Management Implications

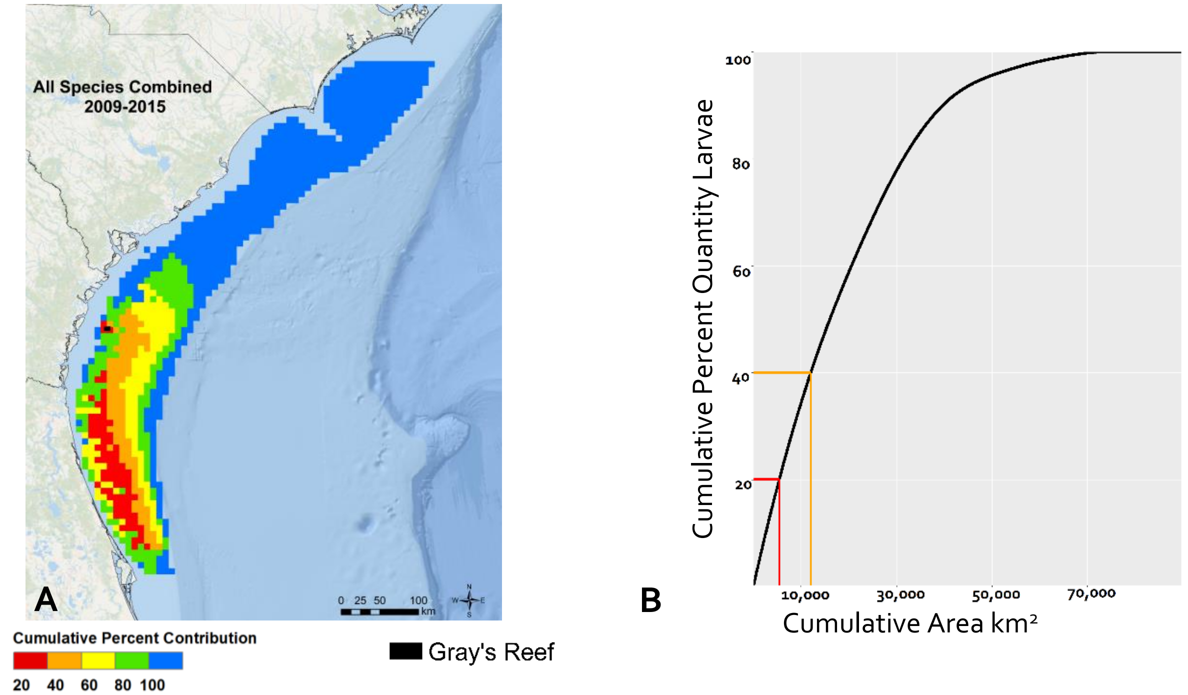

Figure 2. (A) the cumulative percent larval contribution to Gray's Reef for all species combined (2009 – 2015). The red areas are the most important sites seeding Gray's Reef. (B) The minimum amount of area needed to capture a target percentage of larvae.

To understand the management implications of these results, we used the estimated site connections to Gray's reef (Fig 2A) to calculate the minimum size for a new protected area that could achieve any target larval contribution (Fig. 2. B). The results show the smallest new protected area that could meet any given recruitment goal. Depending on the Sanctuary's objectives and the pressures affecting unprotected areas, sanctuary managers can use these tools to design solutions. Based on our results, Sanctuary managers have dual options for enhancing populations at Gray's Reef – expansion of the existing sanctuary and/or creating an additional marine protected area to the South of Gray's Reef.

Moving Forward

Alternative sites with similar conservation benefits may have different socioeconomic and political costs. Weighing the costs of protecting places with similar benefits will be an important next step.

Forecasts of larval connectivity may help other Sanctuaries better understand which other regional sites warrant protection to achieve key conservation goals.

Acknowledgements

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A Greater Gray

Ecological Connectivity at Gray's Reef National Marine Sanctuary

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Faculty Advisor: Dr. Steve Gaines

ON THE WEB AT http://grays-reef.weebly.com/ Spring 2017

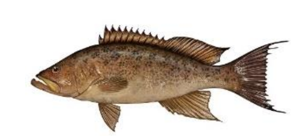
Background

Gray's Reef National Marine Sanctuary (GRNMS), off the coast of Georgia, is one of the smallest National Marine Sanctuaries, at 57 square km in size. As one of only a few natural protected areas of "live-bottom" reef in the Carolinian Ecoregion, GRNMS is an important spawning ground and habitat for many of the marine species in the region. Overfishing , along with other human pressures, have led to population declines for several economically important fish species living in the sanctuary. To address this problem we explored ways to increase fish populations by identifying key sources of larvae to Gray's Reef National Marine Sanctuary.

