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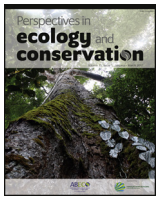

Research letters

The end of the line? Rapid depletion of a large-sized grouper through spearfishing in a subtropical marginal reef

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ABSTRACT

The Atlantic goliath grouper, *Epinephelus itajara*, is a large-sized coastal fish that has been heavily overfished, mainly through spearfishing. In order to assess historical catches of the species, we interviewed spearfishers along three generations (young, middle-aged and old) in the traditional fishing village of Arraial do Cabo, southeastern Brazil. We identified a systematic and significant decline in the weight of the largest goliath grouper caught and in the number of individuals caught on the best day's catch through spearfisher generations. Today, the species is functionally extinct in the region and individuals are rarely sighted. Challenges to the conservation of goliath grouper populations throughout the Brazilian coast include the banishment of poaching as well as the support to alternative income sources through non-extractive uses, such as diving tourism.

Introduction

Among marine fishes, groupers are the most important artisanal fishing resource worldwide (Heemstra and Randall, 1993). However, twenty grouper species (12%) are currently listed under extinction risk categories and other 22 (13%) are Near Threatened with extinction worldwide according to the International Union for the Conservation of Nature – IUCN Red List of Threatened Species (Sadovy de Mitcheson et al., 2013). In addition to the threats deriving from heavy exploitation, groupers (Epinephelinae) have biological attributes that contribute to render its populations vulnerable to the effects of fishing such as long life span, slow growth, late maturation, strong site fidelity and the formation of seasonal spawning aggregations (Craig et al., 2011). As a consequence, grouper populations easily collapse when heavily fished, taking a long time to rebound (Heppell et al., 2005).

The Atlantic goliath grouper, *Epinephelus itajara*, (Litchtenstein, 1822) is the largest grouper species of the Atlantic Ocean, reaching over 2 m in length and 400 kg in weight (Bullock et al., 1992). The species has been suffering sharp population declines across its entire range due to overfishing and habitat loss (Craig et al., 2009). Today, the goliath grouper is globally classified as Critically Endangered by the IUCN (Craig, 2011). In Brazil, the decrease in catches and lack of reliable population data led managers to establish a precautionary fishing ban in 2002. Also, in 2014 the species was listed as Critically Endangered by the Brazilian Red List of threatened species.

Spearfishing is recognised as the main cause of the collapse of the goliath grouper (Sadovy and Eklund, 1999; Gerhardinger et al., 2006). Nevertheless, the effects of spearfishing on reef fishes across longer timeframes, such as decadal periods, are poorly known for Brazilian reefs (but see Bender et al., 2014). Here, we use fishers' local ecological knowledge – LEK to investigate trends in historical spearfishing catches of goliath grouper populations in Arraial do Cabo, a fishing village in southeastern Brazil. Specifically, our aims were to assess changes in (i) the number of individuals caught over the years and (ii) the weight of individuals caught over the years. The knowledge of resource users has been widely applied to obtain historical data of marine species and populations not registred by the most conventional approaches (e.g. fisheries statistics; McClenachan et al., 2015). Despite the potential biases that may exist in individuals' memories related to LEK (Papworth et al., 2009), comparisons with biological surveys have shown that when data collection (e.g. interviews, questionnaires, etc.) is well-designed,

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fishers' LEK constitute a reliable source of data (Thurstan et al., 2015).

Material and methods

Study area

Arraial do Cabo (22°57′57″S 42°01′40″W) is a traditional fishing village with approximately 1000 active fishers in which aproximatelly 55 are spearfishers. Fisheries are generally multispecific and apply a variety of fishing gears, such as hook and line, gillnet, beach seine and spearfishing, with beach seine being the most traditional practice. The main fishing targets are the bluefish *Pomatomus saltatrix*, mullets (Mugilidae), jack and trevallies (Carangidae), tunas (Scombridae) and groupers (Epinephelidae). Parrotfishes (Scarinae) became a target in the early 1990s, when the collapse of large predators commenced, and these fishes are mainly captured through spearfishing (Bender et al., 2014). Since 1997, a coastal community-based marine protected area (MPA) was implemented, named Arraial do Cabo Marine Extractive Reserve – ACMER, where fishing rights are granted exclusively to local fishers.

Data collection

Spearfishers were interviewed through semi-structured questionnaires, based on questions used by Saenz-Arroyo et al. (2005). Specifically, we asked three questions: (1) Fishers' age; (2) the weight of the largest goliath grouper ever caught and the year in which that catch was made; (3) the largest number of individuals caught in a single day and the year of such large catch. Prior to each interview, we clearly explained the objectives of our research, highlighting that the interviewee, as well as the data informed, would remain anonymous. This avoids the potential bias that could arise due to the mistrust of fishers in the use of the data and knowledge by researchers (Thurstan et al., 2015).

