Final Report

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

PROJECT RF 06-08

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None of this work would have been possible without funding support of the RFAB, and interest from local fishermen and fishing groups.

SUMMARY OF WORK

Electroretinographic data were obtained from six species, including : summer flounder (*Paralichthys dentatus*), bluefsh (*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*), bluefsh (*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, 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. This flake food 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.

Unfortunately, we lost 10 summer research days due to a malfunction of our monochromator, which controls the intensity of our light stimulus. 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 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 due to a malfunction of the white LED light used for dynamic range and flicker fusion frequency experiments. This unit was also rapidly repaired by the manufacturer and returned to service. 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. 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 “color”. Repeated testing generated accurate and consistent results.

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, and twelve Atlantic menhaden (juveniles and adults). For each specimen, day and night recordings were completed for both 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:

<u>Summer Flounder (Fig. 2):</u> The spectral sensitivity curve of summer flounder (*Paralichthys dentatus*) suggests a broad response from purple through orange, with peaks in blue and yellow-green. 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.

<u>Cobia (Fig. 3)</u>: Cobia (*Rachycentron canadum*) appear to have the narrowest spectral range of any fish we have sampled, 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.

Atlantic menhaden (Fig. 4): 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 appear to resolve wavelengths from the purple to the orange-red border, with peaks in the blue, green, yellow, and orange.

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 at the October meeting of the Virginia Beach Angler's club (10/06/05) and gave a talk at the December meeting of the Peninsula Salt Water Sport Fisherman's Association (12/20/05), June 7 at the VIMS Eastern Shore Laboratory Evening Public Seminar Series (06/07/06) at Boater's World on (08/09/06), at the Big Island Fly Angler's Club (Dec 2006) and at the American Fisheries Society's 136th (Sept 2006) and 137th (Sept 2007) Annual Meetings. 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). Articles discussing this work were also published in the Daily Press in May 2006 and June 2007. A. Horodysky will present results of this research at the Virginia Coastal Fly Anglers Club Meeting. 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.

Finally, we submitted the abstract below for presentation at two scientific meetings in 2006, and one meeting in 2007. This presentation will be based on results from our visual experiments funded by RF 06-08. RFAB's funding support is mentioned throughout the seminar. The conferences include:

1. American Fisheries Society 2-6 Sept San Francisco, CA

ABSTRACT:

Seeing the forage through the trees: visual function in Chesapeake Bay's predatory fishes.

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Little is known about how differences in visual function reflect the lifestyles and feeding strategies of estuarine fishes. We therefore assessed day and night spectral sensitivities (color vision), light sensitivities, and flicker fusion frequencies (FFF: speed of vision) of seven Chesapeake Bay fishes: striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), spotted seatrout (*Cynoscion nebulosus*), red drum (*Sciaenops ocellatus*), summer flounder (*Paralichthys dentatus*), and cobia

(*Rachycentron canadum*) using electroretinography (ERG). Subjects were presented light stimuli covering the spectral range from UV (300 nm) to the near infrared (800 nm) and six orders of magnitude of light intensity via a custom-designed computer-controlled system. Responses were corrected for equal quantal energy at each wavelength. Subjects demonstrated peak sensitivity between 450-575 nm, though retinograms showed strong species-specific differences. Weakfish responded to short wavelength UV light, while striped bass responded to the longer (red) wavelengths. Intensity-response and FFF experiments also revealed species-specific differences in light sensitivity and FFF. The visual systems of these sympatric fishes thus appear to have evolved different functional characteristics that are reflective of their specific niches within the estuarine environment. Visual ecology bears important implications for predator-prey interactions, estimating prey encounter probabilities, and ultimately understanding community-level trophic interactions.

Mr. Horodysky presented this research at In San Francisco 6 September at 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.

