What Has Happened to South Florida's Bonefish?
A Multidisciplinary Approach to Understand the Decline of Recreational Fisheries

¿Qué le Ha Pasado al Bonefish del Sur de la Florida?
Un Enfoque Multidisciplinario para Comprender el Declive de la Pesca Recreativa

Qu'est-il Arrivé aux Bonefish du Sud de la Floride?
Une Approche Multidisciplinaire pour Comprendre le Déclin de la Pêche Récréative

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EXTENDED ABSTRACT

The flats fishery relies on shallow coastal tropical and subtropical habitats is comprised of Atlantic tarpon (*Megalops atlanticus*), permit (*Trachinotus falcatus*), common snook (*Centropomus undecimalis*), and bonefish (*Albula vulpes*). These species support valuable socioeconomic activities locally and regionally and are increasing in popularity as a key component of ecotourism and conservation practices. Despite their high value, population assessments and ecological studies are limited, and key data on spawning and recruitment dynamics, habitat use patterns, and life history remain unknown.

In the past decades, recreational catches of bonefish (*Albula vulpes*) have decreased significantly throughout South Florida (SFL). Fishing guides surveyed in the Florida Keys reported a decline in catches. For instance, a study reported a 50% decline (Larkin et al. 2010), while a later study reported a 68% in guide surveys and interviews (Frezza and Clem 2015). Declines were also reported in tournament catches in the Keys, particularly between 1997 and 2000 (Larkin 2011). These reports lack spatiotemporal resolution on the pattern of decline that could help identify drivers. For instance, these reports lack a characterization of the spatial distribution of bonefishing activities, and how bonefishing has changed over time.

The mechanisms driving these declines are unknown, yet concerning given the socio-economic value of the fishery. Diagnosing a population decline is not straightforward, especially true for what we would call a *data-limited* species, such a bonefish, where the basics of their ecology remain unknown, and where we lack the long-term records on their population numbers. Over the past four years, our research group at FIU has been examining the questions:

i) What are the spatiotemporal patterns of bonefish throughout SFL? And
ii) What factors could be driving this decline? (i.e., the *how, when, where, whom and why* of bonefish decline in South Florida).

We used a combination of fisheries-dependent data (FDD) and local ecological knowledge (LEK) to assess the nature of the temporal trend (i.e., gradual vs. punctuated decline) in bonefish abundance in SFL. Both FDD and LEK, are two sources of information that can be used to generate spatiotemporal assessments of recreational fisheries (Beaudreau and Levin 2014, Aylesworth et al. 2017). FDD consist of the catch/landings reported by recreational anglers or commercial fisherman, that it is often used to derive quantitative information about the stock status and trends (Maunder and Punt 2004). LEK can also be a vital data source to quantify changes and identify vulnerabilities of data-limited recreational fisheries (Beaudreau and Levin 2014) and extract spatial information that is often non-existent (Aylesworth et al. 2017). LEK consists of the knowledge, practices, and beliefs regarding ecological relationships that are gained through a mixture of observations and practical experience that are often placed-based, adapted over time, and shared among local resource users (Gilchrist et al. 2005). We also used different statistical modeling approaches to examine the relative importance of water quality, climatic parameters and habitat dynamics in driving bonefish numbers.

Our proxies of bonefish abundance, bonefish catch from guides reports (FDD) and bonefish number from the online survey (LEK), pointed to the decline in bonefishing in SFL since the early 1980s, as well as, an accelerated decline that started since the late 90s-early 2000s that resulted in an overall 42% and 60% reduction in catch and perceived bonefishing quality (Santos et al. 2018) (Figure 1a, b). Starting in 1990, guides began reporting the targeted species in their reports which allowed us to examine the proportion of successful trips in Florida Bay, and determine three distinct periods in the guide bonefish catches: a high success period in 1990 - 1998 (60% success), a medium success period in 1999-2009 (48%), and a low success period in 2010-2014 (37%, post-2010 cold event) (Santos et al. 2017). Both the online survey and the guide reports indicated a regional and localized decline in bonefish (Santos et al. 2018). Although the online survey respondents perceived a decline of bonefish number across all fishing areas, the decline in Florida Bay resulted in the highest drop in bonefish number perceived by anglers (Figure 1b). In Florida Bay, the inner bay, albeit with much lower bonefish catches, shows a consistently earlier decline relative to the outer Bay.

