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Seasonal, annual, and long-term trends in commercial fisheries for aggregating reef fishes in the Gulf of California, Mexico

Brad Erisman[a,*], Ismael Mascarenas[b], Gustavo Paredes[a], Yvonne Sadovy de Mitcheson[c], Octavio Aburto-Oropeza[a], Philip Hastings[a]

[a] Marine Biology Research Division, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92093-0202, USA
[b] Centro de la Biodiversidad Marina y la Conservacion, La Paz, Baja California Sur, Mexico
[c] Swire Institute of Marine Science, Department of Ecology & Biodiversity, University of Hong Kong, Hong Kong

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ABSTRACT

In order to assess the contribution of fish spawning aggregations and aggregating species to commercial marine fisheries in the Gulf of California, we: (1) investigated associations between the timing of spawning aggregations and monthly trends in commercial landings and ex-vessel revenues for aggregating reef fishes in the southwest Gulf of California and (2) compared present (2000–2005) and past (1956–1961) landings of aggregating species groups from the entire Gulf. Species known to form seasonal spawning aggregations comprised the eight most important commercial reef fish fisheries of the southwest Gulf with respect to landings and ex-vessel revenues, and three of these species increased in annual landings between 1999 and 2007. Peaks in mean monthly landings and revenues for five of eight aggregating species coincided with the timing of their spawning aggregations, whereas commercial fisheries for the remaining three species did not specifically target spawning aggregation periods. Comparisons of past and present landings showed an expansion of targeted species groups, increased landings for most aggregating species groups, and declines in the landings of several large-bodied species groups. Our results suggest that targeted management of spawning aggregations is needed for some but not all species, assessments on the interaction between fisheries and spawning aggregations are needed for most species, and restrictions on certain gear types are necessary to create sustainable fisheries for aggregating fishes in the Gulf.

1. Introduction

Many marine fishes form spawning aggregations, temporally and spatially discrete gatherings that are solely for the purpose of reproduction (Colin et al., 2003). Commercial fisheries often target these aggregations, since they tend to occur at the same locations and times each year and thus provide easy opportunities for large harvests with minimal effort (Sadovy and Domeier, 2005a). However, such predictability in time and space also makes fish spawning aggregations particularly vulnerable to overexploitation (Sadovy de Mitcheson and Erisman, 2010), which likely explains why 79% of documented aggregation sites in the tropics have declined (Sadovy de Mitcheson et al., 2008). The lack of specific fisheries and biological information for aggregating species (i.e., those species that form spawning aggregations) in most areas, including quantitative information on the importance of aggregations to fisheries, locations of major spawning sites, seasonal timing of aggregations, or direct effects of fishing on aggregations seriously compromises our ability to make compelling arguments for the management of aggregating species using strategies that specifically target aggregation sites or time periods (Sadovy de Mitcheson and Erisman, 2010; Sadovy de Mitcheson et al., 2008).

The Gulf of California is one of the most important fisheries regions of the Tropical Eastern Pacific and the most productive fisheries region in Mexico (OECD, 2006). A large portion of this productivity stems from the commercial harvest of groupers, snappers, croakers, jacks and other coastal marine fishes that form spawning aggregations at specific sites during certain seasons (Aburto-Oropeza et al., 2008; Erisman et al., 2007; Román-Rodríguez, 2000; Sala et al., 2003). Persistent overfishing in the Gulf over the past three decades has decimated coastal fish populations and their associated fisheries (DOF, 2004; Ezcurra et al., 2009; McGoodwin, 1979; Sala et al., 2004). As part of this trend, targeted exploitation

* Corresponding author at: Marine Biology Research Division, Scripps Institution of Oceanography, University of California at San Diego, 9500 Gilman Drive, Mail Code 0202, La Jolla, CA 92093-0202, USA. Tel.: +1 858 822 3765; fax: +1 858 822 3310.
E-mail addresses: berisman@ucsd.edu (B. Erisman), otolino@gmail.com (I. Mascarenas), gparedes@ucsd.edu (G. Paredes), yjsadovy@hkucc.hku.hk (Y. Sadovy de Mitcheson), maburto@ucsd.edu (O. Aburto-Oropeza), phastings@ucsd.edu (P. Hastings).

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Table 1
Aggregating reef fishes of commercial importance in the southwest Gulf of California, their spawning seasons within the region, and references documenting their spawning and aggregating behavior.

Species	Spawning season	References
Balistes polylepis	May–September	Thomson et al. (2000), Avendaño-Ibarra et al. (2004), Sánchez-Velasco et al. (2009)
Hoplopagrus guentherii	May–September	Thomson et al. (2000), Zapata and Herrón (2002)
Lutjanus argentiventris	May–September	Sala et al. (2003), Aburto-Oropeza et al. (2009), Piñon et al. (2009)
Lutjanus peru	May–September	Dumas et al. (2004), Reyna-Trujillo (1993)
Mycteroperca rosacea	March–June	Aburto-Oropeza et al. (2007a), Erisman et al. (2007), Sala et al. (2003)
Paralabrax auroguttatus	March–May	Pondella et al. (2001), Sadovy and Domeier (2005b), Erisman (unpublished data)
Paranthias colonus	May–September	Sala et al. (2003), Erisman and Aburto-Oropeza (unpublished data)
Seriola lalandi	March–May	Sala et al. (2003), Erisman (unpublished data)

