Caribbean-wide Geospatial Analysis of the Location of Transient Reef Fish Spawning Aggregation sites using remote sensing

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ABSTRACT

Most large Caribbean reef fish species form transient spawning aggregations at specific times and locations. Though reef fish spawning aggregation sites from many areas have been described and mapped, there has been no comprehensive geospatial analysis of the similarities and differences among them. The aim of this study was to analyze the locations of all known transient reef fish spawning aggregation sites in relation to 1. shelf edges and 2. reef bending points using remote sensing and field-collected position data. Our analysis includes both published and previously unpublished data from the Bahamas, Belize, the Cayman Islands, Cuba, Mexico, Puerto Rico, Honduras, the Turks and Caicos Islands, and the Virgin Islands. Satellite-derived images of coral reef environments can receive the bottom reflectance in the depths up to 30 meters in clear water. The locations of many spawning aggregation sites are visible in these images, while some are deeper. To test our assumption that location of shelf edges could be fairly delineated using satellite images, we compared the positions of shelf edges from field-collected data, to shelf edges derived from satellite images. This study forms part of an ongoing project focusing on the geomorphologic, geospatial, and oceanographic aspects of transient reef fish spawning aggregation sites.

KEYWORDS: transient spawning aggregation, shelf edge, geospatial analysis, remote sensing

Análisis Geoespacial en la Región Caribeña de Localidades Transitorias de Agregaciones de Desove de Peces de Arrecife usando Teledetección.

La mayoría de especies de peces del caribe se agregan para desovar a horas y lugares específicos. A pesar de que los sitios de agregación para desove de estos peces han sido descritas y mapeadas, un análisis geoespacial extenso de las similitudes y diferencias entre ellos hace falta. La finalidad de este estudio fue la de analizar las localidades de todas las agregaciones de desove de especies de peces de arrecife transitorias en relación a 1. límite de plataforma y 2. puntos de flexión del arrecife, usando teledetección y data de posición recolectada en campo. El análisis incluye data publicada, como también, data no publicada previamente de los siguientes países: Bahamas, Belice, Islas Caimán, Cuba, Méjico, Puerto Rico, Honduras, las Islas Turku y Caicos, y las Islas Vírgenes. Imágenes derivadas satelitalmente de entornos de arrecifes de coral pueden recibir el fondo reflectante hasta la profundidad aproximada de 30 mts. en aguas claras, y la localidad de varias áreas de agregaciones de desove son visibles en estas imágenes, mientras que algunas son más profundas. Para probar nuestra asumpción de que los bordes de las plataforma podrían ser equivocadamente delineados usando imágenes satelitales, se comparó la data colectada en campo, de las posiciones de las localidades actuales de los bordes de las platafomas, con la data derivada de imágenes satelitales. Luego se evaluó la localidad de cada agregación de desove en relación con la de bordes de plataforma, como también la de los puntos de flexión del arrecife. Este es un proyecto en desarrollo que se enfoca los aspectos geoespaciales, geomorfológicos y oceanográficos de los lugares de agregación de desove de los peces de arrecife transitorios.

PALABRAS CLAVE: agregaciones de desove, transitorio, borde de plataforma, análisis geoespacial, teledetección

INTRODUCTION

Many commercially important fishes, including groupers and snappers, aggregate at the same few common spawning sites throughout their own spawning seasons. These aggregations generally form at sites with specific reef geomorphologies. Though the type of reef area may vary by geographic location, in many cases these sites are located on the outer edges of reefs (Koenig *et al*. 2000, Heyman and Requena 2002, Claro and Lindeman 2003), where favorable conditions encourage egg survival and larval dispersal (Johannes 1978, Colin 1992). Several aggregations have been observed on these reef promontories (Munro *et al.* 1973, Johannes 1978, Colin *et al*. 1987, Heyman and Requena 2002).

Reef promontories in the Caribbean are not the only suitable location for spawning aggregations. Aguilar-Perera (1996) commented that an aggregation site off Mahahual, Mexico was located at the forereef, with the shelf edge 500 m seaward. Colin (1992) noted spawning sites in both reef flats and along shelf edges in Bahamas. The type of reef area used by spawning aggregations in the greater Caribbean seems to vary but the geographical variability and geomorphology of spawning aggregation sites have not been studied well.

The goal of this study is to identify the locations of transient reef fish spawning aggregations in relation to reef geomorphologies in the greater Caribbean. Shelf edge lines were delineated using remote sensing and field-

collected position data in order to analyze the position of aggregation sites in relation to shelf edges and reef bending points.

Remote-sensing is a useful tool for monitoring and assessing coral reef environments. Satellites can successfully capture images of bottom reflectance of coral reef environments in depths up to 30 m in clear water. As a result, the locations of many spawning aggregation sites in the Caribbean are visible in these images.

METHODS

The Society for Conservation of Reef Fish Aggregations (SCRFA) provides a global database of reef fish spawning aggregations based on published documents (http://www.scrfa.org). This database provided geospatial information for The Bahamas, Belize, the Cayman Islands, Cuba, Mexico, Puerto Rico, Honduras, the Turks and Caicos Islands, and the Virgin Islands. The original references used for the database were carefully reviewed to derive the relationship between species and the geomorphology of their preferred spawning habitat at each documented location.

