Modeling a Yellowfin Grouper (*Mycteroperca venenosa*) Spawning Aggregation with Passive Acoustic Telemetry on the Grammanik Bank, St. Thomas, US Virgin Islands

Modelado de una Amarilla Grouper (*Mycteroperca venenosa*) Agregaciones Reproductivas de Acoustic Telemetría Pasiva en el Banco Grammanik, St. Thomas, Islas Vírgenes Estadounidenses

Modélisation d'un Albacore Mérou (*Mycteroperca venenosa*) Frai Agrégation avec Passif Télémétrie Acoustique sur la Banque Grammanik, St. Thomas, Îles Vierges Américaines

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EXTENDED ABSTRACT

Yellowfin grouper (*Mycteroperca venenosa*) form transient Fish Spawning Aggregations (FSAs) from January to May on the Grammanik Bank, St. Thomas, United States Virgin Islands (USVI). Heavy fishing during spawning led to the creation of a seasonal closure from February 1st to April 30th of a 1.5 km^2 area on the Grammanik Bank and of yellowfin grouper in 2005 (Kadison et al. 2011). Diver observations of spawning yellowfin grouper suggests large periods of time are spent outside the Grammanik Bank. The current boundary of the Grammanik Bank seasonal closure is ineffective as the fish are traveling outside of the protected area. If the seasonal ban on the fish is lifted and the current boundary is not redrawn, the yellowfin grouper may be vulnerable. The purpose of this study examines the current boundary of the Grammanik Bank seasonal closure to determine its effectiveness, and proposes management options to increase protection of the yellowfin grouper FSA.

Passive acoustic telemetry was used to determine where the fish are spending their time. From 2007 to 2010 a passive acoustic receiver array using Vemco Vr2 and Vr2W (69 kHz) receivers was maintained on the Hind Bank year round closed area and on the seasonally closed Grammanik Bank (Figure 1). Receivers were attached to lines extending roughly 10m off the seafloor from a concrete base, and data was downloaded with batteries replaced roughly every 8 - 12 months. Vemco V13-1L and V16-4H coded transmitters were implanted into 13 yellowfin grouper; 8 males and 5 females, 4 in 2007, 5 in 2008, and 4 in 2010. The receiver detects the implanted transmitter and records the unique code for each fish and the time of detection (Heupel et al. 2006). By knowing when and how long fish are spending in different areas of the spawning site will allow for the effectiveness of the Grammanik Bank closure to be determined.

To establish a reliable detection range sentinel range testing was analyzed from May to September 2011, and then verified with boat range testing in September 2014. The definition from Kessel et al. (2013) of a detection range, *the probability of detection given the distance between the transmitter and the receiver*, was used. A logistic curve was fitted to the sentinel transmitter data to determine what the detection range distance was given an 80% probability (Starr et al. 2000). The detection range varied by the time of day, as the middle of the day had the highest detection range, while sunset had the lowest. This was accounted for by assigning a corrected detection range to each time the fish was detected based on the time of day.

The sample unit was an individual's first detection to last detection during the monthly spawning aggregation. Of the 13 fish only two returned to the spawning site an additional month, and none were detected consecutive years. The detections and tracks of each fish were plotted and an ellipse was drawn around each receiver or between two receivers with the size determined by the detection range. The time between the detections at each receiver or two receivers was then attributed to the ellipse. Rather than discarding large gaps of missing time, the swim speed of yellowfin grouper was calculated (0.59 m/s), and the maximum distance the fish could have traveled in the missing time was determined and added to the detection range. A grid of 500 x 500 m cells was overlaid on the 10 x 5 km study area clipped by the 100 m depth contour. The ellipses were dissolved into the grid cells, and the total time from each ellipse standardized by the percent of area it covered in each cell was calculated. The proportion of time the fish spent in each grid cell was then found by taking the time in the cell divided by the total time the fish spent at the spawning event.

The end result is a time distribution map showing the proportion of time the fish spent in a location during spawning (Figure 1). Before all 15 instances of spawning were averaged together, the Getis-Ord Gi* statistic, a z-score taking into account spatial weights, was calculated for each grid cell to compare differences among the years and between sexes (Getis and Ord 1992). No differences were detected among the years (Repeated Measure ANOVA, F = 1.39, $p = 0.25$) or between the sexes (Hotelling T^2, $T^2 = 2.12$, Distribution = X^2, $p = 0.145$), and therefore all instances of spawning were averaged together and examined.

