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Indicators for assessing the ecological dynamics and sustainability of southern Florida's coral reef and coastal fisheries

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ABSTRACT

Commercial and recreational fisheries target hundreds of fish and shellfish species across the seascape of southern Florida including inshore coastal bays, the flats of barrier islands, coral reefs and offshore pelagic waters. The ecological dynamics and economic sustainability of these valuable fishery resources are key conservation concerns. This study examined two ecological indicators of fishing impacts on exploited populations: (1) the more traditional metric catch per unit of fishing effort (CPUE); and (2) the non-traditional metric average length ($\bar{L}$) in the exploited life stage of a population. We show that both indicators were closely related to stock productivity via fisheries population dynamics theory, and that either indicator could be used to estimate fishing mortality rates (F). Data requirements are much less stringent for estimating F from the $\bar{L}$ indicator than CPUE, making it more practical for data-poor situations common to tropical marine fisheries. Using indicator-based estimates of $\hat{F}$ within a population dynamic modeling framework enabled an evaluation of fishing impacts on sustainability at both the species and community levels, an important step toward ecosystem-based fisheries assessment and management. A comparison of these approaches applied to the assessment of southern Florida coral reef fisheries suggested that fishing has fundamentally altered the ecological structure of the fish community by depleting the biomass of higher-trophic level carnivores to the extent that the stocks are unsustainable.

1. Introduction

The coastal and coral reef ecosystem in southern Florida supports lucrative tourism and fishing industries that generate over US $6 billion in economic activity per year (Ault et al., 2005a). A variety of commercial and recreational fisheries operate across the seascape targeting many species of fish and shellfish representing a wide range of taxa and trophic groups (Fig. 1) with high economic value that includes, for example: shrimp, crabs, spotted seatrout, mullet, red drum, bonefish, snook and tarpon in coastal bays and nearshore flats of barrier islands; snappers, groupers, and lobsters in offshore hardbottom and coral reef habitats; and, pelagics such as mackerels, dolphinfish, tunas, and billfishes seaward of the barrier coral reefs. The ecological persistence and economic sustainability of these valuable marine species is a key conservation concern as demand for access and use of these fishery resources continues to increase with a growing human population in South Florida.

Overfishing, habitat degradation and prey reduction are the principal threats to sustainability of coral reef and coastal fisheries in Florida. In this context, fishery sustainability is defined as the ability of an exploited population to produce goods and services, including yields (i.e., landings) at suitable levels in the short term, while maintaining sufficient stock reproductive capacity to continue providing these goods and services at similar levels into the indefinite future (Ault et al., 2008). Food and sport fisheries intensively fish a complex of over 70 reef fish species including snappers, groupers, grunts, wrasses, jacks, and porgies (Ault et al., 1998; Coleman et al., 2000). Small ornamental reef fish and invertebrate species are captured for marine aquaria. Other fisheries are directed toward key prey species (shrimps, baitfish) of

