SAFMC Fishery Ecosystem Plan II

South Atlantic Food Web and Connectivity Section

Executive Summary - November 2016

Introduction

A key tenet of ecosystem-based fisheries management (EBFM) is the explicit consideration of indirect effects of fisheries, such as through food web processes, when developing harvest strategies and management plans. This is crucial because of the high likelihood that fishing may leads to unintended and unforeseen consequences on the ecosystem. These indirect effects of fishing can usually arise through disruptions to the food web, whether they are “top-down” (predator dominated) or “bottom-up” (nutrient driven) disruptions to the food web, or both. For example, over exploitation of predators can cause an increase in abundance of their prey and a decline of organisms two trophic levels below them, a phenomenon known as a trophic cascade (Carpenter et al. 1985). Fishing on lower trophic level species, planktivorous “forage” fishes for example, can also have effects on other components of the system (e.g. Okey et al. 2014). When the net productivity of a prey species is diverted to harvest, predator populations will ultimately decline (Walters and Martell 2004). Interspecific competition for food occurs when there are two or more species that overlap in time and space and utilize the same limited resource. Competition within a food web also has implications for management, for example when simultaneously rebuilding two competing species or when a non-native species becomes established. Changes in primary production can have noticeable effects on the food web. These “bottom-up” processes are largely driven by changes in climate or physical oceanography, particularly those that drive patterns of precipitation or upwelling and therefore nutrient input. While dynamics of lower trophic level species are more strongly tied to environmental forcing, for most species it’s the combination of both fishing and environmental forcing that drive changes in population size (Chagaris and Mahmoudi 2009; Mackinson et al. 2009).

Food webs also serve to connect different components of the larger ecosystem. Seasonal and ontogenetic migrations by some species out of estuaries to coastal areas where they become prey is one mechanism that transfers energy from the inshore to offshore environments. Latitudinal (north-south) migrations provide a means to transfer energy from seasonally productive regions where prey is abundant to less productive regions at other times. Connectivity between the benthic and pelagic food webs is also important for transfer of pelagic and midwater production to seafloor communities and vice versa. For example, food web linkages connect pelagic forage fishes and their piscivorous predators to demersal carnivores. This connectivity between food webs over space, time, and depth creates multiple energy pathways that enhance ecosystem stability and resilience.

One way to incorporate food web processes into management is through models. Mathematical trophic-dynamic models are particularly useful because they can assist in determining the tradeoffs associated with harvesting fish from different parts of the food web while also allowing for examination of impacts resulting from changes in primary production and other bottom-up processes. Food web models are increasingly being utilized by fisheries managers as ecological prediction tools because they provide the capability to simulate the entire ecosystem from primary producers to top predators and fisheries. Such models can be used to screen policy options for unintended consequences on the system and evaluate their effectiveness in an ever changing environment. Additionally, food web models can serve to inform single species assessment and management and are capable of generating reference points (Walters et al. 2005) and ecosystem-level indicators (Coll et al. 2006; Fulton et al. 2005).

The overall objective of this chapter is to provide background, contextual information about food webs that should be considered by the SAFMC when developing single species and fisheries ecosystem plans in the South Atlantic. When possible we provided case studies and examples that are specific to South Atlantic species and ecosystems, however we also recognize that many of the principles discussed in this chapter have not been studied in the region. This is a critical realization as the primary current dynamics (Gulf Stream) makes our area substantially different from even the Gulf of Mexico which has many of the same species. This chapter begins with a brief overview of estuarine, nearshore, and offshore food webs of the South Atlantic Ecosystem. Next we discuss energy flow through food webs and provide contextual information on basal energy sources, the processes regulating energy flow, dominant energy pathways, and how these attributes are related to ecosystem stability and resilience. We then describe how various sub food webs are linked through inshore-offshore, benthic-pelagic, and seasonal connections. The fourth section describes important fishery and non-fishery related threats to food webs. The fifth section gives an overview food web models and is followed by a brief description of food web indicators. Lastly, we end with a discussion of how these principles and topics can be applied in a fisheries management context and provide summary recommendations for improving our understanding of food webs.

