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Determining conservation potential of an opportunistically defined MPA boundary using fish telemetry

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ABSTRACT

Marine protected areas (MPA) that are created opportunistically must be evaluated in an ecological context to ensure that conservation goals and societal expectations are achievable. This study used acoustic telemetry to investigate movements of reef fish relative to the boundary of the Virgin Islands Coral Reef National Monument (VICRNM) in Coral Bay, U.S. Virgin Islands. Although created to enhance ecosystem protection, VICRNM boundaries were established purely on the basis of adjacency to public versus privately owned lands. Transmitters were implanted into a diversity of reef fish species representative of the local community whose movements were logged for one year on an array of acoustic-receivers that were positioned within, outside, and along the MPA boundary. Results indicate that the boundary has coincidentally aligned with a deep sandy area that does not cross through continuous reef or mangrove habitat. This acted as a natural barrier to movements of species such as *Lutjanus griseus, Epinephelus guttatus*, *Cephalopholus cruentatus*, *Holocentrus rufus*, and *Sparisoma aurofrenatum*. Other species were more mobile and were routinely detected outside VICRNM, especially at night, such as *L. synagris, Haemulon plumierii,* and *H. sciurus.* In addition to fish movements in relation to the VICRNM boundary, network analysis revealed several hotspots of concentrated fish activity including a reef promontory and bay mouths. Investment in enforcement of existing regulations to protect fish is warranted to realize the full potential of this MPA. Using these types of data, management actions in this and other MPAs can be focused on those species and locations that would experience the greatest benefit.

1. Introduction

Despite the multitude of analytical tools and theoretical recommendations now available to guide the design of marine protected areas (MPA), many are still created opportunistically where ease of designation plays the lead role in their inception (Agardy et al., 2011; Devillers et al., 2015). Such MPAs can perform as intended, but must be carefully evaluated to ensure that conservation goals and societal expectations are achievable (Knight and Cowling, 2007; Monaco et al., 2007; Day, 2008).

The Virgin Islands Coral Reef National Monument is one such area (hereafter VICRNM, or the Monument). Located in the northern Caribbean Sea in the US Virgin Islands, it was created in 2001 by Presidential Proclamation 7399 (2001) to expand the protected area of marine ecosystems around the island of St. John under the management of the National Park Service (NPS). The Proclamation defines ecosystem broadly and includes all of the interdependent organisms as well as the interconnected habitats necessary to sustain them. The boundary of the Monument however, is based entirely on land ownership records and the political opportunity offered by the Territorial Submerged Lands Act (1974). The Act transferred submerged areas within 3 n mi of shore from federal to territorial control, excluding "all submerged lands adjacent to property owned by the United States". This federal ownership of land and the adjacent submerged parts of Coral Bay area of St. John made it possible to convert them to National Monument status. Public and private land ownership records around Turner Point placed the boundary separating federal versus territorial control along the midlines of two smaller bays within Coral Bay, Hurricane Hole and Round Bay (Johnson and Thormahlen, 2002) (Fig. 1). The boundary ranges from ~0.25 to 1.25 km from shore. Therefore, although created to protect a marine ecosystem, ecology was never actually considered when the geographic boundaries of the Monument were established (Monaco et al., 2007). The Presidential Proclamation 7399 (2001) further states that the boundaries are "the smallest area compatible with the proper care and management of the objects to be protected", including the reef fish that reside within it. This study investigates the

