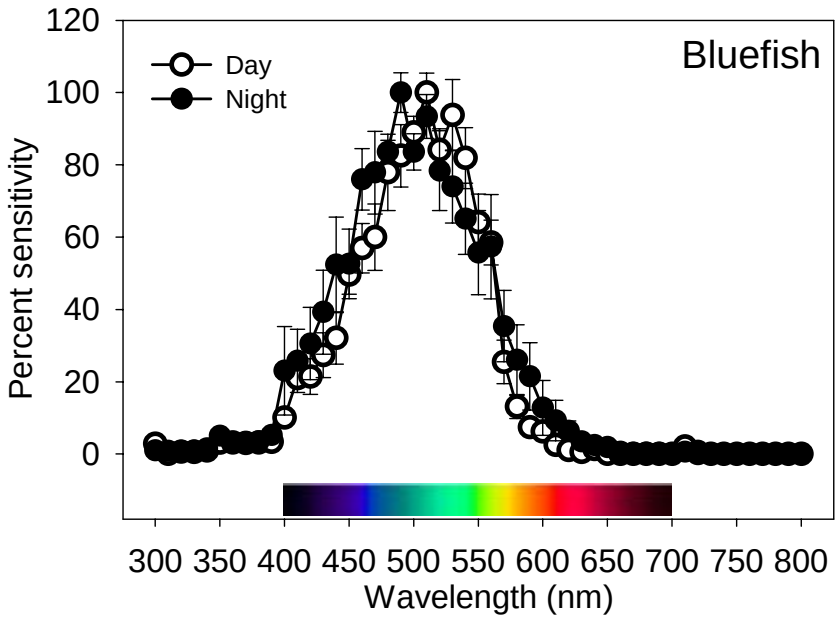

Bluefish
Day
Night
Percent sensitivity
120
100
80
60
40
20
0
300 350 400 450 500 550 600 650 700 750 800
Wavelength (nm)

Fig. 4

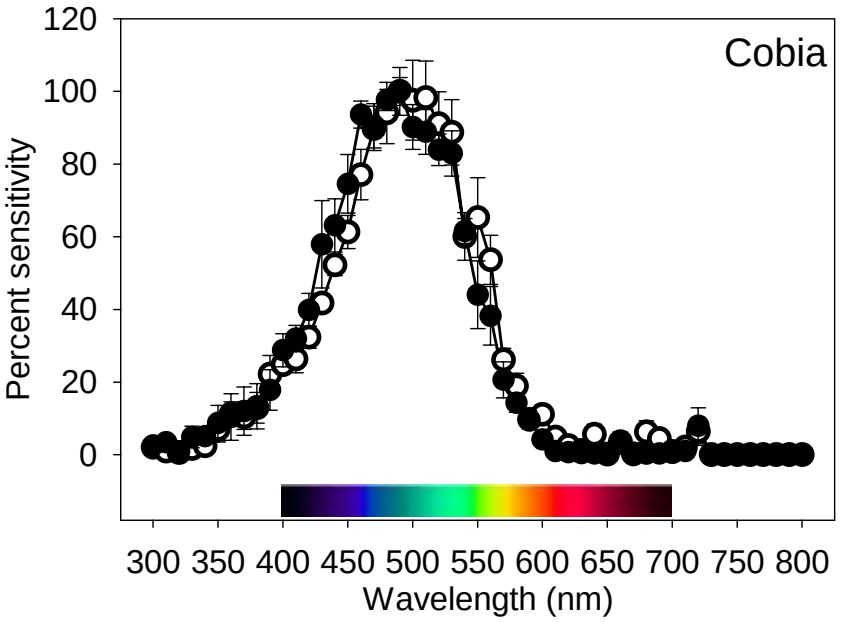
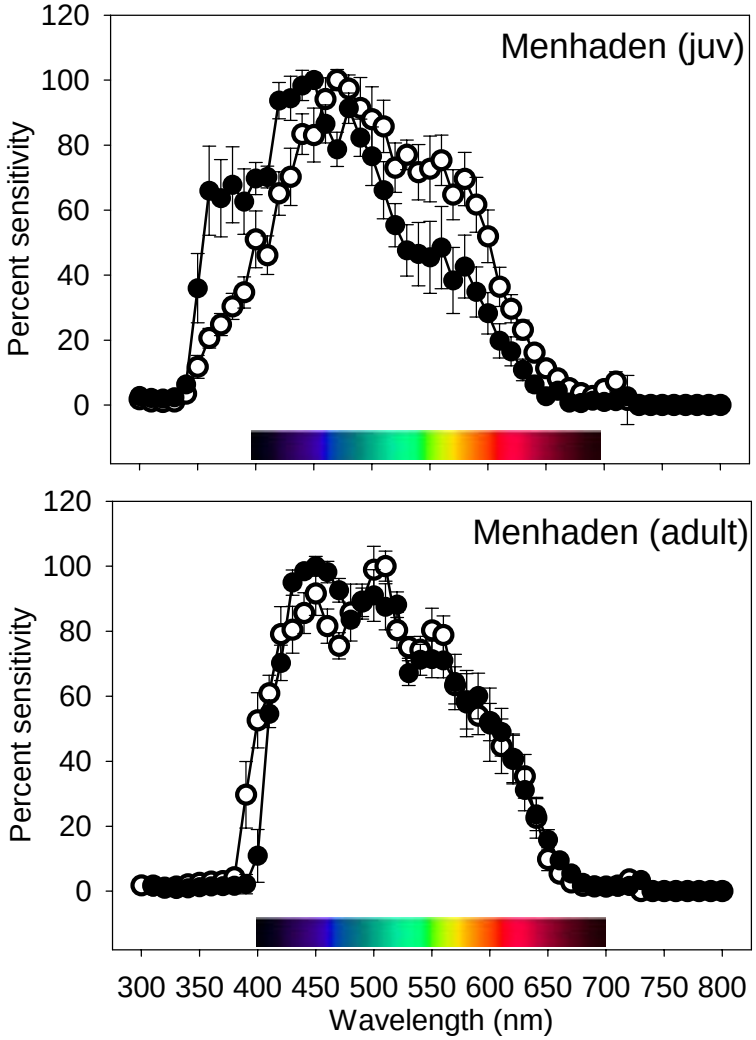

Cobia
Percent sensitivity
120
100
80
60
40
20
0
300 350 400 450 500 550 600 650 700 750 800
Wavelength (nm)

Fig. 5


Menhaden (juv)
Menhaden (adult)
Percent sensitivity
120
100
80
60
40
20
0
300 350 400 450 500 550 600 650 700 750 800
Wavelength (nm)