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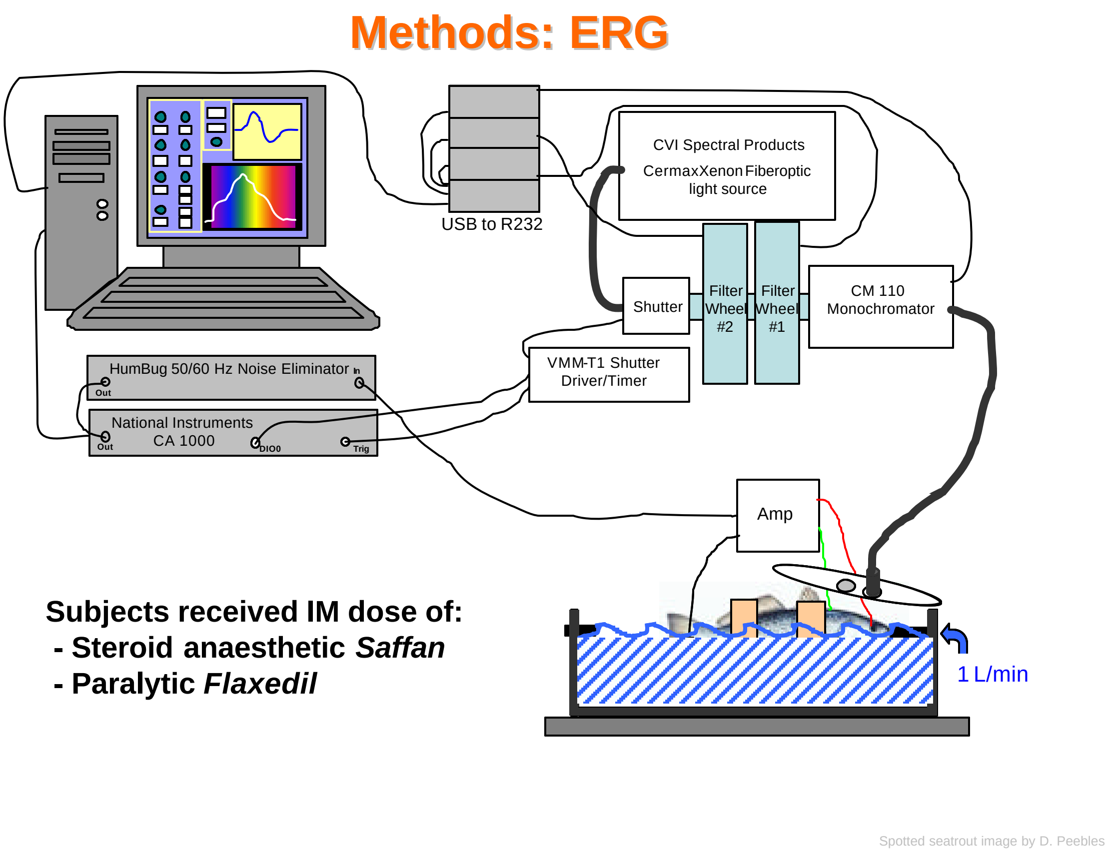
