NOAA Office of Ocean Exploration

Final Report Format

I. OVERVIEW

Grant Number (If applicable): NA050AR4601059

Amount of funding from Ocean Exploration: $44005

Project Title: Operation Deep-Scope II: Characterization of Benthic and Pelagic Ecosystems Using New Techniques

Area of Operation (if applicable): Gulf of Mexico

Principle Investigator (name, address, contact information): Tamara Frank, Harbor Branch Oceanographic Institution, 5600 U.S. 1 N, Ft. Pierce, FL 34946; 772-465-2400 x 311; frank@hboi.edu

Participating Institutions:

Edith Widder, Ocean Recon

Sonke Johnsen, Duke University

Mikhail Matz, Whitney Labs

Justin Marshall, University of Queensland, Australia

Tom Cronin, University of Maryland Baltimore County Campus

Award Period: From _1 July 2005_ To 30 June 2006____

Period Covered by this Report: From _1 July 2005___ To 30 June 2006__ (ref: Semi-Annual Performance Report)

II. Summary

1. Abstract – 1-paragraph description of final report

Operation Deep Scope 2005 brought together an international team of scientists that deployed the unobtrusive Eye-in-the-Sea camera for 24 and 48 h recording periods, utilized a variety of cameras and filter to study polarization and fluorescence in the deep-sea environment, and employed new collection techniques to collect live deep-sea species for study in shipboard labs. Diving to depths of 1,840 feet with the Johnson-Sea-Link submersible, as well as blue water SCUBA diving, scientists examined the visual physiology and optics of deep-sea invertebrates, gathered additional data to determine whether deep-sea organisms are blinded by exposure to brightly lit submersibles, studied fluorescence as a major mechanism of visual communication between organisms at intermediate depths, and analyzed the "breaking" of the ultimate camouflage of invisibility with the ability to see polarized light. Education and outreach activities included mission logs and interviews coordinated by OE's Education Specialist and Harbor Branch Oceanographic Institution's Media Lab and posted on OE and HBOI

websites, an "Ask an Explorer" forum on the OE website, and a very popular post-expedition professional development workshop in Ft. Pierce, Florida, during which educators participated in lesson plan activities directly related to the mission and talked with the expedition's scientists.

2. Purpose of Project:
    a. Describe issue that was addressed

One of the mission objectives for OE is the "characterization of benthic and pelagic habitats and ecosystems". This has proven to be a great challenge in the deep-sea environment, as many of the large predators flee from noisy, brightly lit submersibles and ROVs. In addition to the temporary disruption of normal behavior, animals with photoreceptors designed for the dimly lit deep-sea environment are often permanently blinded by the very lights we use to find them. Anthropomorphic biases have also affected descriptions of animal interactions, in that animals that may be transparent, and therefore virtually invisible to humans under bright submersible lights, may be much more visible to animals with polarization and/or UV sensitivity. Lastly, the tendency of human observers to use bright white lights for all their studies may have hindered efforts to "locate, characterize and collect organic and inorganic materials", as demonstrated by the discovery of bright fluorescence from methane hydrates on ***Deep-Scope 2004***.

    b. Describe/list the project objectives

1) Continue unobtrusive observations with the Eye-in-the Sea camera
2) Examine ecological roles of fluorescence in marine organisms
3) Quantify of the deep-sea light environment as it is perceived by its inhabitants
4) Develop and implement new collection technology using the *Johnson-Sea-Link* submersible for recovery of living deep-sea organisms with intact visual systems
5) Examine of the visual physiology/optics of epipelagic, mesopelagic, bathypelagic and deep-benthic invertebrates

3. Approach:
    a. Describe the work that was performed

In situ fluorescence observations were made utilizing special lights and filters on the JSL. Laboratory based measurements of fluorescence were also made on organisms collected from a variety of depths using both the submersible and the midwater trawl net. The Eye-in-the-Sea camera was deployed a total of four times at two unique locations in the Gulf of Mexico. From these deployments, 1,240 1-minute videos were recorded and analyzed. New collection techniques utilizing the benthic traps, Bio-boxes and suction sampling were utilizing to collect deep-benthic crustaceans with intact photoreceptors. From these samples, the first physiological recordings ever made of spectral sensitivity of deep-sea benthic crustaceans were obtained. Photoreceptors from hagfish caught in traps were collected in RNAse later for molecular work. Vision and fluorescence studies were

conducted on shallow-living pelagic organisms collected with a plankton net. Hundreds of images of various benthic species collected on submersible dives, in particular chirostylid crabs, were split into three color channels (red, blue and green) and calibrated to examine cryptic coloration in benthic organisms.