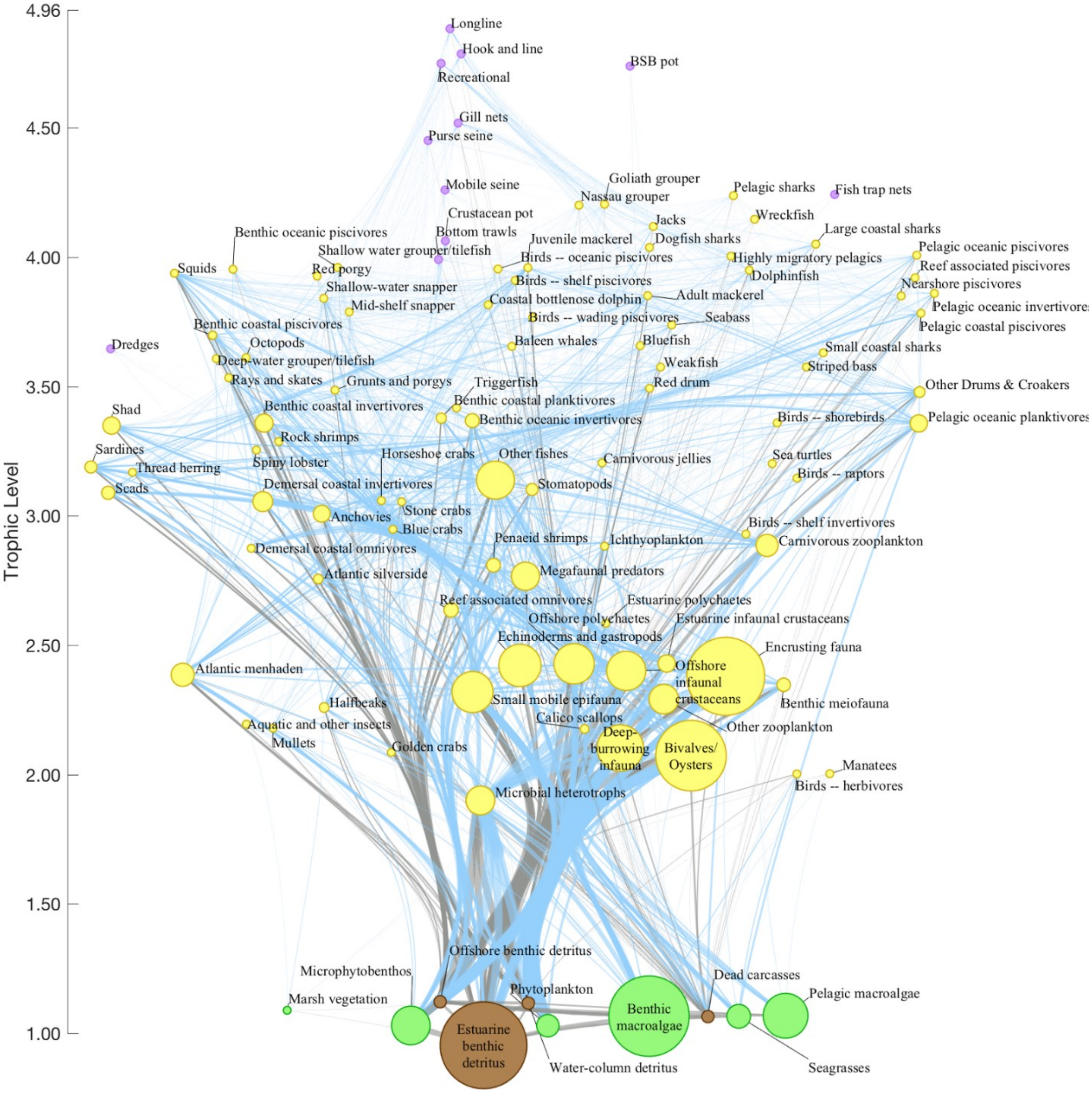

Figure 1-1. The marine food web of the South Atlantic Bight, based on the latest iteration of the SAB Ecopath model as described in Okey et al (2014), based originally on a preliminary model by Okey and Pugliese (2001). Nodes are colored based on type (green = producer, brown = detritus, yellow = consumer, purple = fleet). Blue for all edges except flows to detritus, which are gray. Diagram produced by Kelly Kearney, UW Joint Institute

for the Study of the Atmosphere and Ocean and NOAA Alaska Fisheries Science Center, April 2015.