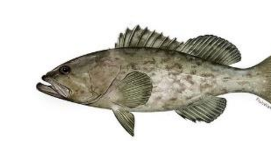
We selected four focal reef fish species, each facing local fishing pressure, to identify ecological connectivity in the Carolinian Ecoregion through the dispersion of their larvae. These species represent the diverse populations at Gray's Reef because they span a range of life histories, have all experienced overfishing, and are economically important to the region.

Black Sea Bass

Red Snapper



Scamp Grouper



Gag Grouper

Significance

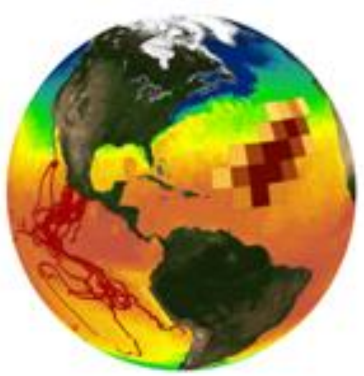
This project will identify possible areas for protection that have a strong, demonstrated ecological connection to Gray's Reef, benefiting fish populations and recreational fishing interests at the Sanctuary. To find important reef areas that act as a source of juvenile fish for Gray's Reef, we modeled ecological connectivity using larval movement. This will help locate areas that contribute high quantities of fish larvae to Gray's Reef and replenish populations under pressure. Protection of these high-contributing areas can address heavy fishing pressure on these species.

Objective

This project hopes to aid Grays Reef National Marine Sanctuary (GRNMS) in using larval connectivity modeling to improve management decisions. To achieve this outcome, our project's objective was to:

- ❖ Study ecological connectivity, through larval distribution, to identify potential areas for protection that would most benefit fish populations at Gray's Reef National Marine Sanctuary

Connectivity Modeling



DUKE MGEL

Marine Geospatial Ecology Tools

Open source geoprocessing for marine research and conservation

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Ecological connectivity was modeled using larval movement to understand where reef fish at GRNMS originate from. Fish larvae are weak swimmers and move largely with ocean currents. Therefore this project used ocean currents to predict larval movements from spawning reefs in the Carolinian Ecoregion to GRNMS. As many reef fish at GRNMS have high site fidelity and spend a large portion of their life in close proximity to the Sanctuary, identifying areas for protection outside sanctuary bounds, that seed GRNMS with juvenile fish, can help boost these populations. Therefore, percent larval contribution is a reasonable metric for identifying priority areas of conservation.

Modeling was performed using Marine Geospatial Ecological Tools (MGET), a GIS-based model. MGET uses daily oceanographic currents data, known spawning locations, and other species-specific parameters to track larval movement through the region after a spawning event. We modeled four species for each month during their peak spawning season from 2009 to 2015. These runs were aggregated to visualize trends across years and species.

References

Farmer NA, Heyman WD, Karnauskas M, Kobara S, Smart T, Ballenger J, Reichert M, Wyanski D, Tishler MS, Lindeman KC, Lowerre-Barbieri S, Switzer T, Solomon J, McCain K, Marhefka M, Sedberry GR. (2017). Timing and location of reef fish spawning activity in the Atlantic Ocean off the southeastern United States. PLOS ONE (*In Press*).; Roberts JJ, Best BD, Dunn DC, Treml EA, Halpin PN (2010) Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS Python, R, MATLAB, and C++. *Environmental Modelling & Software 25(10): 1197-1207*. doi: 10.1016/j.envsoft.2010.03.029.