b. Describe how the project was organized and managed

T. Frank was chief scientist on the cruise and coordinated the diving activities. Fluorescence work was carried out by M. Matz. Eye-in-the-Sea work was conducted by E. Widder, E. Raymond and L. Frey. Benthic crustacean collections were made by sub pilots/investigators whenever possible. Electrophysiological recordings from photoreceptors of benthic crustaceans were conducted by T. Frank. Sample collection for land-based studies were conducted by T. Frank, J. Marshall and M. Matz. Vision studies on shallow-living pelagic organisms were conducted by J. Cohen. Cryptic coloration and polarization imaging studies were conducted by S. Johnsen and J. Marshall.

c. Describe how data was organized, processed, and archived

Each PI maintained the data sets for their projects. Processing depended on the data that were collected, as discussed in detail in the original proposal. Copies of all images and videos made from the JSL were given to Ocean Exploration personnel participating on the cruise.

4. Findings:
   a. Describe actual accomplishments and findings

1) Fluorescence – M. Matz

During the 2005 cruise we were able to make only two submersible dives equipped for fluorescence detection, due to losing 7 days to Hurricane Katrina. Still, we've were able to obtain video footage of a fluorescent shark (Fig. 1), which made national news, as well as a fluorescent batfish, in addition to the greeneye fish that we found in 2004.

Figure 1. *In situ* image of fluorescent cat shark, taken with the *Johnson-Sea-Link* submersible at the southwest Florida Shelf lithoherms site. Photo by M. Matz.

Fluorescence has been previously observed mostly in invertebrates. The presence of fluorescent coloration in several deep-sea fishes prompts the question about corresponding visual adaptations. Due to the limited submersible operations, we put more effort into characterizing fluorescence in the open ocean surface communities – sargassum weed fauna and plankton ("Operation Shallow Scope"). Remarkably, we found that many crustaceans of these communities – several species of sargassum shrimp and planktonic copepods (Fig 2) – use fluorescence very extensively to produce colored patterns.

Preliminary characterization of their visual sensitivities (see below) confirmed that their eyes are tuned to the wavelengths of their fluorescence. This fact strongly supports our hypothesis that animals would tend to adopt fluorescent coloration instead of absorption-based color because it is much more efficient within the oceanic light field.

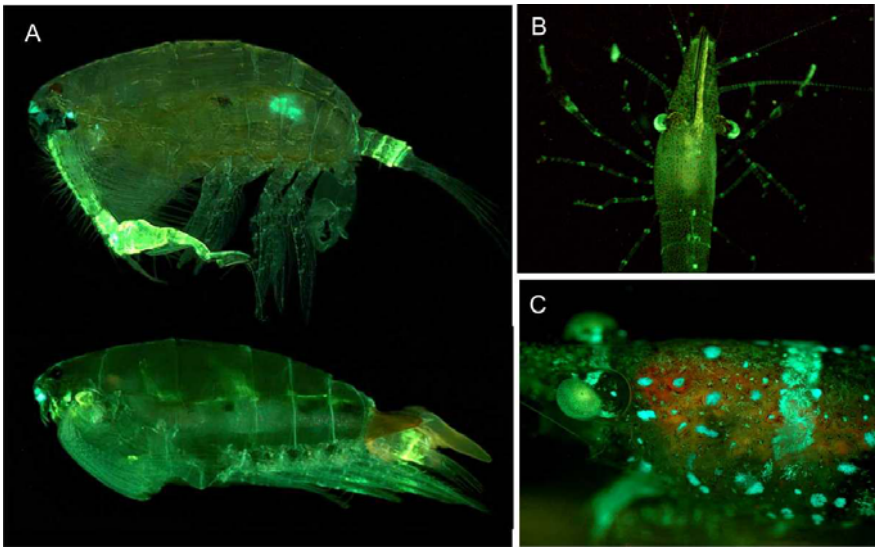
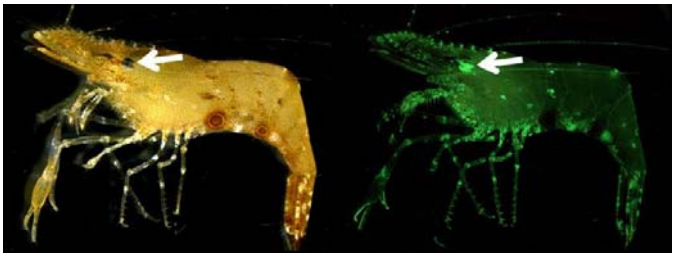


Figure 2: Some fluorescent crustaceans of the open ocean (from the DeepScope-2005 collection). **A**: Planktonic copepod *Pontella securifer*. Top – male, bottom – female. **B**: Sargassum shrimp. Note green fluorescent leg joints and yellow fluorescent rostrum. **C**: Close-up of another sargassum shrimp displaying three types of chromophore cells: fluorescent cyan, fluorescent green and non-fluorescent brown. Photos by M. Matz.

