Fish Community Composition on Artificial Reefs in the Northeast Gulf of Mexico Before and After the Deepwater Horizon Oil Spill

Composición de la Comunidad de los Peces en los Arrecifes Artificiales en el Noreste del Golfo de México Antes y Después del Derrame de Petróleo de Deepwater Horizon

La Composition des Communautés de Poissons sur les Récifs Artificiels dans le Nord du Golfe du Mexique Avant et Après le Déversement de Pétrole de Deepwater Horizon

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EXTENDED ABSTRACT

The 2010 Deepwater Horizon oil spill, one of the largest in U.S. history, has been implicated in a variety of environmental and biological changes in the region (Williams et al. 2011, McCrea-Strub et al. 2011, White et al. 2012, Barron 2012, Silliman et al. 2012, Murawski et al. 2014). One of these is drastic reductions in reef fish abundance and substantial shifts in reef fish community composition (Patterson and Jagoe 2012).

We deployed small (1.42 m^3) artificial reefs on the seafloor (depth: 14 - 23 m) in the Northeast Gulf of Mexico (offshore from Fort Morgan, Alabama) in mid-to-late summer each year from 2009 to 2014. Reefs were deployed in two spatial zones (offshore: 2009 - 2010, and inshore: 2010 - 2014) separated by approximately 5 km. These spatial zones differed slightly in depth (inshore mean: 15.5 m, offshore mean: 19.9 m) but were otherwise very similar. The study area was approximately 160 km NNW from the Deepwater Horizon (DWH) oil spill site, and the area underwent between 2 and 10 cumulative days of surface oiling in the months following the spill event, with inshore reefs experiencing approximately 2 to 5 days of surface oiling and offshore reefs experiencing approximately 6 to 10 days of surface oiling (NOAA 2015). We conducted fish community surveys approximately one month after reef deployment each year. Surveys were conducted by pairs of observers using SCUBA, who identified, counted, and sized all reef fish. Archival digital photographs were also taken from a standardized distance and angle from each reef, and were used to verify reef condition and species identification. Reef deployment and survey timing were intended to coincide with average annual peak red snapper recruitment in late August/early September. We used multivariate tools including non-metric multidimensional scaling ordination (NMDS), permutation-based multivariate analysis of variance (perMANOVA), and similarity percentage analysis (SIMPER) to examine potential changes in reef fish community composition among years. Analyses were conducted in the R software environment (R Core Team 2013) using the vegan package (Oksanen et al. 2015). We used Bray-Curtis distances and removed species occurring on < 5% of reefs (McCune et al. 2002). Based on Monte Carlo simulations (50 permutations) our final NMDS ordination provided more reduction in stress than would be expected by chance ($p = 0.02$), and visual examination of scree plots of stress against number of axes suggested that a 2D solution was optimal. We ran the ordination routines using a variety of transformations and relativizations and compared stress and non-metric fit statistics. Untransformed, non-relativized data provided the lowest stress and highest non-metric fit. The final instability of the ordination, as measured by Procrustes residual mean squared error, was 0.0004. A single perMANOVA model was run to test for a global difference in community composition among years. This was followed by pairwise perMANOVAs, with a Bonferroni correction for multiple comparisons, to test for specific differences between pairs of years. We followed this with a SIMPER analysis to determine which species were contributing most to the observed differences among years.

