# Through the Eyes of the Cod

*Conservation through direct investigation of the cod eye, and behavioral responses of cod to visual stimuli.*

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*Our strategy to rebuild a sustainable fishery for the future must stand in contradiction to how we have managed the fishery over the last thirty years. As we move forward, we need better science, more conservation management practices, fewer plants, fewer fishermen, fewer trawlers, fewer seals, less political interference, more control over foreign over-fishing, and better harvesting technologies and practices.*

Vic Young, Atlantic Vision Conference, October 1997 (from Lament for an Ocean)

*The problems we have today will not be solved by thinking the way we thought when we created them.*

Albert Einstein

Fisheries the world over are plagued with numerous problems relating to management, politics, conservation, over-exploitation, and over-capitalization. Over 90% of the world's fish stocks have been over-exploited (Hutchings 1996), an astonishing number that states all too clearly the complexities of this industry and the overwhelming necessity for conservation. While a variety of different factors contribute to the problem of overexploitation, the inability to control fishing mortality through bycatch has certainly played an important role. Bycatch, by definition, is the catching of unwanted animals while pursuing a specific species or suite of species. This can consist of (1) unwanted species, and/or (2) juveniles of the desired species which are too small to legally harvest. After spending minutes to hours in the codend (the back) of the trawl, much of the bycatch is pulled dead or dying from the sea. These fish are often returned to the waters only after prolonged periods on a relatively dry deck in the hot sun. As a consequence, most fish caught accidentally by fishermen do not survive the experience (Fowler & Stobo, 1999). This waste often makes up a large portion of the catch, costing the fishermen time and effort, and costing the stock much needed biomass and breeding stock.

We propose a landmark study – conservation of cod and other ground fish through direct observation of visual responses to trawl nets of various different designs. The proposed work, complementary to Dr. Shumway's accepted 2000 John Prescott Fund, will focus on developing a comprehensive understanding of the cod eye, and creating innovative adaptations of current eye-tracking technologies for use with fish. Accompanying elements will include habitat complexity and behavioral studies in the field. Our goal is to produce a trawl net designed in accordance with the actual behavioral responses of the animals – that is, to produce a trawl net which is more efficient at capturing adult cod while not capturing the unwanted bycatch of juvenile cod. This study will lay the foundation for future conservation efforts and research projects. In short, we seek to provide for "better science, more conservation…. and better harvesting technologies and practices." (Vic Young, Lament for an Ocean).

**RATIONALE**

During the last few years, many of the world's cod (*Gadus morhua*) stocks have declined to the point that fishing, commercially and recreationally, has been effectively eliminated. Increased fishing mortality and poor or misguided management practices have driven the Atlantic cod to the verge of commercial extinction. (Harris, 1998; Hutchings, 1996; Myers et. al., 1997; Myers et. al., 1996). Much of this mortality is bycatch in the form of juvenile cod, caught accidentally before they are of age to breed. The reduction or elimination of this bycatch problem would be a great step towards the recovery of the Atlantic cod population.

Previous work related to the reduction of bycatch with cod and other ground fish species has primarily focused on the modification of trawls, often towards the codend of the net. Studies have shown that species and size groups (ie. age classes) can be separated according to their behavioral responses to various parts of the trawl net. Researchers have shown that modifications to net design can significantly reduce bycatch when fishing for shrimp, squid (Glass et. al., 1998), and assorted ground fish species (Glass, et. al. 1993; Glass, et. al., 1995a; Glass, et. al., 1995b). And, if these redesigned nets can be proven more efficient, fishermen will readily adopt them. It is imperative that

research into the behavior of commercially harvested fishes is continued, and is allowed to evolve as technology does.

In order to successfully conserve any species, we must first understand the relevant environmental and anthropogenic cues and their resultant behavioral responses. For the vast majority of fish (cod included) visual stimuli are their primary means of observing and reacting to their surrounding environment and threats. Until now, we have been limited to studying behavioral responses and attempting to infer which visual or non-visual stimulus produces the reaction. The alternative, direct studies into vision, has required invasive surgeries and methodologies (Fernald 1885), or working with severely restrained animals.

Today, due to significant advances in technology, we are able to track eye-movements in a non-invasive and highly accurate manner. In the last year, we have become aware of a new eye-tracking technology which will contribute significantly to the success of our proposed work. Applied Science Laboratories (ASL) has refined its eye-tracking hardware and software so that head-tracking is possible, and necessary physical restraint of research subjects is at a minimum. ASL's eye-tracking tools will allow us to *more accurately* determine point of gaze with our fish. These systems are often used with humans, and have been adapted for use with primates and mice (ASL, pers. comm.). We believe that further, simple adaptations will allow for a safe and effective "window" into the perception of cod, and ultimately other threatened ground fish. *The proposed study will be the first of its kind to work with fish*

The Atlantic cod is a species of vast importance – providing employment, food, and security to vast numbers of families and communities all along the northern Atlantic coast in North America (Harris, 1998). Beyond the cod, the harvest of fish species throughout the world is of huge economic and social importance – a value of US $85 billion in 1996, not including aquaculture which netted an additional US $47 billion (Harris, 1998). And, the economic and societal worth of the world's fisheries are only expected to increase in the coming decades. A resource of such great importance requires conservation programs which will challenge assumptions, and examine problems from new and exciting angles. We believe that our proposed Bycatch Reduction research program will do just this.

**METHODS**
Our methods are broken into four components, or phases, outlined below. We are currently seeking funding for Phase I only, and will pursue additional funding at the close of this period of work.