A number of planktonic and benthic fluorescent specimens were collected for further molecular analysis that may lead to development of new biotechnology tools, and NIH funding has recently been obtained to analyze these specimens.

2) Visual Ecology of the fluorescent Sargassum Shrimp – J. Cohen

Mats of the floating alga *Sargassum* were collected with dip nets at the surface throughout the cruise, and a small shrimp, *Leander tenuicornis*, was found that proved quite interesting. Several investigators (J. Cohen, M. Matz, J. Marshall, and S. Johnsen) conducted experiments addressing aspects its visual ecology, which is particularly interesting given the cryptic nature of animal coloration in this habitat. *Leander tenuicornis* were found to have fluorescent leg joints and a fluorescent eye (Fig. 3).



Photos by M. Matz.

Figure 3. A female sargassum shrimp, *Leander tenuicornis*, under white light (left), and in fluorescence under blue light (right). Arrows point to the animal's eye, which has a cryptic banding pattern. The animals' mottled brown coloration matches that of sargassum leaves.

Electroretinograms were used to characterize the spectral sensitivity of the shrimp's visual system (Fig. 4). While experiments conducted during the cruise suggested *L. tenuicornis* possesses a single visual pigment that absorbs maximally at 527 nm (Fig. 4), subsequent experiments with this species collected off the Atlantic coast of Florida indicate a short-wavelength visual pigment absorbing in the UV may be present as well.

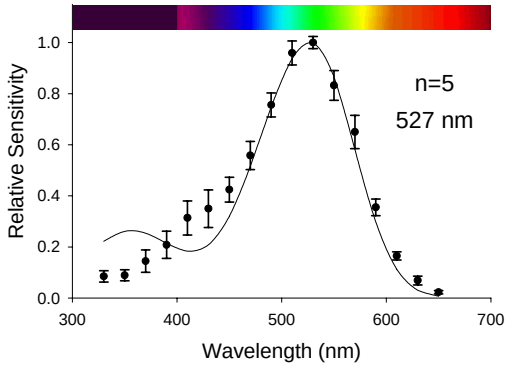


Figure 4. Visual spectral sensitivity of *Leander tenuicornis*. Circles represent mean (± SEM) relative visual sensitivity as a function of wavelength. The solid line is the modeled absorption spectrum for a rhodopsin visual pigment absorbing maximally at 527 nm, which is the best-fit rhodopsin for these data.

□

3) Photosensitivity and resolution of photoreceptors of deep-sea benthic organisms (T. Frank)

During Operation Deep-Scope 2005, new techniques were used which proved to be very successful at allowing us to obtain deep-sea benthic crustaceans with intact photoreceptors. The JSL's DeepSea Power and Light HMI lights were fitted with orange and red cut-off filters (minimum cut-off wavelength 580 nm – Fig. 5). Previous work has shown that deep-sea species are very insensitive to wavelengths above 570 nm (Frank and Case, 1988; Frank and Widder, 1999), so collections could be made without blinding the animals. Two collection techniques proved to be very successful. A new, open trap design was used (Fig. 6), which allowed us to determine why so many of the closed-design PVC traps (sent down open and closed after 5 hours with a magnesium link) were coming up empty. Large *Chaceon* crabs that were too big to get inside the traps and get the bait, surrounded the traps and warded off all others (Fig 7), including hagfish and the smaller crustaceans we were after. After this, a decoy bait bag was used, which attracted the larger crabs and allowed the smaller crabs to enter the traps. The traps were recovered under orange/red light and deposited into a black BioBox (Fig 8), which was thermally insulated and light tight when closed at depth.

