Progress Report, June 2015

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Passive Acoustic Monitoring of Fish Spawning Aggregations in Puerto Rico

Background and Activity Summary

Large predators contribute to the resiliency of healthy coral reef ecosystems. However, many populations of these species are depleted on the insular shelves of the U.S. Caribbean. Commercially important species, *e.g.*, large groupers, that gather annually to spawn, are highly susceptible to overfishing, and managers need better data on aggregation locations and dynamics. This project, in partnership with the University of Puerto Rico-Mayagüez (UPRM) Department of Marine Sciences and the Caribbean Coral Reef Institute (CCRI), is supporting continued and expanded use of passive acoustic methods off western Puerto Rico, to locate, assess, and monitor reef fish spawning aggregations (FSAs). Our current focus is on five species of winter-spawning groupers. In addition, we developed designs and plans for using continuous sound recorders as drifters or stationary monitors off the west coast and in the NE Reserves of Puerto Rico (Caribbean Habitat Focus Area) to confirm spawning locations, spawning species, aggregation timing, and spatial boundaries of spawning activity.

Field Activities from October 2013-June 2015:

1. Completed (presumed pre-spawning) deployment of digital spectrogram (DSG) long-term acoustic recorders (Loggerhead Instruments Inc.) for passive acoustic monitoring at each study site each year
2. Completed (presumed post-spawning) recovery of DSGs from each study site except one (MI) where extended, year-long, recording will be accomplished
3. DSG data downloaded, processed, and backed up in UPRM (Appeldoorn) lab
4. DSG data analysis continuing (project-supported UPRM grad students)
5. Underwater visual surveys for species, abundance, size structure, and spawning behavior completed each spawning season
6. Continued collection of information on NE spawning sites and outlined methods to proceed with more comprehensive information gathering

Project Basics

Puerto Rico's priority coral reef management goals include - *Protect coral reef ecosystems from large- and small-scale fisheries impacts* – and – *Enhance management programs to reduce fishing impacts to coral reef ecosystems*. These needs are especially keen in marine protected areas (MPAs) and depend on robust knowledge of reef fish populations. Many fish stocks on the insular shelves of the U.S. Caribbean, including large predators such as groupers that contribute ecological resistance and resilience in healthy coral reef ecosystems, are depleted or are near depletion. Predictable aggregative spawning behaviors have made groupers easy to overfish. Managers know far less about these sites and their status than fishers, who have exploited these aggregations for decades, even to the point of fishing-out some aggregations. To enhance management, we need better data on site locations and dynamics. We need answers to key questions:

- Where and when do aggregations occur?
- Which species use each location?
- How abundant are spawners during the aggregation?
- Can abundance at aggregations be used as an index of population abundance at resident reefs?

For successful management, effective conservation, and to recover these critical reef resources, spatial boundaries and seasonal fishing regulations must match the timing and locations of FSAs to reduce the threat of overexploitation. Prior attempts to locate and monitor aggregations were highly dependent on fishermen interviews coupled with diver or other visual surveys, which depend on good weather, adequate light, and the precision of the descriptions. Visual surveys and searches are usually spatially limited. The current research project continues and expands the successful use of passive acoustic monitoring (PAM) to quantify spawner-generated sounds at known and reported FSA sites off western PR, in combination with diver surveys for groundtruthing. Passive acoustic receivers (*i.e.*, DSGs) record, and researchers identify, species-specific "calls" of fish at aggregation sites.

Previous studies have identified reproductive behaviors that are accompanied by sound for multiple grouper species. These courtship-associated sounds (CAS) are restricted to reproductive behaviors exhibited during the formation of spawning aggregations. The species of western Atlantic grouper with described sound signals include *Epinephelus guttatus* (red hind)*, E. striatus* (Nassau grouper)*, E. morio* (red grouper)*, E. itajara* (goliath grouper)*, Mycteroperca venenosa* (yellowfin grouper)*,* and

M. bonaci (black grouper) (Mann et al. 2009, 2010, Nelson et al. 2011, Schärer et al. 2012a, 2012b, Schärer et al. 2014a). Other species such as *M. tigris* (tiger grouper), *M. interstitialis* (yellowmouth grouper), *Scarus guacamaia* (rainbow parrotfish), and *Canthidermis sufflamen* (ocean triggerfish) have also been documented at spawning aggregations showing reproductive behaviors, but sound identification has not yet been confirmed. The species-specific sounds serve to document the presence at spawning aggregation sites and, for the most abundant ones, a high-resolution (hourly) time series can be generated to determine peaks in reproductive activity. We continue to research protocols to equate sound levels with numbers of spawning individuals.

