

Evaluation of Two Habitat Complexity Metrics and Their Relationship with Fish Abundance and Diversity

Evaluación de Dos Métricas de Complejidad de Hábitat y su Relación con la Abundancia y Diversidad de Peces

Évaluation de la Métrologie de la Composition et de la Qualité de l'Abondance et de la Diversité des Espèces

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EXTENDED ABSTRACT

It has been demonstrated throughout the literature that many reef species demonstrate strong associations with specific habitat types (Roberts and Ormond 1987, García-Charton and Pérez-Ruzafa 2001, Almany 2004, Gratwicke and Speight 2005). Despite what appear to be strong relationships between fish and habitat, with a few exceptions, single habitat composition variables (e.g. % coral coverage) collected in the Southeast Area Monitoring and Assessment Program (SEAMAP) reef fish video survey (RFV) of the Gulf of Mexico (GOM) are rarely significant in Generalized Linear Mixed Models used to estimate abundance indices (e.g. Delta Log-Normal). Other studies have demonstrated a lack of explanatory capacity associated with underlying micro-habitat data even for species with strong habitat associations such as Pomacentrids (Wilson et al. 2008). Additionally, there is evidence that habitat complexity variables, such as rugosity, have shown strong relationships to fish abundance and diversity (Roberts and Ormond 1987, Kuffner et al. 2007).

One of the most common approaches to evaluating habitat complexity is to measure rugosity which is defined as the true surface area divided by the geometric surface area and captures fine-scale variations in amplitude over a defined area or transect (Kuffner et al. 2007). Common observations show that increasing rugosity is positively related to fish abundance and diversity. For video-based sampling tools directly measuring rugosity is often not possible without either bathymetric maps or by deploying stereo-cameras that can be used to range habitat features and get coarse measurements of rugosity. In lieu of direct measurements of rugosity a different approach is to scale habitat-complexity by ranking the observed scene complexity (Wilson et al. 2007). This method is a relatively quick way to annotate data and scale habitat complexity but scaling metrics need to have clearly defined methods and thorough quality control measures to deal with observer bias. While the visual habitat complexity ranking method is to compile during annotation, it may be too time intensive to create for long time series with thousands of historical video drops. In those cases there is some potential to use existing habitat data to calculate habitat complexity metrics without having to annotate historical videos.

The intent behind this investigation is to make use of a subset of video from the SEAMAP-RFV survey of the GOM to compare a visual habitat complexity metric with the automated habitat diversity metric derived from historic habitat annotations. This analysis will focus on data collected at the Florida Middle Grounds (FMG), and The Elbow (TE) which lie at the center of a productive snapper-grouper fishery of the eastern GOM and host a diverse assemblage of pelagic and demersal fish (Pierce and Mahmoudi, 2001). Survey design and information on cameras and deployment methods follow standard protocols described in detail in Campbell et al. (2015). Video annotation procedures identify all fish to the lowest taxonomic level possible using the MaxN method (Ellis and DeMartini 1995). In addition percent coverage of generic habitat types has been tracked since the inception of the survey and includes data on composition of sand, shell/gravel, rock, attached epifauna, grass, sponge, algae, hard coral, soft coral, and seawhips. In addition, average and maximum relief (m) at the site was estimated.

Two separate habitat complexity metrics were generated and tested. The first habitat complexity metric was created by ranking the habitat on a scale of 1-5 (HCR, Figure 2). Habitats of rank 1 were low relief (< 0.5 m) and had no accompanying features such as epifauna (e.g. seawhips and soft coral). Habitats of rank 5 featured high relief (> 3 m), had high rugosity (e.g. craggy), and featured supplemental epifauna (e.g. seawhips and soft coral). The second habitat complexity metric utilized the previously mentioned habitat variables except the two relief measurements. Each habitat variable was turned into a Boolean value where presence (minimum of 1% coverage) was considered present (i.e. 1). Those values were then used to calculate a Shannon-Wiener diversity value (H') the value of which is used as the measure of habitat complexity (HCD).