Figure 5 Orange and red filtered HMI lights on JSL

Figure 6 Benthic trap designed to fit in BioBox

Figure 7. Chaceon crabs protecting traps

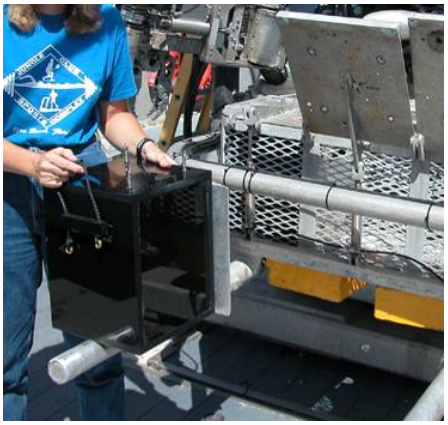


Figure 8 One of the BioBoxes being loaded onto the submersible

Using the suction sampler to pick up crabs and deposit them into the BioBox also proved to be a very effective way to collect live animals with intact eyes. Even though over half the cruise was lost due to Hurricane Katrina, we managed to collect 7 crustaceans – 1 *Gastroptychus sp*, 3 *Eumunida picta*, 1 *Munidopsis tridentata*, 1 *Munidopsis eranacea*, 2 *Bathynectes longispina*, and 1 large decapod shrimp, *Plesionika*. A surprising discovery from electrophysiological recordings revealed that *Gastroptychus* has an ultraviolet photoreceptor, in addition to the usual blue receptor (Fig. 9). What such a deep-living crab, found at 550 m at the South Florida lithoherm site, is doing with an ultraviolet receptor remains a mystery, but preliminary data from the caridean shrimp suggests that it too possesses UV sensitivity, while the other four crab species, found at the same depths, do not (Fig. 10)

a

b

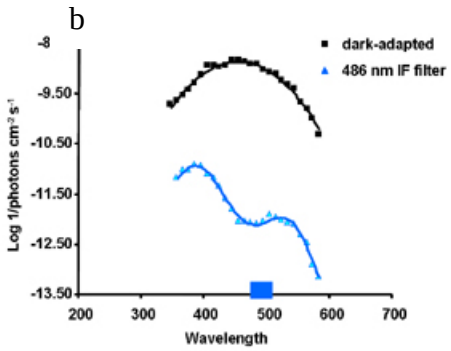


Figure 9 a) *Gastroptychus spinifer*, a benthic species found at 550 m depth, possess UV sensitivity. **b)** Spectral sensitivity curves show that a clear UV peak is revealed under blue chromatic adaptation.

a b

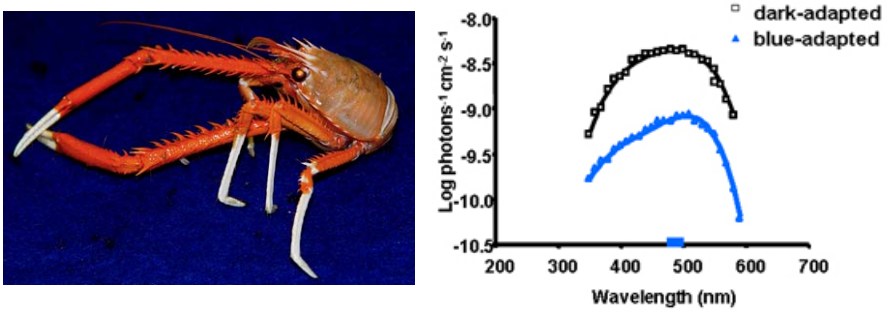


Figure 10 *Eumunida picta* (a) is representative of the other 4 species of benthic crabs, displaying a single blue peak in both the dark-adapted and blue adapted eye (b).

Frozen photoreceptors were sent to Tom Cronin (UMBC), who conducted microspectrophotometry measurements of the absorbance of the visual pigments. His data closely matched the ERG calculated absorbance spectra, demonstrating the efficacy of ERG recordings. MSP techniques are usually not able to find secondary pigments sequestered only 1 of the 8 cells that make up decapod rhabdoms, but the results of the ERG data, including both chromatic effects on spectral sensitivity as well as waveform responses, clearly demonstrate the presence of the secondary pigment. As no UV remains from downwelling sources at these depths, the UV sensitivity in *Gastroptychus* may be utilized to identify near UV bioluminescence in their preferred prey or habitat. Observations from the submersible indicate that this species is usually found off the bottom, hidden in a gorgonian, which may be bioluminescent. Unfortunately, the research cruise was cut short, so this remains to be studied.

Temporal resolution and latency data have been analyzed, and indicate that these deep-sea benthic crabs have some of the slowest eyes ever discovered, which means that these crabs are physiologically adapted to maximize their sensitivity to the dimmest light available. Experiments had been planned to determine the quantity of light that these photoreceptors could be exposed to without damage, but due to losing half the cruise, not enough specimens could be collected to undertake these experiments.

Fixation techniques are being worked out on the large photoreceptors of some large, easily retrieved, shallow living benthic crustaceans, as infiltration of plastic into large photoreceptors is a problem. Due to the scarcity of tissue available for the deep benthic crabs, their tissue will not be fixed until we're confident that we have a consistent technique for getting good infiltration of large photoreceptors.