The NMDS ordination revealed a distinct grouping of reef communities by year and no apparent difference between spatial zones in 2010 (the only year for which we had representation from both zones). The perMANOVA test provided further evidence that fish community composition differed globally among years (perMANOVA: $F = 16.04$, $p < 0.0001$, Figure 1), but did not differ between spatial zones (perMANOVA: $F = 0.60$, $p = 0.7034$). While the community appeared to shift dramatically between 2009 (pre-spill) and 2010 (early post-spill) time periods (Table 1), we also observed substantial community shifts between consecutive years after 2010 (Table 1). In fact, the largest shift appears to have occurred between 2013 and 2014 (Table 1). Reef fish communities surveyed in 2014 shared the least overlap with observations from other years. SIMPER analysis suggested that community differences between 2009 (pre-spill) and 2010 (early post-spill) were driven primarily by a decrease in red snapper (40.6% contribution to overall dissimilarity) and vermillion snapper (20.2%), and an increase in tomtate (6.1%). Differences between 2014 and other years were driven primarily by an increase in gray triggerfish during 2014. These unusually high densities of juvenile gray triggerfish were observed approximately three months after a federal recreational fishery closure for this species.

While substantial community changes were coincident with the DWH oil spill, this system appears to be characterized by high inter-annual variability, making it difficult to conclude whether or not the oil spill caused the observed changes. Long-term monitoring programs for reef fish communities could provide the kind of data necessary to accurately and comprehensively assess the effects of environmental disasters such as the DWH oil spill.

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Table 1. Results (F / p) of parwise perMANOVA tests (with Bonferroni correction for multiple comparisons) among years. Bold text indicates a statistically significant difference in community structure.

	2010	2011	2012	2013	2014
2009	**16.04 / < 0.0015**	4.27 / 0.0525	**13.64 / < 0.0015**	**7.27 / 0.0075**	**27.29 / < 0.0015**
2010		**10.70 / < 0.0015**	**7.57 / 0.0030**	**7.80 / < 0.0015**	**27.45 / < 0.0015**
2011			**15.42 / 0.0045**	3.33 / 0.618	**30.74 / < 0.0015**
2012				**9.67 / 0.0045**	**29.22 / < 0.0015**
2013					**21.40 / < 0.0015**

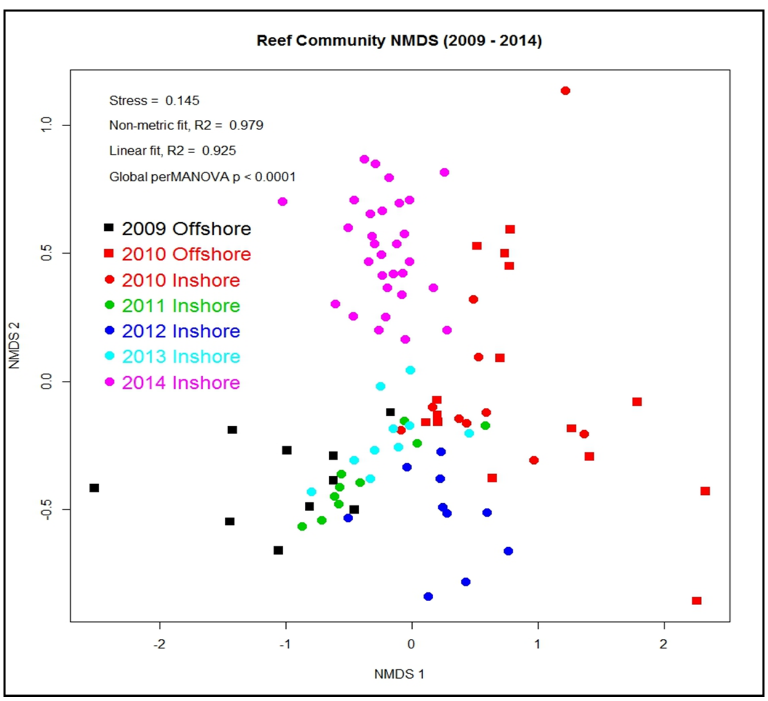

Figure 1. Non-metric multidimensional scaling ordination of fish communities on artificial reefs in the Northeastern Gulf of Mexico. Data points are shape and color coded by year and spatial zone (offshore vs. inshore) according to the included key. See inset for critical statistics of the ordination and an associated global perMANOVA test for differences among groups (years and spatial zones).