Broad-scale Movements of Three Species of Reef Fish Within a Marine Protected Area in the U.S. Virgin Islands

Los Movimientos a Gran Escala de Tres Especies de Peces de Arrecife Dentro de un Área Marina Protegida en las U.S. Virgin Islands

Mouvements à Grande Échelle de Trois Espèces de Poissons de Récif dans une Zone Marine Protégée dans les U.S. Virgin Islands

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EXTENDED ABSTRACT

Introduction

The ability to quantify animal movement is fundamental to the understanding of a suite of important individual- and population-level processes that are likely to influence overall fitness and survival (Finn et al. 2014). Almost every process related to animal ecology is intimately linked to movement; including foraging, spawning patterns, dispersal, and migration. Movement patterns can help delineate optimal habitats which reflect both sufficient food availability and a decrease in predation risk (Furey et al. 2013). Essential habitats generally remain understudied for most marine fishes (Boström et al. 2011, Furey et al. 2013), yet are vital for appropriate management decisions.

The implementation of acoustic telemetry in marine environments has provided a new level of resolution to monitoring movement patterns (Humston et al. 2005; Finn et al. 2014), however, longer term (i.e. seasonal and yearly) fine-scale movement patterns are still unknown for most species of fish. A recent advancement in acoustic telemetry uses a closely spaced grid of receivers to triangulate a fish's location providing fine-scale movement resolution (Espinoza et al. 2011; Furey et al. 2013). Outcomes for this type of information include providing data for extremely dynamic systems allowing for optimization of protection measures employed, including the development of location, size, and boundaries of protected areas. In general, there is limited data on quantifying species ranges and habitat use in which to guide future management decisions to ensure a species' persistence (Klein et al. 2015).

Methodologies

Buck Island Reef National Monument (BIRMN) is a MPA managed by the National Park Service (NPS) and located 1.5 km to the northeast of St. Croix, USVI (Smith-Vaniz et al. 2006). The original monument was established in 1961 but the boundaries were significantly expanded in 2001 from 283 to 7339 ha of water. In 2003, NPS implemented interim rules restricting all extractive activities within monument boundaries as well as confining anchoring to specific zones (Pittman et al. 2014). The monument, initially designated to protect one of the finest coral reef ecosystems in the Caribbean, has extensive habitat types distributed in a mosaic patchwork ranging from linear reef, seagrass beds, colonized hardbottom, and sand substrates.

An array of 111 passive acoustic receivers (model VR2W; 69 kHz; VEMCO, Halifax, Nova Scotia, Canada) are installed throughout BIRNM's shallow water habitat as part of a large collaborative acoustic network. Of those 111 receivers, 28 are part of the VEMCO Positioning System (VPS) installed in July 2015. The array is downloaded biannually via SCUBA and free diving by NPS employees and volunteers.

Three species of reef fish, Yellowtail Snapper *Ocyurus chrysurus*, Mutton Snapper *Lutjanus analis*, and Horse-eye Jacks *Caranx latus*, all which serve unique ecological roles within the environment were the focus of this study. All fish were caught inside BIRMN by trolling with typical recreational fishing gear that uses artificial lures and by jigging on a full moon event. Upon capture, fish were visually assessed to ensure they were in the best condition possible (i.e. no physical trauma present, no gut hooking). If this requirement was met, fish were fitted with an individually coded acoustic tag (model V9 or V13, 69KHz, approximate 632-day or 1299-day battery life respectively, VEMCO, Halifax, Nova Scotia, Canada).

Broad scale movements of reef fish were visually analyzed using network analyses methods described by Finn et al. (2014). A bipartite graph was generated for the three fish species with two types of nodes (vertices) representing both the receivers and tagged individuals. The movements of fish between receivers is represented by the connections or edges between those nodes which can be weighted to indicate more use. Additionally, the amount of edges connecting to a certain node is considered the node's degree, where a node that is small has relatively few connections (i.e. a fish that could have a small home range) as opposed to a larger node which has many more connections (i.e. a fish that is making large scale movements). Spatial plots were also produced to assess the actual movements of fish based on placing the receivers in their actual (x,y) locations (Finn et al. 2014). A graph was created for each individual fish to determine if variability was occurring between the same species and across species. Arrows accurately represented the direction of movements to the successive receiver visited. If a fish was detected at the same receiver for two or more consecutive detections a loop back to that receiver is present.

