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Impact of increasing market access on a tropical small-scale fishery

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ABSTRACT

Small-scale fisheries have historically been marginalized in management and policy investments, and they often remain under-reported in national economic and fisheries statistics. Even so, small-scale fisheries are not entirely buffered from the impacts of globalization, such as the introduction and expansion of markets. This study measures the long-term impact of market-access on a coastal fishery on Nicaragua's remote Atlantic Coast from approximately the time when fishermen had access to stable and predictable local markets until the present, when the region has been transformed by road connection. In the last four years, fisheries trade has expanded as road connection has facilitated export to distant markets. Fishery-independent surveys were used to measure changes in indicators of fish-community status such as length-frequency, mean trophic level, and relative biomass. Species-level changes in relative biomass of common snook *Centropomus undecimalis* and gafftopsail catfish *Bagre marinus* were also evaluated since these species are the most economically valuable and likely account for the most fish biomass in the system. Using historical records, reports, current observations and interviews, changes in indicators of fishing intensity and market access over the past 17 years were assessed. From 1994 to 2011, community and species-specific metrics of the lagoon fishery declined significantly across all indicators examined. The potential social and economic outcomes of the decline in the fishery are far-reaching for the region, because this tropical fishery comprises the main source of protein and income for residents of twelve indigenous and Afro-descendent communities.

1. Introduction

There is a noted lack of small-scale fisheries assessments from tropical developing countries even though these fisheries employ most of the world's fishermen, harvest half of the world's catch, and are important to economic and food security for vulnerable human populations [1,2]. Given the challenges of collecting standardized data in small-scale fisheries, long-term assessments are especially rare but crucial to understanding the impact of changes in economic development, socio-economic conditions and fishing intensity on the local fishery [3].

The transition from subsistence to commercial harvest occurs via integration into a market economy. Improved market access can have both positive and negative outcomes depending on the timescale, social, economic or ecological variable being measured as well as other mitigating factors [4–7]. Markets can incentivize protection of resources or drive exploitation to unsustainable levels, and the development of new markets can have a profound impact in remote areas when few other income-generating opportunities exist [8–10].

Traditional single-species assessments are usually not adequate to describe the impact of fishing on small-scale fisheries, which are often characterized by multi-species targets using multiple harvest techniques with shifting resource-based livelihoods and human populations vulnerable to unpredictable changes. Quantitative indicators for ecosystem-based management are used increasingly to understand interactions between environmental, socio-economic and biological factors that affect communities of fish and the ecosystem [11,12].

We evaluate changes in fish community size distribution, trophic spectra and relative abundance in a small-scale fishery transitioning from primarily subsistence to increasingly market-oriented harvest over almost two decades. Trophic spectra

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describe the distribution of multi-species catch, biomass or abundance across trophic levels and are useful for assessing shifts in community structure and function [13]. Several studies have explored the accuracy of indicators designed to measure aquatic ecosystem dynamics, and indicators that are sensitive to fish community changes over time have become more commonly used [14–16]. The Convention on Biological Diversity designated mean trophic level (or Mean Trophic Index, MTI) as one of the indicators to measure performance toward stemming global biodiversity loss by 2020 [17].

Changes in a small-scale fishery on the Atlantic Coast of Nicaragua over a period of rapid development in the last 17 years were explored. Since a large development project in the 1990s greatly expanded fisheries capacity, the region has progressed steadily toward increasing commercialization, which was further intensified by road connection in 2007 [5,6]. Declines in mean trophic level, mean standard length and relative biomass of harvested fishes as the fishery became increasingly market-oriented were expected. Survey data from 1994 were compared against 2011 survey data to examine, respectively, pre- and post-market expansion.