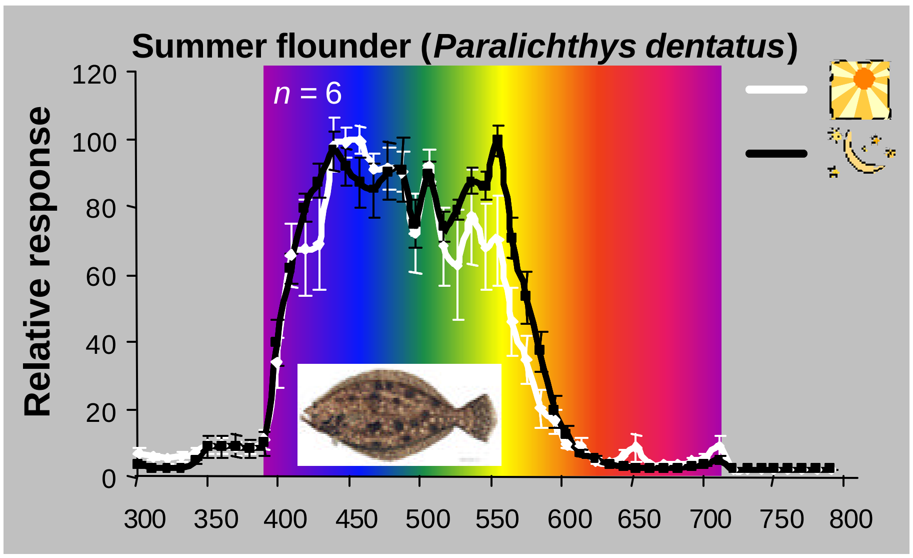
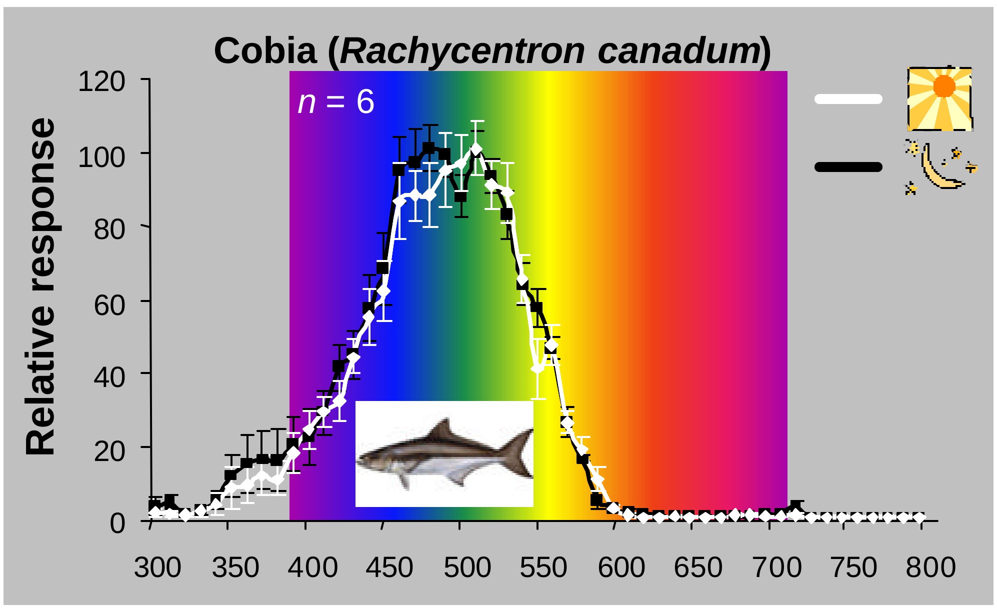