Results and Discussion

Over the course of three separate tagging trips (May 2015, January 2016, and August 2016), a total of 15 yellowtail snapper, 7 mutton snapper, and 8 horse-eye jacks were acoustically tagged. Yellowtail Snapper ranged in size from 21.0 to 35.5 cm (FL) with a mean (±SD) of 29.4 (± 4.02). Mutton Snapper were overall much larger and ranged in size from 31.0 to 61.0 cm (FL) with a mean (±SD) of 51.6 (± 8.36). Only five Horse-eye Jacks were used for this analysis, due to three being recently tagged in August 2016 with no detection history available yet. Horse-eye Jacks ranged in size from 35.5 to 62.0 cm (FL) with a mean (±SD) of 50.5 (±10.4). In total, 27 fish were used for all analyses.

Detection histories for each individual fish varied based on the time they were recorded within the receiver array. For example, four Yellowtail Snapper, two Mutton Snapper, and two Horse-eye Jacks were detected almost every day since the time of release by at least one receiver. In contrast, the majority of individuals showed varying levels of detections over time suggesting a more scattered use of the monument.

The bipartite graph showed a tight clustering of both individual fish and VPS receiver nodes (Figure 1). Most yellowtail snapper (13 out of 15; 87%) showed a high affinity for receivers located within this area. Only seven fish (26%) showed stronger connections to receivers outside of the VPS array. In addition, one Yellowtail Snapper and two Horse-eye Jacks traveled to Lang Bank, an area approximately 10 km outside of the closest BIRNM boundary. These directed movements remain unclear; however, Lang Bank is a known red hind *Epinephelus guttatus* spawning aggregation site (Nemeth et al. 2007).

The spatial movement plots for each fish varied based on species and between individuals. Yellowtail Snapper were predominately detected within the VPS array with some small movements north along the shallow shelf habitat (Figure 2). Individual Mutton Snapper exhibited variable movement patterns, with a few fish showing an identical pattern to the yellowtail snapper. Two individuals showed highly variable movements, with one fish only visiting two receivers and the other fish moving between receivers only located south of Buck Island. Each Horse-eye Jack showed highly variable movements with most fish exhibiting large movements around the entire monument.

The spatial network graphs produced for three species of reef fish shed light into the variability of movement among individuals and between different species. Incorporation of positioning data collected from the VPS will be used to determine specific habitat preference, movement directionality, and timing of movements for these species. Future analytical techniques, including geostatistical mixed models, will be explored and applied to address remaining questions on habitat usage, effects of environmental variables, and interactions between tagged species occupying the same space.

KEYWORDS: Acoustic telemetry, network analysis, reef fishes, marine protected areas