Relationships between total fish counts and the habitat complexity metrics were tested using generalized additive

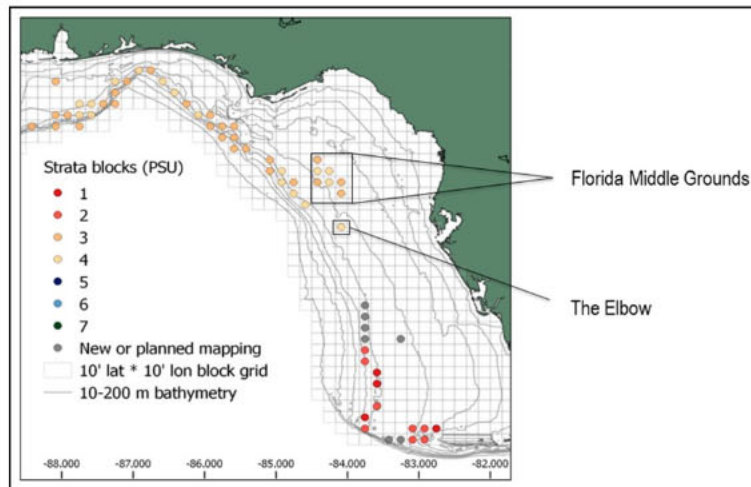


Figure 1. Map of the eastern Gulf of Mexico including our selected sampling blocks in the Florida Middle Grounds and The Elbow that were utilized in the analysis.

models (GAM) in the mgcv package of the R statistical package (CRAN R project). Models were formulated as: Abundance/Diversity \sim s (max relief, habitat complexity). Two models were run per for each habitat complexity metric (HCR and HCD) and for each reef (Table 1). In all cases model fit was evaluated by using the gam.check function in the mgcv package to generate QQ plots and other diagnostics. Biplots of the GAM output were generated using the vis.gam package to visually interpret results.

Results from the GAM analyses show that in general, both habitat complexity metrics were effective at explaining the observed trends in total fish counts and fish diversity. In all cases the observed trends in both fish abundance and fish diversity were positively correlated with habitat complexity and maximum relief. This result

was not unanticipated given that the relationship between complexity and reef fish abundance and diversity have been strongly linked in other studies (Roberts and Ormond 1987, Friedlander and Parrish 1998). In general the models developed for TE explained more deviance and had better r^2 values than those estimated for the FMG. Evaluation of the utility of habitat complexity metrics (HCR, HCD) showed that within a reef the models were estimating similar percent deviance explained values. Thus both HCD and HCR were equally effective metrics to explain increases in fish diversity and abundance.

One discernible difference is that for the HCD metric at TE the response surface for both abundance and diversity models are flattened at low complexity and low relief in contrast to the HCR responses (Figures 3 and 4). We surmise that this difference is likely due to the

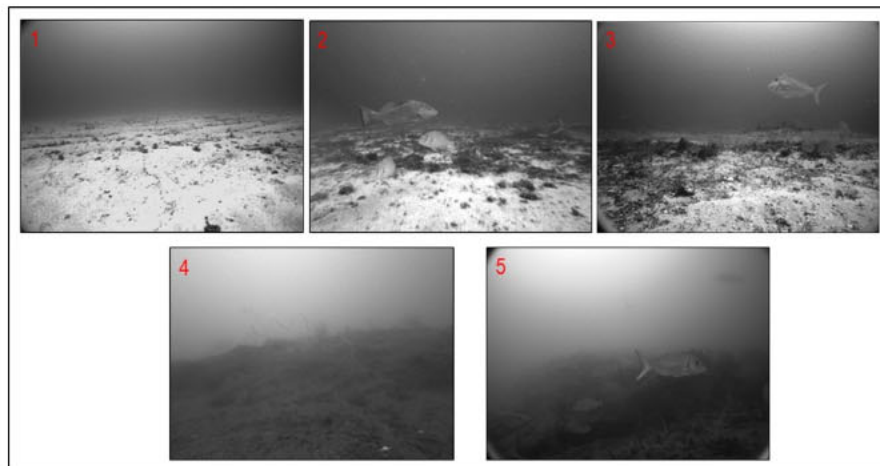


Figure 2. Example imagery of ranked habitat complexity (HCR) from least complex (1) to the most complex (5). The HCR scores integrate both the bathymetric and biotic complexity into a single value and can be thought of as a visual complexity metric.

