Use of Passive Acoustics to Map Grouper Spawning Aggregations, with Emphasis on Red Hind, *Epinephelus guttatus*, Off Western Puerto Rico

TIMOTHY J. ROWELL[1]*, RICHARD S. APPELDOORN[1], JOSÉ A. RIVERA[2], DAVID A. MANN[3], TODD KELLISON[4], MICHAEL NEMETH[1], and MICHELLE SCHÄRER-UMPIERRE[1]

[1]*Department of Marine Sciences University of Puerto Rico, PO Box 9000 Mayagüez, Puerto Rico 00681.*

**tjrowell@gmail.com*. [2]*Polytechnic University of Puerto Rico, HC-02 Box 1736, Boquerón, Puerto Rico 00622-9300.*

[3]*Collece of Marine Science University of South Florida, 140 7th Avenue South St. Petersburg, Florida 33701 USA.*

[4]*NOAA Fisheries Beaufort Laboratory, 101 Pivers Island Road, Beaufort, North Carolina 28516 USA.*

ABSTRACT

Most large groupers form spawning aggregations at predictable locations and times, resulting in their susceptibility to overfishing and other ecological threats. Research, management, and enforcement of such aggregations could be enhanced if their exact locations were known. Traditional detection methods of diver and catch surveys are time consuming, especially when considering multiple species and sites. Many groupers such as red hind, *Epinephelus guttatus,* are soniferous and increase sound production at specific locations during periods of courtship and spawning, permitting the use of passive acoustics to locate and map these aggregations more efficiently. During January and February 2010 on days and hours known to have high call rates, passive acoustics were used to map a spawning aggregation of red hind off western Puerto Rico. A hydrophone attached to a mobile digital audio recorder was lowered from a boat as the vessel drifted over a suspected spawning aggregation area, while the global positioning system (GPS) coordinates were simultaneously recorded. After listening to the audio recordings, occurrences and intensities of red hind calls were charted with their GPS locations in GIS. The eastern and western boundaries of the aggregation were successfully mapped. The southern and northern boundaries were not defined due to aberrant drift patterns and the end of the spawning period, which resulted in the cessation of red hind calls. Divers confirmed the presence of reproductively active red hind. These time-saving methods and technologies can be expanded to other soniferous groupers, and potentially can be automated so that results can be determined in near-real time.

KEY WORDS: Spawning aggregations, passive acoustics, mapping, red hind

El Uso de Acústicas Pasivas para Trazar Mapas de Agregaciones de Desove de Meros, con Énfasis en el Mero Cabrilla, *Epinephelus guttatus*, en el Oeste de Puerto Rico

La mayoría de los meros grandes forman agregaciones de desove en lugares y tiempos predecibles, resultando en su susceptibilidad a la sobrepesca y otras amenazas ecológicas. Si conocemos la ubicación exacta de las agregaciones facilitamos su estudio y protección. En los métodos tradicionales de detección, como las encuestas de buceo y pesca, se consume mucho tiempo; especialmente cuando se consideran múltiples lugares y especies. Muchos meros, incluyendo el mero cabrilla, Epinephelus guttatus, producen sonidos y aumentan la producción de sonidos en lugares específicos durante los periodos de cortejo y desove, lo que permite el uso de acústicas pasivas para localizar y trazar mapas de estas agregaciones de una manera más eficiente. Durante los meses de enero y febrero de 2010, en días y horas conocidas por altas tasas de llamadas, se utilizaron acústicas pasivas para delinear una agregación de desove de cabrilla en el oeste de Puerto Rico. Un hidrófono conectado a una grabadora móvil de audio digital se sumergió de un barco a la deriva en un área de agregación de desove, mientras que el sistema de posicionamiento global (GPS) registraba las coordenadas simultáneamente. Después de escuchar las grabaciones de audio, se trazaron las ocurrencias e intensidades de las llamadas con sus ubicaciones de GPS en un SIG. Los límites al este y oeste de las agregaciones fueron mapeados exitosamente. Los del norte y sur no se definieron como resultado de anomalías en las corrientes y el final del período de desove, que resultó en el cese de las llamadas de cabrillas. Los buzos confirmaron la presencia de cabrillas reproductivamente activas. Estos métodos y tecnologías ahorran tiempo y pueden aplicarse a otros meros que producen sonidos, y potencialmente se puede automatizar la detección de los sonidos para determinar resultados casi instantáneamente.