Research is conducted in cooperation with partners, SERO, CCRI, University of Puerto Rico-Mayagüez (UPRM), and Loggerhead Instruments. Coordinated companion projects are ongoing with UVI (R. Nemeth) and PR DNER (SEAMAP-C) and additional funding sources are continuously pursued to expand and extend this research across the U.S. Caribbean.

Monitoring and Research Setting

Fish spawning aggregation (FSA) sites in the waters off western Puerto Rico have been studied with diverse, constantly improving methodologies for almost a decade leading towards standardization of methods. Sites (Fig. 1), including known FSAs at Abrir la Sierra (ALS), Mona Island (MI) and Monito, Bajo de Sico (BDS), and Tourmaline (B-8) are monitored with passive acoustics, underwater visual surveys, and autonomous audio/video recording methods. Two of these locations (ALS and MI) have been monitored with passive acoustic methods continuously since 2007 for multiple species (Mann et al. 2010, Rowell et al 2012, Schärer et al. 2010, 2012a, 2014b). Four FSA sites [MI, ALS, B-8, plus El Seco (off Vieques on the PR east coast)] were identified as priority sites for red hind and data are being collected in collaboration with/on behalf of SEAMAP-C. BDS is a priority site for Nassau grouper, which is listed as *threatened* under the Endangered Species Act. An overlapping research project funded by the Caribbean Fishery Management Council (CFMC) documented that BDS is a multi-species spawning

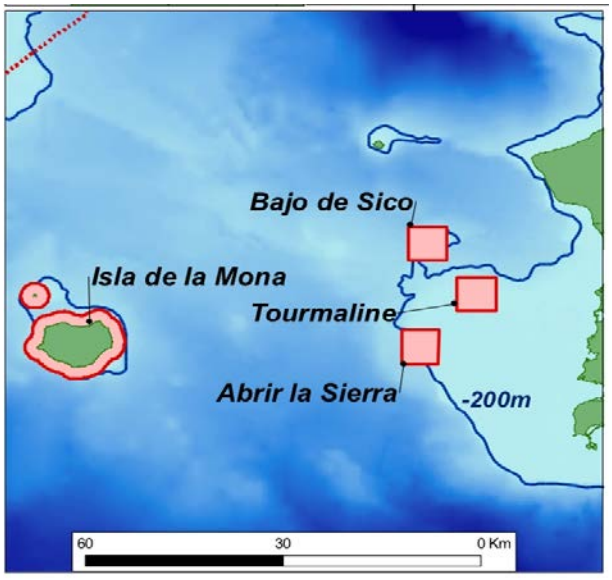

Figure 1. Map of western Puerto Rico fish spawning aggregation sites currently being researched and monitored. Bathymetry is color shaded and shelf edge is marked with 200 m depth contour.

aggregation site (Schärer et al. 2014b). Several of the FSA study sites are now known to be used by multiple species of groupers, snappers, and parrotfishes. El Seco (ES), off of Vieques, PR, the Hind Bank, and the Grammanik Bank, both off St. Thomas, USVI, are being investigated using consistent technological approaches, with logistics handled collaboratively by Dr. Rick Nemeth (UVI) but data archiving and analysis by UPRM.

This year, long-term passive acoustic monitoring was conducted at multiple sites simultaneously and underwater visual surveys were conducted at two priority sites off western Puerto Rico.