4) The deep-sea light environment as it is perceived by its inhabitants (Johnsen, Marshall, Widder)

The preliminary analyses from this cruise suggest that the camouflage of deep-sea benthic species is not as good at greater depths (e.g. Fig. 11,12). This is exciting because it suggests that the selective pressure for camouflage decreases with decreasing light levels. It also raises the question of what the colors of animals at great depths are for.

In addition to digital imaging, measurements of downwelling irradiance were made with LoLAR II, to significantly deeper depths than have made been made before in the Gulf of Mexico. These data will be used together with measurements of photosensitivity to provide a realistic image of the benthic environment as seen by one of its inhabitants.

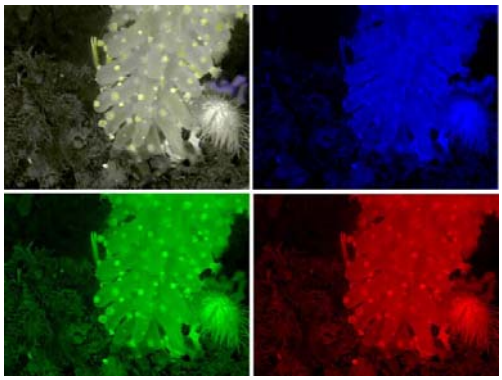


Figure 11: Yellow zooanthids on a glass sponge. Note that, though highly conspicuous under full light, they blend in with the sponge at blue wavelengths.

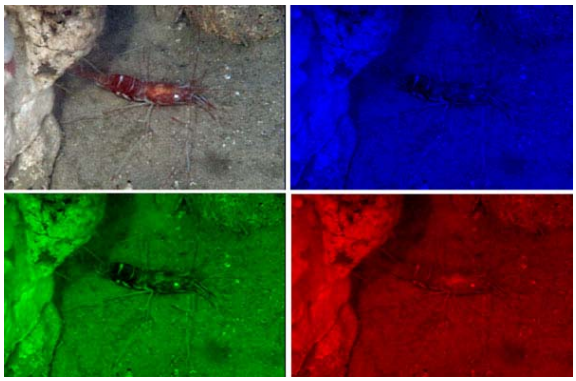


Figure 12 Deep-sea shrimp. Unlike what was seen at shallower depths, this animal is not most camouflaged at blue wavelengths (which occur naturally), but actually blends in with the background best at red wavelengths.

5) The Eye-in-the Sea: A Window into the Deep Sea (Widder)

During ***Operation Deep-Scope 2004*** and ***2005***, the Eye-in-the-Sea camera system evolved into a robust, highly dependable tool for ocean exploration. Eye-in-the-Sea is an autonomous, battery-powered, unobtrusive deep-sea observatory that uses red illumination in combination with a low-light video camera designed to record deep-sea megafauna activity down to 1000 m. The system is also equipped with and optical electronic jellyfish lure capable of imitating five different luminescent displays. The system can be programmed to record in time-lapse and/or triggered mode. In triggered mode, a bioluminescent flash, detected by a PMT, activates the system.

During ***Operation Deep-Scope 2005,*** the Eye-in-the-Sea camera was deployed a total of four times at two unique locations in the Gulf of Mexico. Deployments were made using baited traps and an electronic jellyfish lure capable of imitating five different luminescent displays, including highly conspicuous "burglar alarm" displays. All parameters are fully programmable by the user and EITS was operated in a variety of modes during each deployment. Red illuminators, 685 nm, were fitted with 711 nm high-pass filters, dramatically decreasing the amount of light visible to organisms at deployment sites. From these deployments, 1,240 1-minute videos were recorded and analyzed. Type and number of individuals present in each 1-minute video segment were noted along with the e-jelly mode and absence/presence of the submersible.

Biodiversity studies in the deep sea conducted with ROV's, submersibles and trawl nets are biased by their collection methods. Organisms repelled by white light and sound are under-sampled by these methods. In our 2004 OE proposal, we hypothesized that noise generated from ROV and submersible thrusters deter many deep-sea creatures. EITS video analysis from 2004 & 2005 deployments in the Gulf of Mexico illustrated a decrease in species richness and the number of recorded species during periods of submersible activity. Exceptional footage included schooling behavior of deep-sea sharks (Fig. 13), sixgill shark feeding behavior, and an attack sequence from a large novel deep-sea squid.

