Using Opportunistic Datasets to Infer Spatial Management Strategies of Local Fisheries in the U.S. Caribbean Region

Uso de Datos Oportunistas para Inferir Estrategias de Manejo Espacial de las Pesquerías Locales en la Región del Caribe de Estados Unidos

Utilisation d'Ensembles de Données Opportunistes pour Déduire les Stratégies de Gestion Spatiale des Pêcheries Locales dans la Région des Caraïbes des États-Unis

ORIAN E. TZADIK[1], WILLIAM S. ARNOLD[2], MALLORY BROOKS[3], JUAN JOSE CRUZ-MOTTA[4], GRACIELA GARCIA-MOLINER[3], MARIA DEL MAR LOPEZ[2], TAUNA L. RANKIN[5], ALEXIS M. SABINE[6], and SARAH P. STEPHENSON[2]

[1]*The Pew Charitable Trusts*
100 Carretera 115, #1418, Rincón, Puerto Rico 00677 USA.
[2]*National Oceanic and Atmospheric Administration*
National Marine Fisheries Service, Southeast Regional Office, St. Petersburg, Florida 33701 USA.
[3]*Caribbean Fishery Management Council*
San Juan, Puerto Rico 00918 USA.
[4]*University of Puerto Rico at Mayagüez*
Department of Marine Science, Mayagüez, Puerto Rico 00682 USA.
[5]*National Oceanic and Atmospheric Administration*
National Marine Fisheries Service, Silver Spring, Maryland 20910 USA.
[6]*U.S. Virgin Islands Department of Planning and Natural Resources*
Division of Fish and Wildlife, St Thomas, Virgin Islands 00802 USA.

EXTENDED ABSTRACT

Traditional approaches to fisheries management, notably single species stock assessment methods, are limited in scope, and often unreliable for complex multi-species fisheries, such as those found on coral reefs (Simberloff 1998, Levin et al. 2013, Marshall et al. 2018). In the United States, the National Oceanic and Atmospheric Administration (NOAA) has laid out a roadmap, for each regional fisheries council, to transition from the traditional single species approach to an ecosystem-based approach that incorporates a more wholistic view towards management (National Marine Fisheries Service (NMFS) 2018). The initial step of this transition in the U.S. Caribbean (i.e., Puerto Rico, St Thomas/St John, and St Croix) included the recent conversion of the regional management plans to island based fishery management plans (IBFMP). The island-based approach represents the first such strategy among the 8 regional councils in the United States, and therefore a new and untested approach to management, unique to the U.S. Caribbean. The new plans account for nuances on each individual island, including different target species, the use of different gear types, and cultural preferences among others (CFMC 2018). The present study used opportunistic datasets (publicly available, easy to access, and long running) of visual fish surveys to assess whether the regional fish community differed spatially and therefore warranted different considerations among each island.

Three primary datasets were used to assess spatial variability in the regional fish communities, including:

i) Legacy data from the National Centers for Coastal Ocean Science (NCCOS),
ii) Data from the Coral Reef Ecosystem Studies (CRES) program, and
iii) Contemporary data from the National Coral Reef Monitoring Program (NCRMP).

All three datasets were federally funded by NOAA. We used multivariate analyses to test spatial and temporal patterns within each of the datasets to determine the scale of spatial heterogeneity, and whether temporal variations were apparent. Upon initial exploration of the NCCOS data via principal coordinate analysis, sites across years grouped strongly by habitat type (i.e., hard bottom, soft bottom, and mangrove). Upon further exploration using only the sites with the hard bottom habitat class, there was an apparent division among each island. The apparent spatial division by island was tested and verified using an np-MANOVA ($F = 15.77$, $p = 0.001$, $df = 51$), and further verified with a CAP (Trace stat = 1.83, $p = 0.001$, variability explained = 57.92%, CA-1 correlation = 0.98, m = 4). The model produced by the CAP reclassified random samples to the appropriate island-group with a 100% success rate. Compared to the success rate of 33.4% of the random allocation model, the model produced by the CAP was superior. Fish communities at hard-bottom sample sites, among islands were unique and statistically identifiable by their assemblages (Figure 1).

The second dataset (CRES data) was also tested for spatial heterogeneity among the fish community. Fish assemblages differed across a depth gradient, with a pronounced difference among shelf-edge sites, and those located on the insular shelf (Figure 2). The apparent division among sites was verified using an np-MANOVA ($F = 31.70$, $p = 0.001$, $df = 86$), and further explored using a CAP (Trace stat = 5.47, $p = 0.001$, variability explained = 83.23%, CA-1 correlation = 0.99, m = 9). This division by depth was largely driven by 92 statistically significant indicator species ($\alpha = 0.05$). The third dataset

(NCRMP data) was organized differently than the previous two. The NCRMP data was the shortest running dataset, with samples from only 1 or 2 years at each study location. The NCRMP data also had the broadest spatial distribution of any of the datasets used in this study. In order to test spatial heterogeneity, an np-MANOVA was used among "biotopes" within each island that was sampled. These biotopes were artificially designated by the researchers as unique regions within each island. The np-MANOVA verified differences among each biotope within each island that was tested ($p = 0.001$).