Activities and Accomplishments for FY-14-15

Preparations for fieldwork in the 2014-2015 spawning season began in November of 2014. This included meetings with partner institutions to identify priority locations and seasons for study, conditioning and staging of equipment, and acquisition of materials. Study sites selected for the season were visited in early December prior to the expected beginning of grouper spawning season. At least one long-term acoustic recorder, *i.e.*, digital spectrogram (DSG-Ocean; Loggerhead Instruments Inc.) was prepared for deployment at each study site (Figure 2). At two multi-species FSA sites, MI and BDS, three and four DSG were deployed, respectively. The purpose of this design was to record at different FSA locations on the insular platform where different species are known to congregate. At all other sites one DSG was deployed per site.

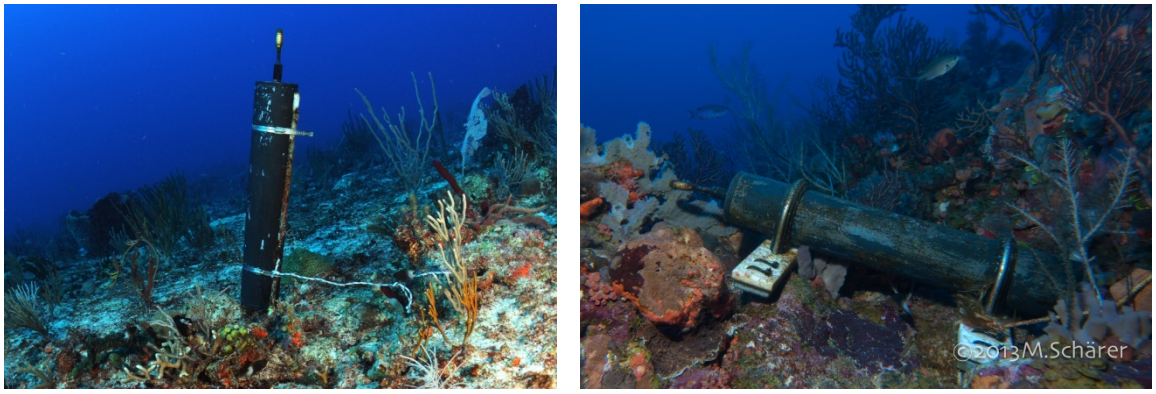

Figure 2. Deployment methods for DSGs on the seafloor, vertical rebar attachment at left (photo by J. Zegarra), horizontal weighted base attachment at right (photo by M. Schärer).

Each DSG was programmed to record six months with a sampling schedule of 20 seconds every 5 minutes. Data were recorded onto removable 32-gigabyte secure digital high capacity (SDHC) flash memory cards. Files were digitized at a sample rate of 10 KHz. Units were powered by an array of 24 D-cell batteries for the duration of the

deployment. DSG recorders were attached within the aggregation sites either with hose clamps to rebar inserted into the substrate or secured to weighted bases (Fig. 2).

The deployment schedule of the DSGs is summarized in Table 1. After deployment, the DSGs were inspected *in situ* for proper functioning, as indicated by the LED lights on the tip of the unit's hydrophone, whenever diver surveys were conducted at the site. In the 2014 field season, only one DSG, at BDS-1.5, wasn't functioning properly, as indicated by a continuously lit rather than a blinking LED on the hydrophone. This DSG was recovered on 25-Feb-2014 and another unit was deployed there on 27-Feb-2014. The recorder had malfunctioned due to a faulty SD card (128 GB capacity) and did not record properly. Standard method now prescribes 32 GB cards for all units.

Table 1. 2014 and 2015 deployment and recovery schedules for DSGs from western Puerto Rico grouper spawning sites. Multiple entries are listed for sites where DSGs were replaced mid-season due to mechanical problems or were replaced to extend recording duration.