The average yellowfin grouper spent close to 15 - 25% of its time near the FSA site, while the rest was spent outside of it. Currently yellowfin grouper only spend 24.9% of their time inside the Grammanik Bank closure, with about half of the time spent outside of a protected area (Figure 1). A short term proposed modification by simply altering the shape and not the area, will increase the time spent in the closed area to 33.1% (Figure 1). This should help reduce by-catch, and prevent trap interference with spawning fish. A long term resizing is recommended for when the seasonal closure of yellowfin grouper is lifted, increasing the time spent in the Grammanik Bank closure from 24.9% to 50.5% (Figure 1). The model provided a useful estimate of where the fish was when not at the FSA site. Future studies may examine what yellowfin grouper are doing when not at the FSA site, as well as examine the temporal effectiveness of the seasonal closure on the Grammanik Bank.

KEY WORDS: Yellowfin grouper, spawning aggregation, passive acoustic telemetry, marine protected areas

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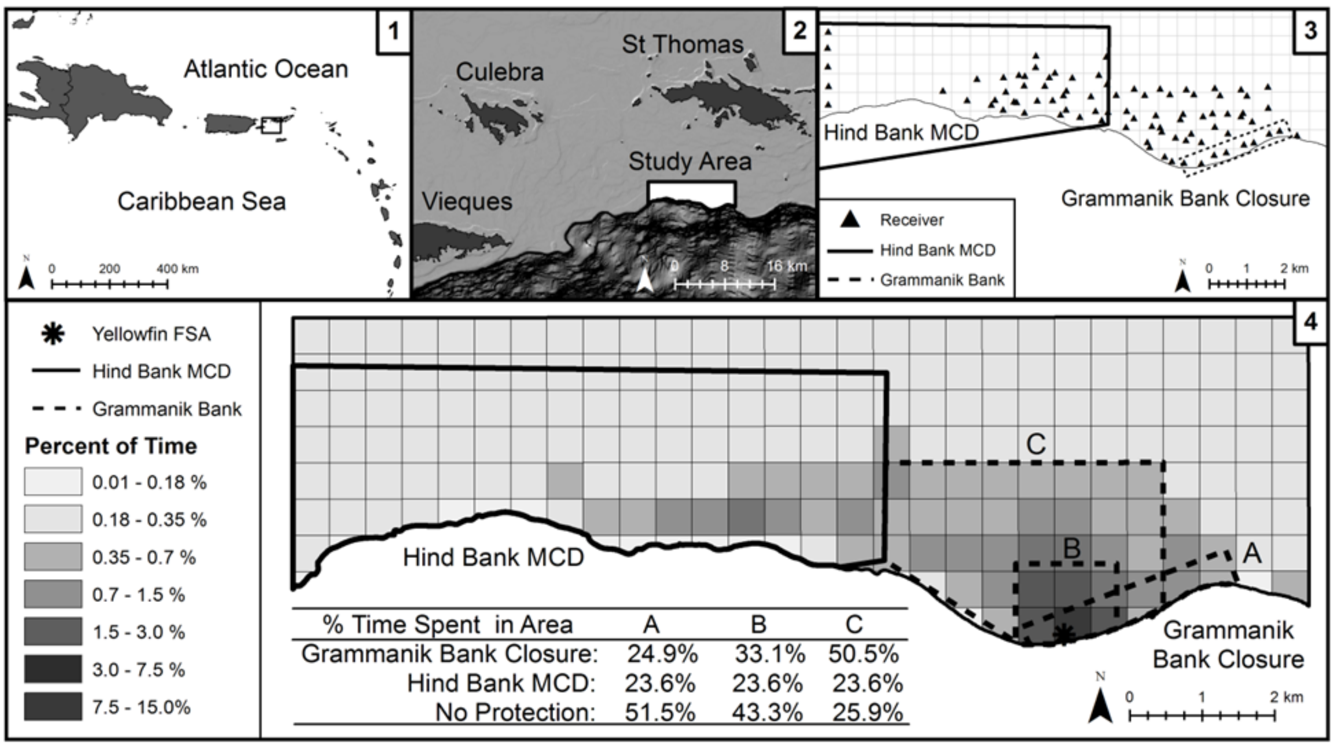

Figure 1. (1) The Grammanik Bank is located in the US Caribbean east of Puerto Rico, (2) and roughly 16 km south of St. Thomas, US Virgin Islands. (3) A passive acoustic receiver array has been present on the both the Hind Bank and Grammanik Bank from 2007 - 2010, with receiver stations added and subtracted from the array. (4) Percent of time the average yellowfin grouper (n = 15) spent in each 0.25 km^2 grid cell; the percent of time spent in each protected area is given in the table for the different proposed boundaries (A = current, B = short term, C = long term).