The analyses presented in this study support the notion of a spatial management strategy in the U.S. Caribbean as spatial differences were noted, while no temporal trends were apparent. Due to the heterogeneity of the local fish communities, spatial strategies that are unique to each location present the most reasonable strategy for management. While the scale at which the heterogeneity occurs within the fish communities remains unclear, spatial management strategies will help account for nuances among and within island platforms. As fishery management in the United States shifts towards ecosystem-based approaches to fisheries management, spatial strategies will need to be considered (Berkeley et al. 2004). Successful strategies on smaller scales (i.e., those with artisanal fisheries) are often successful when co-management strategies are employed (Cinner et al. 2012), and local stakeholders are included in the management process. The results of this study suggest that a similar strategy can and should be adopted for the U.S. Caribbean, given the spatial nature of the fish communities, and the differences of the local human population on each island.

LITERATURE CITED

Berkeley, S.A., M.A. Hixon, R.J. Larson, and M.S. Love. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. *Fisheries* **29**:23 - 32. doi.org/10.1577/1548-8446(2004)29[23:FSVPOA]2.0.CO;2

Caribbean Fishery Management Council. 2018. *Draft Island Based FMPs*. https://www.caribbeanfmc.com/fishery-management/draft-island-based-fmps. June 2017 (accessed December 2018).

Cinner, J., T. McClanahan, M. MacNeil, et al. 2012. Comanagement of coral reef social-ecological systems. *Proceedings of the National Academy of Sciences of the United States of America* **109**(14):5219 - 5222.