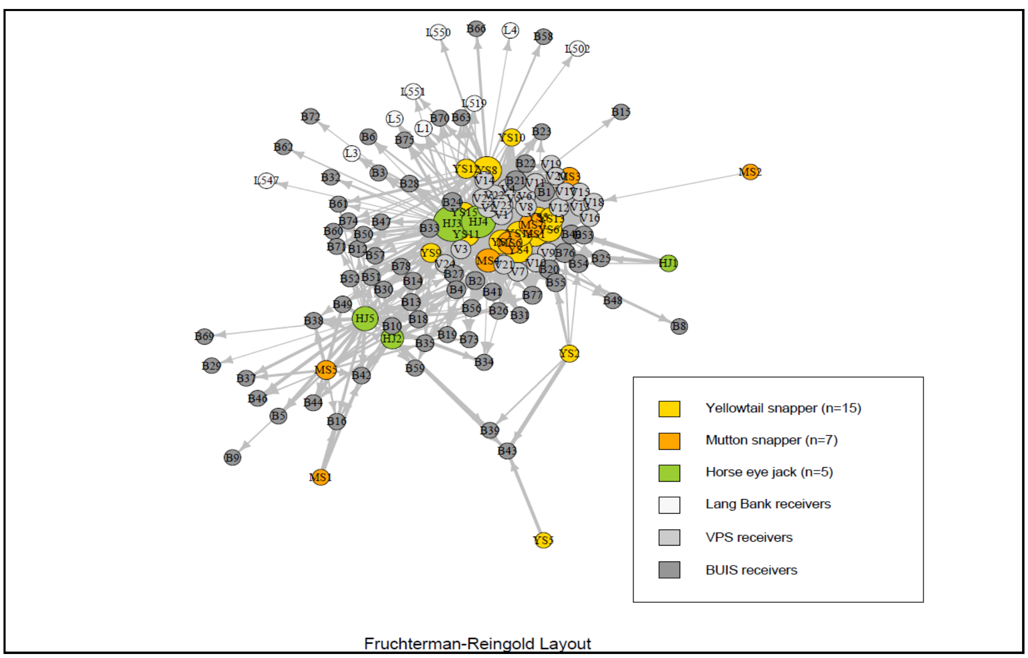

Figure 1. Bipartite graph of three species of reef fish tagged within BIRNM. Data are from May 2015 to May 2016 and have been filtered for simultaneous detections. Receivers have been divided into Lang Bank receiver nodes (outside of the MPA), VPS receiver nodes, and general receiver nodes placed in the broad-scale array (BUIS).

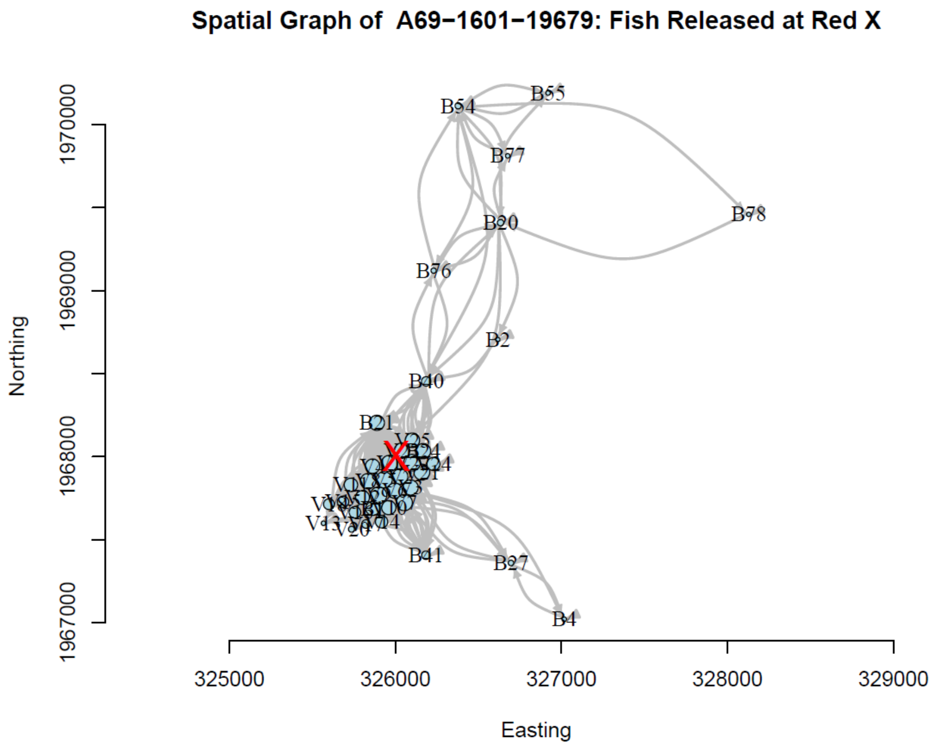

Figure 2. Example spatial movement plot of yellowtail snapper (A69-1601-19679). This individual had a total of 176,638 filtered detections from May 2015 to May 2016. The red X indicates the release location of the fish. Receiver nodes in the VPS are labeled with "V" and the general receivers in the array are labeled with a "B".

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