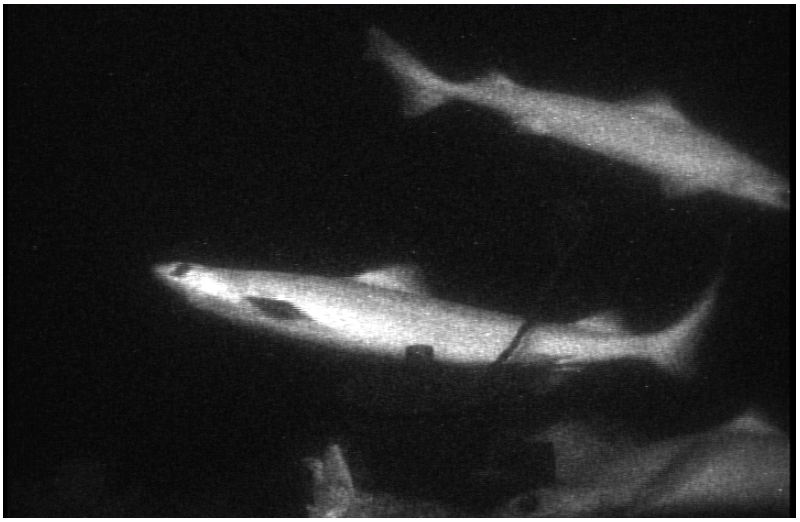


Figure 13 Eye-in-the-Sea footage of a school of *Centrophorus granulosus* during Deep-Scope 2005

During ***Operation Deep Scope 2004*** in the Gulf of Mexico, when EITS was positioned near the edge of the Brine Pool, we recorded the first ever *in situ* footage of a large (> 2 m length), previously undescribed species of deep-sea squid. This squid is so new to science that it cannot be placed into any known family (M. Vecchione pers. comm.). The squid attacked just after the electronic jellyfish initiated a bioluminescent burglar alarm sequence. During ***Operation Deep Scope 2005*** in the Gulf of Mexico, we once again recorded a large squid (Fig. 14) that attacked during a bioluminescent burglar alarm display and that appears to be the same unknown species as we saw in 2004. Clearly this innovative lure has fantastic potential for attracting large predators that are not scavengers.

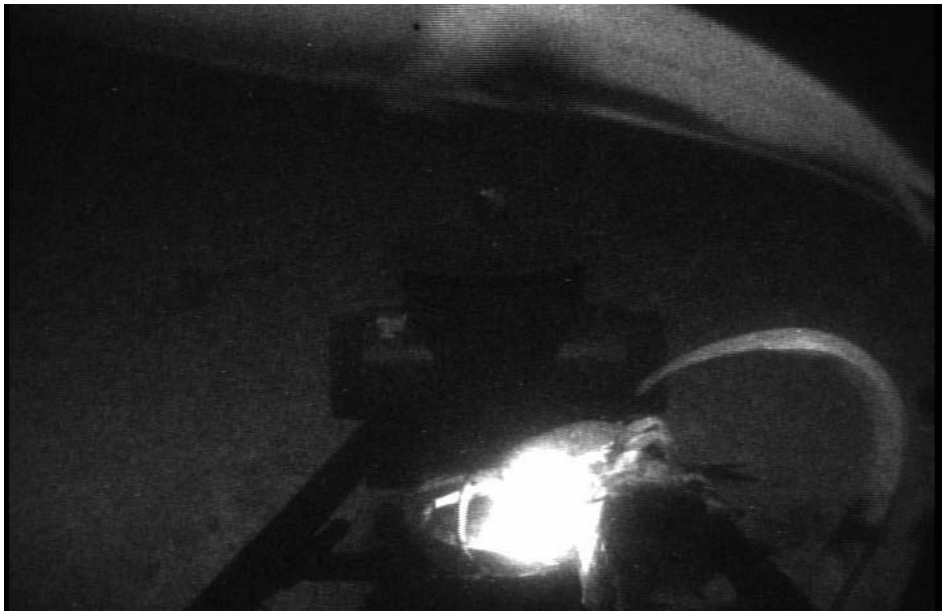


Figure 14 Eye-in-the-Sea footage of previously undescribed species of deep-sea squid during Deep-Scope 2005.

We hypothesize that noise generated from ROV and submersible thrusters deter many deep-sea creatures. Therefore, species richness was calculated in the presence and absence of the submersible to determine the effect of submersible activity on species present. These analyses demonstrated, using the standard Simpson Reciprocal Index, that both species abundance and diversity were significantly less in the presence of the submersible.