PALABRAS CLAVE: Agregaciones de desove, acústicas pasivas, cartografía, mero cabrilla

L'utilisation des Acoustiques Passives pour Tracer des Chemins des Méroux Frayères, en Mettant L'accent sur le Mérou Couronné, *Epinephelus guttatus*, à la Côte Ouest de Porto Rico

L'emplacement de certaines frayères de mérous est souvent prévisible d'une année à l'autre, les rendant vulnérables à la surpêche ainsi qu'à d'autres menaces écologiques. La recherche, la gestion, et la mise en place de mesures de protection de ces agrégations pourraient être améliorées si leurs emplacements exacts étaient connus. Les méthodes traditionnelles de détection, comme les interviews de pêcheurs et l'observation directe par des plongeurs requièrent de beaucoup de temps, surtout quand on considère les nombreuses espèces et sites. De nombreux mérous, tel que le mérou couronné (*Epinephelus guttatus*), émettent des sons (« appels ») et augmentent la production sonique durant les périodes de parade nuptiale et de frai, permettant ainsi l'utilisation de méthodes d'acoustique passive pour localiser et cartographier plus efficacement leurs agrégations. En janvier et février 2010, mois durant lesquels cette espèce se reproduit et les taux d'appels sont particulièrement élevés, une agrégation a été cartographiée à l'aide d'acoustique passive. Un hydrophone connecté à un enregistreur audio numérique mobile fut submergé depuis une embarcation passant au dessus d'un lieu de frai présumé. Les coordonnées géographiques furent simultanément enregistrées à l'aide d'un GPS. Après avoir écouté les enregistrements audio, l'emplacement et l'intensité des appels de mérous couronnés ont été placés dans un Système d'Information Géographique. Les limites orientales et occidentales de l'agrégation ont été cartographiées avec succès,

tandis que les limites Nord et Sud ne purent être déterminés à cause d'anomalies dans le patron des courants et la cessation des appels à la fin de la période de frai. Des plongeurs ont confirmé la présence de poissons reproductifs. Cette méthode, permettant de gagner du temps, peut être employée dans le cas d'autres espèces produisant des sons nuptiaux. Une éventuelle automatisation permettrait de collecter des donnés en temps quasi réel.

MOTS CLÉS: Agrégations, frayères de mérous, acoustique passive, cartographiée, mérou couronné

INTRODUCTION

Many species of large groupers (Epinephelidae) in the tropical western Atlantic Ocean are known to form transient spawning aggregations (Claydon 2004, Domeier and Colin 1997). Red hind, *Ephinephelus guttatus*, is a commercially important grouper found from Bermuda to Brazil that assembles annual spawning aggregations at specific times and locations (Colin et al. 1987, Sadovy et al. 1994, Shapiro et al. 1993a). Throughout most of its range, red hind typically spawn in the months of January and February during the week around the full moon (Beets and Friedlander 1992, Colin et al. 1987, Cushion et al. 2008, Sadovy et al. 1994, Shapiro et al. 1993b, Whiteman et al. 2005). The predictability of grouper aggregations makes them extremely vulnerable to negative effects of overfishing (Aguilar-Perera 2006, Aguilar-Perera and Aguilar-Davila 1996, Coleman et al. 1996, Sadovy 1994, Sadovy and Domeier 2005). Therefore, the ability to locate and monitor spawning aggregations of groupers, such as red hind, can prove pivotal in protecting them. Traditional methods are often time consuming, expensive, and destructive. In addition, many of the red hind spawning aggregations are located along insular shelf edges (Nemeth 2005, Shapiro et al. 1993a) where conditions are often adverse during spawning periods, making data collection difficult.