	2013-14 Field Season			2014-15 Field Season		
Site	**DSG #**	**Deployed**	**Recovered**	**DSG #**	**Deployed**	**Recovered**
Abrir la Sierra	1138	18-Dec-13	3-Jun-14	1017	9-Dec-14	17-Jun-15
BDS-00	1274	18-Dec-13	23-Jul-14	1275	23-Jul-14	15-Mar-15
BDS-1.5	1275	18-Dec-13	25-Feb-14	-	-	-
BDS-1.5	1289	27-Feb-14	23-Jul-14	-	-	-
BDS-01	1018	3-Jan-14	26-Jul-14	1273	9-Dec-14	17-Jun-15
BDS-09	1014	18-Dec-13	23-Jul-14	1276	9-Dec-14	17-Jun-15
BDS-2.5	57	18-Dec-13	31-Jul-14	-	-	-
BDS-6.5	-	-	-	1274	9-Dec-14	17-Jun-15
Mona-Elbow	1273	27-Dec-13	3-Jun-14	1018	8-Jan-15	30-Jun-15
Mona-H5	1017	27-Dec-13	3-Jun-14	1016	3-Jun-14	8-Jan-15
Mona-H5	-	-	-	1014	8-Jan-15	30-Jun-15
Mona-H6	55	27-Dec-13	3-Jun-14	55	8-Jan-15	30-Jun-15
Monito	1276	27-Dec-13	1-Aug-14	-	-	-
Tourmaline	1137	18-Dec-13	30-Jun-14	-	-	-

Underwater visual surveys to estimate abundance and size structure are conducted with complementary methods. Video and laser caliper surveys, with a GoPro®[1] camera and calibrated underwater lasers, are performed as divers drift in one direction through the aggregation site (Fig. 3) towing a surface buoy with handheld GPS attached. Each grouper encountered during the dive is recorded with video and the lights of two red lasers, a known distance apart, are pointed and held at a perpendicular

[1] Mention of trade names or products does not represent an endorsement by NOAA, NMFS, UPRM or the authors

angle on the side of the fish. Still images are extracted from the video, processed and analyzed to estimate the size of each individual and subsequently develop length frequency distributions. The purpose of the video is to record the fish lengths, while the other diver conducts a total abundance count.

Figure 3. Video and laser caliper method at left (photo by M. Schärer) and lights from red laser on Nassau grouper at right (photo by H. J. Ruiz).

The density of each species of grouper is estimated by dividing the total abundance encountered during the transect time by the total transect length as estimated in GIS. The length of the drift transect is estimated by calculating the distance based on the geographic coordinates of the track recorded on the handheld GPS. The length of the transect is multiplied by 4m wide (*i.e.*, diver's effective width of view) to get the total area surveyed. GIS mapping also provides the relative locations of groupers by extracting the timecode from the video and matching with the GPS.

Due to the depth, geomorphology of the seafloor, and strong currents that impede any estimate of area surveyed using the traditional surface buoy method, at the BDS site a roving search method is employed over the same consistent area. The surveys quantify the maximum number of Nassau grouper and the color phases with the courtship arena, a 300m by 100m area (30,000 m^2) delineated by underwater landmarks. This area is also where the DSG is located, and it is used to calculate the density of grouper per day.

During 2015, divers conducted surveys at a subset of priority sites at MI, BDS and ALS. Forty dives were conducted on 15 dive days (Table 2). Three multi-species aggregation sites were surveyed. Drift surveys with a handheld GPS on the surface buoy (after Colin, pers. com.) were conducted at ALS and MI to document the abundance and distribution of red hind. The surveys to document grouper were done with video and laser calipers (Figure 3) to estimate fish lengths, and the maximum abundance of groupers by species was estimated on each dive. On peak spawning days at BDS the different color-phases of Nassau grouper were quantified with closed

circuit rebreather (CCR) due to the depths at which grouper aggregate (140' to 170'). All other surveys were conducted with open circuit diving between 60' and 90' depths.

Table 2. Fieldwork accomplished to date in the 2014-15 spawning season

Date	Task	Sites	Number of Dives
9-Dec-14	Deploy DSGs	BDS, ALS	7
8-Jan-15	Deploy DSG	MI	4
15-Jan-15	Survey	ALS	2
16-Jan-15	Deploy DSG & surveys	ALS	2
17-Jan-15	Deploy DSGs	BDS	2
9-Feb-15	Survey	BDS	2
10-Feb-15	Survey	ALS	2
11-Feb-15	Survey	BDS	1
15-Feb-15	Survey	BDS	2
10-Mar-15	Survey	ALS	2
14-Mar-15	Survey	BDS	3
15-Mar-15	Recover DSG & surveys	BDS	4
16-Mar-15	Survey surface acoustics	BDS	0
19-Mar-15	Survey	BDS	3
1-Apr-15	Survey	BDS	1
2-Apr-15	Survey	BDS	3
17-Jun-15	Recover DSG & survey	BDS, ALS	4
30-Jun-15	Recover DSG & survey	MI	3