Table 1. Abundance and diversity GAM model output for the Florida Middle Grounds (FMG) and The Elbow (TE) using either the rank (HCR) or the diversity (HCD) habitat complexity metrics.

| Model | Habitat Complexity Metric | n | Intercept | Maximum relief | Habitat complexity | s(maximum relief, habitat complexity) | Deviance explained | r ² |
|---------------|---------------------------|----|-------------|----------------|--------------------|---------------------------------------|--------------------|----------------|
| Abundance FMG | HCR | 72 | <2e-16 *** | - | - | <2e-16 *** | 20.9% | 0.21 |
| | HCD | 72 | <2e-16 *** | - | - | <2e-16 *** | 16.3% | 0.15 |
| Abundance TE | HCR | 13 | 0.05 | 0.002 ** | 0.0026 ** | - | 23.8% | 0.3 |
| | HCD | 13 | <2e-16 *** | - | - | 3.5e-11 *** | 32.3% | 0.24 |
| Diversity FMG | HCR | 72 | 8.5e-13 *** | - | - | 1.3e-09 *** | 7.4% | 0.06 |
| | HCD | 72 | <2e-16 *** | - | - | 1.7e-07 *** | 6.1% | 0.05 |
| Diversity TE | HCR | 13 | 2.4e-07 *** | 0.0003 *** | 0.0004 *** | - | 35.9% | 0 |
| | HCD | 13 | 5.6e-08 *** | - | - | 3.8e-10 *** | 34.7% | 0.45 |

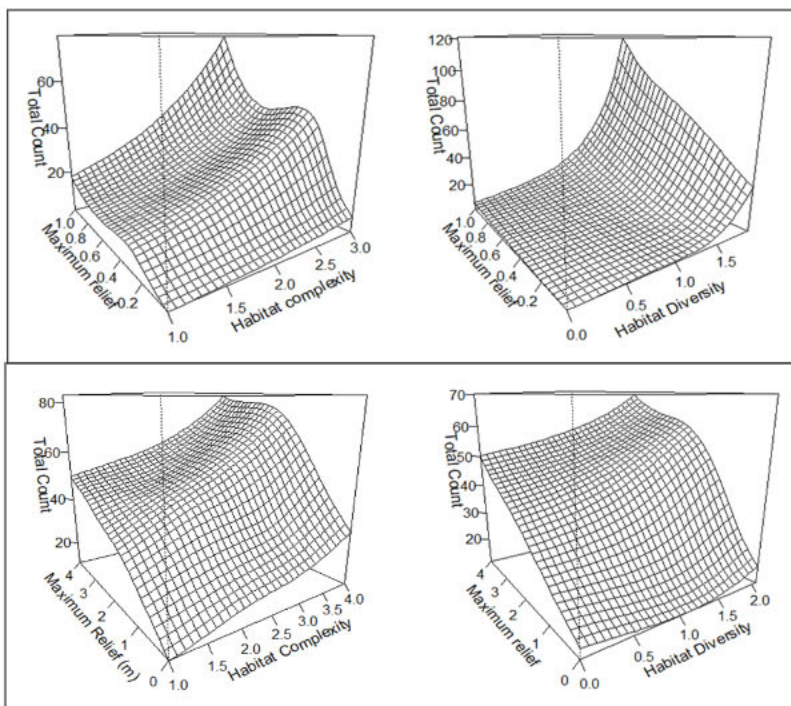


Figure 3. Biplots showing the relationship between habitat complexity (rank), maximum relief (m) and total fish abundance observed at The Elbow (top panels) and the Florida Middle Grounds (bottom panel). Left and right panels demonstrate the difference between using the habitat complexity rank (HCR) versus the habitat diversity metric (HCD).