Various species of groupers produce sound (Fish and Mowbray 1970), and courtship associated sound production at spawning aggregations has been documented for goliath grouper, *Epinephelus itajara* (Mann et al. 2009), yellowfin grouper, *Mycteroperca venenosa* (Scharer et al. Unpubl. data), and red grouper, *Epinephelus morio* (Montie et al. Unpubl. data). Male red hind also display soniferous behavior while present at spawning aggregations. Mann *et al*. (In press) successfully recorded and identified a species-specific call for red hind, and determined that peak sound production occurs during the late afternoon and early evening hours five to ten after the full moons in January and February at a site named Abrir La Sierra, Puerto Rico.

Luczkovich et al. (1999) successfully depicted how passive acoustics can be used to locate spawning areas, after finding an association between weakfish (*Cynoscion regalis*) sound production and early-stage collected eggs. Passive acoustics have also been successfully used to find spawning aggregations of other soniferous species (Luczkovich et al. 2008b, Walters et al. 2009), where the data collected with hydrophones served as a proxy for spawning activity. The recent decline in grouper landings coupled with current trends of exploitation and overfishing of aggregations (Sadovy and Domeier 2005) warrant the need to develop new methods to locate, map, and monitor grouper aggregations. Passive acoustics is a developing technology that can utilize grouper acoustic behavior to locate, map, and monitor spawning aggregations with greater time and cost efficiency (Luczkovich et al. 2008a, Mann et al. 2008), which is especially important when trying to study many species and sites within a short spawning period.

We sought to:

i) Use passive acoustics to map a known spawning aggregation of red hind,
ii) Develop methods which can be expanded to other species of soniferous groupers, and
iii) Determine if passive acoustics can be used to locate and map undocumented spawning aggregations of groupers.

METHODS

Abrir La Sierra, a known spawning aggregation of red hind within a seasonal marine protected area off the west coast of Puerto Rico, was visited during the late afternoon and early evening hours five to ten days after the full moons in January and February 2010. A hydrophone attached to a mobile digital audio recorder (M-Audio MicroTrack II) was lowered from a boat (with engines off) to a depth of 1 - 2 m above the sea bottom as the vessel drifted over the suspected spawning aggregation area. Geographic coordinates were simultaneously recorded with a handheld global positioning system (GPS) unit (Garmin GPSmap 76), generating a point every 10 seconds. A headset was connected to the audio recorder to listen for the presence of red hind calls in real time. Each drift continued until no more red hind calls were heard. This process was repeated, yielding a series of drifts in the direction of surface currents and winds.

After each day of data collection, the audio recordings were listened to and analyzed to determine the occurrences and intensities of red hind calls. Occurrences and intensities of individual red hind calls with high sound pressure levels (loud) were charted with their GPS locations in GIS in order to identify the limits of the aggregation. Diver surveys were conducted on SCUBA to verify that recorded red hind calls corresponded to the presence of reproductively active fish during the study. A long-term digital audio recorder (DSG; Loggerhead Instruments) positioned at Abrir la Sierra was used to record daily red hind call production at the site throughout the spawning season.

RESULTS

Abrir La Sierra was visited during late afternoon and early evening hours on January 8th and 9th, and February 4th, 8th, and 9th 2010, which corresponded to five to ten days after the full moons. A series of 16 passive acoustic drifts were conducted. Recorded red hind calls with high sound pressure levels (SPL) were charted with their GPS locations successfully (Figure 1). Red hind calls were recorded on all days except February 9th, ten days after the full moon. The long-term digital audio recorder captured red hind sound production on all days of the study except for February 9th. Diver surveys confirmed the presence of reproductively active red hind prior to February 9th.

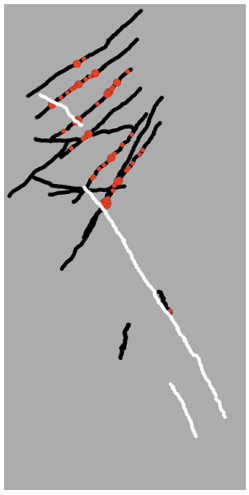

Figure 1. A non-descriptive view Abrir La Sierra, Puerto Rico. The 16 drifts (black and white transects) are charted with the locations of red hind calls with high sound pressure levels (red circles). Louder red hind calls are represented by larger red circles. The white drifts were conducted on February 9th and yielded zero red hind calls.

