

## Project Report

To: John Tschirky  
MMAS

From: Will Heyman, PI  
Phil Lobel, co-PI

RE: Spawning Aggregation Ecotourism: What is the effect of ecotourism on reef fish spawning behavior?

Date: 22 June 2010

### □ Status of Research:

- The project has progressed very well, especially considering mid-course adjustments that needed to be made. Specifically, and as indicated in our preliminary report dated 9 March 2009 - an intensive focus on snappers rather than groupers and snappers, and based on logistical constraints, a change to more of a data-mining approach from one more experimental. Nonetheless, we have been highly productive and have produced a variety of publishable results but also a great deal of information that is highly applicable for management of marine natural resources, and which has been transmitted to appropriate stakeholders.

### □ Results to Date: Provide a summary of data collected to date and preliminary findings.

Data collected to date are from four categories and are summarized as follows:

- 1) fish spawning behavior and analysis of disturbance as mined and analyzed from historical video footage
- 2) longitudinal data on Cubera snapper spawning aggregation site fidelity 1998-2009 as mapped on to bathymetric maps and compared with historical documentation from local dive guides
- 3) information on current speed and directions at the spawning site (added to the project)
- 4) audible data on courtship and spawning sounds of Cubera snapper
- 5) audible sounds from 3 different boats taken at the spawning site to evaluate impact on aggregations.

Detailed Summary:

1) From 1998-2008, Heyman has dived regularly on the aggregations and recorded observations with video. Many of these shots contained divers in them and we have quantified the behaviors using the template table below (and including 6 event entries). Fish and diver behaviors and their interactions totaled 561 min (9 h 22 min) comprising 744 unique events. Of these, 213 events show aggregation activity of Cubera snapper (*Lutjanus cyanopterus*), 184 of dog snapper (*L. jocu*), and 113 of Nassau grouper (*Epinephelus striatus*). Other members of the snapper-grouper complex (*L. analis*, *E. guttatus*, *Mycteroperca bonaci*, *M. tigris*, *M. venenosa*) accounted for 20

Event #	Clip Name	Clip Length (s)	Date	Days after full moon	Location	Species	Estimate # of Fish	Where in water column	# of divers	Diver behavior	closest distance fish to diver	Natural Behavior	Disturbed Behavior
1	April 11 2004 Gladden Spit 215	11-Apr-04	+6	Gladden SpitL.	cyanopterus	100	5-10m depth	2	approaching slowly and filming with video	2-5 m	Spawning	none	
2	April 11 2004 Gladden Spit 227	11-Apr-04	+6	Gladden SpitL.	cyanopterus	300	5-10m depth	5	approaching slowly and filming with video and flash photography	2-10 m	Spawning	none	
3	April 11 2004 Gladden Spit 222	11-Apr-04	+6	Gladden SpitL.	cyanopterus	400	2-15m depth	2	approaching slowly and filming with video and flash photography	2-10 m	Spawning	none	
4	April 11 2004 Gladden Spit 213	11-Apr-04	+6	Gladden SpitL.	cyanopterus	400	5-10m depth	2	diver stationary	5-10 m	Spawning	none	
5	April 11 2004 Gladden Spit 315	11-Apr-04	+6	Gladden SpitL.	cyanopterus	400	20-30m depth	4	approaching slowly and filming with video and flash photography	2-10 m	Spawning	none	
6	April 11 2004 Gladden Spit 356	11-Apr-04	+6	Gladden SpitL.	cyanopterus	400	20-30m depth	3	approaching slowly and filming with video and flash photography	2-10 m	Courtship and Spawning	none	

events. There were an additional 175 events dominated by the presence of the whale shark (*Rhincodon typus*), and 39 events that focused on schools of jacks (Family Carangidae). The footage included 180 spawning events including 100 by *L. cyanopterus*, 71 by *L. jocu* and 7 by *E. striatus*. For this reason, we focused our analysis on these three important members of the snapper-grouper complex, as well as the charismatic megafauna *R. typus*. The following section details the observed disturbances for these four fishes. Summarizing the results, the interactions showed some responses of the fish to the divers, but these were limited in time and duration and did not appear to constitute major disturbances. We cautiously conclude, therefore, that controlled ecotourism diving; following careful guidelines (e.g. those presently in place at Gladden Spit) could be adopted elsewhere using a precautionary, adaptive approach to spawning aggregation ecotourism, based on best available science.