***Understanding the Cod Eye***
Building upon Dr. Shumway's work throughout the past year, the formative stage will allow us to move with greater accuracy, efficiency, and knowledge towards the completion of the below three components. The research we propose is a landmark study – never before considered – using the visual patterns of cod to redesign and restructure trawl nets for greater conservation efficiency. Being the first of its kind, there is no previous research to draw upon concerning the physiological and behavioral aspects of cod vision. Therefore, before we can pursue the work originally proposed by Dr Shumway in 2000 (and described again below), we must first answer a collection of questions. It is this preliminary data collection that the formative stage will address.

Our planned activities include:

*Phase I: An organized look at the anatomy and physiology of the cod eye*
Although a great deal is known about the general biology of fish eyes and vision (ed. Ali, 1975), only a small amount of research has been done related to the cod visual system (Anthony & Hawkins, 1983. Specifically, no studies exist which address the anatomy and movement specific to the cod eye, or the interpretation of visual stimuli in cod. Before we can accurately pursue research related to the visual behavior of cod, we must first identify and understand their visual system. This necessitates studies into general cod eye anatomy, mobility, field of view, curvature of the cornea, and specific measurements and dimensions. Cod, captured dead as bycatch, will be used at either the New England Aquarium or the Manomet Center for Conservation Sciences to address the above questions. This work may also be supplemented by observations of visual behavior in live cod contained in tanks, and in the field through submersible video cameras.

*Phase II: The creation of videos & images to be used in lab/visual experiments (outlined below)*

Video and still images will be used throughout the lab-based visual experiments to produce a behavioral response in cod. We will create these moving and still images during Phase II. Video and images represent various designs of trawl nets, focusing on color and shape of the webbing.

*Phase III: Adaptation of current eye-tracking technologies for use with fish*
Our proposed research, eye-tracking of a fish while submerged, is the *first of its kind*. We will therefore need to test all proposed methods in order to determine the most correct methodology for this project. Working with ASL, we will adapt their current technologies (suitable for eye-tracking humans, primates, mice, etc.) for use with fish in a full aquatic environment. We will follow the methods outlined in Dr. Shumway's accepted 2000 John Prescott Fund proposal, and will work to refine the methods in order to guarantee the validity of our results. Upon successful proof of concept, we will apply for additional funding to support further work with the project.

*Phase IV: Review and troubleshooting*
This will be the final step prior to moving forward and looking for additional funding sources. Here we will address and amend any problems in the methods, acquire any additional needed materials, apply for additional outside funding, and make final preparations for additional lab and field work.

Please note: The work proposed above is complementary to the existing John Prescott Fund award, which proposed the following:

*Lab/Visual Experiments*
Reflecting the results from Phase I, we will work to determine which features of a trawl net are visually important to juvenile cod. The fish, which will be maintained at the New England Aquarium, will be removed from their home tank and placed, one at a time, into the experimental tank. After an acclimation period of a set time, fish will be gently restrained in a sock, and will be presented with various visual stimuli. The cod will be trained to look at specific points in the test tank which will allow for calibration of the ASL eye-tracking equipment. The eye movement of the individual cod will be tracked and recorded using technology provided by ASL. We will test visual reaction of cod to various different parts of the trawl as well as different trawl designs and colors. Observations and results concluding from this phase will contribute to a redesigning of trawl nets. This is an important step towards the continued recovery of cod and other ground fish stock in the northwestern Atlantic waters.

*Field Behavior/Tests*
Following the methodology used by Dr. Glass, submersible digital video cameras will be mounted onto and within commercial cod trawl nets. These cameras will capture cod behavior in the field, in reaction to trawls of several designs in various different circumstances and environments. Laboratory analysis of this footage will allow us to observe both juvenile and adult cod interact with the net, as well as assorted other ground fish species. This phase of work will allow us to test our preliminary findings regarding visual response to net elements, and may also provide us with the first chance to test trawl nets designed with the lab results in mind.

*Survey of Habitat Complexity*
Concurrent with, or following after the field behavioral studies, the survey of habitat complexity will identify high-priority cod spawning grounds and nurseries. We will work in collaboration with a cohort of commercial cod fishermen, identified by the Manomet Center for Conservation Sciences. Previous research projects with cichlids (Shumway et al., 2000) and coral communities have shown that areas of increased habitat diversity are also likely to have an increased diversity and abundance of species. Using optical density video analysis, a scale-independent methodology recently developed by Dr. Shumway (Shumway et al., 1999), we will be able to look at the complexity of habitats frequented by adult and juvenile cod. These results will allow us to identify high-priority spawning and nursery grounds for cod and other ground fish, and will make it possible to steer fishermen away from those areas with high densities of juvenile and spawning cod.

**RESULTS (Understanding the Cod Eye)**
Throughout the implementation of Phase I, the team will analyze the results in order to create a complete picture of the cod's visual system and the research requirements involved with this species. We will have identified physiological and behavioral characteristics of cod vision, determined research parameters and baselines, created

quality digital video and still images, and completed a proof of concept regarding Phase II. We anticipate that all these findings will provide us with the necessary knowledge to move confidently and swiftly into Phases II-IV.

**TIME FRAME**

In order to properly address all parameters of this research project, a timeframe spanning several years is necessary. Within this larger timeframe, we plan to use the next year towards the completion of a formative stage. Such development is necessary to ensure proper research methods, identification of correct parameters and baselines, and quality husbandry and animal use throughout the lifetime of this research project.

The rough time frame for this project is listed below:

| *Understanding the Cod Eye* | |
|---|---|
| Physiology and characteristics of the cod eye | June-September |
| Video/image creation | October-December |
| Acquisition of live juvenile cod | January |
| ASL/Proof of concept | January-February |
| Review and Troubleshooting | March-End |

Note that analysis of results and acquisition of necessary materials will occur concurrently with the above listed activities.

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