DISCUSSION

The 16 drifts revealed an area of high densities of reproductively active red hind. Details of exact locations are not presented in an attempt to protect the aggregation. The eastern and western boundaries of the aggregation site were found with the passive acoustic methods, while the northern and southern boundaries were not identified during the 2010 spawning season due to aberrant drift patterns and the end of the spawning period. On the final day of data collection, February 9th, the lack of recorded calls was found to be a product of the cessation of spawning/call production after examining the audio data from the long-term digital audio recorder. As a result, additional work is needed in the upcoming years to locate the northern and southern boundaries, and should be executed prior to ten days after the full moons in January and February, assuming that trends are consistent from year to year. Red hind possibly aggregate loosely along the entire shelf edge in western Puerto Rico. Future investigations will shed light on this hypothesis after examining the southern and northern reaches of this aggregation.

Diver surveys verified that the occurrences of courtship-associated calls corresponded to the presence of reproductively active red hind. Therefore, passive acoustic surveys can be used as a method to delineate spawning aggregations of red hind. These methods can be used more efficiently than traditional methods and during difficult conditions, including after sunset, when visual surveys would be difficult. The reliance on surface currents and wind as a determinant of drift direction and speed was one limitation to this study. The lack of strong currents on one day in particular (February 8th) inhibited the coverage of a large area. In future studies, it is recommended that a grid be created over the suspected study site with selected sample stations prior to entering the field. Therefore, on days with non-ideal currents, sample stations can be visited and short acoustic surveys can be carried out at each station. This preparedness will increase the efficiency of the methodology, and will allow more sites to be examined during a short spawning period. The audio recordings were manually listened to for this study, but recent developments in signal processing with custom MATLAB software will allow for the use of automated call detection algorithms in the future.

Work has been done to identify other possible areas of spawning aggregations in Puerto Rico through fishermen surveys (Ojeda-Serrano et al. 2006). However, these sites have not been officially documented or located. The results of these surveys can be used to target areas for future passive acoustic studies. Acoustic methods will allow for a rapid and efficient search to locate and map these sites. With the knowledge of a species-specific courtship-associated call and probable timing of spawning/sound production, the use passive acoustic can be expanded to locate and map spawning aggregations of other soniferous groupers. Pending results will prove valuable for developing future monitoring, management, and enforcement strategies.

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LITERATURE CITED

Aguilar-Perera, A. 2006. Disappearance of a Nassau grouper spawning aggregation off the southern Mexican Caribbean coast. *Marine Ecology Progress Series* **327**:289-296.

Aguilar-Perera, A. and W. Aguilar-Davilá. 1996. A spawning aggregation of Nassau grouper, *Epinephelus striatus* (Pisces: Serranidae) in the Mexican Caribbean. *Environmental Biology of Fishes* **45**:351-361.

Beets, J. and A. Friedlander. 1992 . Stock analysis and management strategies for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **42**:66-80.

Claydon, J. 2004. Spawning aggregations of coral reef fishes: characteristics, hypotheses, threats and management. *Oceanography and Marine Biology: An Annual Review* **42**: 265-302.

Coleman, F.C., C.C.Keonig, and L.A. Collins. 1996. Reproductive styles of shallow-water grouper (Pisces: Serranidae) in the eastern Gulf of Mexico and the consequences of fishing spawning aggregations. *Environmental Biology of Fishes* **47**:129-141.

Colin, P.L., D.Y. Shapiro, and D. Weiler. 1987. Aspects of the reproduction of two groupers, *Epinephelus guttatus* and *E. striatus* in the West Indies. *Bulletin of Marine Science* **40**:220-230.

Cushion, M., M. Cook, J. Schull, and K.M. Sullivan-Sealey. 2008. Reproductive classification and spawning seasonality of *Epinephelus striatus* (Nassau grouper), *E. guttatus* (red hind) and *Mycteroperca venenosa* (yellowfin grouper) from The Bahamas. *Proceedings of the 11th International Coral Reef Symposium* **22**:994 -998.