Shelf edges were delineated through a digital image processing of satellite images. Multi-spectral Landsat imagery data with 30 m spatial resolution were downloaded from the Millennium Coral Reef Mapping project archives (http://oceancolor.gsfc.nasa.gov/cgi/landsat.pl). All images were classified using RSI ENVI software into three categories: land, shallow water area, and deep water area through the ISODATA unsupervised classification process. This classification method groups pixels into distinct clusters based on similar spectral reflectance. Water absorbs infrared and red bands at the surface layer, making it relatively simple to distinguish between land and sea. The difference between shallow and deep water areas is based on visible bands: how much light is reflected from the water column and the bottom. In deep water, light can penetrate deeper than 30 m, but may not reflect back up towards the sky. As part of the post-classification process, similar features were clumped and all grid data were converted into a polygon vector file. The classified image was edited for clouds and the shelf edge lines were derived from this vector file using ArcGIS.

The locations of 14 spawning aggregation sites in Belize were collected by field sampling using a hand-held GPS. Bathymetric data were collected using a Lowrance LCX-17M echosounder at two sites in Belize. All points data representing latitude, longitude and depth were imported into ArcGIS and used for creating a triangulated irregular network (TIN) based bathymetry (Heyman *et al*. 2007). Slope of the reef was calculated from the bathymetric data. The slope and depth data were then overlaid onto image channels, from which the maximum discernible depth was determined to be 25 to 30 m, depending on location.

RESULTS AND DISCUSSION

There are 131 out of 134 spawning aggregation records in the database reported to aggregate at or near the shelf edges (www.scrfa.org, accessed 15 May 2006). In Belize, all known spawning aggregation sites were located at shelf edges. These results were used to validate the remote-sensing-based shelf edge lines.

The 12 Belizean spawning aggregation sites within Turneffe Islands Atoll (4 sites), Lighthouse Reef Atoll (5), Glover's Reef Atoll (2) and Gladden Spit (1) were overlaid onto the derived shelf edge lines' layers. These point data of aggregation sites went across the remote-sensing based shelf edge lines (Figure 1).

Eleven out of 12 spawning aggregation sites were on or near (50 ± 51 m) remote-sensing-based shelf edge lines. One exception was the site at Caye Bokel, southern Turneffe Atoll. The spawning aggregation site was 400 m off the remote-sensing based shelf break line. This is because this area had a lot of sediment, increasing turbidity and decreasing light penetration depth. As a result, light could not reflect off the bottom and the site was misclassified as deep water and thus it required more manual contextual editing to reassign a group of misclassified pixels to an adequate category.

According to bathymetric data for the Halfmoon Caye and Gladden Spit sites, the shelf drop-off, where the slope increased dramatically (30 – 80 degrees) was found within a 100 m of both the spawning aggregation sites and the derived shelf edge lines. The depths of the spawning aggre-

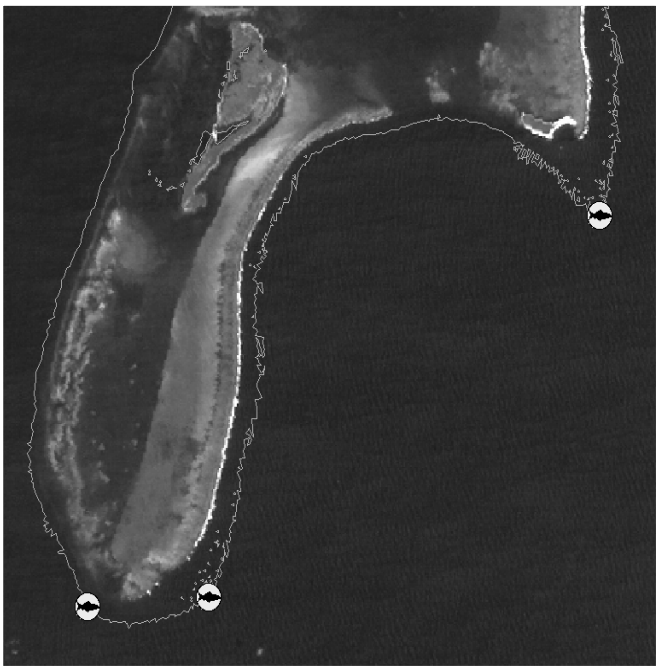

Figure 1. Shelf edge lines derived from remotely-sensed image for the southern Lighthouse Reef atoll. Fish marks indicate spawning aggregation sites.

gation in both sites were between 25 – 30 m. These also indicate that the remote-sensing based lines suitably fit the shelf edges.

Remote-sensing based shelf edges and bathymetric map information are helpful to identify geomorphologic features of spawning aggregation sites, including water depth, distance from the shelf edges, and the shape of the shelf. This methodology can be applied to the other region to understand the difference or similarities among spawning aggregation sites.

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