The results also show that the spatial core of bonefishing significantly shifted over time (Santos et al. 2018) (Figure 1c). From our interviews and surveys, we learned that over time, good flats are disappearing in the Upper Keys and Florida Bay, and by the early 2000s only a small number of fishing flats are good, while at the same time, bonefishing is shifting to the

Lower Keys. At the same time, fishing effort is concentrated in a smaller subset of fishing locations, with a higher number earlier in late 1970s-early 1980s.

We used the record of 35-years of bonefish catches for Florida Bay to test whether changes in this record were related to changes in the climate and hydrology. We were able to include only those factors for which we also have 35 years of information. At the same time for some of these factors, the best available information is indices or indirect measures of the factor. A dynamic factor analysis (DFA) identified that the time-series time-series of environmental factors were best explained with a single underlying trend (Large et al. 2015) (Figure 2a). This trend related mostly to the Atlantic Multidecadal Oscillation (AMO), high-temperature events, El Niño, and variation in salinity (Figure 2b). Over the 35 years, the bonefish timeline tracks the changing climate and hydrology of Florida Bay (Figure 2a). As for bonefish decline, the frequency of water high-temperature events is increasing, salinity is becoming less variable, and there is a positive change in the Atlantic Multidecadal Oscillation (known to influence summer rainfall).

Spatiotemporal dynamics in juvenile bonefish recruitment and habitat use represent significant knowledge gaps for the South Florida bonefish (Brownscombe et al. 2018). In South Florida, it is increasingly important to determine the reliance on the nearshore estuarine environment as recruitment and nursery habitats for bonefish due to the persistent and drastic alterations to freshwater inputs. We measured concentrations of the element Strontium (a marker for salinity) along each ring of the otoliths of 40 bonefish from South Florida and 10 from Cuba to determine the connectivity between estuarine and marine habitats across the life of bonefish (Santos et al. 2019). If bonefish experienced higher salinities as they age, we would expect concentrations to be low at the core of the ear bone and increase as go further out. In sum, about 68% of the bonefish in South Florida, and 70% for Cuba showed that early in their lives, bonefish are using a less saline environment. Changepoint analysis showed that these shifts to high salinity environments occurred suddenly, and early in life, suggesting an ontogenetic habitat change.

In sum, our findings on the pattern of decline tell that the decline is a large scale issue that has been affecting all of South Florida, but at the same time, there may be local environmental stressors in places such as Florida Bay that