2) The location of the Cubera snapper aggregation has been highly consistent 1998 – 2009 with one year providing an exception. The location of the aggregations has been carefully mapped in relation to bathymetric maps created for the area (Heyman et al., 2005; Heyman and Kjerfve 2008). Our study, however, documented that the location of the aggregation occurred nearly 2 km to the north of the normal spawning site during May 2008, and re-occurred the following year at the known spot. We initially hypothesized that the movement was due to the increased presence of tourist boats and divers. Meanwhile, however, GPS positions of local ecological knowledge for the location of the aggregation have been offered by Brian Young, veteran dive guide and owner of Seahorse Dive Shop. His data indicate that the Cubera aggregation occurs nearly exactly where it did in 2008, when currents are strong from the south. Along with Tal Ezer (Old Dominion University) we reanalyzed local currents during the may spawning time for 1998 - 2010 (using satellite altimetry data from AVISO satellites). Our results are consistent with the observations of Brian Young. We conclude with the suggestion that the aggregation movement in 2008 is a result of abnormal reversal of the normal north-south current conditions. This story will make a note to a journal.

3) The oceanographic conditions at the Gladden Spit spawning aggregation site are likely distinctive from adjacent areas and contribute to the site's value as a multi-species spawning aggregation site. A suite of oceanographic instruments were installed at Gladden Spit Reef promontory during May 2009 and data downloaded December 2009 and were again downloaded in May 2010 and reinstalled. These data are being collected with an Acoustic Doppler Current Profiler (measuring speed and direction of currents in 1m depth bins between the bottom in 32 m and the surface) at the aggregation site, a reef normal transect that bisects the spawning site of four RBRs (pressure transducers that also measure temperature) installed at the bottom between 10 and 35 m water depth. An S4 electromagnetic current meter was installed 2 km north of the spawning site (measuring current speed and direction, salinity, temperature and pressure). There are a variety of hypotheses being tested with these instruments, along with a corresponding high resolution numerical simulation model, nested in the WCS ocean model (Ezer et al., 2005). Funding for the purchase, maintenance, operation and analyses of data produced with these instruments is being provided by Texas A&M, in concert with the existing project, funded by CI MMAS. The results from these study are presently under analysis and a minimum of two papers are likely to emerge, co-authored with Chris Houser, Tal Ezer, Björn Kjerfve and Pablo Granados-Dieseldorff.

4) One of the key unknowns in snapper behavior is what role sounds may have in their courtship and spawning. It is widely accepted that snappers make sounds, especially when handled by fishers. For example, the dog snapper (*Lutjanus jocu*) was known to produce swimbladder-type sounds when electrically and manually stimulated (Fish and Mowbray 1970). However, natural sound production by wild fishes while behaving normally had never been recorded. Our research was to determine if these fishes produced meaningful sounds during courtship and spawning. Phil Lobel has recorded the sounds of boats and divers on the aggregation site with the Lobel Lab's custom video-acoustic underwater recorders and the courtship sounds of Cubera snapper. He collected these data using a state-of-the-art re-breather to eliminate his own bubble sounds. He recorded fishes while they were gathered in pre-spawning groups near the bottom at depths of about 100ft and while they were spawning up in the water column nearer the surface. He found

that the snappers did produce two distinctive sounds. One sound appears associated with the startle response to a diver and the second is a pulsed-series sound that may be associated with the courtship behavior. The data indicate that Cubera do indeed make courtship sounds – a new finding. The acoustic data are presently being analyzed and characterized for publication.

5) The sounds of three boat engine types/sizes were collected at 60 feet depth below them near the aggregation site at Gladden Spit. The boats were dive or research boats that commonly use the area and included a single 60hp Yamaha 4-stroke outboard engine on a 23' skiff, twin 115hp Yamaha 4-stroke outboard engines on a 28' foot skiff, and twin 435 hp Caterpillar diesel inboard engines on a 39' foot boat. The acoustic data associated with these boats are presently being analyzed in relation to the sounds of courtship. Courtship sounds from pre-spawning fishes may be masked by the sounds of engines from boats on the surface but again, spawning seems to have been either unaffected, or only marginally affected.