Summary and Recommendations

The variety of habitats in the South Atlantic support diverse food webs, that also are interconnected by proximity, energy pathways, migration / immigration, and by life history. Many components are shared among habitat-specific food webs, from algae to marine mammals. Ontogenetic, seasonal, spawning and diel migrations, predator avoidance, and foraging behaviors transfer energy and food web participants among the various habitats within the South Atlantic. While seasonal may cover spawning aspects, the magnitude of seasonal migrations for a number of species (gag, greater amberjack, banded rudderfish, king mackerel, etc.) have significant effects.

Specific to this report, the paucity of data for offshore, non-commercially important species and pelagic species equate to a difficulty in applying EBFM. As in other sub-tropical to temperate areas, food webs in the South Atlantic rely heavily on grass detritus (marsh or seagrass) and phytoplankton as carbon sources. As one moves offshore, the reliance on phytoplankton increases as terrestrially-derived organic carbon diminishes. SA food webs are regulated by seasonal and long-term environmental variability (bottom-up; e.g. temperature, upwelling, day length, Gulf Stream Index, nutrient loading) and top-down factors such as fishing of large snapper-grouper and natural predation. Ultimately, energy flow within the system is tightly mediated by predator-prey interactions. Forage species (e.g. Menhaden, Shrimp, and Pinfish) are critical links in energy transfer within and among food webs in the SA and thus in stability of these webs. Unfortunately, population dynamics of the vast majority of these critical species are poorly understood. Potential impacts of climate change on consumption rates, foraging behaviors, and the primary producers in the system also are unknown.

Food webs are impacted both directly (fishing, introduction of invasive species) and indirectly (water quality changes, alteration of habitats) and these impacts are often, if not primarily, anthropogenic in origin. Other systems provide well-documented examples of trophic cascades following perturbations and multiple perturbations likely have synergistic or cumulative impacts. Trying to predict impacts, whether they be positive such as the recovery of overfished species or negative such as habitat destruction, increasingly relies on modelling approaches. Modelling approaches often trade-off between being simplistic, needing very little data, but limited in predictive capabilities for whole ecosystems, or complex, needing extensive data sources and computational power, but better able to address multiple questions or hypotheses if uncertainty can be limited.

The goal of understanding food web components, connections, energy, and complexity is to provide useable information to direct management or future research needs. As such, indicators have been employed to summarize the state of knowledge of an ecosystem or food web and serve as a benchmark to inform future actions. Indicators may range from point estimates such as measures of diversity to those that are dynamic such as non-linear relationships between the ecosystem and pressures upon it. Suites of indicators are likely to increase in importance as we move from single-species management and assessment approaches to EBFM. Food web models and indicators are essential tools to predict coupled, synergistic, or cumulative effects of management practices.

Prior to the development or use by managers of tools to characterize, quantify, and predict, the SA region has specific outstanding data needs. Diet, energy, and biomass for non-economically important species must be determined. Uncertainty in complex food web models must be minimized and empirical data such as those mentioned above are crucial to these efforts. Impacts of human activities and climate need to be determined specifically for the SA.

Forage species are a small, but critical piece of the ecosystem puzzle. In order to ensure that the integrity of South Atlantic food webs and the interconnectedness of fish populations and their environments are maintained, essential science and monitoring information should be obtained to account for the dietary needs of predators for forage species. Also, the abundance of important forage species needs to be monitored and quantified for inclusion in stock assessments, ecosystem models, and other scientific tools and processes to enable comprehensive and sound management decisions that incorporate ecosystem considerations and economic tradeoffs.