6) Ancillary projects

a) Visual Physiology of the Pontellid Copepod *Pontella securifer*

An unusual small crustacean, the copepod *Pontella securifer*, was found in surface plankton tows. This organism (~4 mm in length) is in the copepod family Pontellidae, a shallow-dwelling group characterized by their unusual eye morphologies. Little is known about how pontellid eyes function, or indeed what purpose vision serves in these animals. *Pontella securifer* is unusual among the pontellids, and all animals known, as it has a unique triplet lens eye. Electrophysiology experiments conducted by J. Cohen aboard ship found that this eye is highly sensitive at ultraviolet wavelengths, which matches what he has found on other cruises in another surface dwelling copepod, *Labidocera aestiva*, but is lacking in a deep-dwelling copepod species, *Gaussia princeps*. A potential role for ultraviolet vision in the plankton could be to break the transparent camouflage of potential prey. Future physiological and behavioral experiments will better characterize UV vision in pontellids, and investigate how these animals use their eyes.

b) Molecular Biology of the Hagfish Eye

Hagfish collected as (unwanted) by catch in the benthic traps were killed with an overdose of MS222, and the heads were removed and preserved in RNAlater. Samples were sent to Dr. Shaun Collin at the University of Queensland, Australia, where they will be used to clone the complement of visual pigment genes expressed in the retina and in the genome in order to expand on their studies of the phylogeny of opsin genes in vertebrates and the evolution of colour vision. This is currently being carried out and will help them trace the gene duplication events which have taken place to give rise to the first opsin genes (in particualr the LWS and SWS1 genes). Critical information and how important the hagfish material can be found in Collin, S. P., Knight, M. A., Davies, W. L., Potter, I. C., Hunt, D. M. and Trezise, A. E. O. (2003) Ancient colour vision: multiple opsin genes in the ancestral vertebrates. Current Biology 13(22): R864-865. Their approach is to characterize the photoreceptor types at both the molecular and electron microscopy levels (using the EM fixed material also collected).

In addition to the opsin gene story, the evolution of the cornea is also being traced, where the anatomy of the hagfish cornea (including the corneal microprojections from the superficial epithelial cells) will be compared with lampreys, early ray-finned fishes, lungfish, elasmobranchs and a range of teleosts.

b. Inventory of activities (number of submersible dives, CTD, net tows, etc.)

Number of submersible dives conducted: 12
Number of plankton tows conducted with ½ m plankton net – 6
Number of blue-water dives completed – 5

c.. Inventory of samples collected NA

d.. Describe/list resulting publications, Web sites, presentations, etc.

Presentations:

Ocean Sciences 2006, Hawaii – Ocean Exploration Symposium OS44L-06 – TM Frank – UV photosensitivity in a deep-sea benthic crab

Ocean Sciences 2006, Hawaii – Fish Biodiversity Symposium OS24I-05– EH Raymond and EA Widder - TI: Unobtrusive Observations of Deep-Sea Megafauna in the Gulf of Mexico

Harbor Branch Ocean Science Lecture Series – Open to the general public
Vision in the Deep-Sea – a Crab's Eye View, March 15, 2006 – TM Frank

University of Queensland Neurobiology Series - "Recent advances in seeing sexy partners" (Brisbane, Australia 2006) – JM Marshall

WebSites:

http://www.oceanexplorer.noaa.gov/explorations/05deepscope/welcome.html

http://www.at-sea.org/missions/deepscope2/preview.html

Education and Outreach

Education and outreach activities included mission logs and interviews coordinated by OE's Education Specialist and Harbor Branch Oceanographic Institution's Media Lab and posted on OE and HBOI websites, an "Ask an Explorer" forum on the OE website, and a very popular post-expedition professional development workshop in Ft. Pierce, Florida, during which educators participated in lesson plan activities directly related to the mission and talked with the expedition's scientists.

Media coverage:

Discovery Channel, Canada, Sept. 9, 2005 – Dr. Frank interviewed on "Daily Planet" about discovery of UV photoreceptor, fluorescent shark and Eye-in-the-Sea footage (http://www.exn.ca/dailyplanet/archivelist.asp)

ABC online, Sept. 3, 2005 – coverage of fluorescent animals and UV visual pigment (http://www.abc.net.au/news/newsitems/200509/s1452555.htm)

Science Daily – 9/2/2005

LA Times – 9/3/2005 (http://www.latimes.com/news/nationworld/nation/la-na-seacreatures3sep03,1,6517243.story?coll=la-headlines-nation) - This Science Page is reprinted in 15 other newspapers and used weekly in the Tampa School system.

Associated Press and Reuters among others were on conference call made during Deep-Scope cruise, resulting in more than 170 stories thus far across the US, Australia, China and elsewhere

The fluorescent shark was on the National Geographic web site "photo in the news"

e. Location and status of data archive and/or sample storage N/A

III. Evaluation:

1. Accomplishments – Explain special problems, differences between scheduled and accomplished work

Due to Hurricane Katrina and problems with the tow winch of the submersible, we lost 7 science days, which meant that each PI on thecruise only made two dives. This impacted Matz, Johnsen and Marshall significantly, as their studies required direct observations from the JSL. Frank and Widder fared better, as their traps/cameras could be deployed on their own dives, as well as those of the other PIs. In spite of losing half of our science days, as can be seen by the list of accomplishment, significant scientific discoveries were made on this cruise, in addition to the educational and outreach activities.