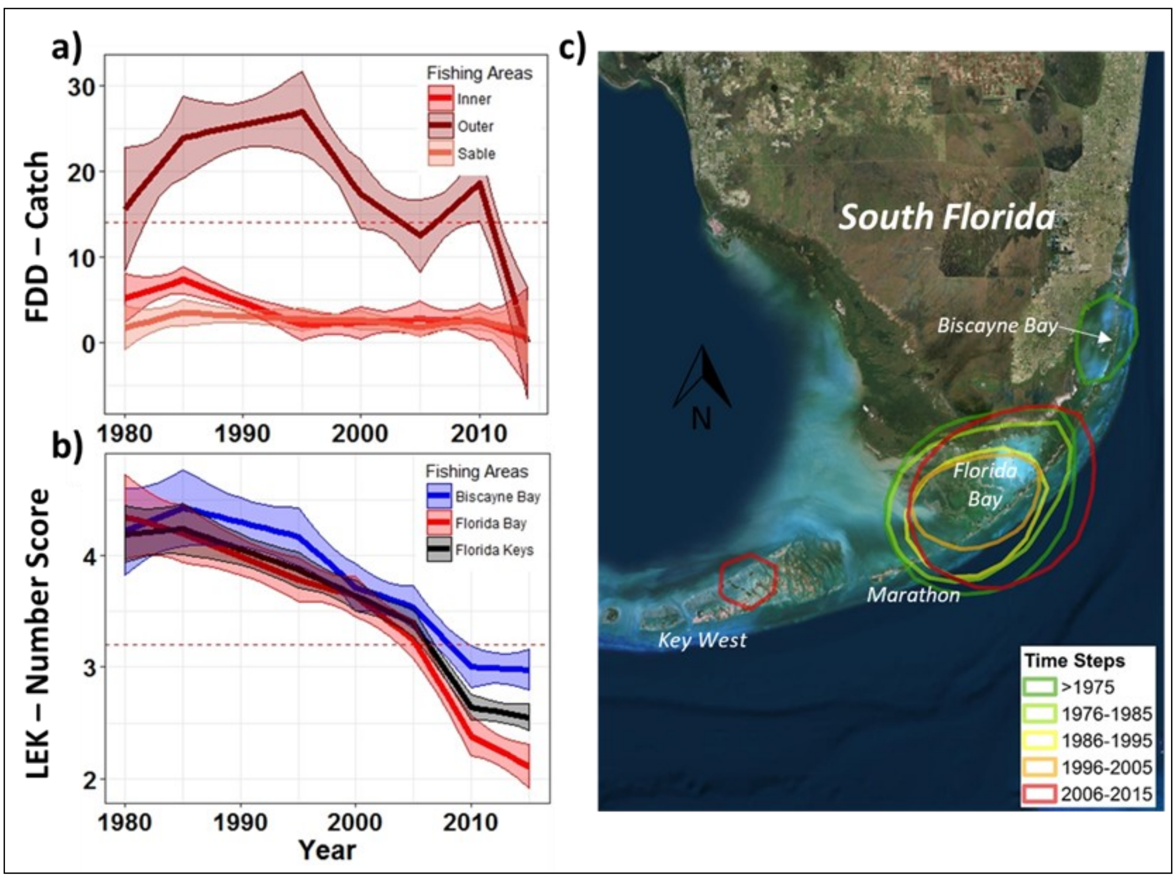

Figure 1. Mean a) fitted values for bonefish catch in Florida Bay fishing areas (bold lines, Inner Bay – red, Outer Bay – dark red, Cape Sable – coral) from 1980 to 2014, and b) fitted scores for bonefish numbers (number of shots) across the seven time steps between 1975 and 2015 that anglers scored bonefishing quality. Also illustrated c) the fishing core (i.e., 50% kernel estimation of utilization distribution) for the combined fishing area used by all LEK interviewees across five decadal periods (from green – before 1975 to red – between 2006 and 2015).

could be hindering the recovery of bonefish. Thus, our results point to the need for bonefish conservation efforts to encompass both juveniles and adults, to tackle both local and regional factors, and to consider the stronger connection between healthy bonefish fisheries and coastal water management.

KEYWORDS: Recreational fisheries, time series analysis, online survey

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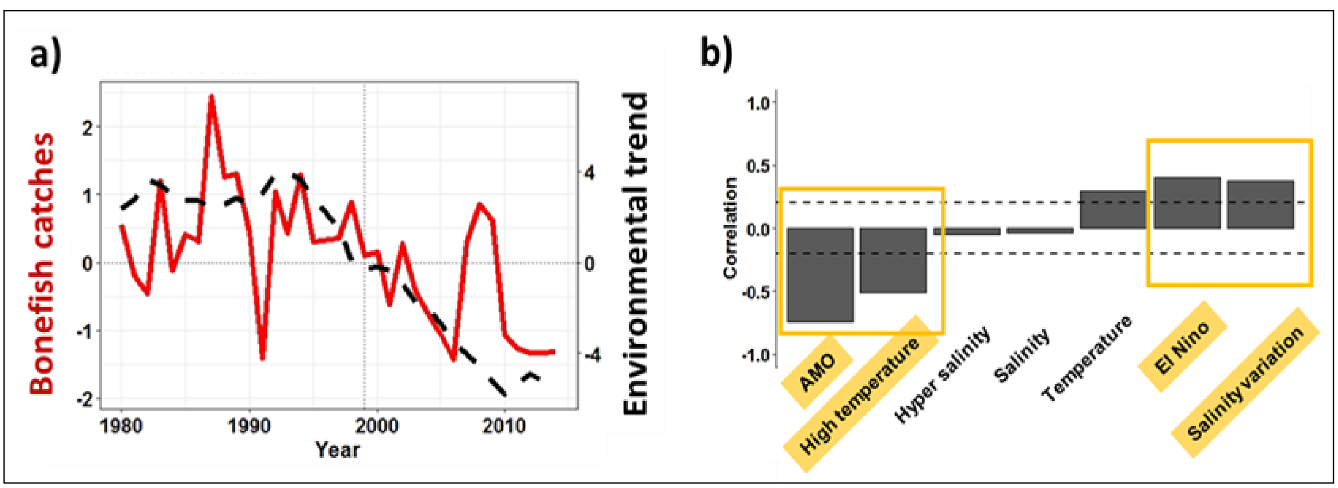

Figure 2. Plot a) of Florida Bay bonefish catches (red solid line) and of the overall environmental trend (black dotted line)) (i.e., trend identified by DFA) seen for the same time period. Canonical correlation b) indicating the breakdown of the environmental factors driving the underlying trend (black dotted line). Factors in yellow are contributing the most.