In summary, based on the data collected to date is that the fish are indeed making courtship sounds and yet there does not seem to be negative effects from fish encounters with the divers. Extensive boat traffic and associated boat engine noises may negatively impact fishes' courtship communication but this remains untested. We are testing the hypothesis that site fidelity of the aggregation is maintained during normal current conditions (from the north) but that when strong south currents prevail, the aggregation moves to the north. Our early recommendations for management is therefore to try to reduce boat traffic, in part by slowing boat speeds near the aggregation site and conducting "drift dives" for tourists whereby they are tracked with a surface buoy instead of a hovering boat. We also plan to continue our study during the May 2009 spawning aggregation to either reject or support our working hypothesis.

- **Data: Provide a metadata catalog describing the data submitted in the format specified by CI (TBD). Provide a copy of data collected since the last progress report.**

See above. Data collected include some video footage and sounds collected in 2008, GPS points showing the new location of the aggregation, and quantitative analysis of historical video data using the template spreadsheet above.

- **Publications & Deliverables: Provide copies (or references) of publications based on the study results. Copies of any other relevant materials particularly those geared toward target audiences (e.g. posters, maps, white papers) are appreciated. Principal investigator and CI/MMAS field representatives should collaborate in preparing the information for these quarterly summaries.**

We are working up the data for several peer-reviewed publications describing the findings to date. One of these has been submitted to *Marine Ecology Progress Series* and another has been submitted to *Ocean Dynamics*. They are both presently in review. Several others are in preparation and nearing completion. Two new papers did emerge that are highly relevant to the present study as they document the multi-species aggregations at reef promontories in Belize (Heyman and Kjerfve 2008 and Kobara and Heyman 2010). They are both attached as appendices to this report. The other papers will be submitted to MMAS when they emerge.

Ezer, T., W.D. Heyman, C. Houser, and B. Kjerfve. Numerical simulations and observations of high-frequency flow variability at a reef fish spawning aggregation site in the Caribbean. Submitted to *Ocean Dynamics*.

Heyman, W.D., L.M. Carr, and P. Lobel. Dive ecotourism and disturbance to reef fish spawning aggregations: It is better to be disturbed than to be dead. Submitted to *Marine Ecology Progress Series*.

Heyman, W.D., P. S. Lobel, L. Carr, L. Garbutt. et al., A code of responsible dive tourism on reef fish spawning aggregations. In preparation for *Ocean and Coastal Management*.

Heyman, W.D., T. Ezer, L.M. Carr, S. Kobara, B. Young, and P. Granados-Dieseldorff. Site fidelity of Cubera snapper spawning aggregations as influenced by ocean currents. Note to be submitted to *Bulletin of Marine Science* or *Environmental Biology of Fishes*

Lobel, P.S. and W.D. Heyman. Sounds of courtship and spawning in Cubera snapper. In preparation.

- **Science to Action: Provide summary of status of efforts to engage target audiences and identifying and developing deliverables. Information on conferences, workshops or other fora (e.g. community meetings, one-on-one meetings with government officials) where results were shared is also requested. Principal investigator and CI/MMAS field representatives should collaborate in preparing the information for these quarterly summaries.**

Using data collected in the study, GIS maps, and video recordings with audio recordings of boat, diver and fish courtship sounds, Heyman offered one-on-one meetings with key stakeholders in Government, NGO communities during February 2009. Brief presentations were given to James Azueta, Isaias Majil, and Carcamo in the Fisheries Department and Lindsay Garbutt and Shane Pech from Friends of Nature. Further presentations were offered in informal community meetings and discussions during March and May 2009, and February 2010 and May 2010. A direct verbal report of our observations was presented to Nellie Catzim of Executive Director of SEA in May 2010. Finally, we have produced a short **video** that was distributed nationally in Belize, and that is presently posted online at the [TAMU Marine and Coastal Geography YouTube site](http://www.youtube.com/user/MarineCostalGeogTAMU#p/u/4/rk4ghqLIDBw), *Disturbing Divers: fishing dive tourism, and the future of Belize's spawning aggregations*.