Data analysis

Respondents were categorized into three groups with ages ranging through three generations: young (15–30 years), middle-aged (31–54 years) and old (≥55 years). A polynomial regression was fitted to verify the relationship among weight of the largest goliath grouper ever caught and greater days' catch along the years. To compare the largest individual ever caught and greater days' catch according to spearfishers' generation, we used the nonparametric ANOVA (Kruskal–Wallis test) since the response distribution was non-normal and data was nonparametric. A post-hoc test was conducted using Dunn's test – package dunn.test (Dinno, 2017).

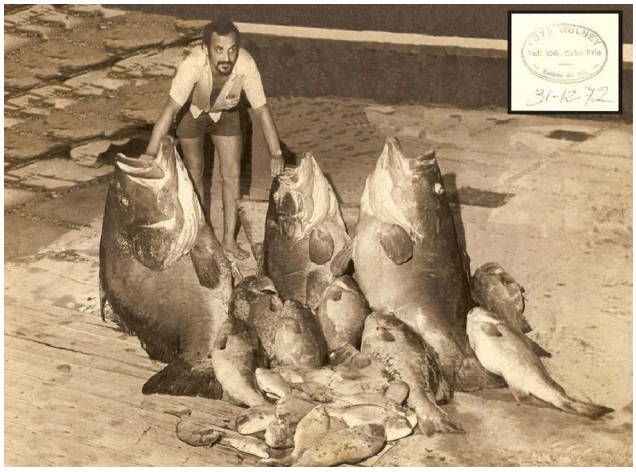

Fig. 1. Spearfishing catches in a single day at 1972 in Arraial do Cabo.

Analyses were performed using the software R (R Core Team, 2016) at a significance level of $p < 0.05$.

Results

We interviewed 42 spearfishers between August 2007 and August 2008 across three different generations: young ($n = 10$), middle-aged ($n = 15$) and old ($n = 17$), corresponding to ~75% of active spearfishers in Arraial do Cabo during the time of the survey. All spearfishers reported catches of goliath grouper individuals in the past (see Fig. 1). Overall, the average weight of the largest individual ever caught was 169 ± 15.8 kg (±SE). The smaller catch reported was an individual of 20 kg caught in 2005, and the largest weighed 400 kg, captured back in 1979. We identified a significant decline in the size of largest individual caught throughout the years (Polynomial regression $r^2 = 0.52$, $p < 0.001$; Fig. 2A) and across spearfishers' generations (Kruskal–Wallis $x^2 = 28.72$, $p < 0.001$, Fig. 2B). Best days' catch revealed a marked decline along the years ($r^2 = 0.36$, $p < 0.001$; Fig. 3A) and across spearfishers' generations ($x^2 = 29.1$, $p < 0.002$; Fig. 3B).

Discussion

By assessing spearfishers knowledge, we verified a marked decline in both the abundance and the weight of goliath grouper individuals caught in an interval of 23 years (from 1975 to 2008) in Arraial do Cabo. Historically the species was caught mainly through spearfishing in the region. Behavioral characteristics, such as

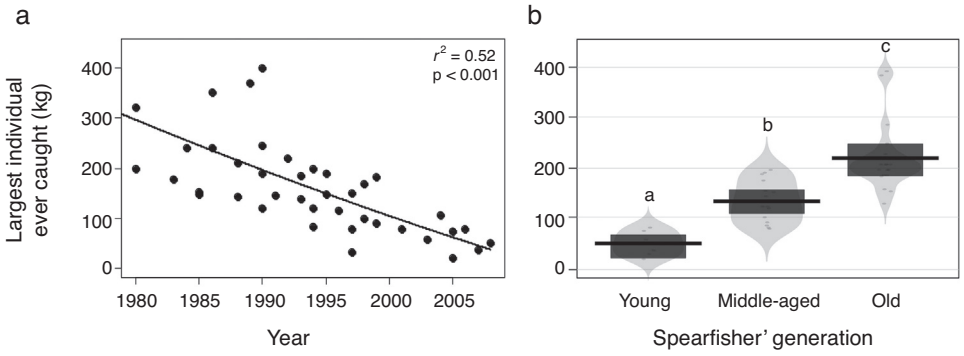

Fig. 2. Largest goliath grouper individuals caught according to (A) years and (B) spearfishers' generation in Arraial do Cabo, southeastern Brazil. Generations are defined as: young (15–30 years; $n = 10$), middle-aged (31–54 years; $n = 15$) and old (≥55 years; $n = 17$). In (B) points are the raw data, black line represents the average, bean is the inference interval. Different letters above pirateplots indicate significant differences (Dunn's test, $p < 0.05$).

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