Domeier, M.L. and P.L. Colin. 1997. Tropical reef fish spawning aggregations: defined and reviewed. *Bulletin of Marine Science* **60**:698-726.

Fish, M.P. and W.H. Mowbray. 1970. *Sounds of Western North Atlantic Fishes*. Johns Hopkins Press, Baltimore, Maryland USA.

Luczkovich, J.J., D.A. Mann, and R.A. Rountree. 2008a. Passive acoustics as a tool in fisheries science. *Transactions of the American Fisheries Society* **137**:533-541.

Luczkovich, J.J., R.C. Pullinger, S.E. Johnson, and M.W. Sprague. 2008b. Identifying Sciaenid critical spawning habitats by the use of passive acoustics. *Transactions of the American Fisheries Society* **137**:576-605.

Luczkovich, J.J., M.W. Sprague, S.E. Johnson, and R.C. Pullinger. 1999. Delimiting spawning areas of weakfish *Cynoscion regalis* (family Sciaenidae) in Pamlico Sound, North Carolina using passive hydroacoustic surveys. *The International Journal of Animal Sound and its Recording* **10**:143-160.

Mann, D.A., A.D. Hawkins, and J.M. Jech. 2008. Active and passive acoustics to locate and study fish. Pages 279 - 309 in: J.F. Webb, A.N. Popper, and R.R. Fay (eds.) *Fish Bioacoustics*. Springer, New York, New York USA.

Mann, D.A., J.V. Locascio, F.C. Coleman, and C.C. Koenig. 2009. Goliath grouper *Epinephelus itajara* sound production and movement patterns on aggregation sites. *Endangered Species Research* **7**:229-236.

Mann, D.A., J.V. Locascio, M. Schärer, M. Nemeth, and R. Appeldoorn. [In press]. Sound production by red hind *Epinephelus guttatus* in spatially segregated spawning aggregation. *Aquatic Biology*.

Nemeth, R.S. 2005. Population characteristics of a recovering US Virgin Islands red hind spawning aggregation following protection. *Marine Ecology Progress Series* **286**:81-97.

Ojeda-Serrano, E., R. Appeldoorn, and I. Ruiz-Valentin. 2006. Reef fish spawning aggregations of the Puerto Rican shelf. *Proceedings of the Gulf and Caribbean Fisheries Institute* **59**:467-474.

Sadovy, Y. 1994. Grouper stocks of the western central Atlantic: the need for management and management needs. *Proceedings of the Gulf and Caribbean Fisheries Institute* **43**:43-65.

Sadovy, Y. and M. Domeier. 2005. Are aggregation-fisheries sustainable? Reef fish fisheries as a case study. *Coral Reefs* **24**:254-262.

Sadovy, Y., A. Rosario, and A. Román. 1994. Reproduction in an aggregating grouper, the red hind, *Epinephelus guttatus*. *Environmental Biology of Fishes* **41**:269-286.

Shapiro, D.Y., Y. Sadovy, and M.A. McGehee. 1993a. Size, composition, and spatial structure of the annual spawning aggregation of the red hind, *Epinephelus guttatus* (Pisces: Serranidae). *Copeia* **1993**:399-406.

Shapiro, D.Y., Y. Sadovy, and M.A. McGehee. 1993b. Periodicity of sex change and reproduction in the red hind, *Epinephelus guttatus* a protogynous grouper. *Bulletin of Marine Science* **53**:1151-1162.

Walters, S., S. Lowerre-Barbieri, J. Bickford, and D. Mann. 2009. Using a passive acoustic survey to identify spotted seatrout spawning sites and associated habitat in Tampa Bay, Florida. *Transactions of the American Fisheries Society* **138**:88-98

Whiteman, E.A., C.A. Jennings, and R.S. Nemeth. 2005. Sex structure and potential female fecundity in a *Epinephelus guttatus* spawning aggregation: applying ultrasonic imaging. *Journal of Fish Biology*. **66**:983-995.