of important spawning aggregation sites for several large-bodied species has contributed to the collapse of their fisheries, and these species are now endangered (Cisneros-Mata et al., 1995; Musick et al., 2000; Sáenz-Arroyo et al., 2005a; Sala et al., 2004). Despite such pervasive and dramatic declines and known interactions between fisheries and spawning aggregations, neither quantitative evaluations of the importance of spawning aggregations to fisheries nor the impacts of fisheries on these aggregations have been evaluated in the Gulf. As a result, only one aggregating species is protected from commercial harvest (totoaba; *Totoaba macdonaldi*), and the management of only one commercial species (Gulf corvina; *Cynoscion othonopterus*) includes any protection of its spawning season and spawning aggregation sites (Cisneros-Mata et al., 1995; Román-Rodríguez, 2000).

Here we evaluate the current contribution of fish spawning aggregations and aggregating species to commercial reef fisheries in the southwest Gulf of California and summarize annual and seasonal trends in landings and markets for aggregating species in the region. We also compare annual landings of fisheries for aggregating species in the entire Gulf during the 1950s with those during the period of 2000–2005 to identify long-term fisheries trends. Finally, we provide general recommendations for the management and research of fish spawning aggregations and associated fisheries in the region.

2. Materials and methods

2.1. Monthly and annual trends in commercial reef fish fisheries of the southwest Gulf of California

We acquired commercial fisheries data directly from three local fisheries offices (Santa Rosalia, Loreto, La Paz; Fig. 1) of the Mexican National Commission of Fisheries and Aquaculture (CONAPESCA) in the state of Baja California Sur and compiled them into electronic formats. These data contained monthly records of landings (kg) and ex-vessel prices (pesos/kg), classified to the level of species, for all months from 1999 to 2007. Data prior to 1999 were either unavailable, incomplete in terms of lacking data for some months, or did not contain species level data. Calculations of fishing effort or catch-per-unit effort were not possible, because commercial fishers are not required to submit detailed daily logs of fishing activities. Despite the shortcomings, these data provided much higher taxonomic (i.e., species level) and temporal resolution (i.e., monthly) than fisheries data available at the central CONAPESCA office in Mazatlán, Sinaloa, Mexico (see Section 2.2). Ex-vessel revenues were calculated by multiplying landings by ex-vessel prices, and the resulting values in Mexican pesos were then converted to US dollars using published monetary exchange rates.

We identified the eight most important commercial reef fishes known to form spawning aggregations based on mean annual landings and ex-vessel revenues (see Section 3.1). A combination of published data, unpublished data, and observations by the authors was used to confirm the existence of spawning aggregations for each of these eight species and to identify the months during which spawning aggregations occur (Table 1). We estimated the contribution of spawning aggregations to fisheries for each of the eight species by summing the landings recorded during spawning months and dividing these values by the total annual landings. Based on prior research on the reproductive behavior of these species (see references listed in Table 1), we assumed that spawning aggregations persisted throughout the reproductive season rather than being limited to specific periods (e.g., full or new moons). We multiplied landings recorded during spawning months by monthly ex-vessel prices to estimate ex-vessel revenues from spawning aggregations.

A one-way ANOVA tested for differences in landings and ex-vessel prices among months. Where significant relationships were found, post hoc multiple comparisons were performed using Tukey tests. Monthly landings data were log transformed, because raw data did not conform to the assumptions of parametric testing. Because mean monthly ex-vessel price did not differ significantly among months for any species (see Section 3.2), we used linear correlation to confirm that monthly trends in landings and ex-vessel revenue were not significantly different.

2.2. Long-term fisheries trends for aggregating fishes of the Gulf of California

A quantitative analysis of long-term trends in commercial fisheries for aggregating species of the entire Gulf was not possible, because official fisheries landings data for the Gulf of California are inconsistent across years and regions, long-term databases for the entire Gulf that record species-specific data do not exist, and data for most years are not available in electronic formats (Aburto-Oropeza et al., 2007b). Therefore, we relied on two databases that allowed general comparisons between species composition and mean annual landings of fisheries for aggregating species of the entire Gulf during the 1950s and 2000s. The first database was published by the Mexican Navy and included annual landings data of marine species groups from the entire Gulf of California from 1956 to 1961. The second database was obtained from CONAPESCA and contained annual landings for marine species groups from the entire Gulf from 2000 to 2005.

Species groups for both databases were classified by regional common name, which varied considerably in taxonomic specificity from a single species (e.g., huachinango = *Lutjanus peru*) to a suite of species from the same family (e.g., cochito = *Balistes polylepis*, *Pseudobalistes naufragium*) or order (e.g., mantaraya = Myliobatiformes). Fisher interviews, market surveys, personal knowledge of the authors, online databases (www.fishbase.org; www.neotropicalfishes.org), and published reference materials were used to identify individual species associated with regional common names (Allen and Robertson, 1994; Fischer et al., 1995; Humann and DeLoach, 2004; Thomson et al., 2000).