<http://www.youtube.com/user/MarineCostalGeogTAMU#p/u/4/rk4ghqLIDBw>

A variety of talks have been presented that include aspects of this work (and funding acknowledgement to CI MMAS) as follows:

Heyman, W.D. "Responsible dive tourism on reef fish spawning aggregations". Sponsored by the Department of Ecosystem Science and Management and Applied Biodiversity Science Program. Texas A&M University. 23 February 2010.

Heyman, W.D. "Biology, conservation and management of multi-species reef fish spawning aggregations in Belize". Invited lecture at the Center for Marine and Environmental Studies, University of the Virgin Islands. St. Thomas, USVI. 18 February 2010.

Heyman, W.D., P. Lobel, and L. Carr. "Developing a code of responsible dive tourism on fish spawning aggregations". Science to Action Summit, sponsored by the Marine Managed Areas Science Program of Conservation International. Belize City, Belize. 5 February 2010.

Heyman, W.D. "Permanent protection for multi-species spawning aggregations in the Gulf and Caribbean". Symposium Introduction: Reef Fish Spawning Aggregations, 62<sup>nd</sup> Annual Meeting of the Gulf and Caribbean Fisheries Institute, Cumaná, Venezuela. 5 November 2009.

Heyman, W.D. "People and fish: Can they coexist?" Café Scientifique. Revolutions, Bryan Texas. 14 July 2009.

Heyman, W.D. "Marine Conservation Success". Presented as a Panel Presentation- *in Oceans in Peril: Unsustainable Fishing Practices in the Global Fishing Industry*. Sponsored by MSCC L.T. Jordan Institute for International Awareness. 14 April 2009.

Heyman, W.D. "Four-dimensional resource partitioning and disturbance at a multi-species reef fish spawning aggregation: Implications for management". Association of American Geographers Annual Meeting, Las Vegas. 26 March 2009.

Heyman, W.D. and D. Wright. Panel Discussion Leaders: "Marine geomorphology as a determinant for essential life habitat: An ecosystem management approach to planning for marine reserve networks". Association of American Geographers Annual Meeting, Las Vegas. 25 March 2009.

Kobara, S. and W. D. Heyman. "Three dimensional analysis of spawning aggregation sites in Belize and Cayman Islands" Associate of American Geographers 2009 Annual Meeting. Las Vegas. 25 March 2009. <http://marinecoastalgis.net/aag09>

Heyman, W.D. "Reef fish spawning aggregations in Belize and the Caribbean". Invited lecture, delivered in Spanish in the symposium: Ecología, Manejo y Conservación de Agregaciones Reproductivas de Peces within the 9<sup>th</sup> Annual Meeting of the Ichthyology Society of Mexico. La Paz, Baja California, Mexico. 28 October 2008.

Heyman, W.D. "Biology, geomorphology, oceanography and the conservation of reef fish spawning aggregations in Belize". Invited lecture, Department of Ocean, Earth & Atmospheric Sciences, Old Dominion University, Norfolk, VA. 25 September 2008.

- ***Capacity Building: Provide summary of status of any capacity building efforts, including status of hiring in-country scientists, incorporating community members into the research team, engaging other stakeholders (e.g. government officials) as part of research team, providing training, supporting existing scientific networks, and ensuring long-term support for partners. Principal investigator and CI/MMAS field representatives should collaborate in preparing the information for these quarterly summaries.***

Due to the highly technical nature of the diving and the need to control the number of divers in the water to reduce the impact of sound, we have limited the number of participants on research dives to the minimum. Nonetheless, our team coordinated closely with the monitoring team and the enforcement teams of Friends of Nature during our May 2008, May 2009, and May 2010 field work. We also disseminated our findings in community meetings, short videos, and short written reports for the lay public. Our dive master and guide, Jason William was certified as for DAN oxygen delivery by Phil Lobel and received extensive training on night navigation using GPS by Will Heyman. Many informal conversations were held with community members and fishers, describing the work that we are doing, the equipment we are using, and the findings that we may produce. These occur at the docks, in restaurants and on the dive site (see above). Phil and Will both participated in the MMMAS sponsored S2A workshop in February 2010 and presented our results to national stakeholders at that time.

The final outcome of this project will include a "Code of Responsible Dive Tourism" that is presently being worked up in concert with a variety of partners and will become another final product of this project and can be used for further capacity building on dive ecotourism for spawning aggregations both in Belize and around the world.