Laboratory Analysis and Planning

During this year, passive acoustic data collected during in the 2013-2014 spawning season was post-processed, standardized and quantified for red hind. The temporal analysis is continuing for these datasets. Some of the recorders had problems with faulty memory SD cards and had to be sent to Loggerhead Instruments for recovery of data.

All DSG recoveries for 2015 were completed, as planned. Data were downloaded and backed up and analysis is underway. Figure 4 illustrates a preliminary analysis product, showing average sound levels across the spawning season of 2015 for red hind at ALS. Two peaks show high levels of CAS during January and February and a minor peak in March. Repeated surveys have demonstrated the unexpected variation in the timing of spawning from year to year. Data from videos and counts from underwater surveys will be processed and analyzed in order to get size and abundance estimates for each day surveyed.

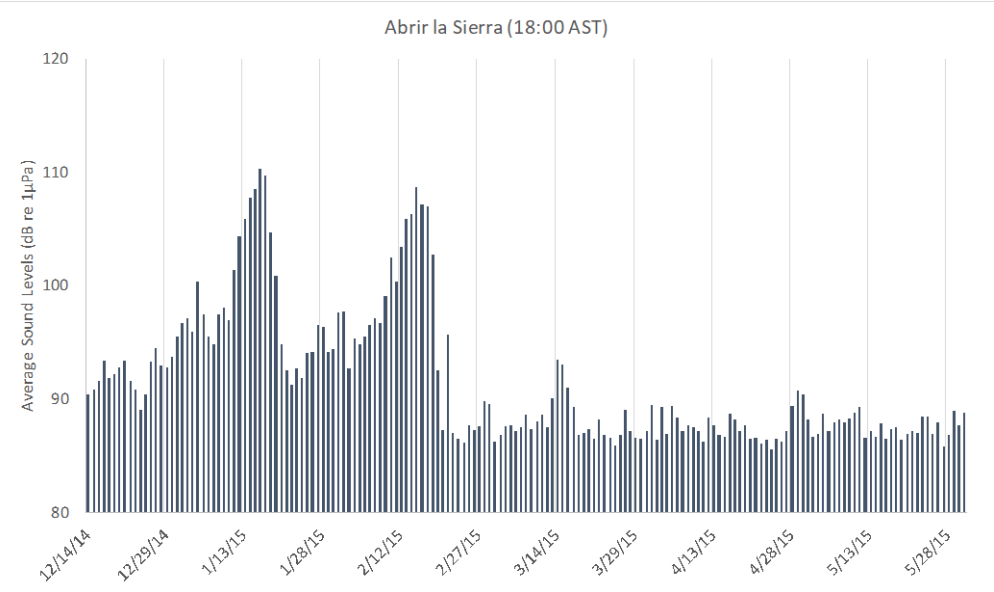

Figure 4. Average sound levels for red hind courtship associated sounds (CAS) at Abrir la Sierra for the 2015 spawning season.

Fisher Input into Northeast Spawning Sites

A number of contacts have been made, primarily through the CFMC, with fishers and divers familiar with purported spawning aggregation sites in the NE Reserves. Data from these participants include sites for goliath grouper and red hind and are being compiled. Data will be examined to identify appropriate study sites going into next season's surveys.

Contributing Partner Institutions

SEFSC: Passive acoustics research, western and NE Reserves, PR (CRCP funding, FY-14-16; R. Hill and J. Doerr)
CCRI: Passive acoustic research of spawning aggregations (Year 9; PI - M. Schärer)
CFMC: Nassau grouper project (Year 2; PI - M. Schärer)
UVI-CMES: Fish spawning aggregation research (Year 2; PI - R. Nemeth)
SEAMAP-C: Red hind passive acoustic monitoring (Year 3; PI - R. Appeldoorn)

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