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Short communication

A comparison of diver vs. acoustic methodologies for surveying fishes in a shallow water coral reef ecosystem

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ABSTRACT

Studies show worldwide declines in coral reef community health and fish density, however, evidence of decline on limited spatial scales may mask reef-wide patterns. New methods are necessary to investigate reef communities at greater spatial and temporal scales. We examined fish densities derived by concurrent diver and acoustic surveys on a series of linear relict reef lines in southeastern Florida, USA. Fish density estimates displayed differences in magnitude, but similar patterns across independent sampling units. Estimates of fish lengths derived by both methods suggest that a seasonal increase in size occurred across the surveyed reefs. The efficacy of diver-based surveys declined with increasing visibility, while acoustic survey results remained insensitive to changes in water column visibility. Results between survey methods correlate statistically, suggesting that studies may utilize combined methods to investigate fish density distributions on large spatial scales not typically examined.

1. Introduction

Increasingly common anthropogenic pressures including eutrophication, sediment loading, and rising global temperatures have led to severe declines in coral reef health that are concomitant with declines in fish density (Hoegh-Guldberg et al., 2007). However, minimal spatial resolution of current methodologies that use diver surveys to quantify fish and coral densities has limited our ability to extrapolate these results to larger spatial scales (Andrefouet and Riegl, 2004). Given the economic and ecological value of coral reefs and the increasing emphasis being placed on scientifically-informed resource management, it is critical to complement current methods of spatially-intensive diver surveys and explore new methodological approaches that will allow for more coverage in an effort to minimize uncertainty associated with sampling approaches.

Data from diver surveys provide detailed insight into estimated fish length distributions, species compositions, and both abiotic and biotic reef characteristics (Carr et al., 2013). However, due to highly variable water quality and visibility, limited bottom time, and logistical difficulties in surveying large reef areas, current methods may result in evidence of fluctuating fish community health that may not be representative of entire reef tracts (Harvey et al., 2002; Irigoyen et al., 2013). Acoustics offer a rapid and non-invasive alternative method to collect spatially-explicit, high-resolution biological data across large areas of reef. Subject to their own biases, such as an acoustic "dead zone", and difficulty in partitioning survey data to relevant taxonomic levels, studies using acoustics often emphasize a need to combine methodologies. This is evident in studies without accompanying diver surveys having potentially "suspect" conclusions in estimates of population sizes (Ehrhardt and Deleveaux, 2007; Colin, 2012). The use of diver surveys as an acoustic ground truthing tool could ease the logistical constraints of using divers to describe large areas of reef, while offering in acoustic results the same confidence afforded to traditional surveys (Guillard and Verges, 2007).

In this paper, we compare the results of a series of concurrent observations between traditional diver-based and acoustic surveys in a coastal coral reef ecosystem in southeast Florida. Specifically, our objective was to compare fish density estimates from each method and examine variation in fish density based on different reef characteristics (e.g. depth, visibility). Local factors including proximity to sources of estuarine mixing and spatially distant, but structurally similar linear reef tracts, were also investigated.

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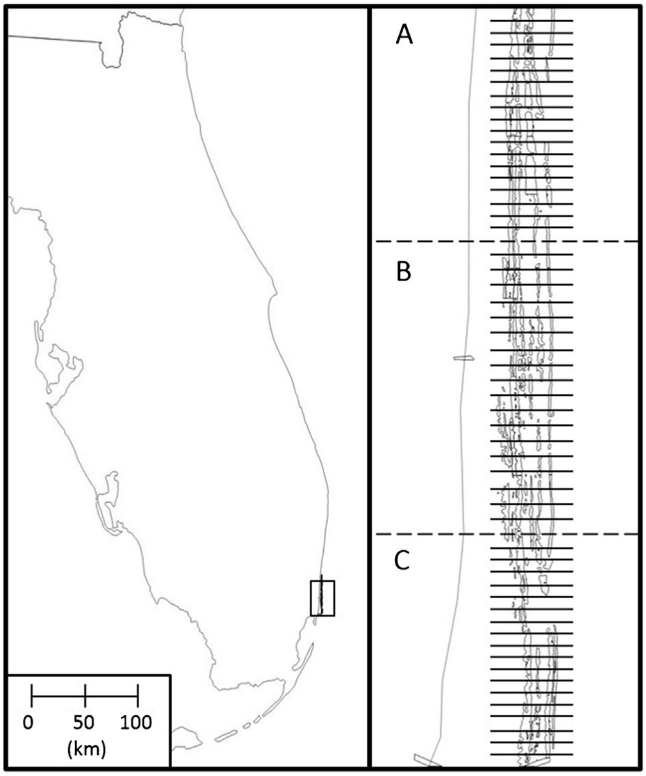

Fig. 1. Range of survey strata in southeastern Florida. Benthic reef maps courtesy of SEFCRI (2011).