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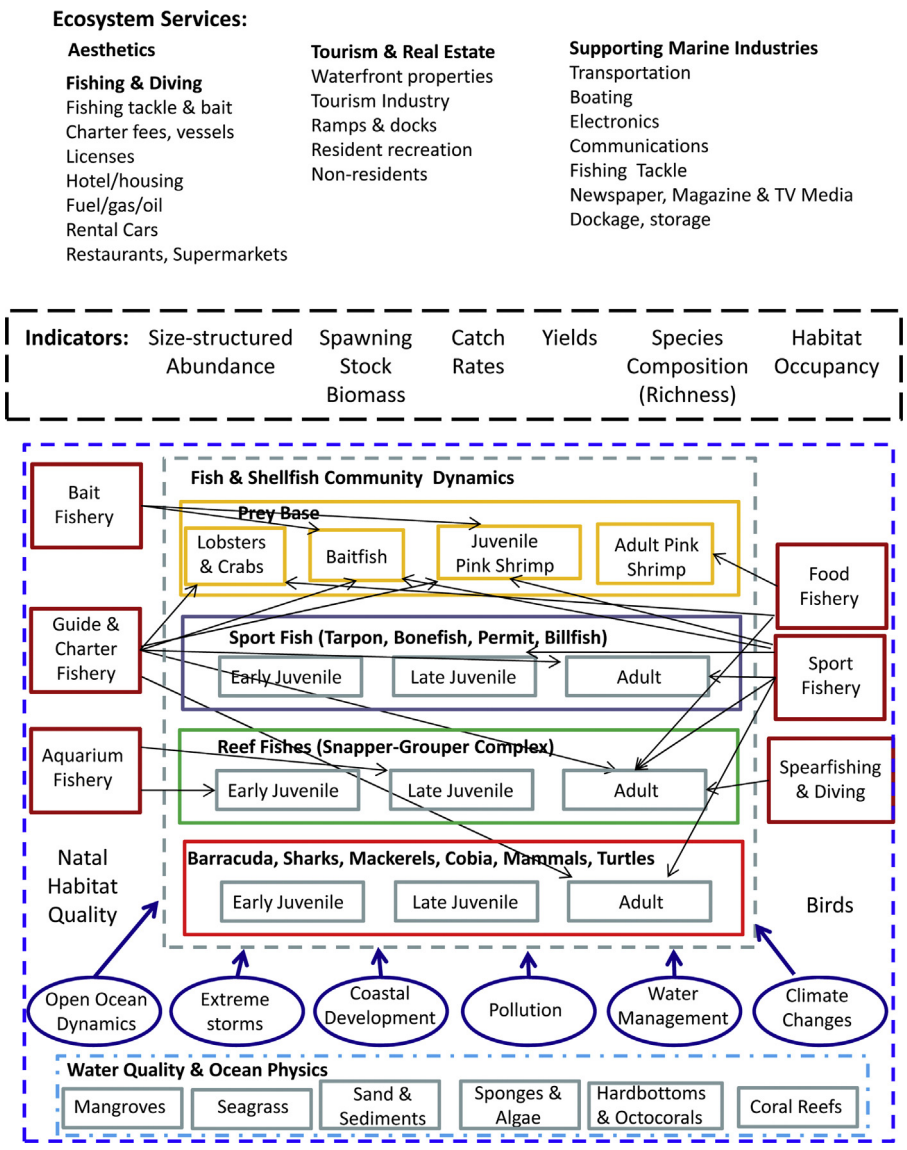

Fig. 1. Conceptual diagram of the ecological and fishery inter-relationships of the southern Florida marine ecosystem.

the snapper–grouper complex. Coral reef habitats are impacted by coral bleaching, disease, and vessel groundings, resulting in loss of both vertical structure and coral cover (Alvarez-Filip et al., 2009). Inshore nursery grounds of reef species are being altered by shoreline development, channel dredging, pollution, and changes in the volume, timing, and distribution of freshwater inflows (Lindeman et al., 2000; Wang et al., 2003; Ault et al., 1999, 2003, 2005a; Clua et al., 2005).

An interesting feature of the snapper–grouper complex is that any given fishing trip in the reef environment could potentially capture any one of the over 70 species. This is because the main reef fishing gears (e.g., hook-line, traps) are relatively non-selective and the species co-occur in similar habitats (Bohnsack and Ault, 1996; Ault et al., 2005b). The recreational and commercial fleets thus target the reef-fish complex as a whole rather than focus on any particular species. Efforts to manage coral reef fisheries from an ecological community perspective, however, have been hindered by the lack of data needed to evaluate sustainability status using conventional stock assessment methods. The required data for these conventional methods include demographic rates and historical time-series of age-size structured catches for each species, and the associated fishing effort by fleet and gear (Quinn and Deriso, 1999; Haddon, 2011). This paper describes the theoretical and empirical basis for an alternative approach to sustainability analysis at the species and community levels that bypasses the most problematic data requirements of conventional assessment methods, i.e., long time-series of catch and effort data. This alternative approach makes use of the indicator variable 'average length of the exploited life stage' ($\bar{L}$, L bar) that can be estimated from length composition data collected for most fisheries.

2. Methods

2.1. Indicators of sustainable fisheries: some theoretical inter-relationships

Here we explore the theoretical inter-relationship of two principal ecological indicators of fishing impacts on exploited populations: (1) catch (in weight or numbers) per unit of fishing effort (CPUE); and, (2) average size (in length or weight) in the exploited phase of the population, i.e., the mean of the distribution of size-structured relative abundance.

The CPUE indicator variable is an index of population productivity of the fishery resource, and mathematically relates to a dynamic