Methods: ERG
USB to R232
CVI Spectral Products
CermaxXenon Fiberoptic
light source
Shutter
Filter Wheel #2
Filter Wheel #1
CM 110
Monochromator
HumBug 50/60 Hz Noise Eliminator
In
Out
National Instruments
CA 1000
Out
DIO0
Trig
VMM-T1 Shutter
Driver/Timer
Amp
Subjects received IM dose of:
- Steroid anaesthetic *Saffan*
- Paralytic *Flaxedil*
1 L/min
Spotted seatrout image by D. Peebles

Figure 1



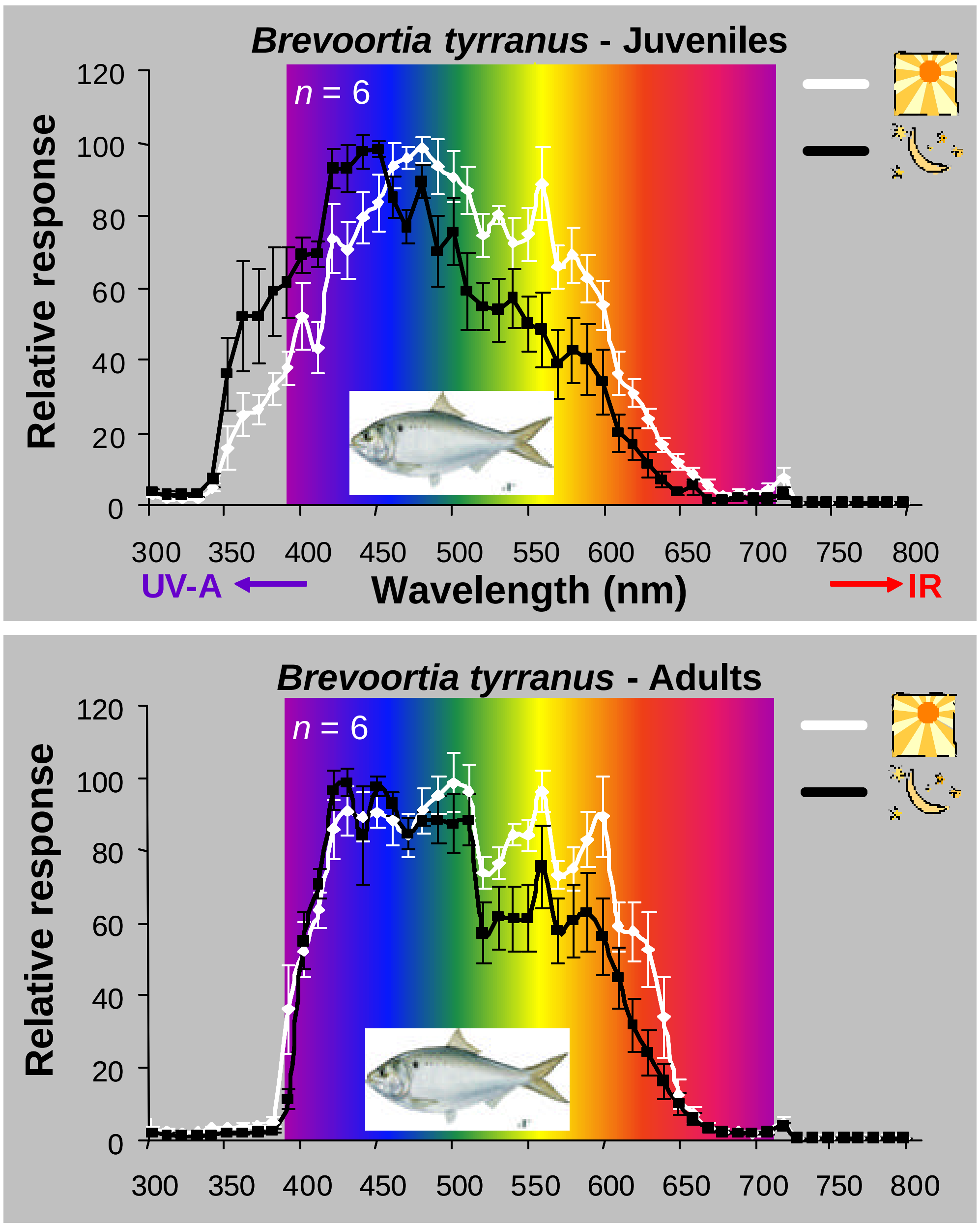
Summer flounder (*Paralichthys dentatus*)
n = 6
Relative response
0
20
40
60
80
100
120
300
350
400
450
500
550
600
650
700
750
800

Figure 2



Cobia (*Rachycentron canadum*)
n = 6
Relative response
120
100
80
60
40
20
0
300
350
400
450
500
550
600
650
700
750
800

Figure 3



Brevoortia tyrranus - Juveniles
n = 6
Relative response
120
100
80
60
40
20
0
300 350 400 450 500 550 600 650 700 750 800
UV-A
Wavelength (nm)
IR
Brevoortia tyrranus - Adults
n = 6
Relative response
120
100
80
60
40
20
0
300 350 400 450 500 550 600 650 700 750 800

Figure 4