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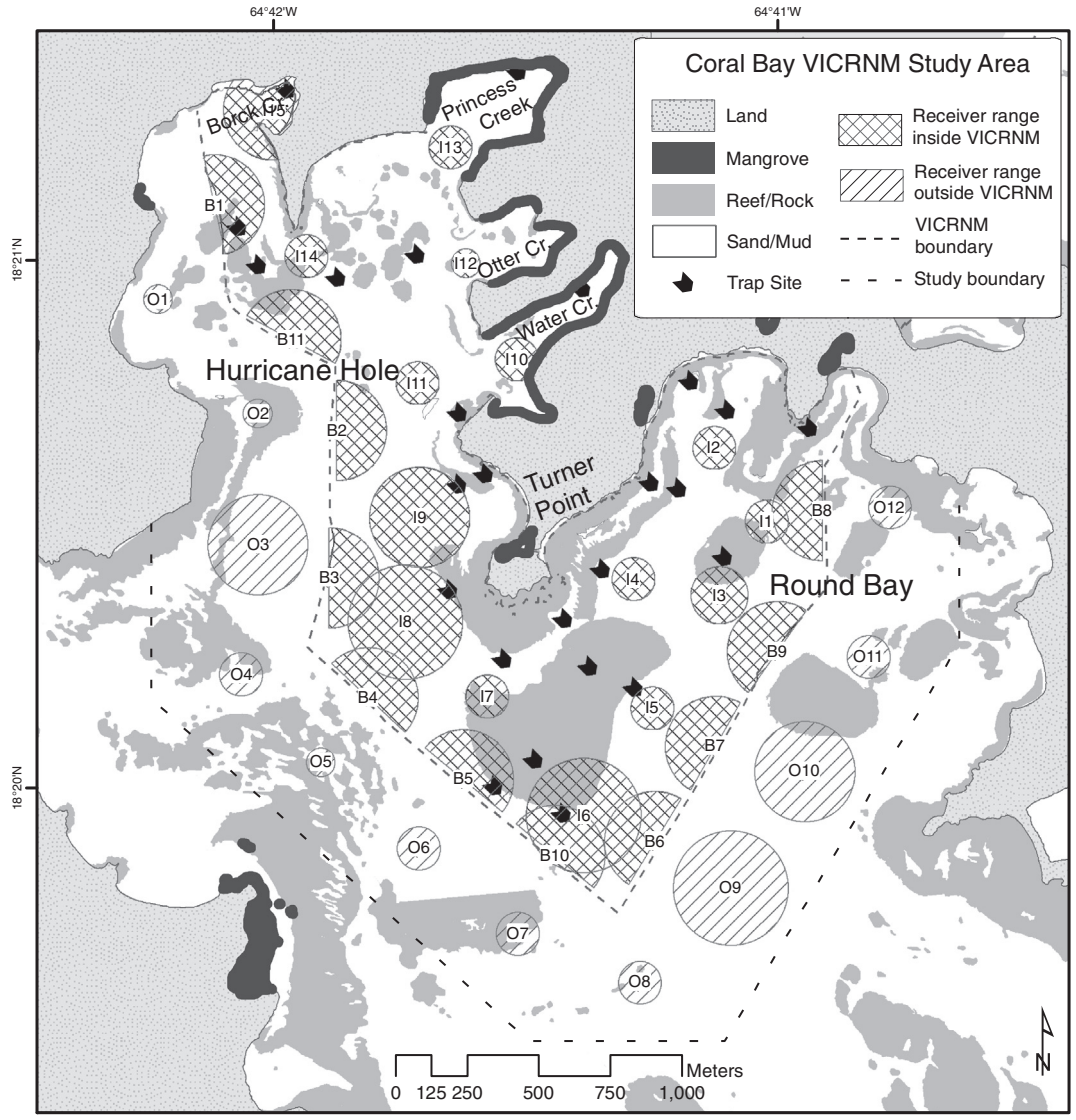

Fig. 1. Coral Bay portion of the VICRNM. Caribbean Sea, St. John US Virgin Islands.

movements of reef fish relative to the boundary of the Coral Bay portion of the Monument and evaluates its potential for reef fish protection.

The study area consists of mangrove-lined bays with scattered seagrass, sand and mud bottoms, fringing and patch reefs, rocky promontories, pavements, and spur and groove reefs (Costa et al., 2013) (Fig. 1). Biodiversity in this area has among the highest values throughout St. John and especially large numbers of several snapper (Lutjanidae) and grunt (Haemulidae) species reside there (Boulon, 1992; Friedlander et al., 2013b). Apart from permitted gathering of bait fish, all forms of extractive use as well as anchoring and tying to mangroves are prohibited (Presidential Proclamation 7399, 2001). Despite added protections, reef fish populations in the Virgin Islands have continued an overall decline (Rogers and Beets, 2001; Pittman et al., 2014b).

Many species of reef fish present in Coral Bay move among habitats during various phases of their life history. Many snappers and other species are known to utilize seagrass and mangroves as juveniles but then shift to coral reefs once they grow larger (Gratwicke et al., 2006; Huijbers et al., 2015). Several snapper and grunt species are known to undergo nightly migrations of several hundred meters from reefs to forage in adjacent sand habitats (Beets et al., 2003; Kendall et al., 2003; Luo et al., 2009; Hitt et al., 2011). Reef residents have diverse home range sizes that may take them across 10–100's of m of continuous reef (Kramer and Chapman, 1999; Pittman et al., 2014a). Transient species including many jacks and sharks range even more widely among habitats on a daily basis (Wetherbee et al., 2004; Brown et al., 2010; Friedlander et al., 2013a). Less frequently, lunar- or seasonal-migrations take place for reproduction or foraging (Nemeth et al., 2007; Afonso et al., 2009; Luo et al., 2009; Pittman et al., 2014a). Each of these movement behaviors has the potential to temporarily or permanently relocate fish outside of the protected confines of the VICRNM boundaries. The timing and frequency of these movement behaviors relative to the local landscape, dimensions, and configuration of the VICRNM boundary in Coral Bay are unknown.

Acoustic telemetry is an effective tool for quantifying habitat utilization patterns, home range size, site fidelity, migration pathways, MPA boundary crossing, and the timing of such movements for marine fish (e.g., Wetherbee et al., 2004; Heupel et al., 2006; Garcia et al., 2014; Pittman et al., 2014a). In this approach, an acoustic transmitter that emits a unique identification code is implanted into a fish of interest. The fish's movements are logged on an array of acoustic receivers that are strategically positioned throughout the fish's ecosystem to track the location and timing of the fish's activity.

The objective of this study was to monitor movements of reef fish relative to the opportunistically drawn boundary of the Monument. Specifically, we sought to quantify residence patterns of reef fish