2. Expenditures:
   a. Describe original planned expenditures
      $44005
   b. Describe actual expenditures
      $44005
   c. Explain special problems, differences between planned and actual expenditures
      N/A

3. Next Steps:
   a. Planned or expected reports (professional papers, presentations, etc.)

The discovery of UV sensitivity in a deep-sea crab is being written up for publication. The data obtained from the Eye-in-the-Sea on the effect of noise/lights on animal behavior are being combined with data sets obtained on other cruises, and once analyses from all these cruises are complete, will be written up for publication in 2007. The data on benthic camouflage/contrast will be presented at the SICB meetings in January, 2007.

b. Brief description of need for additional work, if any (next project phase, new research questions, unaccomplished work, etc.)

Fluorescence work: preliminary analysis of visual capabilities of two representatives of these surface communities - planktonic copepod *Pontella securifer* and sargassum shrimp, *Leander tenuicornis* - indicated that their visual systems are tuned to their own

fluorescent signals, being offset with respect to the overall blue background of the ocean. We hypothesize that these animals use fluorescence to generate contrast against the blue water background and therefore need to analyze fluorescence, color and vision in organisms found deeper (200 m, 100 m, 50 m) on future cruises. Our previous observations also suggested that the bright green fluorescence of some benthic deep-sea predators, such as tube anemones, and fish might be related to prey capture. This function is strongly suggested by the pattern of fluorescence distribution in these animals. Due to the extreme scarcity of light that may excite these fluorescent signals, such a function implies truly extraordinary visual adaptations and/or behavioral responses of the prey organisms. We therefore need to collect organisms on future cruises exhibiting hypothetically prey-attracting fluorescence and examine their gut contents using the technique of DNA barcoding, to determine the taxonomic affiliation of the prey and evaluate the degree of feeding specificity. We will also continue basic surveys of deep-sea benthic organisms for unexpected cases of fluorescence, such as fluorescence of the chain cat shark – the only fluorescent shark documented thus far. We hope that repeated observations of animals such as this shark would provide an indication of the biological relevance, if any, of their fluorescent coloration.

Vision: Having now demonstrated that it is possible to retrieve benthic species with intact photoreceptors, we are excited by the possibility of what further explorations may bring. The discovery of novel UV photosensitivity in the small sample size available raises the possibility that there may be other benthic species with this unusual adaptation, and brings forth the question of what characteristics are shared by the UV sensitive species. The benthic species discovered thus far with UV photoreceptors are not bioluminescent, so the answer to their UV sensitivity may lie in bioluminescent prey that emit UV light, currently thought to be a very rare phenomenon. We hope to collect a greater sample of deep-sea species and test their vision and bioluminescence emission spectra, as the possibility that many deep-sea benthic animals can see ultraviolet light opens up a whole new chapter on behavioral interactions in the deep-sea benthos. In addition, our earlier study demonstrated that crabs collected under white light and brought to the surface in unprotected containers are blind. However, these sub light exposures were of quite long duration, were directly focused on the animals, and include exposure to blinding surface light levels as well. It is important to assess the effect of more normal submersible illumination, such as sweeping passes with submersible lights as transects are conducted, or indirect illumination as other organisms are collected, without the confounding factor of surface illumination, and we hope to be able to do these experiments on future cruises.

Camouflage: The preliminary analyses from this cruise suggest that the camouflage of deep-sea benthic species is not as good at greater depths, suggesting that the selective pressure for camouflage decreases with decreasing light levels. It also raises the question of what the colors of animals at great depths are for. We hope to continue this work, focusing on two issues that arose during the previous cruises: 1) the effect of visual acuity on the appearance of objects at depth, and 2) the potential for novel colors of animals and bioluminescence at great depths.

Eye-in-the-Sea: For Deep-Scope 2005 we succeeded in creating an illumination level that clearly recorded bioluminescence, while still providing enough red-light illumination to reveal the organisms. In spite of the limited deployments we were able to make in 6 days, we once again recorded a large squid that attacked during a bioluminescent burglar alarm display and that appears to be the same unknown species as we saw in 2004. Clearly this innovative lure has fantastic potential for attracting large predators that are not scavengers. We would also like to test a mechanical lure that simulates the vibrations associated with a struggling fish. Both of these techniques should provide a wealth of information about animal interactions in the benthic environment.

Prepared By: Tamara Frank _____ 9 August 2006 _____

Signature of Principal Investigator Date