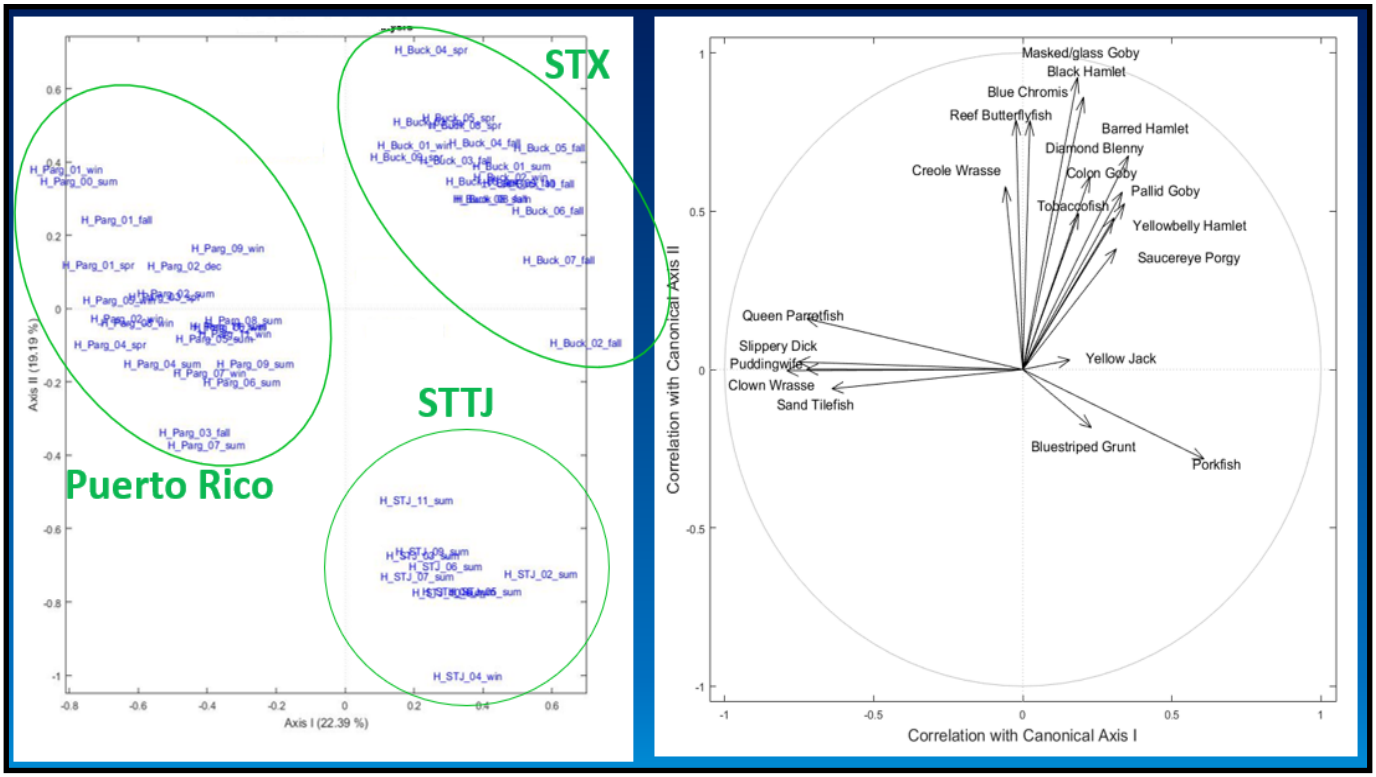

Figure 1. Fish communities at hard-bottom sample sites, among islands were unique and statistically identifiable by their assemblages

Levin, P.S., C.R. Kelble, R.I. Shuford, C. Ainsworth, et al. 2013. Guidance for implementation of integrated ecosystem assessments: a US perspective. *ICES Journal of Marine Science* **71**:1198 - 1204. doi.org/10.1093/icesjms/fst112

Marshall, K.N., P.S. Levin, T.E. Essington, et al. 2018. Ecosystem based fisheries management for social-ecological systems: renewing the focus in the United States with Next Generation fishery ecosystem plans. *Conservation Letters* **11**(1):1 - 7. doi.org/10.1111/conl.12367

National Marine Fisheries Service. 2018. Ecosystem Based Fishery Management Draft Implementation Plans. https://www.fisheries.noaa.gov/national/ecosystems/ecosystem-based-fishery-management-draft-implementation-plans.

Simberloff, D. 1998. Flagships, umbrellas, and keystones: Is single species management passé in the landscape era? *Biological Conservation* **83**(3):247 - 257. doi.org/10.1016/S0006-3207(97)00081-5

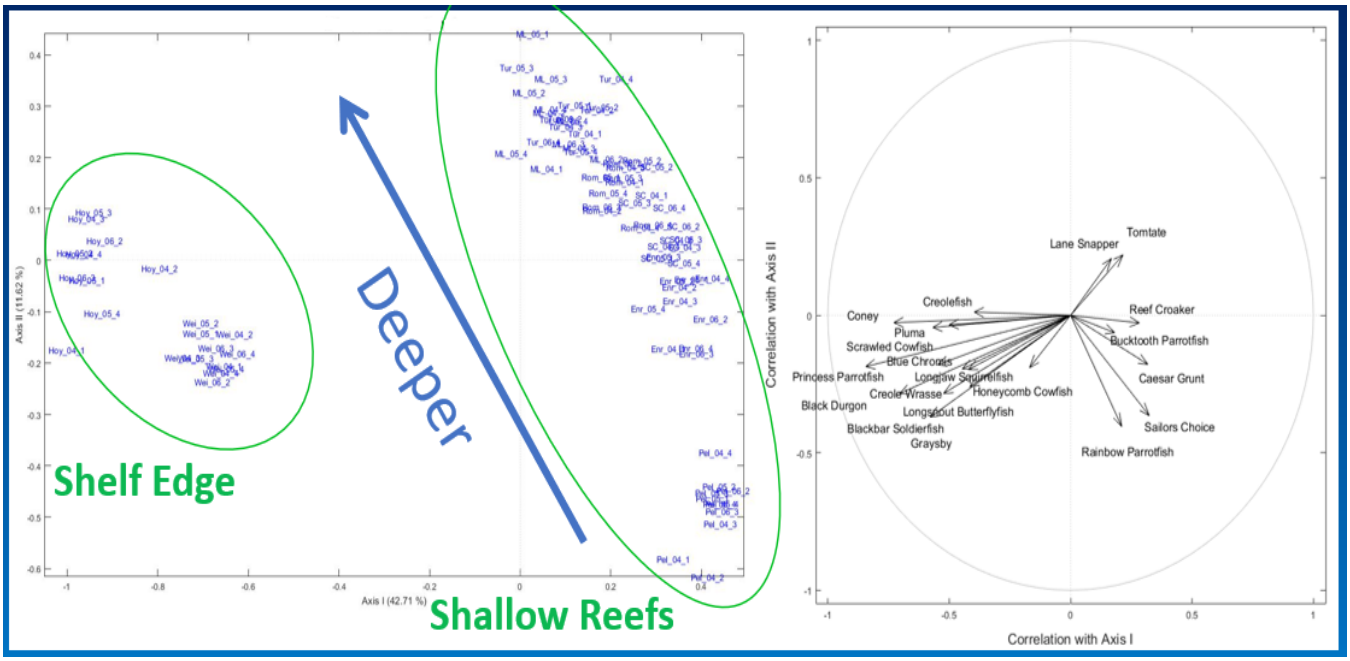

Figure 2. Fish assemblages among shelf-edge sites, and those located on the insular shelf