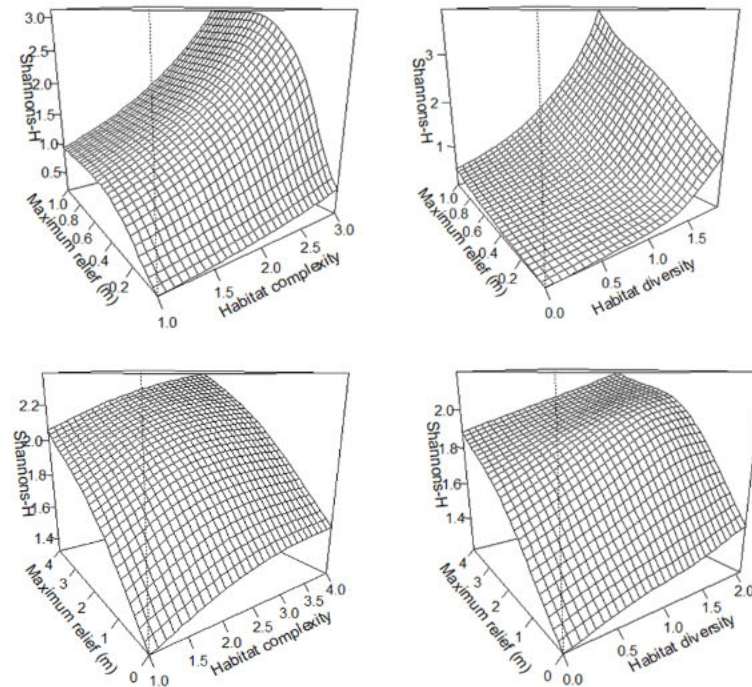


Figure 4. Biplots showing the relationship between habitat complexity (rank), maximum relief (m) and fish diversity observed at The Elbow (top panels) and the Florida Middle Grounds (bottom panel). Left and right panels demonstrate the difference between using the habitat complexity rank (HCR) versus the habitat diversity metric (HCD).

geomorphology and size of the features that we analyzed. The FMG is a large reef (~1,300 km²), in general has high relief (3-10 m) and due to the size tended to show more patchiness across the spatial frame. In contrast TE is a small reef (~140 km²), is primarily composed of a low-relief ridge feature (1-3 m) and because it is a singular feature has reduced patchiness in comparison to the FMG. The HCD metric appears to be less sensitive to increases in abundance and diversity at habitats that are more homogeneous and compact in space such as TE. This difference could also be associated with improved human interpretation of complex scenery that the suite of habitat variables used to create the HCD index could not detect.

We recommend the collection of some form of habitat data for optical-based surveys and experiments at all times. At a minimum this should be presence/absence data, or if possible percent coverage data, and include some form of a rank visual complexity variable as well. Data should also conform to NOAA's Coastal and Marine Ecological Classification Standard (CMECS) so that they are useful to other interested groups who could refer to those standards. One issue we encountered was that some areas might have low structural complexity but high biotic complexity (e.g. algal bed) and vice versa (e.g. sand shoals). The way we

scored habitat complexity treated those two situations equivalently however anecdotal observations of that situation indicate that they are not equivalent (e.g. fewer fish in sand shoals). Due to this issue we have begun to estimate both a rank biotic and a rank structural complexity value and we theorize that these could be used separately or additively. At a minimum we believe this refinement will be able to discern those observed differences. We also calculated and tested Pielou's J evenness scores however those GAM models showed little explanatory capacity in this regard. Despite that result we recommend that new analyses explore other species diversity and evenness metrics.

KEYWORDS: Habitat complexity, abundance, diversity

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