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Role of large coastal jellyfish and forage fish as energy transfer pathways in the northern Gulf of Mexico

Kelly L. Robinson[1], *James J. Ruzicka*[2], *Richard D. Brodeur*[3], *Frank J. Hernandez*[4], *Mary Beth Decker*[5], *W. Monty Graham*[1]

[1]*Dept. of Marine Science, The University of Southern Mississippi, Stennis Space Center, MS, 39529, USA*
[2]*Cooperative Institute for Marine Resources Studies, Oregon State University, Newport, OR, 97365, USA*
[3]*NOAA Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR, 97365, USA*
[4]*Gulf Coast Research Laboratory, The University of Southern Mississippi, Ocean Springs, MS, 39564, USA*
[5]*Department of Ecology and Evolutionary Biology, Yale University, New Haven, CT 06520, USA*

Corresponding Author's Email: kelly.l.robinson@usm.edu

Summary

Fishery management production models tend to stress only the elements directly linked to fish. Large coastal jellyfish are major plankton consumers in heavily-fished ecosystems; yet, they are routinely not included as model components. We explore the relationship between gulf menhaden (*Brevoortia patronus*) and the large scyphozoan jellyfish (*Aurelia* spp. and *Chrysaora* sp.) and provide an examination of trophic energy transfer pathways in the northern Gulf of Mexico. We used a novel energy-flow model developed within the ECOPATH framework. Relative changes in functional group productivity to varying menhaden, jellyfish, and forage fish (i.e., menhaden, anchovies, and herrings) consumption rates were evaluated with static scenarios using ECOTRAN techniques. Scenario analyses revealed forage fish harvest enhanced jellyfish productivity, which in turn, depressed menhaden productivity. Modeled increases in forage fish harvest caused pronounced changes in ecosystem structure, affecting jellyfish, seabirds, and piscivorous and apex predatory fishes. Menhaden were found to be a more direct and important energy transfer pathway compared to jellyfish. Increasing jellyfish caused the relative productivity of all functional groups to decline. Outcomes indicate jellyfish blooms and forage fish harvest can demonstrably affect the structure of the northern Gulf of Mexico ecosystem.

Introduction

Fishery production models tend to emphasize only components in direct ascension to fish (i.e., fish, fish food and fish predators). This tendency is problematic because components like large jellyfish, which are voracious plankton predators, are often ignored. The absence of jellyfish in models is potentially troublesome as evidence suggests bloom size and frequency are enhanced by anthropogenic influences, including overfishing (Purcell, 2012). However, the role of forage fish harvest in promoting jellyfish production, ostensibly though the release from competition for shared prey, is not well understood.

To elucidate the role of forage fish and jellyfish as energy transfer pathways in the heavily-fished northern Gulf of Mexico (GoMex) ecosystem and to examine the effects of forage fish harvest on ecosystem structure, we developed a holistic 'food web' model inclusive of jellyfish and the forage fish, gulf menhaden (*Brevoortia patronus*). Menhaden are an important food source for predatory fishes, birds, and marine mammals and they support the second largest commercial fishery (by weight) in the United States. Menhaden co-occur with blooms of large, planktivorous scyphomedusae jellyfish *Aurelia* spp. and *Chrysaora* sp. Overlap between jellyfish and menhaden likely leads to predatory and potential competitive interactions given shared prey resources (D'Ambra, 2012). Moreover, these interactions are expected to be intensified by fishery removal of menhaden.

Methods

An end-to-end model of trophic energy flow was developed to represent the spatial extent of menhaden fishery and peaks in jellyfish abundance during April-November. The initial, steady-state food web model was constructed in the ECOPATH framework (Christensen and Pauly, 1992; Polovina, 1984) and consisted of 50 groups. This model was aggregated into 32 groups using biomass-weighted mean physiological rates and mean diet of the individual groups. Steady-state model solutions generated by a Monte Carlo routine were transformed to end-to-end models that tracked production flow upwards through the food web (Steele and Ruzicka, 2011). End-to-end models were used to estimate the footprint-and-reach metrics for targeted groups (Ruzicka et al., 2012), and in static scenario analysis (Steele, 2009). We examined through scenario analyses changes in the relative productivity of groups across all trophic levels to a: 1) 50% increase in jellyfish, 2) 20% decrease in menhaden, 3) 20% increase menhaden removal via forage fish (i.e., anchovies, menhaden and other herrings, and mullett) harvest, and 4) 50% reduction in forage fish harvest. We also explored the ecosystem-wide response to total fishery closure.

Results and Discussion

Simulated food webs with the footprint and reach metrics indicate that when jellyfish dominate the pelagic biomass, the fraction of total system production and the efficiency at which it is transferred upwards in the food web is reduced in comparison to menhaden. However, analyses of energy flows via all direct and indirect pathways indicate jellyfish in this region support a multitude of lower-, mid-, and higher-order consumers. Menhaden, in contrast, are direct and more important conduit for energy flowing from lower to upper-level consumers, evidenced by a 10x larger reach-to-footprint ratio. Scenario analysis revealed increased jellyfish caused the relative productivity of all functional groups to decline (Fig. 1.). A direct reduction in menhaden resulted in fisheries productivity declining by 19.0%; the response of other groups was minimal (≤1.2%). A 20% increase in fishery removal of menhaden and other forage fish resulted in productivity declines for a few upper-level consumers; however, jellyfish productivity increased. Outcomes from reducing forage fishing and a total fishing moratorium were similar to each other. Menhaden, piscivorous fishes, seabirds, and apex predatory fish productivity increased. Minor changes were observed all other functional groups.

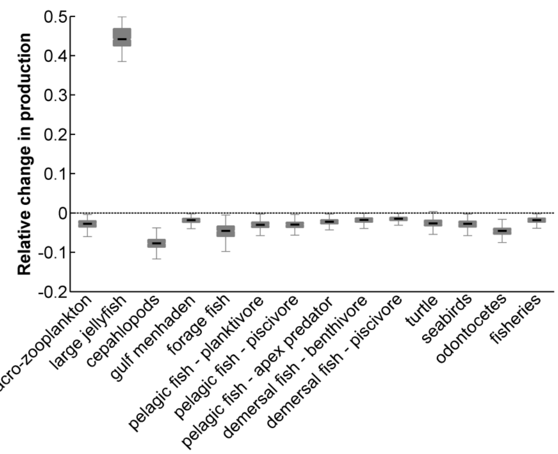

Figure 1. Ecosystem response to a 50% increase in jellyfish consumption.

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