1.1. Study site

Pearl Lagoon refers both to a small town and an estuary. For the purposes of clarity and to be consistent with previous work, the estuary is referred to as the lagoon and the town as Pearl Lagoon. The lagoon is a remote shallow estuary in the Southern Autonomous Region (RAAS) on the Atlantic Coast of Nicaragua (Fig. 1). The 540 km^2 lagoon is surrounded by approximately 12 indigenous and Afro-Caribbean communities, whom rely to varying extent on sustenance and income generated from lagoon fisheries. The lagoon is shallow with measured depths ranging from .6–9.0 m and is fed by several major rivers. As the lagoon maintains a year-long narrow opening to the sea, it supports both resident and migratory fish populations. Common fish species include snook (*Centropomus* spp.), Atlantic croaker (*Micropogonias furnieri*), gafftopsail catfish (*Bagre marinus*), mojarra (*Eugerres plumieri*), and jack (*Caranx* spp.). Major invertebrates include Penaeid shrimp and blue crab (*Callinectes sapidus*). In addition, the lagoon hosts critically endangered and threatened species such as goliath grouper (*Epinephelus itajara*), sawfish (*Pristis* spp.), and the West Indian manatee (*Trichechus manatus*), though the sawfish may be locally extinct. Pearl Lagoon undergoes seasonal changes in its fish assemblage between the wet and dry season, primarily based on shifts in salinity driven by a marked rainy season. The dry season begins in approximately February and lasts until the end of May. The onset of the wet season occurs in approximately June and lasts through August. Mangrove forests reside at the confluence of the terrestrial and aquatic ecosystems of the lagoon and much of the Atlantic Coast. Mangrove species include red (*Rhizophora mangle*), white (*Languncularia racemosa*), and black (*Avicennia germinans*) mangrove as well as buttonwood mangrove (*Conocarpus erectus*) [18].

1.2. Commercialization 1994–2012

Nicaragua emerged from a decade-long civil war in the early 1990s and transitioned more towards a neoliberal economy focused on free trade and integration in world markets. In this context a well-funded bilateral Netherlands-Nicaraguan development project titled, Integrated Development of the Artisanal Fishery in Pearl Lagoon (DIPAL for the Spanish acronym), was established in 1994 and over eight years developed a management plan based on hydro-biological and socio-economic studies, distributed gear and equipment, attempted to commercialize previously untargeted species and aimed to increase efficiency and market value of the Pearl Lagoon fishery [19,20]. Fishermen began using gill nets intensively in this period as DIPAL facilitated the leasing of gill nets to fishermen who paid for them incrementally through deductions taken out of their fish catch [19, P. Ordonez, pers. comm.]. In 1997, DIPAL fisheries experts concluded that the lagoon fishery presented no symptoms of overexploitation [21]. Yet, during the same time community members expressed concern about fishery declines as a result of the commercialization of the fishery and proliferation of gill nets [22].

In 2007, Pearl Lagoon was transformed by road connection that reached the capital, Managua, for the first time and facilitated the arrival of seafood traders from other parts of Nicaragua [6, K. Stevens pers. obs.]. This has resulted in new markets for previously untargeted species, price competition amongst buyers and new incentives for fishermen to increase effort and target different species and/or new fishing locations.

2. Methods

Fisheries-independent gill net surveys were conducted in both the wet and dry seasons of 1994 and 2011. The 1994 study was conducted by the Center for Fisheries Research and Development-Haulover (CIDPH for the Spanish acronym) [23]. In 2011, the same grids in the same months as those surveyed in 1994 were resurveyed, selecting sampling sites that were at the center point of the 1.7 km^2 grid cell. The 1994 gillnet locations were chosen so that sampling sites were within known fishing areas of Pearl Lagoon while also allowing for reasonable spatial coverage of the area [Fig. 1; 23]. Gill nets were anchored using long sticks in water depth between 2.1–3.7 m at dusk and they were removed the following morning.

In both years, one multifilament (No. 12) and one monofilament net (No. 5) were deployed, both 75 ft (23 m) long by 7 ft (2.1 m) tall with a 4-inch (10 cm) mesh. In 1994 the multifilament net was green, and in 2011 it was black. During both sampling years, only the monofilament net was used in the dry season from Feb–April; whereas, both the monofilament and multifilament net were used in the wet season from June to August. Data for wet and dry seasons were combined within each year.

Captured fish were identified to species and their total, standard and fork length, and gutted and whole weight was recorded. In 1994, when catch exceeded time or manpower to individually measure each fish, a sample of captured fish were measured by individual and the total number and weight of those remaining were pooled together. In these cases, average standard length per individual was calculated based on species-specific length–weight relationships. In 2011, all collected fish were measured.

Information about social and economic changes in the region was gathered from the gray literature and cross-validated by government records and interviews with key informants. Non-governmental organizations, development projects and researchers have implemented projects on Nicaragua's Atlantic Coast over the last 17 years and this information was used to construct trends in commercialization, market access and price changes over time [19,20,23,24].

For each net set, catch-per-unit-effort (CPUE) was calculated as the whole weight (kilogram) of the catch, divided by the amount of time nets were in the water (kg/h). A trophic level from Fishbase[2] was assigned for each captured species [25–28]. For

[2] Fishbase provides two types of trophic level calculations – from individual food items and from diet composition. The trophic level based on individual food items was used, which uses a reported list of food items consumed by a particular