Our Findings

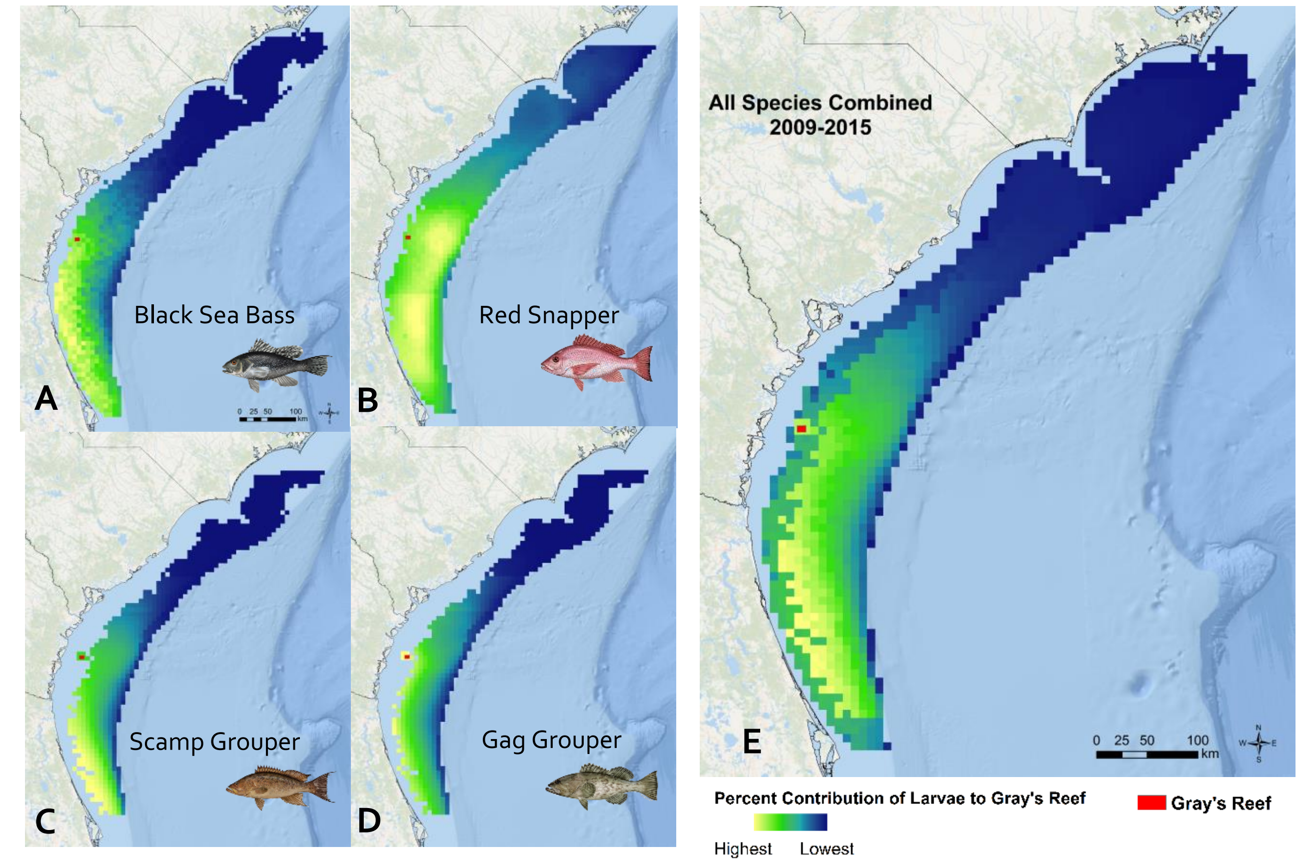

Figure 1. Model results for black sea bass (A), red snapper (B), scamp grouper (C), gag grouper (D), and all species combined (E) from 2009 – 2015. The red box indicates the location of Gray's Reef National Marine Sanctuary. These maps illustrate areas that donate larvae to Grays Reef and are colored to represent areas that contribute the highest (yellow), medium (green), and lowest (blue) amount of larvae to GRNMS.

Results for each individual species were aggregated across spawning month from 2009 – 2015 (Fig. 1. A-D). To find areas for possible conservation that would benefit all species combined, the results for each individual species were aggregated (Fig. 1. E). Results show, when looking at each of the four species individually as well as collectively, that areas of strongest ecological connectivity and highest larval contribution to GRNMS are those areas surrounding the Sanctuary, and to the south of the Sanctuary off the Georgia and Florida coast.

Although the results for each individual species differ slightly, there are consistent trends in the areas of strongest connectivity, and therefore a clear opportunity to choose sites that benefit all four species, despite their differences. Because black sea bass, red snapper, scamp and gag grouper are representative of reef fish at the sanctuary, these results provides an understanding of connectivity for a range of reef species at GRNMS.