2. Methods and materials

2.1. Study site

The study area ranges south of Port Everglades in Fort Lauderdale (26.033°N, −80.073°W) to north of Government Cut, near South Miami Beach (25.779°N, −80.063°W) (Fig. 1). The study area included a series of Holocene relict reefs in this region, including ridge complex, inner, middle, and outer linear reef components (Sathe et al., 2008). For the purposes of this study only the three reef tracts classified as “linear” (Fig. 1) were surveyed, as structural similarities allowed for the most direct observations of community changes.

A random stratified sampling design was implemented, dividing 3 strata such that on a single survey day, 6 transects within each strata could be randomly selected out of a total of 18. (Fig. 1; A. Northern strata; B. Haulover Inlet; C. Southern strata). One transect per reef, per day was ran, such that a total of 6 reef line sites could be surveyed each day. To complement acoustic surveys, during each day, two of the six acoustic transects were randomly surveyed by divers conducting a modified visual census technique, in which the survey diver remained stationary in the center of a 7.5 m radius cylinder to record fish species, estimated length, abundance, and several reef characteristics of interest (e.g. live coral cover, algal cover, depth, visibility, etc) (Smith et al., 2011). In the interest of comparability to acoustic data for spatial distribution and length analysis, small (<10 cm) and cryptic benthic species that would not be easily detected by acoustic methods were eliminated from the comparison analyses. However, for the creation of histograms comparing frequency of length detections by both survey methods, and when comparing the total average lengths of fishes, all fish detections were included.

To control for temporal variation, all diver-based surveys and acoustic transects were conducted on the same day, with at least 30 min between each method to normalize fish behavior. Surveys ran from August of 2013 through March 2014 with each strata surveyed twice per month, for a total of 42 acoustic transects complemented by diver surveys. Acoustic data were collected using a calibrated SIMRAD EK60 scientific echosounder system operating a 38 kHz split-beam transducer (Foote et al., 1987). The echosounder system was configured to transmit at the maximum ping rate (pings s^{-1}), with a pulse duration of 0.256 ms, and power setting of 450 W. Vessel position was recorded using a WASS-enabled USB Garmin GPS unit that was corrected for positional offsets from the face of the transducer. The survey vessel was operated at an average speed of 2 m s^{-1} east to west across all three linear reefs on a randomly selected substrata transect.

Acoustic data were manually inspected and post-processed in Echoview 6.1 (Sonar Data Pty., Ltd.). An analysis threshold of −55 dB was applied to the volume backscattering (S_V) data in addition to a bottom detection algorithm to remove reverberation and unwanted acoustic backscatter. Additional manual inspections removed any remaining undesired data and the echograms were binned into 2.5 m horizontal by 2.5 m depth analysis cells. Infrequent school detections resulted in a survey site or transect falling above the third quartile within site data. Therefore, schools were excluded in both acoustic and diver survey data.

Acoustic fish density estimates were calculated by using the backscattering cross-section ($\sigma_{bs;}$ MacLennan et al., 2002) and average target strength (TS) values [$TS = 10{*}\log_{10}(\sigma_{bs})$] of single targets detected on a reef site (Eq.(1)). The area backscattering coefficient, s_a [$s_a = \int_{z1}^{z2} Sv * dz$], was then used to calculate fish densities (fish m^{-2}) over a reef as described in MacLennan et al., 2002 (Eq.(2)).

$$\sigma_{bs} = 10^{(TS/10)} \quad (1)$$

$$\text{Fish}\,m^{-2} = s_a/\sigma_{bs} \quad (2)$$

Finally, fish lengths estimated acoustically were derived by using the average TS values of single targets within each 2.5 m by 2.5 m analysis cell. Length estimations were obtained following the generalized equation for teleosts described by Love (1977). It should be noted that Love’s equation is highly generalized, and all reported lengths derived from the acoustic data represent estimates of length.

2.2. Density and length analysis

Fish density derived from both acoustic and diver-based methods were transformed to their root form to normalize residuals and meet the assumptions of a Generalized Linear Model (GLM). A GLM using type III sums of squares was then used to test for significance of dependent variables including water depth, reef tract (first linear, second linear, third linear), algal cover (% area), strata (North, Haulover Inlet, South), visibility, and live coral cover (% area). The most parsimonious models were obtained through a stepwise removal of factors that did not significantly explain variance. To examine differences in density between reef tracts, a one way ANOVA was applied to both diver and acoustic estimates of density. A one way ANOVA was also used to determine differences between average depths of each reef tract. Pairwise comparisons were performed with Tukey’s post hoc tests, and estimates are reported as mean and standard error (mean ± s.e). A linear regression was used to explore the relationship between visibility and density estimates by acoustics and diver methods. Finally, a linear regression on diver and acoustic density estimates was conducted to investigate the relationship between the two derived density